TRANSACTIONS

OF THE

AMERICAN INSTITUTE OF MINING ENGINEERS.

VOL. XIII.

FEBRUARY, 1884, TO JUNE, 1885.

NEW YORK CITY:
PUBLISHED BY THE INSTITUTE,
AT THE OFFICE OF THE SECRETARY.
1885.

PHILADELPHIA:
SHERMAN & CO., PRINTERS.

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MAY, 1885.

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*COLTON, HENRY E., ... Chattanooga, Tenn. '83
*COLVIN, CLARENCE K., ... Idaho Springs, Colorado. '82
*COLVIN, VERPLANCK, ... Adirondack Survey Office, Albany, N. Y. '81
*COMSTOCK, GEORGE S., ... Mechanicsburg, Cumberland Co., Pa. '81
*COMSTOCK, THEO. B., ... 25 Euclid Ave., Cleveland, O. '80
*CONANT, T. P., ...are of Harper & Bros., Franklin Square, N. Y. City. '81
'81*CONE, JNO. J., ... 618½ Jersey Ave., Jersey City, N. J. '85
*CONRAD. C. F., ... Roanoke, Va. '83
*CONSTABLE, C., ... 44 Exchange Place, New York City. '75
*CONSTABLE, JAMES, JR., ... Glendon Iron Works, Easton, Pa. '79
*CONVERSE, JOHN H., ... Baldwin Locomotive Works, Philadelphia. '83
*COOK, EDGAR S., ... Warwick Iron Co., Pottstown, Pa. '77
*COOK, PROF. GEORGE H., ... State Geologist, New Brunswick, N. J. '74
*COOK, ROBERT A., ... Bethlehem, Pa. '83
*COOLIDGE, WALTER G., ... 1st Nat. Bank Building, Chicago, Ill. '82
*COOPER, EDWARD, ... 17 Burling Slip, New York City. '74
*COOPER, H. P., ... Parryville. Pa. '81
*COOPER, JAMES R., ... Honghton, L. S., Michigan. '80
*COOPER, WILLIAM H., ... 60 William Street, New York City. '83
†CORNELL, A. B., ... Youngstown, Ohio. '72
*CORNING, ERASTUS, ... 87 State Street, Albany, N. Y. '78
*CORNING, FREDERICK G., ... 78 Broadway, New York City. '77
*CORYELL, MARTIN, ... Lambertville, N. J. '71
*CORYELL, TORBERT, ... Lambertville, N. J. '83
*COURTIS, W. M., ... 449 Fourth Avenue, Detroit, Mich. '71
*COUTIE, WM., ... Troy, N. Y. '84
†COXE, ALEXANDER B., ... Drifton, Luzerne Co., Pa. '80
*COXE, ECKLEY B., ... Drifton, Luzerne Co., Pa. '71
*COXE, W. E. C., ... Reading, Pa. '74
*CRAFTS, WALTER, ... 3 Deshler Block, Columbus, Ohio. '71
*CRANZ, W. S., ... Darwin Mine, via Tubac, Arizona. '82
*CRAWFORD, HUGH A., ... 411 N. Third Street, St. Louis, Mo. '75
*CRAWFORD, JOHN J., ... Placerville, El Dorado Co., Cal. '73
*CRAWFORD, JOHN L., ... Newcastle, Pa. '84
*CREMER, J. H., ... Edgar Thomson Steel Works, Braddock, Pa. '75
†CRERAR, JOHN, JR., ... 109 Dearborn Street, Chicago, Ill. '84
*CROCKER, A. L., ... Minneapolis, Minn. '80
*CROCKER, GEORGE A., ... 32 Cliff Street, New York City. '79
*CROCKER, WILLIAM B., ... 32 Cliff Street, New York City. '79
*CROOKER, RALPH, 3D., ... Care Nat. Tube Works Co., McKeesport, Pa. '81
*CROOKSTON, A. W., ... 19 Wellington Street, Glasgow, Scotland. '80
*CROWE, THOMAS., ... N. Chicago Rolling Mill Co., South Chicago, Ill. '84
*CROWTHER, BENJAMIN, ... Etna, Allegheny Co., Pa. '76
*CROXTON, SAMUEL W., ... Canal Dover, Ohio. '75
*CROZER, S. A., JR., ... P. O. Box 13, Chester, Pa. '83
*CUMMER, F. D., ... Cleveland, Ohio. '83
*CUMMINGS, GEORGE P., ... Marquette, Mich. '81
*CUNNINGHAM, JAMES S., ... Everett, Bedford Co., Pa. '83
*CUNNINGHAM, J. L., ... Ringwood, Passaic Co., N. J. '82

*CURRY, HENRY M., ... Lucy Furnaces, Pittsburgh, Pa. '79
*CURTIS, GRAM, ... 35 Broadway, Room 97, New York City. '80

*DABNEY, CHAS. W., ... Jr.,Raleigh, N. C. '84
*DAGGETT, ELLSWORTH, ... Salt Lake City, Utah. '73
*DAGRON, JAMES G., ... Care Keystone Bridge Co., Pittsburgh, Pa. '84
†DALLIBA, JAMES H., ... Scofield Building, Cleveland, Ohio. '82
*DALLIBA, WILLIAM S., ... 186 Dearborn Street, Chicago, Ill. '83
*DANFORTH, A. H., ... South Pueblo, Colorado. '82
*DANIELS, FRED. H., ... 132 Lincoln Street, Worcester. Mass. '76
*DARLEY, E. C., ... 322 Pine Street, St. Louis, Mo. '83
*DAVENPORT, C. W., ... Erie, Pa. '81
*DAVENPORT, RUSSELL W., ... Midvale Steel Works, Nicetown, Philadelphia. '77
*DAVIDSON, GEORGE M., JR., ... 64 S. Clinton Street, Chicago, Ill. '81
*DAVIES, EDWARD S., ... Pottstown, Pa. '81
*DAVIS, CHESTER B., ... 52 Montauk Block, Chicago, Ill. '78
*DAVIS, PROF. FLOYD, ... Blacksbnrg, Va. '83
*DAVIS, HENRY C., ... 205 Walnut Place, Philadelphia. '81
*DAVIS, LOUIS M., ... Bolivar, Venezuela (care Harriman & Co., Trinidad). '84
†DAYTON, L. M., ... 184 N. Second Street, Cincinnati, Ohio. '84
*DE CAMP, ALFRED H., ... Musquodoboit Harbor, Halifax Co., N. S. '83
*DE CAMP, E. F., ... Halifax Club, Halifax, N. S. '85
*DE CAMP, W. S., ... Lyons Falls, N. Y. '75
*DE CRANO, E. G., ... Union Club, San Francisco, Cal. '72
*DE DEKEN, ALBERT, ... Edgar Thomson Steel Works, Braddoek, Pa. '84
*DE SAULLES, A. B., ... Oliphant Furnace, Fayette Co., Pa. '71
*DE SCHWEINITZ, P. B., ... South Pueblo, Colorado. '82
*DERLAND, ASBURY, ... Boiling Springs, Cumberland Co., Pa. '82
*DESLOGE, JOHN M., ... Bonne Terre, St. François, Co., Mo. '81
*DEVEREUX, W. B., ... Aspen, Colorado. '80
*DEWEY, FRED. P., ... Smithsonian Institution, Washington, D. C. '77
*D'INVILLIERS, E. V., ... 711 Walunt Street, Philadelphia. '82
*DISSTON, H. C., ... Philadelphia, Pa. '84
*DISSTON, W M., ... Philadelphia, Pa. '84
*DIXON, DOUGLAS, ... 6 Crosby Square, Bishopgate Street, London, Eng. '84
*DODGE, WALLACE H., ... Dodge Manuf. Co., Mishawaka, Ind. '84
*DODS, JOHN C., ... Danville, Pa. '81
*DOMINICK, F. J., ... Clintonville, N. Y. '82
*DONALDSON, WILLIAM J., ... 226 Walnut Street, Philadelphia. '81
*DORSEY, E. B., ... American Exhibition, 7 Poultry, London, Eng. '79
*DOWNS, W. F., ... Dixon Crucible Co., Jersey City, N. J. '83
*DOYLE. PAT., ... Care of Rev. James Doyle, Madras, India. '79
*DRINKER, H. S., ... 218 S. Fourth Street, Philadelphia. '71
*DU BOIS, PROF. AUG. JAY, ... New Haven, Conn. '75
*DUDLEY, ... Dr. Charles B.,Altoona, Pa. '78
*DUDLEY, P. H., ... 66½ Pine Street, New York City. '75
*DUDLEY, PROF. W. L., ... American Iridium Co., Cincinnati, Ohio. '84
*DUFF, JOHN, ... 14 Sheafe Street, Charlestown, Mass. '83
*DUMONT, JOHN M., ... Idaho Springs, Colorado. '82
*DUNCAN, JOHN, ... Calnmet, Houghton Co., Mich. '80
*DUNCAN, M. M., ... Roekwood, Tenn. '84

†DUNLAP, THOMAS, ... Stapleton Mills, Amherst Co., Va. '81
*DU PUY, HERBERT,.................................. 171 Western Avenue, Allegheny, Pa. '79
*DURFEE, W. F., ... 89 Courtland Street, Bridgeport, Conn. '76
*DURKEE, HENRY R., ... 87 Dearborn Street, Chicago, Ill. '84
†DWIGHT, ARTHUR S., ... Colorado Smelting Co., South Pueblo, Colorado. '85

*EARLE, FRANK C., ... P. O. Box 15, Tombstone, Arizona. '84
*EARNSHAW, ALFRED., ... 203 Walnut Place, Philadelphia. '81
*EARNSHAW, EDWARD H., ... Chester Furnace, Chester, N. J. '84
*EASTWOOD, PROF. J. F., ... Bethany, W. Va. '82
*ECKERT, HENRY S., ... Reading, Pa, '84
†ECKERT, HUNTER, ... New Ringgold, Schnylkill Co., Pa. '81
*ECKMAN, JOHN W., ... Port Kennedy, Pa. '84
†EDMUNDS, FRANK W.,... P. O. Box 133, Troy, N. Y. '83
*EDWARDS, J. WARNER,....... Delaware Avenue And Green Street, Philadelphia. '76
*EGAN, JOHN M. S., ... P. O. Box 24, Georgetown, Colorado. '82
*EGLESTON, DR. THOMAS, ... 35 West Washington Square, New York City. '71
*EILERS, A.,.. South Pueblo, Colorado. '71
*ELLIOT, MATTHEW P., ... Crystal Plate Glass Works, Crystal City, Mo. '85
†ELY, E. B., ... Washington Building, 1 Broadway, New York City. '79
*ELY, THEODORE N., ... Altoona, Pa. '79
*EMANUEL, W. H.,.. Box 2065, Denver, Colorado. '81
*EMERSON, B. F., ... Copper Falls, Keweenaw Co., Mich. '76
*EMERSON, PROF. G. D., ... Rolla, Phelps Co., Mo. '71
*EMERY, A, H., ... Stamford, Conn. '82
*EMERY, CHARLES E.,................................. 22 Cortlandt Street, New York City. '80
*EMMERTON, F. A.,... Joliet, Ill. '84
†EMMONS, ARTHUR B., ... Newport, R. I. '85
*EMMONS, S. F., ... U. S. Geological Survey, Denver, Colorado. '77
*ENGLE, GEORGE U., ... 912 Mahontongo Street, Pottsville, Pa. '77
*ENGELMANN, HENRY, ... La Salle, Ill. '72
†ENOS, FRANK, ... 28 Monroe Place, Brooklyn, N. Y. '84
*EOFF, CHARLES W.,............................. 1322 Jefferson Street, Kansas City, Mo. '84
*ESTABROOK, J. D.,........................... Coulter Street, Germantown, Philadelphia. '72
*EURICH, E. F., ... Aurora, Ill. '74
*EUSTACE, GEORGE W.,.. Helstone, Cornwall, England. '82
*EUSTIS, W. E. C., ... 4 Pemberton Square, Boston, Mass. '76
*EVANS, JOHN D., ... Chester, Morris Co., N. J. '80
*EYRE, THOS. T., ... Carlisle, N. Mexico. '85
*FABER DU FAUR, A., ... 93 John Street, New York City. '72
*FACKENTHAL, B. F., JR., ... Riegelsville, Pa. '80
*FACKENTHALL, MICHAEL, ... Hellertown, Pa. '80
*FAIRCHILD,................................ A. C.Passaic Rolling Mill Co., Paterson, N. J. '77
*FALDING, FREDERICK J., ... 81 New Street, New York City. '84
*FARRELL, AUSTIN,........................ Care Crozer Iron & Steel Co., Roanoke, Va. '80
*FEGELY, ISAAC, ... Pottstown, Pa. '83
*FELTON, EDGAR C., ... Steelton, Dauphin Co., Pa. '81
*FELTON, S. M., ... 208 S. Fourth Street, Philadelphia. '81
*FERGUSON, E. M., ... 104 Fifth Avenue, Pittsburgh, Pa. '78
†FERGUSON, J. H., ... P. O. Box 2124, Denver, Colorado. '84
†FERGUSON, SAMUEL T.,... Minneapolis, Minnesota. '84

*FERGUSON, WALTON, ...104Fifth Avenue, Pittsburgh, Pa. '79
*FERRIS. J. C., ... Carthage, Ill'83
*FEUSTMAN, L. P., ... P. O. Box 375, Leadville, Colorado. '82
*FIELD, ROBERT P., ... 237 S. Forty-second Street, W. Philadelphia. '73
*FILLEBROWN, JOHN P., ...Secaucus, Hudson Co., N. J. '79
*FINDLAY, CHARLES FARQUHAR, ... Trinity Hall, Cambridge, England. '82
*FINLEY, C. B., ...Philipsburg, Pa. '81
*FIRMSTONE, FRANK, ... Glendon Iron Works, Easton, Pa. '71
*FIRMSTONE, H., ... Longdale, Alleghany Co., Va. '75
@FISCHER, ANTHONY C., ... 906 G Street, N. W., Washington, D. C. '83
*FISHER, CLARK, ...Trenton, N. J. '71
*FISHER, HARVEY, ...Duncannon, Perry Co., Pa. '76
*FISHER, H. H., ... Allentown, Pa. '80
*FISHER, JOHN J., ... Allentown, Pa. '81
*FITZHUGH, CHARLES L, ... Shoenberger & Co., Pittsburgh, Pa. '79
*FLAGLER, JOHN H., ... 104 John Street, New York City. '82
*FLEMING, H. S., ... 117 W. 8th Street, Chattanooga, Tenn. '84
*FOHR, FRANZ, ... Leadville, Colorado. '75
*FOOTE, EMERSON L., ... 411 N. Third Street, St. Louis, Mo. '82
*FOOTE, HERBERT C., ... 37 Arlington Court, Cleveland, Ohio. '75
*FORD, E. L., ... Youngstown Steel Co.,Youngstown, Ohio. '79
*FORD, S. ALFRED, ... Edgar Thomson Steel Co., Pittsburgh, Pa. '75
*FORD, ROBERT G., ... Bellwood, Blair Co., Pa. '82
*FORSYTH, ROBERT, ... Union Steel Co., Chicago, Ill. '75
*FORSYTH, WILLIAM, ... Aurora, Ill. '84
*FOSTER, ERNEST LE NEVE, ... Georgetown, Colorado. '75
Foucar, Edonard L., ... P. O. Box 107, El Paso, Texas.
*FOWLER, A. L., ... Tombstone, A. T. '84
*FRANCKLYN, CHARLES G., ... 48 Wall Street, New York City. '80
*FRANKLIN, WALTER S., ...Ashland, Baltimore Co., Md. '79
*FRAZER, DR. PERSIFOR, ... 201 S. Fifth Street, Philadelphia. '71
*FRAZER, ROBERT, ... 209 S. Third Street, Philadelphia. '76
*FRAZIER. PROF. B. W., ...Lehigh University, Bethlehem, Pa. '71
*FRECHEVILLE, R. J., ...5 Holyrood Place, Plymouth, England. '84
*FRECHEVILLE, WILLIAM, ...Hoover Hill, Randolph Co., N. C. '84
*FREELAND, FRANCIS T .... Box 2279, Denver, Colorado. '85
*FREEMAN, H. C., ... Box 1, Alto Pass, Union Co., Ill. '78
@FREEMAN, WILLIAM COLEMAN, ...Cornwall, Lebanon Co., Pa. '77
*FRICK, H. C., ... 104 Fifth Avenue, Pittsburgh, Pa. '79
*FRICKE, F. G., ...Buffalo Gap, Va. '79
*FRINK, GEORGE S., ... Irondale, N. Y. '85
*FRITZ, JOHN, ...Bethlehem, Pa. '72
*FRY, JOHN E., ...Springfield Iron Co., Springfield, Ill. '75
*FULLER, HOMER T., ... Worcester, Mass. '84
*FULTON, HENRY, ...Georgetown, Colorado. '81
*FULTON, JOHN, ... Cambria Iron Co., Johnstown, Pa. '72
*FULTON, R. C., ... Conshohocken, Pa. '83
*FURMAN. HOWARD V., ... 137 W. Thirty-fourth Street, New York City. '80
*FUSZ, PAUL A., ...941 N. Second Street, St. Louis, Mo. '79

*GAERTNER, ERICH G., ... Chicago, Ill. '84

*GARDNER, G. CLINTON,	15 Broad Street, New York City.	'78
*GARDNER, GEORGE C,	Room 35, Portland Block, Chicago, Ill.	'83
*GARRETT, ALBIN,	208 S. Fourth Street, Philadelphia.	'82
*GARRETT, WILLIAM,	Oliver & Roberts Wire Co., Pittsburgh, Pa.	'81
*GARRISON, FRANK L.,	1523 Girard Ave., Philadelphia.	'83
*GARTHWAITE, E. H.,	Care of W. W. Garthwaite, Oakland, Cal.	'82
@GATEWOOD, R.,	Care Navy Department, Washington, D. C.	'84
*GAY, HARRY S.,	Wilkes-Barre, Pa.	'85
*GAYLEY, JAMES,	Birdsboro, Pa.	'80
@GAZZAM, JOSEPH P.,	Joliet, Ill.	'84
*GENTH, F. A., JR.,	4014 Chestnut Street, W. Philadelphia.	'77
*GEORGE, RICHARD,	Dover, N. J.	'75
*GEORGE, S. W.,	Chester, N. J.	'84
*GEORGE, W. R.,	Dover, N. J.	'81
@GIBB, FRANK W.,	Little Rock, Ark.	'82
*GIBSON, C. H.,	Lock Box 1705, New York City.	'82
*GILBERT, EDWARD G.,	Troy, N. Y.	'83
*GILL, JOHN L., JR.,	32 N. 5th Street, Philadelphia.	'76
*GLADWIN, F. E.,	Care Dr. F. C. E. Mueller, El Plomo, Sonora, Mexico.	'84
*GLENN, WILLIAM,	South Strafford, Vermont.	'81
*GOETZ, GEORGE W.,	Otis Iron and Steel Co., Cleveland, Ohio.	'82
*GOGIN, GEORGE W.,	Norway Iron Works, Boston, Mass.	'77
*GOING, CHARLES B.,	Cincinnati, Ohio.	'83
*GOODALE, CHARLES W.,	Tombstone, Arizona.	'76
@GOODWIN, H. STANLEY,	Bethlehem, Pa.	'71
*GOODYEAR, S. W.,	Waterbury, Conn.	'82
*GOODYEAR, WATSON A.,	Blake Crusher Co., New Haven, Conn.	'71
*GORDON, ALEXANDER,	Hamilton, Ohio.	'84
*GORDON, FRED W.,	226 Walnut Street, Philadelphia.	'80
*GORHAM, AUSTIN G.,	21 Cortlandt Street, New York City.	'81
@GORTON, FRANK S.,	Chicago Forging Co., Chicago, Ill.	'84
*GOSLING, EDGAR B.,	School of Mines, New York City.	'83
@GOWEN, FRANKLIN B.,	119 N. Fourth Street, Philadelphia.	'72
*GRAHAM, FRANK,	P. O. Box 280, Georgetown, Colorado.	'84
*GRAHAM, JOHN, JR.,	Camden Iron Works, Camden, N. J.	'83
@GRAHAM, THOMAS,	233 S. Third Street, Philadelphia	'75
*GRAHAM, THOMAS H.,	400 Chestnut Street, Philadelphia.	'81
@GREEN, EDWARD M.,	Troy, N. Y.	'83
*GRIDLEY, EDWARD,	Wassaic, Dutchess Co., N. Y.	'77
*GRIFFEN, GEORGE S.,	Phœnixville, Pa.	'80
@GRIFFEN, H. M.,	Georgetown, Colorado.	'82
*GRIFFITH, J. K.,	Midvale Steel Works, Nicetown, Philadelphia.	'80
@GRIFFITHS, HOWARD B.,	2327 Ridge Avenue, Philadelphia.	'77
*GRISCOM, SAMUEL E.,	324 N. Eighth Street, Philadelphia.	'76
*GRISWOLD, CHESTER,	11 Pine Street, New York City.	'79
*GRISWOLD, FRANCIS B.,	Troy, N. Y.	'83
*GRISWOLD, J. WOOL,	Troy, N. Y.	'83
*GRITTINGER, HENRY C.,	Cornwall, Lebanon Co., Pa.	'79
*GROESBECK, J. D.,	P. O. Box 96, Tombstone, Arizona.	'82
*GROSS, HENRY S.,	119 Market Street, Harrisburg, Pa.	'81
*GROSS, LOUIS N.,	Box 411, Deadwood, Dakota.	'85

*GROVE, JOHN H., Danville, Pa. '80
*GURLEY, WILLIAM, Troy, N. Y. '83

*HABIRSHAW, W. M., 159 Front Street, New York City. '84
*HACKETT, WILLIAM H., 56 W. Harris Street, Atlanta, Ga. '81
*HACKNEY, HERBERT, Portland, Oregon. '83
†HADLEY, WALTER C., Las Vegas, N. M. '83
*HAGERMAN, J. J., 86 Michigan Street, Milwaukee, Wis. '75
*HAGUE, ARNOLD, University Club, New York City. '74
*HAHN, ALBERT G. C., 64 Perry Street, New York City. '85
*HAHN, IGNATIUS, P. O. Box 155, Sharpsburg, Allegheny Co., Pa. '79
*HAHN, O. H., P. O. Box 8, South Pueblo, Colorado. '71
*HAINES, REUBEN, 123 West Chelten Ave., Germantown, Philadelphia. '82
*HALBERSTADT, BAIRD, Pottsville, Pa. '84
*HALE, PROF. ALBERT C., P. O. Box 65, Brooklyn, N. Y. '82
*HALE, ALBERT W., 71 Broadway, New York City. '75
*HALL, C. C., 313 Iron Street, S. St. Louis, Mo. '82
*HALL, EDWARD J., JR., 80 Astor House, New York City. '76
*HALL, HENRY J., Palace Hotel, San Francisco, Cal. '80
*HALL, ROBERT W., 3 W. Fifty-Sixth Street, New York City. '76
*HALSEY, FRED A., 23 Park Place, New York City. '82
*HALSEY, WILLIAM S., ...Care Of F. M. Davis, 8th & Larimer Sts., Denver, Col. '82
*HAMILTON, ALEXANDER., Drawer Pp., Johnstown, Pa. '78
*HAMILTON, WILLIAM G., 24 West Street, New York City. '7
*HAMMOND, CHARLES L., 40 S. Clark Street, Chicago, Ill. '78
*HAMMOND, JOHN HAYS, 56 Wall Street, New York City. '81
*HAMMOND, W. B., Deadwood, Dakota. '83
*HARDEN, E. B., 537 N. Thirty-Third Street, Philadelphia. '73
*HARDEN, J. H.Phoenixville, Pa. '71
*HARDMAN, JOHN E, Oldham Gold Mines, Nova Scotia. '82
*HARKER, O. H., Leadville, Colorado. '82
*HARNICKELL, A.P. O. Box 2503, New York City. '74
*HARRINGTON, DR. B. J., Mcgill College, Montreal, Canada. '77
*HARRIS, JOSEPH S., 226 S. Third Street, Philadelphia. '72
*HARRIS, O. D., Ste. Genevieve, Mo. '84
*HARRISON, RUSSELL B., Superintendent U. S. Assay Office, Helena, Montana. '77
*HART, PROF. EDWARD, Lafayette College, Easton, Pa. '81
†HART, WILLIAM R., 224 S. Third Street, Philadelphia. '77
*HARTMAN, JOHN M., 1235 N. Front Street, Philadelphia. '75
*HARTRANFT, S. S., Custom House, Philadelphia. '77
*HARTSHORNE, J., Care Pottstown Iron Co., Pottstown, Pa. '73
*HARTY, WILLIAM, P. O. Box 207, Portsmouth, Ohio. '79
†HARVEY, WILLIAM H., Commonwealth Iron Co., Cleveland, Ohio. '80
*HASTINGS, ROBERT E., 819 Filbert Street, Philadelphia. '84
*HAWS, H. Y., Johnstown, Pa. '81
*HAYDEN, DR. F. V., 1803 Arch Street, Philadelphia. '81
*HAYDON, J. C., Jeansville, Luzerne Co., Pa. '74
*HEARD, JOHN, Care Aug. Heard, 39 Nassau Street, N. Y. '83
*HEARNE, FRANK J., Wheeling, West Va. '74
*HEARTT, JONAS S., Troy, N. Y. '83
*HECKSCHER, A., 212 Walnut Street, Philadelphia. '79

*HEGELER, EDWARD C., La Salle, Ill. '81
*HEINRICH, OSWALD J., Drifton, Luzerne Co., Pa. '73
*HEMENWAY, E. P., Cambria Iron Co., Johnstown, Pa. '81
*HEMPHILL, JAMES, Twelfth And Pike Streets, Pittsburgh, Pa. '75
*HENDERSON, C. HANFORD, 201 S. Fifth Street, Philadelphia. '83
*HENRICH, CARL, Noble, Richland Co., Ill. '82
*HERNDON, EDWARD L., 210 N. Third Street, St. Louis, Mo. '82
*HERR, H. B., P. O. Drawer 132, Chicago, Ill. '76
*HERRICK, J. A., 6 Crosby Square, Bishopgate Street, London, Eng. '76
*HERRICK, J. T., Fairplay, Park Co., Colorado. '82
*HEWETT, G. C., Winifrede, Kanawha Co., W. Va. '83
*HEWITT, ABRAM S., 17 Burling Slip, New York City. '71
*HEWITT, GEORGE H., 2 Wall Street, New York City. '80
†HEYWOOD, GEORGE H., Gardner, Mass. '83
*HIBBARD, HENRY D., Norway Iron Co., S. Boston, Mass. '79
*HIBBS, JAMES M., 1330 Buttonwood Street, Philadelphia. '83
†HICKOX, CHARLES V., 175 Dearborn Street, Chicago, Ill. '84
†HILDRETH, R. W., 25 Madison Ave., New York City. '85
†HILDRETH, WALTER E., 52 Broadway, New York City. '75
*HILL, FRANK A., 1600 Arch Street, Philadelphia. '83
*HINCHMAN, CHARLES S., 208 S. Fourth Street, Philadelphia. '79
*HITCHCOCK, PROF. C. H., State Geologist, Hanover, N. H. '79
*HITCHCOCK, E. A., St. Louis Ore And Steel Co., St. Louis, Mo. '80
*HOATSON, THOMAS, Calumet, Michigan. '80
*HODGES, A. D., JR., 97 Mt. Pleasant Ave., Roxbury, Mass. '84
*HOFFMAN, E. O., Care Barney & Smith M'f'g Co., Dayton, O. '84
*HOFFMAN, JOHN W., 208 S. Fourth Street, Philadelphia. '76
*HOFFMANN, OTTOKAR, Corner 5th And Bryant Streets, San Francisco, Cal. '84
*HOFMAN, H. O., 2102 Mt. Vernon Street, Philadelphia. '82
*HOFFSTOTT, F. N., P. O. Box 177, Pittsburgh, Pa. '82
*HOLBROOK, F. N., El Paso, Texas. '75
†HOLBROOK, LEVI, P.O. Box 536, New York City. '78
*HOLLENBECK, J. I., Audenried, Carbon Co., Pa. '82
*HOLLERITH, HERMAN, 617 Seventh Street, Washington, D. C. '83
*HOLLOWAY, J. F., Detroit And Center Streets, Cleveland, Ohio. '75
*HOLMAN, F. C., Mansfield Valley, Pa. '81
†HOLT, GEORGE H., Crested Butte, Gunnison Co., Colorado. '82
*HOOKER, W. A., 2 Wall Street, New York City. '80
*HOOPER, WILLIAM, Ticonderoga, N. Y. '78
*HORTON, N. W., 23 Park Place, New York City. '77
*HOTCHKISS, JED., Staunton, Va. '79
*HOUGHTELING; JAMES L., 244 S. Water Street, Chicago, Ill. '84
*HOUSTON, C. B., Thurlow, Delaware Co., Pa. '83
*HOUSTON, T. J., Thurlow, Delaware Co., Pa. '82
*HOWALD, FERDINAND, Fire Creek, Fayette Co., W. Va. '84
*HOWE, FRANK P., Danville, Pa. '79
*HOWE, HENRY G., P. O. Box 196, Tombstone, Arizona. '83
*HOWE, HENRY M., 75 State Street, Boston, Mass. '71
*HOWELL, BENJAMIN P., Scottdale, Pa. '84
*HUBER, H., SOCORRO, N. M. '82
*HULBERT, EDWIN J., Middletown, Conn. '74

†HULBERT, THOMAS H.,.. Middletown, Conn. 81
†HULICK, WILLIAM H., ... Easton, Pa. '82
*HULST, NELSON P., ... 300 Knapp Street, Milwaukee, Wis. '76
†HUMBERT, WILLIAM S.,.................................. 7 Nassau Street, New York City. '83
*HUMPHREY, CHAS., ... Carlisle, N. M., Via Lordsburg. '85
*HUMPHREY, D. W., ... 902 Cedar Avenue, Scranton, Pa. '82
*HUMPHREY, GEORGE S.,.. Ithaca, N. Y. '84
*HUMPHREYS, ALEX. C.,.................................. 333 Walnut Street, Philadelphia. '85
*HUMPHREYS, A. W.,................................... 45 William Street, New York City. '72
*HUNGERFORD, W. S., ... Low Moor, Va. '82
†HUNICKE, AUG.,................................... Washington University, St. Louis, Mo. '83
*HUNT, ALFRED E.,....................................... 98 Fourth Avenue, Pittsburgh, Pa. '79
*HUNT, FRED. F., ... P. O. Box 335, Quebec, Canada. '80
*HUNT, JOSEPH, ... Catasauqua, Pa. '71
*HUNT, JOSHUA, ... Catasauqua, Pa. 78
*HUNT, ROBERT W., ... Albany And Rensselaer Iron And Steel Co., Troy, N. Y. '74
*HUNT, DR. T. STERRY, ... Montreal, Canada. '71
†HUNTINGTON, FRED. W.,....................... 109 S. Oxford Street, Brooklyn, N. Y. '85
*HUTCHINSON, E. S.,.. Newtown, Pa. '80
*HUTTER, E. S.,.. Honston Mines, Botetourt Co., Va. '83
*HUTTON, FRED. R.,........................... 6 W. Thirty-Third Street, New York City. '75
*HUTTON, WILLIAM R.,....................................... 35 Broadway, New York City. '82

*IHLSENG, AXEL O.,..Golden, Colorado. '82
†INGHAM, WILLIAM A.,......................................320 Walnut Street, Philadelphia. '72
*INMAN, ALVIN L.,... Plattsburgh, N. Y. '76
*IRVING, PROF. ROLAND D.,................ University Of Wisconsin, Madison, Wis. '72
*IRVING, WILLIAM, ... Chicago Club, Chicago, Ill. '81
†IRWIN, JOHN H., ... Morton, Delaware Co., Pa. '81

*JACKSON, EDWARD F.,...................... 3706 Washington Avenue, St. Louis, Mo. '83
*JAMES, ISAAC E.,.. Duncan, Arizona. '82
*JAMES, REESE,... South Pueblo, Colorado. '79
*JAMES, SAMUEL, JR., ... Rico, Colorado. '76
*JAMES, THOMAS, ... Braddock, Pa. '83
†JAMES, DR. WALTER M., ... 1123 Spruce Street, Philadelphia, Pa. '84
†JAMES, WILLIAM, ... St. James, Phelps Co., Mo. '82
*JAMME, GEORGE, ... Londonderry, Nova Scotia. '79
*JANIN, ALEXIS,... 610 Hyde Street, San Francisco, Cal. '85
*JANIN, HENRY, ... 12 Fifth Avenue, New York City. '72
*JANIN, LOUIS,.. 310 Pine Street, San Francisco, Cal. '72
*JANNEY, MORRIS P.,.. Pottstown, Pa. '74
†JARVIS, W. F., ... 34 Campan Building, Detroit, Mich. '84
*JENNEY, WALTER P., ... Box 283, Hailey, Idaho. '74
*JENNINGS, E. P., ... Sterlington, Rockland Co., N. Y. '76
*JENNINGS, HENNEN, ... Quicksilver Mining Co., New Almaden, Cal. '84
*JENNINGS, W. H., ... C. H. V. & T. Railway, Columbus, O. '84
*JETER, J. TINSLEY,.. Wilkesbarre, Pa. '84
*JEWELL, EDWARD E.,.................................. Calumet I. & S Co., Cummings, Ill. '84
*JEWETT, ELIOT C.,.. U. S. Assay Office, St. Louis, Mo. '81
*JOHNSON, LIEUT. D. D.,.. Fort Monroe, Va. '82

*JOHNSON, ISAAC G., ... Spuyten Duyvil, New York City. '79
*JOHNSON, J. E.,.. Longdale, Alleghany Co., Va. '80
*JOHNSON, W. G., ... Pine Grove, Pa. '84
*JOHNSTON, WALTER N., ... Buchanan, Botetourt Co., Va. '81
*JOLLIFFE, WILLIAM, ... Lexington, Va. '81
*JONES, B. F.,.................................... Jones & Laughlin's Works, Pittsburgh, Pa. '78
*JONES, D. N.,..................... Colorado Coal And Iron Co., Bessemer, Colorado. '75
*JONES, GRIFFITH,.. Pottstown, Pa. '81
*JONES, JOHN T.,.. Quinnesec, Menominee Co., Mich. '80
*JONES, R. R., ... Union Iron And Steel Co., Chicago, Ill. '82
*JONES, T. CATESBY, ... Va. Nail & Iron Works, Lynchburg, Va. '81
*JONES, THOMAS D., ... Ebervale, Pa. '75
†JONES, THOMAS D., ... 33 Portland Block, Chicago, Ill. '84
*JONES, W. R., ... Braddock, Pa. '75
*JONES, WASHINGTON, ... 1632 N. Fifteenth Street, Philadelphia. '81
*JOPLING, JAS. E., ... Marquette, Mich. '84
*JOUET, C. H.,.. Roselle, N. J. '83
*JUDSON, JNO. N., ... 2201 Park Ave., St. Louis, Mo. '84
†JULIAN, FRANK,.................................. Iron Mountain, Menominee Co., Mich. '81
*KAERCHER, EDW. E., ... Shamokin, Pa. '84
*KAUFMAN, WILLIAM M.,.. Reading, Pa. '84
*KAY, PROF. EDGAR B.,... 18 Fourth Street, Troy, N. Y. '83
*KEAN, JOHN, JR., ... Elizabeth, N. J. '81
*KEARNEY, HENRY S., ... P. O. Box 338, Leadville, Colorado. '82
*KEBLER, ELIOT A., ... Newport, Ky. '84
*KEBLER, JULIAN A., ... Ottumwa, Iowa. '85
*KEELEY, JEROME,.. 206 Walnut Place, Philadelphia. '76
*KEEN, BARTON L., ... 175 Dearborn Street, Chicago, Ill. '84
†KEITH, H. A., ... Chicago, Ill. '84
*KEITH, N. S., ... 9 Murray Street, New York City. '76
*KELLER, ARTHUR H., ... P. O. Box 48, Silverton, Colorado. '83
*KELLER, HERMANN A., ... P. O. Box 267, Leadville, Colorado. '81
*KEMP, WILLIAM, ... Troy, N. Y. '83
*KEMPTON, C. W., ... 61 Broadway, New York City. '75
KENNEDY, HUGH,.. Etna, Allegheny Co., Pa. '81
*KENNEDY, JOHN S., ... Lock Box 5, Steelton, Dauphin Co., Pa. '81
*KENNEDY, JULIAN, ... Braddock, Allegheny Co., Pa. '79
*KENT, JOSEPH C., ... Phillipsburg, N. J. '72
*KENT, R., ... Standard Steel Works, Lewistown, Pa. '84
*KENT, WILLIAM ST. G.,.. Phoenixvillle, Pa. '72
*KENT, WILLIAM, ... Babcock & Wilcox Co., 30 Cortlandt St., New York City. '76
†KERR, THOMAS B.,................................... 110 Diamond Street, Pittsburgh, Pa. '82
*KERR, PROF. W. C., ... Raleigh, N. C. '76
*KEYES, W. S., ... P. O. Box 1716, San Francisco, Cal. '72
*KIDDIE, THOMAS,................. P. O. Box 44, New Brighton, Staten Island, N. Y. '82
*KIMBALL, HIRAM, ... City Forge, Cleveland, Ohio. '82
*KIMBALL, DR. J. P., ... Lehigh University, Bethlehem, Pa. '72
*KINEALY, JAMES R., ... Baden, St. Louis City. Mo. '83
*KING, CHARLES F.,... Steelton, Dauphin Co., Pa. '80
*KING, DANIEL, ... Pine Grove Furnace, Cumberland Co., Pa. '81

*KING, FRANK, ... Van Buren Furnace, Shenandoah Co., Va. '81
†KING, J. H., ... Painesville, Lake Co., Ohio. '80
*KING, THOMAS M.,... B. & O. R. R., Pittsburgh, Pa. '82
*KINGSLEY, J. COOK, ... P. O. Box 48, Silverton, Colorado. '82
*KINKEAD, MAX., ... Altoona, Pa. '82
†KIRBY, EDMUND B., ... Oregon Avenue And Juniata Street, St Louis, Mo. '84
*KIRCHHOFF, CHARLES, JR.,.. 83 Reade Street, N. Y. '75
*KLEPETKO, FRANK, ... Opechee, Houghton Co., Mich. '80
*KNAP, CHARLES, ... 1730 H Street, Washington, D. C. '81
*KNAP, JAMES G., ... Ogdensburgh, N. Y. '80
*KNAP, JOSEPH M., ... 365 West Street, New York City. '81
*KNIGHT, ALBERT B., ... Virginia City, Montana. '84
*KNIGHT, E.,... Albany Iron Works, Troy, N. Y. '83
*KNORR, A. E., ... 1344 R Street, N. W., Washington, D. C. '83
*KNOX, JOHN H., ... Lebanon, Hunterdon Co., N. J. '80
*KOENIG, PROF. GEORGE A.,........ University Of Pennsylvania, W. Philadelphia. '74
*KRAMER, FRANK J.,... Parryville, Carbon Co., Pa. '81
*KRIETE, HENRY C.,.................................. 17 Metropolitan Block, Chicago, Ill. '84
*KROM, S. R., ... 93 Washington Street, New York City. '85
*KUNHARDT, WHEATON B., ... 32 Beaver Street, New York City. '80

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*LAGERFELT, C. O., ... 15 Cortlandt Street, New York City. '81
†LAMBERTON, WILLIAM B., ... 216 Market Street, Harrisburg, Pa. '83
*LAMBORN, DR. ROBERT H.,.......................... 32 Nassau Street, New York City. '76
*LANE, J. S., ... Akron, Ohio. '80
*LANDIS, EDWARD K., ... 264 S. Thirty-Eighth Street, Philadelphia. '82
*LANDSBERG, E., ... Aachen, Germany. '83
*LANGDON, N. M.,... Pen Argyl, Pa. '81
*LATHROP, W. A.,.. Snowshoe, Center Co., Pa. '83
*LAUDER, GEORGE,........................... Larimer's Station, Westmoreland Co., Pa. '78
*LAUREAU, L. G., ... 226 Walnut Street, Philadelphia, Pa. '78
*LAWRENCE, BENJAMIN B.,........................ Montezuma, Summit Co., Colorado. '82
*LAWRENCE, W. L., ... Burden, Columbia Co., N. Y. '83
†LEARY, DANIEL J.,... 138 Keap Street, Brooklyn, N. Y. '81
*LEAVITT, E. D., JR., ... 604 Main Street, Cambridgeport, Mass, 76
*LEAVITT, W. A., ... 2032 N. Twenty-Second Street, Philadelphia. '81
†LE BARON, J. FRANCIS,... Jacksonville, Fla. '84
*LECKIE, ROBERT G., ... Sherbrooke, Quebec, Canada. '79
†LEE, GEO. B., ... School Of Mines, New York City. '85
*LEE, R. H., ... Lewistown, Pa. '76
*LEE, R. H., JR., ... Lewistown, Pa. '83
*LEE, RICHARD HENRY, ... Duluth, Minn. '76
*LEGGETT, THOMAS H., ... Flushing, L. I., N. Y. 82
*LEHMAN, A. E, ... 711 Walnut Street, Philadelphia. '83
†LEHMAN, F. L.,... 99 John Street, New York City. '82
*LEISENRING, E. B., ... Mauch Chunk, Carbon Co., Pa. '82
*LEITH, ALEXANDER J.,.. 11 Pine Street, New York City. '79
*LENNIG, NICHOLAS,....................................... 112 S. Front Street, Philadelphia. 82
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*LEWIS, JAMES B., ... Dover, N. J. '75
*LEWIS, JAMES F., ... 23 Park Place, New York City. '75
*LEWIS, JOHN C., ... 22 Cortlandt Street, New York City. '80
†LEWIS, SAMUEL W., ... 55 Broadway, New York City. 82
*LILIENBERG, N., ... 150 Broadway, New York City. '84
*LILLY, WILLIAM, ... Mauch Chunk, Pa. '79
*LINCOLN, CHARLES J., ... English High School, Boston. Mass. '83
*LINDGREN, WALDEMAR, ... P. O. Box 2160, San Francisco, Cal. '84
*LINDSLEY, STUART, ... Orange, N. J. '82
*LITTLE, FRANK J., ... North Chicago Rolling Mill Co., S. Chicago, Ill. '84
*LIVINGSTON, HERMAN, ... Catskill Station, Columbia Co., N. Y. '82
*LOBANOFF, PAUL F., ... 277 Lasalle Avenue, Chicago, Ill. '83
*LODGE, RICHARD W., ... North Chicago Rolling Mill Co., So. Chicago, Ill. '83
†LOGAN, JOHN P., ... 319 Walnut Street, Philadelphia. '83
*LOISEAU, E. F., ... 1326 Girard Ave., Philadelphia. '73
*LOISEAU, OSCAR, ... Ougrée, Belgium. '82
*LONG, JOHN C., ... Mont Alto, Franklin Co., Pa. '81
*LONG, WILLIAM H., ... Fairlee, Vermont. '82
*LONGACRE, ORLEANS, ... 141 Centre Street, New York City. '81
*LONGNECKER, G. A., ... Mechanicsburg, Pa. '83
*LORD, PROF. N. W., ... Ohio State University, Columbus, Ohio. '75
*LORD, R. F., ... Georgetown, Colorado. '82
†LUCE, EDWARD M., ... Milwaukee, Wis. '84
†LUDLAM, JOSEPH S., ... Lowell, Mass. '81
*LUKENS, JAWOOD E., ... Conshohocken, Pa. '84
†LUNN, MAURICE J., ... Lewis Block, Pittsburgh, Pa. '84
*LUTHER, HENRY M., ... Ashland, Pa. '84
*LUTHER, R. C., ... Pottsville, Pa. '84
*LUTSCHER, GAUDENZ, ... Care Of Otis I. & S. Co., Cleveland, Ohio. '85
*LUTTGEN, EBERHARD, ... Catasauqua, Pa. '85
*LYMAN, BENJAMIN SMITH, ... Northampton, Mass. '71
†LYMAN, FRANK, ... 130 Water Street, New York City. '77

†MCCALLUM, WM. H., ... New Glen Echo Mills, Wayne Junction, Philadelphia. '84
*MCCANDLESS, E. V., ... Pittsburgh, Pa. '79
*MCCAY, DR. L. W., ... Princeton College, Princeton, N. J. '85
*MCCLELLAN, ARTHUR, ... Drifton, Luzerne Co., Pa. '71
*MCCLURE, ROBERT J., ... C. B. & Q. R. R. Co., Chicago, Ill. '84
*MCCOMB, A. M., ... 93 Lake Street, Chicago, Ills. '80
*MCCORMICK, HENRY, ... Harrishurg, Pa. '74
*MCCREATH, ANDREW S., ... 223 Market Street, Harrishurg, Pa. '75
*MCCULLOH, E. A., ... P. O. Box 2346, New York City. '80
*MCDERMOTT, WALTER, ... 2 Wall Street, New York City. '74
*MCDOWELL, FREDERICK H., ... 120 Liberty Street, New York City. '78
†MCELMELL, THOMAS A., ... Keams Cafion, Apache Co., Arizona, '82
*MCFADYEN, JOHN, ... Johnstown, Pa. '78
*MCGINNESS, MAJOR J. R., ... Jefferson Barracks, St. Louis Co., Mo. '79
*MCGUFFIN, J. A., ... Sewell Depot, C. & O. Ry., Fayette Co., Va. '81
†MCINTOSH, WILLIAM A., ... 41 Fifth Avenue, Pittsburgh, Pa. '79
†MCKENZIE, DR. JOHN C., ... 328 Montgomery Street, San Francisco, Cal. '82
*MCKEOWN, S. W., ... Youngstown, Ohio. '83

*McLanahan, J. King, ... Hollidaysburg, Pa. '81
*McLeavy, John, ... Punxsutawney, Pa. '75
*McLeod, H. S., ... Troy, N. Y. '83
*McMillan, ... PROF. CHAS., Princeton, N. J. '84
*McNair, Thomas S., ... Hazleton, Pa. '71
*Macdonald, Charles, ... 18 Broadway, New York City. '75
*Mackintosh, James B., ... 55 Garden Street, Hoboken, N. J. '76
*Macy, Arthur, ... Silver King, Arizona. '76
*Maffet, W. R. .... Wilkes-Barre, Pa. '74
*Mahon, Prof. R. W., ... Lafayette College, Easton, Pa. '83
*Male, John,. .... Troy, N. Y. '83
*Mann, H. F., ... P.O. Box 1028, Pittsburgh, Pa. '79
*Manning, Thomas, ... 53 Beaver Street, New York City. '82
*March, William J., ... Ribon & March, Jersey City, N. J. '80
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*Markham, Alfred, ... Markhamville, N. B, Canada. '82
*Markle, John, ... Jeddo, Luzerne Co, Pa. '79
*Marple, William M., ... Scranton, Pa. '81
*Mars, John H., ... Albany, N. Y. '81
*Marshall, Charles A., ... P. O. Box 766, Johnstown, Pa. '82
*Martin, E. P., ... Dowlais, Glamorgan, Wales. '81
*Martin, R. L., ... Fairchance, Fayette Co., Pa. '81
*Martine, Charles A., ... Georgetown, Colorado. '79
*Martyn, William, ... 18 Brighton Street, Charlestown, Mass. '83
*Marvin, Selden E., ... Albany, N. Y. '78
*Mason, Prof. William P., ... Troy, N. Y. '83
†Massie, Frank A., ... Vesuvius, Va. '82
Masters, W. U., ... Cleveland, Ohio. '79
*Mather, Samuel., ... 1011/2 Water Street, Cleveland, Ohio. '79
*Mathieu, Jean A., ... 832 Walnut Street, Philadelphia. '82
*Mathis, T. S., ... Telluride, Colorado. '79
*Mattes, W. F., ... Scranton, Pa. '81
*Matthiessen, F. W., ... Lasalle, Ill. '84
*Maury, M. F., ... Avondale, Cincinnati, Ohio. '74
*Maxon, John H., ... 2305 Washington Avenue, St. Louis, Mo. '74
*Maxwell, J. R., ... Hamilton, Ohio. '84
*Maxwell, J. W., ... 46 Kellogg Street, Syracuse, N. Y. '81
*May, De Courcey, ... 1230 Spruce Street, Philadelphia. '79
*May, William A., ... Lock Box 173, Scranton, Pa. '77
*Maynard, George W., ... 35 Broadway, New York City. '71
*Mayo, James H., ... 1 Broadway, New York City. '82
*Meade, Spencer, ... N. Central Railway Co., Elmira, N. Y. '81
†Means, Archibald, ... Peru, La Salle Co, Ill. '82
*Meier, John W., ... 102 N. Main Street, St. Louis, Mo. '74
†Meigs, Prof. John, ... Pottstown, Pa. '81
*Meily, James, ... Wilmington, Del. '83
*Meister, Herman, ... 3013 Mararamec Street, Station B, St. Louis, Mo. '77
*Mell, Prof. P. H., Jr., ... Auburn, Alabama. '79
*Mercur, Frederick, ... Wilkes-Barre, Pa. '71
†Merrill, F. J. H., ... 126 E. Sixtieth Street, New York City. '85
*Merritt, William Hamilton, ... 15 Toronto Street, Torouto, Canada. '79

†MERRYWEATHER, GEORGE, ... 94 Dearborn Street, Chicago, Ill. '80
*METCALF, O., ... Colorado Springs, Colorado. '79
*METCALF, WILLIAM, ... Pittsburgh, Pa. '75
*MEYER, CARL., ... Limburg, A. D. L., Germany. '83
*MICHAELIS, CAPT. O. E., ... Frankford Arsenal, Philadelphia. '82
*MICKLEY, EDWIN, ... Hokendauqua, Pa. '74
*MILLER, CHARLES W., ... Aspen, Colorado. '84
*MILLER, HORACE B., ... 96 Fulton Street, New York City. '81
*MILLER, REUBEN, ... Pittsburgh, Pa. '75
*MILLIKEN, GEORGE F., ... Room 27, 120 Broadway, New York City. '79
*MILLS, FRANK P., ... Stambaugh, Mich. '83
*MILLS, JAMES E., ... Quincy, Plumas Co., Cal. '77
*MILNES, WILLIAM, JR., ... Milnes, Page Co., Va. '82
*MOEN, PHILIP W., ... Worcester, Mass. '82
*MOFFAT, E. S., ... Scranton, Pa. '71
MONELL, JOSEPH T., ... P. O. Box 49, Bonne Terre, Mo. '81
MOORE, CHARLES J., ... P. O. Box 1247, Leadville, Colorado. '82
*MOORE, JAMES, ... Sixteenth And Buttonwood Streets, Philadelphia. '75
*MOORE, LYCURGUS B., ... 96 Fulton Street, New York City. '81
*MOORE, PHILIP N., ... Olympia, Bath Co., Ky. '74
†MOORE, WILLIAM P., ... 172 Bank Street, Norfolk, Va. '83
*MORGAN, CHARLES H., ... Worcester, Mass. '74
*MORGAN, JAMES, ... 2528 Sarah Street, Pittsburgh, Pa. '79
*MORGAN, JOSEPH, JR., ... Johnstown, Pa. '81
*MORGAN, T. R., ... Alliance, Ohio. '78
*MORISON, GEORGE S., ... 35 Wall Street, New York City. '79
*MORRELL, T. T., ... Cambria Iron Co., Johnstown, Pa. '79
*MORRIS, HENRY G., ... 209 S. Third Street, Philadelphia. '84
†MORRIS, ISRAEL W, ... 238 S. Third Street, Philadelphia. '75
*MORRIS, S. FISHER., ... Box 790, Yonkers, N. Y. '74
*MORRIS, WILLIAM H., ... 400 Chestnut Street, Philadelphia. '81
*MORSE, H. G., ... Youngstown, Ohio. '81
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*MORSE, PHILIP S., ... P. O. Box 219, Pueblo, Colorado. '84
*MOSES, ALFRED J., ... School Of Mines, New York City. '82
*MOSS, PROF. MILTON, ... Colorado School Of Mines, Golden, Colorado. '82
*MOYER, HORACE I, ... Eckley, Pa. '82
*MUDD, SEELEY W., ... 500 N. Jefferson Avenne, St. Louis, Mo. '83
*MUHLENBERG, N. H., ... Lake Valley, New Mexico. '81
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*MUNSON, GEORGE C., ... Lock Box 1910, Denver, Colorado. '7
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*MURRAY, GEORGE, ... 235 West Twenty-Third Street, New York City. '82
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*NEALE, GEO. F., ... Crystal City, Mo. '85
*NEFTEL, KNIGHT, ... 32 Liberty Street, New York City. '81
*NEILL, JAMES W., ... Mine La Motte, Madison Co., Mo. '79
*NEILL, WILLIAM L., ... Solvay Process Co., Syracuse, N. Y. '80
*NEILSON, JAMES, ... Youngstown, Ohio. '79
*NEILSON, WILLIAM G., ... 3703 Chestnut Street, Philadelphia. '72

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†NEWBROUGH, WILLIAM,............. 128 W. Thirty-Fourth Street, New York City. '83
*NEWELL, JOHN E., ... North Chicago Rolling Mill Co., S. Chicago, Ill. '84
*NICHOLS, EDWARD.,.. Hermitage, Ga. '73
*NICHOLSON, A. H.,..... Care Of Harriman & Co., Trinidad, British West Indies. '82
*NICHOLSON, FRANK, ... 2230 Randolph Street, St. Louis, Mo. '80
*NOBLE, CHARLES M., ... Anniston, Alabama. '80
*NOBLE, SAMUEL,.. Anniston, Alabama. '81
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*NOYES, WILLIAM, ... 2023 Summit Street, Oakland, Cal. '84
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*OGLEBAY, EARL W., ... Wheeling, W. Va. '80
*OLCOTT, E. E., ... 4 Warren Street, New York City. '74
*OLHAUSEN, J. H., ... Pottsville, Pa. '84
*OLIVER, HENRY W., JR.,....................... Oliver Bros. & Phillips, Pittsburgh, Pa. '7?
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*ORDWAY, PROF. J. M., ... Tulane University, New Orleans, La. '73
*ORMROD, GEORGE,EMAUS, ... Lehigh Co., Pa. '81
*ORTON, PROF. EDWARD, ... State University, Columbus, Ohio. '83
*OSTRANDER, F. A.,... Troy, N. Y. '83
†OUTHW AITE, JOSEPH H., ... 101 St. Clair Street, Cleveland, Ohio. '81
*OXNARD, B. A,................................. Water And Dock Streets, Brooklyn, N. Y. '76

*PADDOCK, J. H., ... St. Johnsbury, Vt. '82
*PAGE, WALTER TAYLOR,...................... Grant Smelting Co., Denver, Colorado. '82
*PAGE, WILLIAM BYRD,.. Leadville, Colorado. '77
*PAGE, WILLIAM N., ... Goshen Bridge, Va. '80
†PAINTER, AUGUSTUS E. W.,........................... J. Painter & Sons, Pittsburgh, Pa. '73
†PAINTER, WILLIAM R., ... Carrollton, Mo. '82
*PARDEE, A., JR., ... 237 S. Third Street, Philadelphia. '75
*PARDEE, I. P., ... Stanhope, N. J. '73
*PARK, WILLIAM G., ... Park, Bro. & Co., Pittsburgh, Pa. '81
*PARKER, RICHARD A., ... Atlanta, Idaho. '82
*PARKER, RUSSELL, ... 707 Pine Street, St. Louis, Mo. '82
*PARKES, JOHN C.,.................................... 17 Metropolitan Block, Chicago, Ill. '75
*PARKHURST, H. W.,.... Care Of G. S. Morison, 35 Wall Street, New York City. '82
*PARKIN, CHARLES, ... Pittsburgh, Pa. '75
*PARROTT, EDWARD M.,.................. Greenwood Iron Works, Orange Co., N. Y. '79
*PARROTT. R. D. A., ... Greenwood Iron Works, Orange Co., N. Y. '79
†PARSONS, CHARLES B., ... Bonne Terre, St. Franeois Co., Mo. '74
*PARSONS, CHARLES O., ... 77 State Street, Boston, Mass. '74
*PATCH, MAURICE B.,.. Houghton, Mich. '83
*PATTERSON. J. C.,.. 1919 Spruce Street, Philadelphia. '83
*PAYNE, C. Q.,.................. Yale & Towne Manufacturing Co., Stamford, Conn. '81

*PEARCE, RICHARD., ... Argo, Colorado. '74
†PEARIS, CHARLES F., ... Brush Electric Light Works, Cleveland, Ohio. '83
*PEARSALL, H. D., ... Care Of Mander Bros. & H Arper, Grace Church Street, London, England. '82
*PEARSE, JOHN B., ... Roxbury, Mass. '72
*PEARSON, JOHN M., ... Hudson, Columbia Co., N. Y. '82
*PEARSON, JOHN E., ... 59 Moffat-Kassler Block, Denver, Colorado. 82
*PEASE, F. N., ... Altoona, Pa. '82
*PECHIN, EDMUND C., ... 153 Water Street, Cleveland, Ohio. '71
*PECKITT, LEONARD, ... Reading Iron Works, Reading, Pa. '83
*PEELE, R., JR., ... Bloomfield, N. J. '83
*PERKINS, H. C., ... El Callao Mining Co., Ciudad-Bolivar, Venezuela, Via Port Of Spain. 81
*PERRY, NELSON W., ... 238 Auburn Avenue, Cincinnati, Ohio. '76
*PERRY, W. A., ... 86 Liberty Street, New York City. '83
*PETERS, E. D., JR., ... Care Of Dr. Cushing, Percival Ave., Dorchester, Mass. '85
*PETERS,RICHARD, JR., ... Thurlow, Pa. '84
*PETERS, SAMUEL, ... Portland Rolling Mill, Portland, Maine. '83
*PETTEE, PROF. WILLIAM H., ... University Of Michigan, Ann Arbor, Mich. '71
*PETTIGREW, CHARLES, ... Joliet, Ill. '84
*PETTIT, ROBERT E., ... Jersey City, N. J. '81
*PETRE, AXEL, ... Midvale Steel Works, Nicetown, Philadelphia. '83
*PHILLIPS, ENOCH, ... Radford, Pulaski Co., Va. '83
*PIERCE, FRANK M., ... 10 Park Place. New York City. '83
*PIERCE, H. N., ... 448 Madison Avenue, New York City. '84
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*PLATT, FRANKLIN, ... 615 Walnut Street, Philadelphia. '72
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*PLUEMER, A., ... Fourth And Race Streets, Cincinnati, Ohio. '81
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*POMEROY, RICHARD A., ... Lock Box 5, Georgetown, Colorado. '82
*POMEROY, ... S. Harris.,Pittsfield, Mass. '84
*PORTER, GEORGE A., ... Syracuse, N. Y. '84
*PORTER, J. A., ... Durango, Colorado. '74
*PORTER, J. C., ... Spang Steel And Iron Co., Pittsburgh, Pa. '82
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*POTT, JOHN N., ... Pottsville, Pa. '76
*POTTER, EDWARD C., ... North Chicago Rolling Mill Co., Chicago, Ill. '79
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*PROVIS, THOMAS B., ... 15 Woodberry Grove, Finsbury Park, London, N., Eng. '83
*PUGH, CHARLES E., ... 233 S. Fourth Street, Philadelphia. '81
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*RANDOLPH, MARION, ... 133 Jay Street, Albany, N. Y. '83
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*RATTLE, W. J., ... 58 Grand Arcade Building, Cleveland, Ohio. '84
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†RHODES, JAMES F., ... Cleveland, Ohio. '76
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*RICHARDS. ELLEN H., ... Institute Of Technology, Boston, Mass. '79
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*RICKARD, REUBEN, ... Berkeley, Cal. '84
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*RONALDSON, CHARLES E., ... 1001 Chestnut Street, Philadelphia. '84
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*ROSE, WILLIAM W., JR., ... P. O. Box 2287, Denver, Colorado. '82
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*RUTTMANN, FERD. S., ... 51 Broadway, New York City. '81

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*SCAIFE, WILLIAM LUCIEN,.. Pittsburgh, Pa. '79
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*SCHAUFUSS, ERIC C., ... Wilkesbarre, Pa. '83
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*SHEAFER, P. W.,... Pottsville, Pa. '74
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*SHEAFER, W. LESLEY, ... Pottsville, Pa. '81
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*SHERRERD, ALEXANDER H., ... Lackawanna Iron And Coal Co., Scranton, Pa. '75
*SHERRERD, JOHN M.,..... Albany And Rensselaer Iron & Steel Co., Troy, N. Y. '80
*SHIMER, PORTER W.,... Easton, Pa. '79
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*SILLIMAN, PROF. J. M.,....................................... Lafayette College, Easton, Pa. '71
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*SINGER, WILLIAM H., ... 83 Water Street, Pittsburgh, Pa. '73
*SINGER, R. R., ... 83 Water Street, Pittsburgh, Pa. '79
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*SLUDER, EDWIN E., ... Cerillos, N. Mexico. '83
*SMALL, GEO. W., ... Oconomowoc, Wis. '85
*SMALLEY, W. A., ... Silver City, New Mexico. '80
*SMITH, FRANK C., ... Richland Center, Wis. '84

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*SMYTH, C. H., ... Franklin Iron Works, Oneida Co., N. Y. '82
*SNYDER, J. F., ... 1015 Vine Street, Scranton, Pa. '76
*SOULE, R. H., ... Frankfort, N. Y. '81
*SPEER, JOHN Z.,.. Shoenberger & Co., Pittsburgh, Pa. '79
†SPENCER, WILLIAM, ... Buck Mountain, Carbon Co., Pa. '72
†SPERR, FRED W.,................................. Care A. W. Thurman, Columbus, Ohio. '82
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*SPILSBURY, E. G.,... Haile Mine, S. C. '73
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*SQUIRE, JOSEPH,... Helena, Shelby Co., Alabama. '71
*STAFFORD, C. EDWARD, ... Care Shoenberger & Co., Pittsburgh, Pa. '74
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*STAMBAUGH, H. H., ... Youngstown, Ohio. '82
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*STAUNTON, WILLIAM F., JR.,... Tombstone, Arizona. '83
*STEARNS, I. A.,.. Wilkes-Barre, Pa. '71
*STEARNS, THOMAS B.,................. Colorado Machinery Co., Denver, Colorado. '81
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†STETSON, GEORGE W., ... 69 Wall Street, New York City. '83
*STEVENS, GEORGE W., ... 89 Madison Avenue, Chicago, Ill. '83
*STEVENSON, JOHN, JR.,.. New Castle, Pa. '76
*STEYERN, BALTZAR VON,.. .Fainn, Sweden. '85
*STIRLING, W. R., ... Joliet Steel Co., Chicago, Ill. '84
*STOCKETT, LEWIS,.. Mahanoy City, Pa. '81
*STOIBER, EDWARD G.,... Silverton, Colorado. '77
*STONE, GEN. CHARLES P., ... 55 Liberty Street, New York City. '84
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*SUPPES, MAX,. .... Troy, N. Y. '83
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*VAN SLOOTEN, WM., ... 95 Milk Street, Boston, Mass. '84

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*WEIR, CHARLES G., ... Cheyenne, Wyoming. '82
*WEISER, FRANK P., ... Ashland, Pa. '84
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*WELLS, BARD, ... Pottsville, Pa. '80
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*WHINERY, S., ... Somerset, Ky. '80
*WHITAKER, THOMAS D., ... Cedar Grove, Frankford, Philadelphia. '84
*WHITCOMB, GEORGE D., ... Dearborn & Monroe Streets, Chicago, Ill. '83

*WHITE, WILLIAM, JR., ... Braddock, Allegheny Co., Pa. '79
*WHITING, HENRY A.,............ Care S. A. Blatchford, 16 Exchange Place, N. Y. '85
*WHITING, S. B.,.. Pottsyille, Pa. '71
†WHITMAN, JAMES N, ... P. O. Box 380, Beverly, Mass. '83
†WHITNEY, ELI, JR.,.......................... Whitneyville Armory, New Haven, Conn. '75
*WICKES, GEORGE T.,.. Bozeman, Montana. '76
*WIESTLING, GEORGE B.,....................................... Mont Alto, Franklin Co., Pa. '77
*WIGHT, SIDNEY B., ... Newberry, Mich. '80
*WILES, EDWIN L., ... Springfield Iron Co., Springfield, Ill. '82
*WILEY, WILLIAM H.,...................................... 15 Astor Place, New York City. '81
*WILHELM, A., ... P. O. Box 178, Harrisburg, Pa. '77
*WILKES, JOHN, ... Charlotte, N. C. '83
*WILLIAMS, ALBERT, JR.,....................................... Box 591, Washington, D. C. '82
*WILLIAMS, BEN.,.. Bisbee, Arizona. '82
*WILLIAMS, DAVID,... 83 Reade Street, New York City. '80
*WILLIAMS, PROF. EDWARD H.,...................... Jr.,P.O. Box 463, Bethlehem, Pa. '76
*WILLIAMS, FREDERICK H., ... Box 502, Orange, N. J. '80
*WILLIAMS, PROF. J. F., ... Troy, N. Y. '83
*WILLIAMS, HENRY, ... Butte City, Montana. '75
*WILLIAMS, JOHN J., ... 32 Merchants' Exchange, San Francisco, Cal. '83
*WILLIAMS, JOHN T., ... Forty-Fourth Street And East River, New York City. '74
*WILLIAMS, LEWIS,.. Bishee, Arizona. '83
*WILLIAMS, SAMUEL T., ... Care Of Henry Disston & Sons, Philadelphia. '79
*WILSON, EUGENE B.,................................. Cross Creek Collieries, Drifton, Pa. '83
*WILSON, JOHN A., ... 435 Cherstnut Street, Philadelphia. '76
*WILSON, J. CHESTER, ... 419 Walnut Street, Philadelphia. '84
*WILSON, JOHN T.,................................. Wilson, Walker & Co., Pittsburgh, Pa. '79
*WILSON, JOSEPH M., ... 49 Monument Ave., Charlestown, Mass. '82
*WILSON, N. R.,.. P. O. Box 517, Leadville, Colorado. '81
*WILSON, WILLIAM A.,.. Park City, Utah. '83
*WINSLOW, ARTHUR,.. P. O. Box 274, Raleigh, N. C. '81
†WISHON, WALTER W., ... Colorado Springs, Colorado. '82
*WISTER, JONES,.. 230 S. Fourth Street, Philadelphia. '79
*WITHERBEE, FRANK S., ... Port Henry, Essex Co., N. Y. '76
*WITHERBEE, T. F.,... Port Henry, Essex Co., N. Y. '71
*WITHERBEE, W. C., ... Port Henry, Essex Co., N. Y. '80
*WITHEROW, J. P., ... Lewis Block, 6th Ave. And Smithfield St., Pittsburgh, Pa. '76
*WITHERSPOON, JAMES,.. Laredo, Texas. '81
†WITTMACK, CHARLES A.,` .... P. O. Box 1032, New York City. '82
*WITTMAN, N. B.,......................... Pittsburgh Steel Casting Co., Pittsburgh, Pa. '84
†WOLCOTT, HENRY R., ... Denver, Colorado. '82
*WOLF, THEODORE G., ... Scranton, Pa. '79
*WOLFE, ALBERT H., ... 696 W. Monroe Street, Chicago, Ill. '82
*WOLFF, DR. FR. M., ... 12 Hohenzollernstrasse, Berlin, W., Prussia. '82
*WOLISTON, R. T.,... Galena, Colorado. '85
*WOOD, A. B., ... Ann Arbor, Mich. '82
*WOOD, FREDERICK W., ... Steelton, Danphin Co., Pa. '79
*WOOD, THOMAS D., ... Mckeesport, Pa. '79
†WOOD, W. DEWEES,....................................... 111 Water Street, Pittsburgh, Pa. '83
*WOOD, W. J., ... Collinsville, Conn. '81
*WOODBURY, L. S., ... Calumet, Mich. '80

*WOODWARD, E. H., ... 54 Cliff Street, New York City. '81
*WOODWARD, W. H., ... Wheeling, Ala. '84
*WORTHINGTON, CHAS. C., ... 145 Broadway, New York. '85
*WRIGHT, CHARLES E., ... Marquette, Mich. '80
*WRIGHT, JAMES N, ... Calumet, Mich. '79
*WRIGHT, WHITAKER, ... 413 Walnut Street, Philadelphia. '81
*WURTS, CHARLES P., ... New Haven, Conn. '81
*WÜRGLER, A., ... 7 Rue Viéte, Paris, France. '85

*YARDLEY, THOMAS W., ... Troy, N. Y. '83
*YEATMAN, POPE, ... 503 Ware Ave., St. Louis, Mo. '83
*YOUNG, JAMES B., ... Phoenix Roll Works, Pittsburgh, Pa. '79
*YOUNG, W. D., ... Corner Fifteenth And Etna Streets, Pittsburgh, Pa. '83

*ZACHARIAS, H. C., ... Shamokin, Pa. '84
†ZUKOSKI, EDMUND L., ... 1829 Kennett Place, St. Louis, Mo. '84

Honorary Members, 6; Members, 1202; Associates, 153; Foreign Members, 48.

NOTE.--The Following Names Of Persons Elected At The XLIId Meeting, at Chattanooga, May, 1885, are Not Included In The Above List:

*ANDERSON, J. F. T., ... Tredegar Iron Co., Richmond, Va.
*BARTLETT, JAMES H, ... Standard Building, Montreal, Canada.
†BERRY, WILTON G., ... School Of Mines, New York City.
*CHENHALL, JAMES W., ... Anaconda, Montana.
*COLYAR, LEWIS S., ... Chattanooga, Tenn.
*FROSSARD, JOHN D., ... Montreal, Canada.
*HARGREAVES, HENRY W., ... Dayton, Tenn.
*HILL, J. T., ... Whiteside, Tenn.
*HIMROD, CHARLES, ... 186 Dearborn St., Chicago, Ill.
*JOHNS, L. W., ... Pratt Mines, Ala.
*JOHNSTON, JAMES, ... 417 Straight St., Paterson, N. J.
*LEAVENS, H. W., ... 411 Larimer St., Denver, Colo.
*LIPPINCOTT, J. E., ... Swift's I. & S. Mills, Cincinnati, O.
*MCLENNAN, J. S., ... Sidney, Cape Breton, N. S.
*MALO, ALBERT, ... Puente De Sta. Ana, No. 6 Mexico, Mex.
*MARKLE, ALVAN, ... Hazleton, Pa.
*MILLER, GEORGE S., ... Benwood, W. Va.
*NORTON, S., ... Burden, N. Y.
†OSTERHELD, TH. W., ... Yonkers, N. Y.
*PILLSBURY, D. B., ... Whiteside, Tenn.
*POWELL, WM. H., ... Belleville, Ill.
*RICKARD, THOMAS., ... 58 Lombard St., London, Eng.
*RUEGER, R. C., ... Anaconda, Mont.
*SCOVELL, MINOR, ... Pittsburgh, Pa.
*SHOOK, A. M., ... Tracy City, Tenn.
*SIMPSON, C. D., ... Scranton, Pa.

*STOCKWELL, N. S., U. S. Patent Office, Washington, D. C.
*THROPP, JOSEPH E., Edge Hill, Pa.
*VAN HISE, C. R., Madison, Wis.
†WALKER, JOSEPH R., Salt Lake City, Utah.
*WEIMAR, ASA A., Lebanon, Pa.
*WEIMAR, JOHN A., Lebanon, Pa.
*WESTON, FRANCIS E., Upland, Pa.
*WILDER, J. T., Chattanooga, Tenn.

Deceased.

BLOSSOM, T. M., 1876
BRIGGS, ROBERT, 1882
BRINSMADE, J. B., 1884
BROWN, A. J., 1875
CALDWELL, W. B., JR., 1880
CAMERON, JAMES R., 1881
CHISHOLM, HENRY, 1881
CLARK, HENRY G., 1881
CLEMES, J. P., 1876
CONVERSE, JAMES B., 1883
DADDOW, S. H., 1875
D'ALIGNY, H. F. Q., 1875
DAVIDSON, D. R., 1884
DE PEIGER, R. F. J., 1883
DICKSON, THOMAS, 1884
DRESSER, CHARLES A., 1878
DWIGHT, W. S., 1883
FERNEKES, ANTON, 1884
FIRMSTONE, WILLIAM, 1877
FULLER, JOHN T., 1880
GOULD, ROBERT A., 1878
GRIFFEN, JOHN, 1884
GRUNER, L., 1883
HALL, JAMES F., 1884
HARRIS, STEPHEN, 1874
HEALY, MORRIS, 1881
HOLLEY, A. L., 1882
HUNT, THOMAS, 1872
HUSSEY, C. C., 1884
HYNDMAN, E. K., 1884
INGERSOLL, S. WARREN, 1884
JENNEY, F. B., 1876
JERNEGAN, J. L., 1881
LEE, WASHINGTON, 1872
LEISENRING, JOHN, 1884
LIEBENAU, CHARLES VON, 1875

LORD, JOHN C.,	1872
LORENZ, W.,	1884
LORENZ, W., JR.,	1881
LOWE, FRANCIS A.,	1883
MCINTIRE, HENRY M.,	1880
MCKEE, DAVID,	1884
MACKINTOSH, W. S.,	1884
MACMARTIN, ARCHIBALD,	1881
MANTHEY, WILLIAM,	1883
MICKLEY, J. W.,	1880
MOORE, CHARLES W.,	1877
NEWTON, HENRY,	1877
NEWTON, ISAAC,	1884
PAINTER, HOWARD,	1876
PARK, JAMES, JR.,	1883
PHELPS, WALTER,	1878
PHILLIPS, P. E.,	1884
PIERSON, O. H.,	1882
PLEASANTS, HENRY,	1880
PRIEST, J. R.,	1880
RICHTER, C. E.,	1877
RICKARD, R. H.,	1885
ROBINSON, THOMAS W.,	1880
SANTA MARIA, RAYMUNDO DE,	1883
SAYLOR, DAVID O.,	1884
SCHIRMER, J. F. L.,	1877
SCHUCHARD, CHARLES,	1883
SICKLES, T. E.,	1885
SIEMENS, C. WILLIAM,	1883
SILLIMAN, PROF. B.,	1885
STEITZ, AUGUSTUS,	1876
STERLING, HENRY S.,	1882
STINSON, JOHN M.,	1884
ST. JOHN, I. M.,	1880
STOELTING, HERMANN,	1875
THOMAS, DAVID,	1882
THOMAS, SIDNEY G.,	1885
THOMPSON, PROF. C. O.,	1885
WALZ, ISIDOR,	1877
WARNER, L. E.,	1884
WELCH, ASHBEL,	1882
WENDEL, DR. A.,	1881
WHEATLEY, CHARLES M.,	1882
WHILLDIN, W. I.,	1882
WITHERBEE, J. G.,	1875
WORTHINGTON, HENRY R.,	1880
WRIGHT, HARRISON,	1885
WRIGLEY, H. E.,	1882

TABLE

SHOWING THE OFFICERS OF THE INSTITUTE FROM ITS ORGANIZATION TO THE PRESENT TIME.

The offices of President, Vice-President, Manager, Secretary and Treasurer are indicated by their initials.

	1871	1872	1873	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884	1885
ALEXANDER, JOHN S.,......	…	…	…	M	M	M	…	…	…	…	M	M	M	…	..
ASHBURNER, C. A.,..........	…	…	…	…	…	…	…	..	..	..	…	…	…	…	M
ASMUS, GEORGE, ...	…	…	…	…	…	…	…	M	M	M	..	..	…	..	..
BAYLES, JAMES C., ...	…	…	…	…	…	…	…	…	…	M	M	M	..	P	P
BIRKLNBINE, JOHN, ...	…	…	…	..	..	..	…	…	…	…	…	…	M	M	M
BLAIR, THOMAS S., ...	…	…	…	M	M	M	..	…	…	…	…	…	…	…	..
BLAKE, WILLIAM P., ...	V	V	V	V	…	V	V	…	…	…	…	…	…	…	..
BLANDY, JOHN F.,............	V	V	V	…	…	…	…	V	V	…	…	…	…	…	..
BROOKS, THOS. B., ...	…	M	…	…	…	…	…	…	…	…	…	…	..	…	..
BUCK, STUART M., ...	…	…	…	…	…	…	…	…	…	..	…	…	M	M	M
BURDEN, JAMES A., ...	…	…	…	…	…	…	…	…	…	V	V	…	…	…	..
BURNHAM, WILLIAM,.......	…	…	…	…	…	…	…	…	…	…	…	M	M	M	..
CHURCH, JOHN A., ...	…	…	…	…	…	…	…	…	M	M	M	…	…	…	..
COGSWELL, W. B.,...........	…	…	…	V	V	…	…	…	…	…	…	…	…	…	
COOK, EDGAR S., ...	…	…	…	…	…	…	…	…	…	…	…	…	…	M	M
CORYELL, MARTIN,..........	S	S	M	M	M	…	…	…	…	…	…	…	…	…	..
COX, E. T.,.......................	…	…	…	…	…	…	M	M	M	…	…	…	…	…	..
COXE, ECKLEY B., ...	V	V	V	V	…	V	V	P	P	…	…	…	…	V	V
COXE, WM. E. C., ...	…	…	…	…	…	…	…	…	M	M	M	…	…	…	M
DRINKER, HENRY S.,........	…	…	…	…	…	…	…	…	…	…	…	…	…	…	..
DROWN, THOMAS M., ...	…	M	S	S	S	S	S	S	S	S	S	S	S	…	..
DUDLEY, CHARLES B., ...	…	…	…	…	…	…	…	…	…	V	V	…	…	…	..
EGLESTON, THOMAS, ...	M	V	V	V	…	V	V	…	…	…	…	…	…	V	..
EILERS, ANTON, ...	…	…	…	M	M	M	…	…	…	…	…	M	M	M	V
ELY, T. N.,.......................	…	…	…	…	…	…	…	…	…	…	…	V	V	…	..
EMMONS, S. F., ...	…	…	…	…	…	…	…	…	…	…	…	…	V	V	..
FIRMSTONE. FRANK,.........	…	…	M	..	V	V	..	…	…	…	…	…	…	M	..
FRAZER, PERSIFOR	…	…	…	…	…	…	…	…	…	V	V	…	…	…	M
FRAZIER, B. W., ...	…	…	…	M	M	M	…	M	M	M	…	…	…	…	..
FRITZ, JOHN, ...	…	…	…	…	V	…	…	…	…	…	…	…	…	…	..
GAUJOT, E., ...	…	…	…	…	…	…	…	…	…	…	…	…	…	…	
HEINRICH, OSWALD J.	M	M	…	…	..	..	..	…	…	…	…	…	…	…	V
HEWITT, ABRAM S., ...	…	…	…	..	M	M	M	…	…	…	…	…	…	…	..
HOLLEY, A. L., ...	…	M	M	M	M	P	…	..	…	…	…	…	…	…	..
HOWE, H. M., ...	…	…	…	V	P	…	M	M	M		…	…	…	…	..
HUNT, ROBERT W., ...	…	…	…	…	…	…	…	…	V	V	…	…		…	..
HUNT, T. STERRY,............	…	…	…	…	…	M	M	M	…	…	…	…	P	…	..
KENT. JOSEPH C.,.............	…	…	M	M	M	…	P	…	…	…	…	…	…	…	..
KERR, W. C., ...	…	…	…	V	V	…	…	…	…	…	…	…	…	…	..
KEYES, W. S., ...	…	…	…	…	…	…	…	…	…	…		…	V	V	..
KIMBALI., J. P., ...	…	…	…	…	…	…	…	…	…	M	M	M	…	…	..
LESLEY, J. P.,...................	…	…	…	…	…	…	…	…	…	…	V	V	…	…	..
LEWIS, JAMES F., ...	…	M	M	M	…	…	…	…	…	…	…	…	…	…	..
MACDONALD, CHARLES, ..	…	…	…	…	…	…	…	…	M	M	M	…	…	…	..
MAYNARD, GEORGE W., ..	…	…	…	…	…	…	…	…	…	…	…	V	V	…	..
MCCREATH, ANDREW S.,.	M	M	M	M	…	…	…	…	…	…	…	…	…	M	..
MCNAIR, T. S., ...	…	…	…	…	…	…	…	…	…	…	…	M	M	M	M
METCALF, WILLIAM,........	M	…	…	…	…	…	…	…	…	…	…	…	…	…	..
MOFFAT, E. S.,.................	…	…	…	…	…	…	…	V	V	…	P	…	…	…	..
MUNROE, H. S., ...	…	…	…	…	…	…	…	…	…	…	…	…	M	M	..
NEWBERRY, J. S., ...	…	…	…	…	…	…	…	…	…	…	M	M	M	…	M
PEARSE, RICHARD, ...	…	…	…	…	…	M	M	M	…	…	…	…	…	…	..
PEARSE, JOHN B., ...	…	…	…	…	…	…	V	V	…	…	…	…	…	…	..
PECHIN, E. C., ...	…	M	V	…	V	V	…	…	…	…	…	…	…	V	V
PETHERICK, THOMAS, ...	M	M	…	…	…	…	…	…	…	…	…	…	…	…	V
PETTEE, WM. H.,..............	…	…	M	…	…	…	…	…	…	…	V	V	…	…	..
POTTER. WILLIAM B., ...	…	…	…	…	…	…	…	M	M	M	…	…	…	…	..
POWELL, J. W., ...	…	…	…	…	…	…	…	…	…	…	…	V	V	…	..
PRIME, FRED., JR.,............	M	M	M	…	…	…	…	…	…	…	…	…	…	…	..
PUMPELLY, RAPHAEL,......	M	…	…	…	…	…	…	…	…	…	…	…	…	…	..
RAND, THEODORE D., ...	…	…	T	T	T	T	T	T	T	T	T	T	T	T	..
RANDOLPH, J. C. F., ...	…	…	…	…	…	…	…	…	…	…	M	M	M	…	T
RAYMOND. R. W.,............	V	P	P	P	…	V	V	…	…	…	…	…	…	S	..
RICHARDS, ROBERT H.,....	…	…	…	…	…	…	…	…	V	V	…	…	…	…	S
ROBERTS, PERCIVAL, JR., .	…	…	…	…	…	…	…	…	…	M	M	M	…	…	..
ROTHWELL, RICHARD P., .	M	V	V	…	V	V	…	…	…	…	…	P	…	…	..
SHINN, WILLIAM P., ...	…	…	…	…	…	…	V	V	…	P	…	…	…	…	..
SMOCK, JOHN C., ...	…	…	…	..	M	M	M	…	…	…	…	…	…	…	..
SPILSBURY, E. G., ...	…	…	…	…	…	…	..	..	…	…	…	…	…	…	..
STETEFELDT, C. A.,..........	…	…	…	..	…	…	…	…	…	…	…	…	…	…	M
SWOYER, J. H.,.................	V	…	…	..	…	…		..	…	..	…	…	…	…	V
SYMONS, W. R., ...	V	V	M	M	…	…	…	..	…	..	..	..	…	…	..
THURSTON, ROBERT H., ...	…	…	…	…	…	…	…	V	V	..	..	..	..	..	..
THOMAS, DAVID, ...	P	…	…	…	…	…	…	…	…	..	..	..	..	..	..
THOMAS, SAMUEL,...........	..	…	…	…	…	…	…	…	V	V	..	…	..	..	..
THOMPSON,CHARLES O., .	…	…	…	…	…	..	..	..	…	…	V	V	..	..	..
WELLMAN, S. T., ...	…	…	…	..	..	..	..	..	…	..	..	..	V	V	..
WILLIAMS, T. M., ...	M	…	…	..	..	..	..	..	…	..	..	..	..	..	..
WILLIAMSON, J. PRYOR,.....	T	T	…	..	..	..	..	..	…	..	..	..	..	..	..
WITHERBEE, THOS. F., ...	…	…	…	..	..	M	M	M	…	..	..	..	..	..	..

LIST OF THE MEETINGS OF THE INSTITUTE AND THEIR LOCALITIES FROM ITS ORGANIZATION TO FEBRUARY, 1885.

Number.	Place.	Date.	Transactions.	
I.	Wilkesbarre, Pa.,*	May, 1871,	i.	3
II.	Bethlehem, Pa.,	August, 1871,	i.	10
III.	Troy, N. Y.,	November, 1871,	i.	13
IV.	Philadelphia, Pa.,	February, 1872,	i.	17
V.	New York, N. Y.,*	May, 1872,	i.	20\
VI.	Pittsburgh, Pa.,	October, 1872.	i.	25
VII.	Boston, Mass.,	February, 1873,	i.	28
VIII.	Philadelphia, Pa.,*	May, 1873,	ii.	3
IX.	Easton, Pa.,	October, 1873,	ii.	7
X.	New York, N. Y.,	February, 1874,	ii.	11
XI.	St. Louis, Mo.,*	May, 1874,	iii.	3
XII.	Hazleton, Pa.,	October, 1874,	iii.	8
XIII.	New Haven, Conn.,	February, 1875,	iii.	15
XIV.	Dover, N. J.,*	May, 1875,	iv.	3
XV.	Cleveland, O.,	October, 1875,	iv.	9
XVI.	Washington, D. C.,	February, 1876,	iv.	18
XVII.	Philadelphia, Pa.,†	June, 1876,	v.	3
XVIII.	Philadelphia, Pa.,	October, 1876,	v.	19
XIX.	New York, N. Y.,	February, 1877,	v.	27
XX.	Wilkesbarre, Pa.,*	May, 1877,	vi.	3
XXI.	Amenia, N. Y.,	October, 1877,	vi.	10
XXII.	Philadelphia, Pa.,	February, 1878,	vi.	18
XXIII.	Chattanooga, Tenn.,*	May, 1878,	vii.	3
XXIV.	Lake George, N. Y.,	October, 1878,	vii.	103
XXV.	Baltimore, Md.,*	February, 1879,	vii.	217
XXVI.	Pittsburgh, Pa.,	May, 1879,	viii.	3
XVII.	Montreal, Canada,	September, 1879,	viii.	121
XXVIII.	New York, N. Y.,*	February, 1880,	viii.	275
XXIX.	Lake Superior, Mich.,	August, 1880,	ix.	1
XXX.	Philadelphia, Pa.,*	February, 1881,	ix.	275
XXI.	Staunton, Va.,	May, 1881,	x.	1
XXXII.	Harrisburg, Pa.,	October, 1881,	x.	119
XXXIII.	Washington, D. C.,*	February, 1882,	x.	225
XXXIV.	Denver, Col.,	August, 1882,	xi.	1
XXXV.	Boston, Mass.,*	February, 1883,	xi.	217
XXXVI	. Roanoke, Va.,	June, 1883,	xii.	3
XXXVII.	Troy, N. Y.,	October, 1883,	xii.	175
XXXVIII.	Cincinnati, O.,*	February, 1884,	xii.	447
XXXIX	Chicago, Ill.,	May, 1884,	xiii.	3
XL.	Philadelphia, Pa.,	September, 1884,	xiii.	287
XLI.	New York, N. Y.,	February, 1885,	xiii.	587

* Annual meeting for the election of officers. The rules were amended at the Chattanooga meeting, May, 1878, changing the annual election from May to February.

† Begun in May at Easton, Pa., for the election of officers, and adjourned to Philadelphia.

PUBLICATIONS.

The publications of the Institute comprise:

1. The minutes of the Proceedings of each Meeting, published in pamphlet form.

2. Such of the papers presented or read by title at each Meeting as are furnished by the authors and approved by the Council for full publication. (In nearly all cases in which papers, the titles of which appear in the Proceedings, are not subsequently published, they have been with drawn by the authors.) These papers are published separately in pamphlet form, and are marked "Subject to Revision."

3. Annual volumes of *Transactions,* containing the list of officers and members, rules, etc.; the Proceedings and the papers, *revised for final publication*. (In this revision after the preliminary publication, authors are permitted to use the largest liberty; and the changes and additions made in papers are sometimes important. It should be borne in mind, by those who study or quote a paper in the preliminary edition, that they may not have in that form the ultimate and deliberate expression of the author's views. It should be added, however, that in the majority of cases there is no essential change, the correction of typographical errors and additions of later information being the usual alterations.)

4. Special editions of separate papers, for which there is demand. These are fully revised, and usually issued in pamphlet covers.

5. Books. (Under this head the only publications thus far have been an Index to Vols. I. to X. inclusive, a Glossary of Mining and Metallurgical Terms, and a Memorial of Alexander Lyman Holley.)

All the foregoing publications are sent free to members and associates *not in arrears at the time of publication*. They are also for sale at the office of the Secretary, or are sent to purchasers by mail or express, charges paid, on receipt of the price by the Secretary, as follows:

Classes 1 and 2, above mentioned,-price not uniform-a small sum, in no case exceeding 20 cents per copy, to cover cost of printing, storage, clerk-hire, postage, etc.

Class 3 (*Transactions*), at $5 per volume in paper covers, or $6 bound in half-morocco.

Class 4. This class now includes " Steel Rails " (Papers by Messrs. Sandberg, Dudley and Holley, and discussions at two meetings in 1881, from vol. ix. of the *Transactions),* price $1; "Technical Education"

(Papers and discussions at the XVIIth [Philadelphia] meeting, in 1876 -mostly not in the Transactions), price 50 cents; "The Law of the Apex" (including the Appendix), by R. W. Raymond, price 25 cents; " List of Members, Rules, etc.," price 25 cents.

Class 5. Index to Vols. I. to X., inclusive, of the *Transactions*, price, in paper covers, $1; in half-morocco, $2. "Memorial of Alexander Lyman Holley," in cloth, with frontispiece-portrait, price $2. "Glossary of Mining and Metallurgical Terms," by R. W. Raymond (from vol. ix. of the *Transactions)*, in cloth, price 50 cents.

All communications and remittances should be addressed to R. W. Raymond, Secretary, P. O. Box 223, New York City.

RULES

ADOPTED MAY, 1873. AMENDED MAY, 1875, MAY, 1877, MAY, 1878, FEBRUARY, 1880, and FEBRUARY, 1881.

I.

OBJECTS.

THE objects of the AMERICAN INSTITUTE OF MINING ENGINEERS are to promote the Arts and Sciences connected with the economical production of the useful min erals and metals, and the welfare of those employed in these industries, by means of meetings for social intercourse, and the reading and discussion of professional papers, and to circulate, by means of publications among its members and associates, the information thus obtained.

II.

MEMBERSHIP.

The Institute shall consist of Members, Honorary Members, and Associates. Members and Honorary Members shall be professional mining engineers, geologists, metallurgists, or chemists, or persons practically engaged in mining, metallurgy, or metallurgical engineering. Associates shall include all suitable persons desirous of being connected with the Institute, and duly elected as hereinafter provided. Each person desirous of becoming a member or associate shall be proposed by at least three members or associates, approved by the Council, and elected by ballot at a regular meeting upon receiving three-fourths of the votes cast, and shall become a member or associate on the payment of his first dues. Each person proposed as an honorary member shall be recommended by at least ten members or associates, approved by the Council, and elected by ballot at a regular meeting on receiving nine-tenths of the votes cast; Provided, that the number of honorary members shall not exceed twenty. The Council may at any time change the classification of a person elected as associate, so as to make him a member, or vice versa, subject to the approval of the Institute. All members and associates shall be equally entitled to the privileges of membership; Provided, that honorary members shall not be entitled to vote or to be members of the Council.

Any member or associate may be stricken from the list on recommendation of the Council, by the vote of three-fourths of the members and associates present at any annual meeting, due notice having been mailed in writing by the Secretary to the said member or associate.

III.

DUES.

The dues of members and associates shall be ten dollars per annum, payable in advance at the annual meeting; Provided, that persons elected at the meeting following the annual meeting shall pay eight dollars, and persons elected at the meeting preceding the annual meeting shall pay four dollars as dues for the current year. Honorary members shall not be liable to dues. Any member or associate may become, by the payment of one hundred dollars at any one time, a life member or associate, and shall not be liable thereafter to annual dues. Any member or associate in arrears may, at the discretion of the Council, be deprived of the receipt of publications, or stricken from the list of members when in arrears for one year; Provided, that he may be restored to membership by the Council on payment of all arrears, or by re-election after an interval of three years.

IV.

OFFICERS.

The affairs of the Institute shall be managed by a Council. consisting of a President, six Vice-Presidents, nine Managers, a Secretary and a Treasurer, who shall be elected from among the members and associates of the Institute at the annual meetings, to hold office as follows:

The President, the Secretary, and the Treasurer for one year (and no person shall be eligible for immediate re-election as President who shall have held that office subsequent to the adoption of these rules, for two consecutive years), the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. At each annual meeting a President, three Vice-Presidents, three Managers, a Secretary and a Treasurer shall be elected, and the term of office shall continue until the adjournment of the meeting at which their successors are elected.

The duties of all officers shall be such as usually pertain to their offices, or may be delegated to them by the Council or the Institute; and the Council may in its discretion require bonds to be given by the Treasurer. At each annual meeting the Council shall make a report of proceedings to the Institute, together with a financial statement.

Vacancies in the Council may occur by death or resignation; or the Council may, by a vote of the majority of all its members, declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the Council meetings or perform the duties of his office. All vacancies shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; Provided, that the said appointment shall not render him ineligible at the next annual meeting.

Five members of the Council shall constitute a quorum; but the Council may appoint an Executive Committee, or business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary, and recorded by him with the minutes.

V.

ELECTIONS.

The annual election shall be conducted as follows: Nominations may be sent in writing to the Secretary, accompanied with the names of the proposers, at any time not less than thirty days before the annual meeting; and the Secretary shall, not less than two weeks before the said meeting, mail to every member or associate (except honorary members), a list of all the nominations for each office so received, stamped with the seal of the Institute, together with a copy of this rule, and the names of the persons ineligible for election to each office. And each member or associate, qualified to vote, may vote, either by striking from or adding to the names of the said list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing said altered or prepared ballot with his name, and either mailing it to the Secretary or presenting it in person at the annual meeting: Provided, that no member or associate in arrears since the last annual meeting shall be allowed to vote until the said arrears shall have been paid. The ballots shall be received and examined by three Scrutineers, appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices shall be declared elected, and the Scrutineers shall so report to the presiding officer. The ballots shall be destroyed, and a list of the elected officers, certified by the Scrutineers, shall be preserved by the Secretary.

VI.

MEETINGS.

The annual meeting of the Institute shall take place on the third Tuesday of February, at which a report of the proceedings of the Institute and an abstract of the accounts shall be furnished by the Council. Two other regular meetings of the Institute shall be held in each year, at such times and places as the Council shall select, and notice of all meetings shall be given by mail, or otherwise, to all members and associates, at least twenty days in advance. Special meetings may be called whenever the Council sees fit; and the Secretary shall call a special meeting on a requisition signed by fifteen or more members. The notices for special meetings shall state the business to be transacted, and no other shall be entertained.

Every question which shall come before any meeting of the Institute, shall be decided, unless otherwise provided by these Rules, by the votes of a majority of the members then present. Any member or associate may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

VII.

PAPERS;

The Council shall have power to decide on the propriety of communicating to the Institute any papers which may be received, and they shall be at liberty, when they think it desirable, to direct that any paper read before the Institute, shall be printed in the Transactions. Intimation, when practicable, shall be given, at each general meeting, of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting. The reading of papers shall not be delayed beyond such hour as the presiding officer shall think proper; and the election of members or other business may be adjourned by the presiding officer, to permit the reading and discussion of papers.

The copyright of all papers communicated to, and accepted by, the Institute, shall be vested in it, unless otherwise agreed between the Council and the author. The author of each paper read before the Institute shall be entitled to twelve copies, if printed, for his own use, and shall have the right to order any number of copies at the cost of paper and printing, provided said copies are not intended for sale. The Institute is not, as a body, responsible for the statements of fact or opinion advanced in papers or discussions at its meetings, and it is understood that papers and discussions should not include matters relating to politics or purely to trade.

VIII.

AMENDMENTS.

These Rules may be amended at any annual meeting by a two-thirds vote of the members present, provided that written notice of the proposed amendment shall have been given at a previous meeting.

PROCEEDINGS

OF THE

XXXIXth (CHICAGO) MEETING.

MAY, 1884.

THE XXXIXth (CHICAGO) MEETING.

COMMITTEES.

Local Committee of Arrangements.

O. W. Potter, *Chairman;* John Crerar, Jr., *Secretary;* George Merryweather, *Treasurer.*

Reception Committee.

H. A. Keith, John Crerar, G. M. Pullman, W. B. Stirling, John M. dark, E. C. Hegeler, John C. Parkes, H. S. Smith, W. J. Chalmers, W. L. Brown, D. C. Cregier, B. B. Jones, A. M. Wright, H. H. Porter, N. K. Fairbank, B. T. Crane, Robert Forsyth, George W. Stevens, James L. Houghteling, E. C. Potter, W. A. Angell, Morris Sellers, W. E. Barrows, M. C. Bullock, E. L, Ryerson, John T. Crocker.

All the sessions of the meeting were held in the Appellate Court Room, First District of Illinois, in the Grand Pacific Hotel.

At the opening session on Tuesday evening, May 27, Mr. O. W. Potter, Chairman of the Local Committee of Arrangements, after calling the meeting to order, extended a warm welcome to the Institute on behalf of the local membership, and then introduced Hon. Carter H. Harrison, Mayor of Chicago, whose hearty greeting in behalf of the city was received by the Institute with applause. President James C. Bayles responded to these addresses. He spoke of the mutual obligation between Chicago and the engineering profession, and thanked the Local Committee and citizens of Chicago for all they had done to insure a pleasant and profitable meeting.

Mr. Bayles then proceeded to deliver the Presidential address, on The Study of Iron and Steel.

The following papers were then read :

Note on the Miners' Fund of New Almaden, by Professor S. B. Christy, of the University of California, Berkeley, California. Read by the Secretary in the absence of the author.

A Vacuum Pump and Table Blowpipe, by W. F. Durfee, of Bridgeport, Conn.

Note on the *Cerro de Mereado* in Mexico, by John Birkinbine, of Philadelphia.

The papers read at the second session, Wednesday evening, were:

The Rolling of Steel Ingots by their own Initial Heat, by John Gjers, of Middlesbrough, England, member of the British Iron and Steel Institute.

The Hydraulic Cement Works of the Utica Cement Company, La Salle County, Ill., by Henry C. Freeman, of Alto Pass, Ill.

A Complete Gas Assaying-plant, by Walter Lee Brown, of Chicago.

The President announced that he had been requested by the manager of the Pocahontas Coal Mine, Va., shortly after the fatal explosion which occurred in that mine in March last, to appoint a committee of the Institute to investigate and report upon the causes which led to the disaster. While the policy of the Institute had not permitted him to appoint a committee which should report in vindication or condemnation of the management of the mine, yet after consultation with the Council, he had appointed Mr. S. M. Buck, of Coalburgh, W. Va.; Mr. J. H. Bramwell, of Roanoke, Va.; and Professor Edward H. Williams, Jr., of Bethlehem, Pa., a committee to examine the ground, collect testimony, etc., and present such points as were of scientific interest to the Institute in the form of a paper, to be incorporated in the ***Transactions.*** Owing to the non-arrival of the complete paper by reason of detention in the mails, the Secretary read an abstract prepared by Professor Williams of the committee, and Mr. S. M. Buck gave an explanation of the committee's line of investigation, illustrated by a blackboard sketch.

The President announced that the Council had decided to hold the next meeting in Philadelphia, beginning September 2d.

The following papers were read at the session on Friday morning:

Note on Patching Platinum Crucibles, by H. J. Seaman, of Catasauqua, Pa.

Water-tube Steam-boilers at the Lucy Furnace, by William Kent, of New York.

Estimation of Phosphorus in Iron and Steel, by Professor B. W. Cheever, of the University of Michigan, Ann Arbor, Michigan.

In the discussion of Mr. Salom's paper on Analyses and Tests of Steel, which had been made a special order for the Chicago meeting, there were presented written contributions from Mr. Kirkaldy, of England, and Mr. Charles A. Marshall, of Johnstown, Pa. An animated oral discussion of this paper was also participated in by many members of the Institute.

The session was closed by a Note on Hadfield's Patent Manganese Steel, by Mr. J. D. Weeks, of Pittsburgh, Pa.

The last session was held on Friday afternoon, when the following gentlemen were elected members and associates of the Institute:

HONORARY MEMBER.

Oberbergrath Prof. Dr. Theodora Richter, Director of the Royal Mining Academy, Freiberg, Saxony.

MEMBERS.

Matthew Addy	Cincinnati, 0.
Benjamin Atha,	Newark, N. J.
Edward Bailey,	Pottstown, Pa.
B. B. Barnhill	Joggins, N. S.
George F. Becker,	San Francisco, Cal.
Jean Marc Bel	Paris, France.
Robert Bentley,	Youngstown, 0.
Reese G. Brooks	Scranton, Pa.
C. G. Buchanan,	New York City.
J. L. Crawford,	Newcastle, Pa.
William H. Dodge,	Mishawaka, Ind.
Henry Rogers Durkee,	Chicago, Ill.
G. H. Everson,	Scottdale, Pa.
Frederick J. Falding	New York City.
Harry Stuart Fleming,	Philadelphia, Pa.
William Forsyth,	Aurora, Ill.
F. N. Gisborne,	Ottawa, Canada.
Frank Graham,	Georgetown, Col.
William M. Habirshaw,	New York City.
Robert Hastings,	Philadelphia, Pa.
Almond D. Hodges, Jr.,	San Francisco, Cal.
E. O. Hoffman	Pullman, Ind.
Benjamin P. Howell,	Scottdale, Pa.
George Scranton Humphrey	Oxford, N. J.
Hennen Jennings,	New Almaden, Cal.
William Henry Jennings	Columbus, O.
Edward E. Jewell,	South Chicago, Ill.
Barton L. Keen	Springfield, Ill.
R, Kent	Lewistown, Pa.
Henry C. Kriete,	Chicago, Ill.
N. Lilienberg,	New York City.
Frank J. Little	South Chicago, Ill.
F. W. Matthiessen	LaSalle, Ill.
Robert J. MeChure,	Chicago, Ill.
John E. Newell	South Chicago, Ill.
William Noyes,	San Francisco, Cal.
Alonzo W. Paige	Chicago, Ill.

Richard Peters, Jr	Thurlow, Pa.
Charles Pettigrew	Joliet, 111.
S. Harris Pomeroy	Pittsfield, Mass.
George A. Porter,	Syracuse, N. Y.
R. C. Porter	Pittsburgh, Pa.
De Veaux Powel,	Saxton, Pa.
A. Rapp,	Pullman, 111.
William J. Battle	Cleveland, O.
Alfred Rickard,	Idaho Springs, Col.
Frank Clemes Smith	Richland Centre, Wis.
Michael Smith	South Chicago, 111.
William Robert Stirling	Chicago, 111.
General Charles P. Stone	New York City.
Arthur H. Storrs,	Scranton, Pa.
Herbert Strickland,	32 Priory Road, England.
Josef P. L. Westesson	Thurlow, Pa.

ASSOCIATES.

Curtis Alexander	Maryville, Missouri.
William A. Angell,	Chicago, 111.
William M. Claypool,	Bentonville, Ark.
Riohard T. Crane,	Chicago, 111.
John T. Crocker	Milwaukee, Wis.
John Henry Ferguson,	Denver, Col.
Samuel T. Ferguson,	Minneapolis, Minn.
Charles Gordon	Cleveland, O.
Frank S. Gorton	Chicago, 111.
Charles V. Hickox,	Chicago, 111.
John A. Jackman,	Pullman, Ind.
William Fowler Jarvis,	Detroit, Mich.
Thomas D. Jones,	Mineral Point, Wis.
Edward N. Luce	Milwaukee, Wis.
Charles W. Miller	Brooklyn, N. Y.
P. S. Morse	Boston, Mass.
John J. Northrop,	New York City.
Frank B. Richards,	Cambridge, Mass.
T. W. Robinson,	Wareham, Mass.
James Rood, Jr	Chicago, 111.
Frank Scott	Pittsburgh,-Pa.
Joseph M Searle,	Stanhope, N. J.
J. B. Stubbs	Chicago, 111.

The status of the following associates was changed to member!

John H. Banks,	New York City.
H. H. Burden,	Troy, N. Y.
Robert C. Canby,	Pueblo, Col.

Mr. Stetefeldt's paper on Russell's Improved Process for the Lixiviation of Silver Ores, already printed and in the hands of the members, was presented, and a summary and supplement by the author were read and discussed, after which the following papers were read by title:

Notes of a Visit to the Cauca Mining District, by John Hays Hammond, of New York City.

Treatment of Rebellious Ores in Mexico with Hyposulphite of Lime, by John Hays Hammond, of New York City.

The Wolfe Safety-lamp, by Eugene B. Wilson, of Drifton, Pa.

A Blast Furnace with Bosh Water-jackets and Iron Top, by Arthur F. Wendt, of New York City.

A New Method of Shaft-sinking through Water-bearing Loose Material, by James E. Mills, of Quincy, Cal.

The Concentration of Iron Ores, by Arthur F. Wendt, of New York City.

Note on Tantalite and other Minerals accompanying the Tin-ore in the Black Hills, by Professor C. A. Schaeffer, of Cornell University, Ithaca, N. Y.

Note on the Influence of Organic Matter and Iron on the Volumetric Determination of Manganese, by J. B. Mackintosh, Columbia School of Mines, New York City.

Recent Improvements in Copper Smelting, by F. H. McDowell, of New York City.

The Blake System of Fine Crushing, by T. A. Blake, of New Haven, Conn.

Note on the Effect of Coal Dust on Colliery Explosions, by E. S. Hutehinson, of Philadelphia, Pa.

A Mexican Cupellation Hearth, by Dr. W. Lawrence Austin, of Santa Barbara, Mexico.

Note on the Segregation of Impurities in Bessemer Steel Ingots on Cooling, by Professor B. W. Cheever and W. J. Olcott, of the University of Michigan, Ann Arbor, Mich.

A New Rock Drill without Cushions, by A. C. Rand, of New York City.

By direction of the Council, the Secretary presented, with its cordial recommendation, the circular of Section D, of the American Association for the Advancement of Science, addressed to members of the Institute, as follows :

ITHACA, N. Y., March, 1884.

DEAR SIR : In accordance with a resolution adopted at the Minneapolis meeting of the Section of Mechanical Science (D) of the American Association for the Advancement of Science, I am requested to extend to yon a cordial and earnest invitation to attend the Philadelphia meeting of the Association, to join the Association (if not already a member), and to take an active part in the proceedings of the Section.

The British Association will meet next year in Montreal, immediately before the date of assembling of the American Association, and arrangements will be made to bring its members to Philadelphia on September 3d. The presence of the British Association at Philadelphia will lend much additional interest and importance to the meeting of the American Association. The opportunity is thus also offered to make this meeting an occasion for bringing together a larger number of gentlemen interested in the subjects falling under the consideration of this Section than have ever been or are likely for some time to come to be again brought together in this country. It is hoped and expected that the meeting will prove to be one of singular interest, as well as importance, and worthy alike of the occasion and of tin opportunity. Its success will gratify, not only the members of the Association, but every one who is interested in the promotion of the industrial interests of the country and the welfare of the people who are so largely dependent upon those interests. You are urged to make arrangements to attend this meeting, and to interest others in insuring a full attendance and a list of valuable papers for the Section.

A great additional attraction will be found in the Electrical Exhibition to be held in Philadelphia, from September 2d to October 10th. The preparations for the same are progressing rapidly, and the fact that it is to be held under the auspices of the Franklin Institute, is sufficient to insure for it a brilliant success.

The Section, the sessions of which you are invited to attend, is especially devoted to the advancement of all the sciences most directly applicable in the arts, and in the departments of engineering, civil and military, mining, mechanical, and electrical, and in architecture. It is hoped and fully expected that the several great technical societies of the country, as well as the local societies of engineers, will take active part in the promotion of the plan here indicated, and in the inauguration of a series of convocations of all the departments of engineering, and kindred organizations, at the meetings of this Section of the American Association. Members of every related profession will be heartily welcome.

Members (actual or prospective) who intend presenting papers to be read before this Section, can obtain the proper blanks from the Secretary, on which to offer the titles and abstracts of their papers for the consideration of the proper committee.

Papers are usually printed in the *Proceedings* by abstract, and such abstract, ready for printing, must be presented to the Standing Committee, and approved by them, before the paper can be admitted to reading. It is requested that titles and abstracts be sent to the Secretary of the Section as early as possible, before the meeting, accompanied by a statement of what models, apparatus, drawings, etc., will accompany the paper, or, in case the abstract is not ready, a brief outline of the paper can be sent and the abstract furnished at any time before the reading. In addition to the abstract upon the regular blank, five copies of the same should be furnished for the use of reporters and secretaries, and special efforts will be made to secure the immediate publication of abstracts or papers in current periodicals for which they are suited. A list of papers received before August 10th will be mailed to each member of the Section who sends his address to the Secretary as below.

If it is desired to place articles, models, or apparatus on exhibition, a list, and a statement of the space required, should be sent to the Secretary at an early date. If bulky, the Secretary will have the option of giving smaller exhibits the preference. Papers and exhibits void of scientific value are not desired, and everything of an advertising character will he rejected. The Secretary will forward to members, and to those desiring them, the circulars of societies proposing to join in the welcome extended to such members of the allied professions, as may desire to take part in the Philadelphia Meeting of the American Association for Advancement of Science.

R. H. THURSTON,
Vice-president and Chairman of the Section,
Stevens Institute of Technology, Hoboken, N. J

J. BURKITT WEBB,
Secretary,
Cornell University, Ithaca, N. Y.

At the request of the President, Dr. Persifor Frazer, of Philadelphia, made a statement concerning the Philadelphia meeting, as follows:

The next meeting of the. Institute will be held, as the council has already announced to you, in Philadelphia, from the 2d to the 6th of September. This time and place have been chosen in order that those members who can only spare the time for one absence from home in the fall may have the opportunity of taking part in the very unusual meetings which will be held in Philadelphia at that time, and examining the objects of the International Electrical Exposition. This Exposition, held under the auspices of the Franklin Institute of Philadelphia, will also commence on September 2d,and last about a month. The American Institute of Mining Engineers will be formally invited to take part in the opening ceremonies on that date. Exhibitors from all countries of the civilized world will send objects; and it is now believed that this will be the largest and most complete exposition of electrical apparatus, motors, methods, and literature yet held.

On September 4th, the British Association for the Advancement of Science having just completed their annual session (which is held this year in Montreal), many of the members will proceed to Philadelphia to join in the meeting of the American Association for the Advancement of Science, which has been postponed for three weeks in order to enable them to do so. It is not known with certainty how many British members will come, but more than 680 have formally notified the Montreal committee of their determination to visit Montreal, and of these only 150 will be taken on an excursion to the Canadian Rocky Mountains by the Canadian Pacific Railway;

the greater number of the remainder will, it is thought, come to Philadelphia—many of the most prominent, indeed, having signified their intention to do so. The Mechanical Section, the Chemical Section, and the Geological Section will be strongly represented, and will be glad to welcome our members. Excursions will be arranged, to which, as well as to the opening reception at the Academy of Music, on September 4th, the Institute of Mining Engineers will be invited. Such an opportunity to make or renew acquaintances with Europeans foremost in our own professions will rarely present itself.

In addition to this, the State Agricultural Fair will be held at about the same time in the immediate vicinity of Philadelphia, and it is said will be the largest ever held in the Middle Atlantic States.

On account of the number of these events happening nearly simultaneously in Philadelphia, it is hoped that there will be a more than ordinarily large attendance of the members of this Institute, but it will be necessary that the Local Committee be apprised *at a much earlier date than usual* of the intention of each member to be present, in order that the necessary accommodations may be secured.

Mr. J. D. Weeks then moved that the Secretary be instructed in a formal manner and on behalf of the Institute to extend to the different gentlemen and organizations who have so kindly aided us in making this meeting such a pleasant one, the thanks of the Institute—which was carried with enthusiasm.

The Chair, after again thanking all who had contributed to the pleasure of the members, and words of congratulation on the success of the meeting, declared the Institute adjourned to meet in Philadelphia September 2d, 1884.

EXCURSIONS.

On Wednesday the members and ladies accompanying them took a special train of the Illinois Central Railway, kindly provided by the North Chicago Rolling Mill Company, to the Bessemer works and rolling-mills of the Company at South Chicago, which were inspected under the guidance of Mr. O. *W. Potter*, President of the Company. Lunch was served on the train, and the party was conveyed to the town, of Pullman, where the shops of the Pullman Palace Car Company, the Allen Paper Car-Wheel Works, the Pullman foundry and car-wheel works, the Corliss Centennial engine, and the beautiful town itself, were viewed with much delight, under the guidance of the officers of the Company and of the various works. After enjoying an afternoon tea, provided at the Hotel Florence by the Local Committee, the excursiouists returned to Chicago in a special train, as guests of the Pullman Palace Car Company.

On Thursday, at 7.15 A.M., a special train on the Chicago, Rock Island and Pacific Railway, provided by the local committee of members residing in La Salle and vicinity, conveyed a large partv to the quarries and works of the Utica Cement Company, after inspecting which, the party proceeded to La Salle. Here opportunity was offered to visit the zinc-works and rolling-mills of the Illinois Zinc Company and of Matthiessen and Hegeler, the mines of the Union Coal Company, in which the Harrison coal-mining machine is employed, and the glass-works, where a Siemens tank-furnace, containing 225 tons of molten glass, is used in the manufacture of bottles. The excursionists were hospitably entertained and served with lunch at the residences of Messrs. Matthiessen and Hegeler, after which they were conveyed by train to Utica, where carriages were in waiting for a drive of five miles to the lovely gorge and cascade of Deer Park, and subsequently to Starve Rock, a cliff on the bank of the Illinois River, commanding a magnificent prospect. Here refreshments were served, and after a pleasant social hour with the officials and leading citizens of La Salle and vicinity, and a few cordial and appropriate remarks from President Bayles, in recognition of the abundant hospitality extended to the Institute, the party returned to Utica, and thence by train to Chicago, arriving at 10.30 P.M. This excursion was one of extraordinary interest and pleasure, and so well arranged that, in spite of its great length, it was not found to be fatiguing, even by the ladies.

A portion of the members accepted on Friday the invitation of Messrs. Cregier and Artingstall, the City Engineers of Chicago, to visit by steamer the water-works crib in the lake.

The rooms of the Association of Western Engineers were open during the meeting, and members were cordially invited to visit and use them.

On Friday evening the usual subscription dinner was held at the Grand Pacific Hotel.

The following members and associates made their presence at the meeting known to the Secretary:

J. B. Arnold.
Charles A. Ashburner.
James C. Bayles.
G. H. Billings.
John Birkinbine.
H. L. Bridgman.
Alexander E. Brown.
Walter L. Brown.
F. D. Browning.
Stuart M. Buck.
Henry W. Bulkley.
M. C. Bullock.
B. W. Cheever.
F. W. Clark.
W. B. Cogswell.
Edgar S. Cook.
Alexander B. Coxe.
Eckley B. Coxe.
Walter Crafts.
E. T. Crane.
John Crerar, Jr.
John T. Crocker.
George M. Davidson, Jr.
Edward S. Davies.
W. F. Durfee.
E. B. Ely.
Henry Engelmann.
E. F. Eurich.
J. W. Farquhar.
Persifor Frazer.
H. C. Freeman.
George C. Gardner.
John L. Gill, Jr.
J. Hartshorne.
Edward C. Hegeler.
Albert F. Hill.
H. O. Hoffman.
J. F. Holloway.
J. E. Johnson.
D. N. Jones.
R.R. Jones.
Thomas D. Jones.
W. E. Jones.
H. A. Keith.
William Kent.
Frank King.
Charles Kirchhoff, Jr.
Henry C. Kriete.
J. S. Lane.
Edward K. Landis.
George Lauder.
James F. Lewis.
Frank J. Little.
Paul F. Lobanoff.
R. W. Lodge.
M. J. Lunn.
Charles A. Marshall.
Jean A. Mathieu.
George W. Maynard.
Archibald Means.
John W. Meier.
George Merryweather.
Edwin Mickley.
E. S. Moffat.
P. N. Moore.
William H. Morris.
James Neilson.
John E. Newell.
A. W. Paige.
John C. Parkes.
Charles O. Parsons.
William H. Pettee.
R. E. Plumb.
E. C. Potter.
O. W. Potter.
F. L. Potts.
Addison C. Rand.
R. W. Eaymond.
E. B. Reid.
Charles Ridgely.
William Barret Ridgely.
Pedro G. Salom.
John D. Sanders.
Charles A. Schaeffer.
Morris Sellers.
Michael Smith.
George W. Stevens.
William R. Stirling.
William Thaw, Jr.
J.N. Tilemann.
J. C. Walker.
L. E. Warner.
Joseph D. Weeks.
S. T. Wellman.
Edwin L. Wiles.
David Williams.
Joseph M. Wilson.
J. P. Witherow.
Albert H. Wolfe.
A. B. Wood.

PAPERS

OF THE

XXXIXth (CHICAGO) MEETING.

MAY, 1884.

*THE STUDY OF IRON AND STEEL.**

BY J. C. BAYLES, NEW YORK CITY.

Gentlemen of the American Institute of Mining Engineers; Ladies and Gentlemen: The propriety of imitating in everything, so far as I am able, the worthy example of the distinguished gentlemen who have dignified the honorable office of President of the American Institute of Mining Engineers, imposes upon me the agreeable duty of delivering an address from the chair. The prominence which has been accorded in the programme of this meeting to the discussion of subjects connected with the study of metals, especially iron and steel, has naturally given direction to my thought.

It seems to be characteristic of invention and investigation that they conform to no law of regular and uniform development. From the measurably firm ground of accepted truth and verified experience, the work of original investigators is projected into the void of the unknown; and so rapid and important are the accretions of fact around such slender spars of well directed speculation, that it seems for a time as if we might go on extending and building them up until the void was fully and safely bridged. But such a line of investigation is like a cantilever with a pier at one end and nothing at the other. The limitations, not only of knowledge but of speculation, become evident as we load hypotheses upon the unsupported end of our structure; and to make our work of value, we must find a solid basis somewhere else, build thereon a pier, and project therefrom a second cantilever. When these meet and are securely united, we have spanned one of the spaces between facts learned by observation and experience, and can safely pass over to a point from which new speculations and verifications may serve as a basis for further progress.

We are impressed with the appropriateness of this figure when we examine the steps by which we have gained what little knowledge we already possess of the composition and properties of iron and steel. That we know as much as we do concerning them, is surpris-

* President's opening address.

ing when we reflect that among our membership are many whose lives almost include the period in which these materials have been intelligently and systematically studied.

The progress of chemical science applicable to iron and steel analysis, naturally invites attention first. Before quantitative analysis was attempted, certain of the crude reactions of qualitative analysis were recognized. Paracelsus, the marvellous charlatan who lived from 1493 to 1541, knew of some of these; and Boyle, an earnest worker in this field, records several in his " Essay on the Usefulness of Experimental Philosophy," published in 1671. Marggraf, who lived from 1709 to 1783, is the first chemist who is credited with analyses of minerals. Thomson, in his history of chemistry (London, 1831), says of Marggraf's work : "His attempts were rude, but their importance was soon perceived by other chemists, particularly by Bergman (1735 to 1784) and Scheele (1742 to 1786), whose industry and address brought the art to considerable perfection." Bergman, whose *De Analyst Ferri* was published in 1770, has left a very interesting record of his experimental work, which contributed in a material degree to advance the knowledge of the difference between iron and steel. He employed his pupils to collect specimens of iron from the different Swedish forges, and all of these specimens, to the number of eighty-nine, he subjected to a chemical examination by dissolving them in dilute sulphuric acid. He measured the volume of hydrogen gas which he obtained by dissolving a grain weight of each, and noted also the quantity and nature of the undissolved residue. The general result of the whole investigation was that pure malleable iron yielded most hydrogen gas, steel less, and cast-iron least of all. The amount of Bergman's knowledge and the value of his methods may be judged from a table of percentages which he has left us, giving the composition of cast-iron, steel and wrought-iron. This table shows the following results:

	Cast-iron.	Steel.	Wrought-iron.
Inflammable air	40.	48.	50.
Plumbago,	2.20	0.50	0.12
Manganese	15.25	15.25	15.25
Siliceous earth	2.25	0.60	0.175
Iron,	80.30	83.65	84.45

In manganese determinations Bergman evidently took care to avoid the discrepancies which are said to characterize the work of modern chemists, for we find that his manganese percentage is in each case 15.25 per cent. This celebrated chemist confirmed, to his own satisfaction, the conclusions of Reamur (1683 to 1757), who considered steel an intermediate grade of metal between crude and malleable iron. His experiments showed that malleable iron left the smallest quantity of insoluble residue, steel a greater quantity, and cast-iron the greatest of all, and from this he drew his conclusions with respect to the difference between iron, steel and cast iron. "Nothing more was necessary," says Thomson, "than to apply the anti-phlogistic theory to these experiments, as was done some time after by the French chemists, in order to draw important conclusions respecting the nature of these bodies. Iron is a simple body, steel is a compound of iron and carbon, and cast-iron of iron and a still greater proportion of carbon. The defective part of the experiments of Bergman, as recorded in this important paper, is his method of determining the manganese in iron. In some specimens he makes manganese to amount to considerable more than one-third part of the whole. Now we know," continues Thomson, "that a mixture of two parts of iron and one of manganese is brittle and useless. We are therefore sure that no malleable iron whatever can contain any such proportion of manganese. The fact is that Bergman's method of separating iron ores was defective. What he considered manganese was chiefly, and might be in many cases altogether, oxide of iron. Many years elapsed before a good process for separating iron from manganese was discovered." To this I may add that many more years elapsed before steel containing 30 per cent, of manganese, of which some description will be given in one of the papers to be read at this meeting, became a commercial product.

Among other investigations by Bergman were a scries of experiments made by him with a view to ascertaining the cause of brittleness in cold-short iron. He extracted from such iron a white powder, by dissolving it in sulphuric acid. This white powder he succeeded in reducing to a white and brittle metal, by fusing it with a flux and charcoal. Klaproth (1743 to 1817), soon after described this metal as a phosphuret of iron, and Scheele, with his usual sagacity, hit on a method of analyzing it and thus demonstrating its nature. Meyer seems to have conducted a line of experiments in the same direction about the time of Bergman's work, and he made his conclusions known to chemists in time to dispute with Bergman a claim to priority of discovery. As may be supposed, Bergman's processes were rude and very imperfect. It was Klaproth who first systematized chemical analysis, and brought the art to such a state that the processes could be imitated by others with nearly the same results in each case. Klaproth analyzed about 200 specimens of minerals and metals, and most of his conclusions were so nearly correct that his successors have, in most cases, confirmed the results he obtained. When he began his researches, chemists were not acquainted with the true composition of a single mineral substance. The service which Klaproth performed for mineralogy in Germany, was performed equally well in France by Vauquelin (1763 to 1829). To this chemist we are indebted for a description of the element chromium. All of the early analyses of ores, iron and steel are credited to one or the other of these two chemists. Vauquelin announced that in steel the carbon percentage averaged $\frac{1}{140}$th part. By inclosing diamonds in cavities of soft iron and igniting them, they disappeared, and the inner surface of the cavity was found to be converted into steel. I am not aware that this process is employed at the present time, but judging from the disproportion frequently noted in experimental steel manufacture, between the cost and value of the product, one might suppose it is still in use. Berzelius, in the first quarter of the present century,and Ebelmen about ten years later, made important contributions to the knowledge of reagents and methods. Berzelius was the successor of Bergman and Scheele. All previous analyses were revised by him, and modern chemistry begins with his era. One of his iron analyses shows iron 90.80, silicium 0.50, magnesium 0.20, manganese 4.57, carbon 3.90. The pupils of Berzelius were, to a great extent, instructors of the chemists of to-day.

Karsten, in 1820, recognized the influence of carbon on iron, and stated his belief that iron and steel constitute a continuous series, there being no distinct lines of separation between them. In his judgment, it was simply a question of carbon percentage where, in the series, a piece of iron or steel belonged. In his "Metallurgy," published in 1830, he notes the fact that pig iron contains carbon, silicon, sulphur, phosphorus, manganese, calcium, magnesium and chromium. It is probable, however, that all these elements had been previously recognized and described. As early as 1815 there was more or less speculation whether hardness and softness in steel were due to physical or chemical causes. Faraday is credited by Percy with having been, in 1822, the first to point out, that a piece of hardened steel dissolved completely in hydrochloric acid, while soft steel always yielded a certain amount of carbonaceous residue when subjected to the action of. that solvent. David Mushet, in *Iron and Steel* (1840), gives a very good idea of what was known of metallurgical chemistry at that time. He mentions certain ores which contain "phosphat" of iron, which was generally believed to account for the fact that the iron made from them was cold-short. Mushet, however, was by no means certain of the cause of cold-shortness. Phosphorus, he tells us, had long been regarded as the prime cause of this quality in iron ; but by the practical observer this theory could not be considered tenable, for it had always been noticed that the most perfect qualities of iron, notably some of the Swedish makes, gave out in working "a very strong phosphoric smell." Regarding the condition in which carbon exists in iron, Mushet says, "In the works of those who have treated on iron, I have never yet seen carbon which exists in crude iron, distinguished from that absorbed by malleable iron in the process of converting it into steel. I could," he continues, "adduce many facts which to. me appear conclusive, to prove that carbon exists in crude iron in a concrete state separable by mechanical division, and that it is united to steel in a gaseous state by the combustion of its base, inseparable in any form by the most minute mechanical reduction." It is surprising to note the earnestness and gravity with which, in 1840, these statements were made. It shows the newness of the knowledge which now-a-days serves as the starting point for discussion on such topics.

Mushet treats very fully of the effect of different substances on the quality of iron. He made a number of experiments by fusing iron with different fluxes in crucibles, and noting the quality of metal produced. One section of his book is devoted to the different proportions of carbon which constitute iron and steel; and he gives the results of fourteen experiments. His method was to fuse a certain number of grains of wrought-iron with charcoal in varying proportions and note the increase of weight as showing the amount of carbon taken up. Karsten, however, promptly challenged the accuracy of his methods, and proceeded to show that Mushet's tables giving the carbon percentages in iron and steel were entirely wrong—much as chemists of the present day are prone to do upon occasion.

It is unnecessary to follow from this point the progress of metallurgical chemistry towards a scientific basis. Its general employment as a means of assisting makers to control the character of their product concerns us more; and this is almost within the memory of even the youngest of our membership. Most of us can recollect when the dependence of the iron-master and the engineer who cared to know the chemical composition of a piece of iron or steel, was upon the general analytical chemist. When the influence of our technical schools began to be felt, and young men well-equipped for the work began to displace, in the management of furnaces and mills, those who had gained their knowledge in the school of experience, where the instruction is not always thorough in proportion to the cost of tuition, the laboratory began to be recognized as an essential part of an iron or steel-making plant, and in nearly every establishment with any pretensions to completeness, the chemist has become an important member of the staff. But it is not more than fourteen years ago, that this was the exception rather than the rule. Among my letters I have one bearing date of 1872, written by the general manager of an important iron-works. He says: "The president of our company thinks we ought to follow the fashion and have a chemist. To my mind it is a waste of money. When I want an analysis I can have it made—and that is very seldom ; for the furnace-manager who needs a chemist to tell him the quality of ore or limestone, or whether his pig-iron is soft or hard, had better resign and go to farming. However, if the president says chemist, chemist it is. My object in writing is to know if you can recommend a young man competent to fit up a laboratory and take charge of it. We have very little society here, and it is desirable that he should be a gentleman. My wife plays the piano and I do a little on the flute; and if we can get a chemist who plays the violin, we could have some music evenings. If you can suggest a man who combines these qualifications, I could employ him. I do not know what a chemist would expect; but I should not care to pay more than §10 a week."

When the demand for analytical work in connection with the iron and steel industry began to be felt, it brought into the service of the iron-master a great many clever and ingenious chemists at home and abroad, and a varied and valuable literature of metallurgical chemistry was soon created. The need of accurate analyses was so evident that their importance was perhaps somewhat exaggerated ; and for a time it seemed as if we might safely look to the chemist to answer every question which could be raised by the iron-master or the engineer. Our confidence in tabulated percentages of the component parts of a piece of iron or steel resulted largely from the fact that we knew so little what knowledge was needed for a clear and satisfactory explanation of observed phenomena. From this over-confidence in the power of the chemist to explain everything, there has been a natural, and doubtless wholesome, reaction. Experience has shown that, great as the value of a knowledge of the chemical composition of a piece of metal be, it is, after all, only a part of the knowledge we need before we can determine with what we are dealing.

To some extent coincident with this rapid progress of chemical investigation, and within even a shorter period, we have seen the development of the physical test, with the aid of appliances which have attained marvellous perfection in surprisingly few years.

Thomas Tredgold, in his “Strength of Cast Iron,” published in 1823, says: “Lord Bacon's idea of a mechanical history, which Diderot attempted to realize, is not so well calculated to fulfil his own views (concerning the advancement of the arts) as a well-directed course of experiments on the nature, forms and properties of materials .... In chemistry much has been done, but an experimental school of mechanical science remains to be formed.” Referring to the necessity for more knowledge of physical properties than was at that time possessed, Tredgold says; "The manner in which the resistance of materials has been treated by most of our common mechanical writers has also, in some sense, misled the practical men who are desirous of proceeding upon sure ground, and has given occasion for the sarcastic remark that the stability of a building is inversely proportional to the science of the builder.”

Coulomb, in 1784, made some important experiments on torsion, and was probably among the first to study the effect of continued stress upon the elastic limit of iron and steel. In 1818 Wilson estimated the power required to crush cast-iron at 2,240,000 pounds to the cubic inch. Reynolds, quoted by Wilson, recorded an experiment in which a cube of cast-iron one-fourth of an inch square, required 448,000 pounds to crush it. Tredgold considered it necessary to correct these erroneous estimates, and made numerous experiments with cast-iron, testing specimens by static loads and under a drop. The results are given in the work before-mentioned. He also made some experiments upon wrought-iron, correcting or verifying the results reached with crude methods by various European experimenters between 1758 and 1820. The modulus of elasticity of steel was probably first calculated by Dr. Thomas Young, about 1820, from the vibrations of a tuning-fork. The height of a modulus found by this method was 8,830,000 feet, and the weight per square inch was 29,000,000 pounds. That is, a bar of steel 8,830,000 feet in length and 1 inch square in cross-section, would stretch from its own weight to double its original length ; and its weight, 29,000,000 pounds, is the modulus of elasticity as ordinarily expressed.

It is within a century that the work of Navier, Perronet, Poleni, Telford, Brunei and others furnished the basis for a more or less exact knowledge of some of the more easily recognized and described physical properties of iron and steel. Naturally the results reached by these experimenters were as incomplete, and in many instances as mistaken, as their methods and appliances-were rude and unsatisfactory. Drop-hammers, single-lever testing-machines and hydraulic presses were the only power appliances employed in testing during the first-half of the present century. Experiments were mostly directed to ascertaining the tensile strength of materials, chiefly iron, steel and wood, under shocks or stresses which, at a single application, would produce rupture. The breaking-point thus ascertained was termed the ultimate strength of the material; and until very recently the data thus gathered were the only bases for calculating the dimensions of members which were expected to resist tension. Resistance to compression was similarly determined by the application of crushing loads to cubes of unit dimensions; and this was deemed satisfactory until the experiments of Hodgkinson demonstrated the previously unrecognized influence upon resistance to compression of the ratio of diameter to length in test-specimens.

Among the earlier of the experimenters in this field, Navier is entitled to spiecial prominence. He probably did more than anyone else to bring science and practice together and to make one help the other. Navier's theory of rupture under transverse strain, though since found to be correct only within certain limits, is still quite generally accepted as a basis for calculations dealing with such strains. To Woehler in 1858, we are indebted for a knowledge of the influence of the repetition of quiescent stresses. This led to the formulation of Woehler's law, that rupture may be caused by the frequent application of stresses in no instance approximating the original ultimate strength of the metal. The recognition of this law established the significance of the elastic limit in the calculation of dimensions, and marks what is probably the most important epoch in modern methods of dimensioning.

In 1862 Kirkaldy published his "Results of an Experimental Inquiry, etc.," which effected a considerable modification of the views previously held by engineers as to the physical characteristics of materials, especially of steel. These investigations tended in a material degree to popularize experiments with construction-materials in the testing-machine, and created a demand for such machines and for accessory apparatus for measuring elongation, etc. The Messrs. Fairbanks were, I believe, the first to produce, in 1863, a testing-machine on the multiple-lever principle, and though of limited capacity, this was an important improvement upon previous constructions. They were quickly followed by Riehlé Bros., whose testing-machines still hold a high place in the estimation of experimenters. The next great step forward was marked by the production of Thurston's automatic-recording torsional testing-machine. The progress continued until it culminated in the Emery testing-machine, probably the most remarkable instrument of precision ever built, and the most improved type of which dates no further back than 1880. In the line of automatic-recording apparatus the latest form, devised by Abbott, illustrates the high development attained in the construction of testing-machine accessories.

The period from 1850 to 1875 was, without doubt, the most fruitful in additions to our knowledge of the physical properties of iron and steel as revealed by the testing-machine. It comprised the investigations of Navier, Fairbairn, Woehler, Spangenberg, Kirkaldy and Thurston. The work of these and other investigators, brought the physical laboratory fully abreast with the chemical laboratory, and each has given to work done in the other a value it would not otherwise have possessed. But he who should undertake the study of iron and steel with no other light than that which analysis and test can give him, though he would learn much of value, would find himself baffled, at every turn, by mysteries which these methods of investigation cannot solve. This is especially true of steel. In my experience, very few of those who make or use steel are prepared to accept the statement that chemical analysis alone can be relied upon to determine its quality. It may be broadly stated, that certain compositions never make good steel; but the reverse cannot be asserted with equal confidence. With a given composition, the result depends primarily upon the perfect admixture of the ingredients. Imperfect melting will give an unsatisfactory product, no matter what the stock used or the composition shown by analysis of the ingot. It will also be questioned by many, whether a method of accurately determining the oxide of iron in steel would materially increase the confidence we should feel in a judgment of quality from analysis. It is true that chemical methods are becoming more rapid and accurate every day; but with as complete a knowledge of the stock from which steel is made as chemical analysis can give us, there still remain a great many uncertain factors in the equation of quality. In fact, it seems that the value of ingot-analysis may easily be very much exaggerated, and that within certain limits the physical structure of a piece of metal is quite as important to be known as its chemical composition. There are many gentlemen in this audience who could substantiate, by the results of long experience, the broad statement, that without good melting and proper subsequent treatment of the ingot, good steel is impossible with any admixture of ingredients which the chemist may prescribe. Chemistry has its limitations—not quite sharply defined perhaps, but still evident. If the chemist should ever succeed in giving us a report showing the exact proportion of each constituent of a piece of metal, beyond question or doubt, we might still be in the work before us where the builder is when he stands among his bricks and lumber and the sundry materials he makes use of in construction.. If he knew nothing more than the count and tally of his materials, he could build nothing.

Nor is the testing-machine infallible. What it shows is, to a greater or less extent, dependent upon what the operator seeks to have it show. We all know how, on the one hand, by sudden shock applied to a specimen under stress, it can be made to give results far below any recognized standard ; and how, on the other hand, by gentle increments of stress through lengthening intervals of time, a piece of metal may be coaxed to show test-results far above its real value, and apparently inconsistent with its chemical composition. But even when it is possible to have such confidence in a physical test as can only result from a knowledge that everything connected with it has been honest and fair, and surrounded by safeguards against every known source of error, we must look elsewhere than to the chemist for an explanation of many of the phenomena which the testing-machine reveals. If we seek to compare the results of physical and chemical test we shall become hopelessly confused. Generalizations warranted by one relation of composition to quality will often be contradicted by a different relation ; and we should reach the almost despairing conclusion that one or the other of these methods must be accepted as the sole standard by which to judge quality. Which we should choose, would depend upon whether we had formed our opinions in the laboratory or in the mill.

To harmonize what seem to be the often-conflicting results of chemical analysis and physical test, we must seek for a knowledge of causes affecting quality in yet other directions. In this we have already had assistance of the greatest value. The anomalies developed by the steels made by different formulae, and of samples of a given composition taken at different stages in the process of manufacture, has called attention to the fact that the quality of steel does not alone depend upon what it is made of.

In 1873 the building of three large iron-clads was begun at Brest and L'Orient, and steel was largely used in their construction. Lieut. J. Barba, Chief Naval Constructor at L'Orient, investigated some of these anomalies, and to him we are indebted for the first exact observation of the effect of manipulations upon steel. Barba's work was ably supplemented by that of Joessell and continued by Pourcel, Holley, Metcalf, Hill, and others, with the result of showing that the influence of manipulation in processes of manufacture is of prime importance in its relation to the quality of the finished product. It is important to know the chemical composition of muck-bar and ingot, but experiment and experience have shown that the beam, the rail, the ship-plate and the bridge-member on which the safety of the whole structure may depend, may be so far below the standard of quality which analysis would lead us to expect or physical tests of specimens taken at intermediate stages in the process of manufacture warrant us in assuming, that we must seek still further light on the subject in the revelations of microscopic analysis. In the microscope we have an instrument, which promises to supplement the laboratory and the testing-machine, to harmonize their seemingly conflicting records, and to detect the influence of shop-treatment at every step in the process of manufacture. The work of the microscopists who have thus for turned their attention to iron and steel, has not been complete enough as yet, to give us more than a few standards by which to compare our observations; but I do not doubt that within a very few years the microscope will give the laboratory and the testing-machine a value for the iron-master, the steel-maker and the engineer incomparably greater than that they now possess. This branch of special investigation is one which offers many attractions for the conscientious student who will approach it in the earnest spirit of scientific inquiry. Within the little circle of the field of a microscope, there is more to be learned of value to science and the arts than the chemist can predict or the physicist explain. It will bring us to the point beyond which no investigation can proceed. Then, as now, we shall realize that "the utmost still is hid ;" but when we shall have learned all it is possible to learn from the revelations of the microscope, we shall have followed truth to the limit of human intelligence, and seen it fade into infinite mystery.

Meanwhile, let us remember how new is our knowledge of iron and steel; how incomplete; and how dependent is the student by one method upon the knowledge gained by other methods, some as yet almost untried It is too soon for broad generalizations. The key to the mystery seems to lie in the structure of the metal; and until we know more, of this, and can reason from effect to cause through the known phenomena of analysis and test, we may safely distrust that assurance of conviction and positiveness of utterance which Tyndal tells us are ever characteristic of "the confidence of half-knowledge."

A COMPLETE GAS ASSAYING-PLANT.

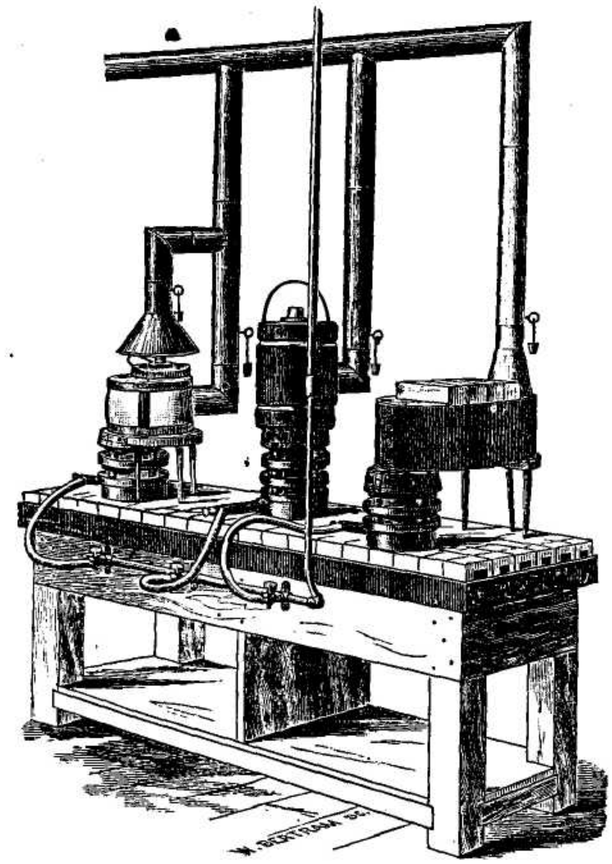
BY WALTER LEE BROWN, CHICAGO, ILL.

ONE of the characteristic steps in the march of modern scientific progress is the substitution of improved time-saving and labor-saving appliances for the antiquated and, in most cases, inconvenient forms of chemical and physical apparatus used by the earlier experimenters.

This fact is strongly impressed upon us when we consider the question of the, employment of illuminating-gas as a source of light, heat and power. Concerning its value as a light-producer, let the record of the past three-quarters of a century speak for itself. As a factor for power, we have evidence of its efficiency in the shape of the gas-engine. But its adaptability as a medium of heat, is the feature to which I wish to call attention, and in a special direction, viz., the assaying of ores.

Gas assay-furnaces have been known and used for some years, but not to any very great extent, in this country at least. Therefore no apology on my part is required for the description I now give of a complete gas assaying-plant.

The illustration accompanying this paper is a faithful representation of the group, as it was designed by, and arranged for myself, and appears in actual running order in my laboratory to-day. Its duty is to do roasting, crucible-fusion, scorification and cupellation. The. furnace at the left is for roasting sulphurets or other ores for experimentation or actual work. It is what is known as a Fletcher No. 163, and consists of a fire-clay body strapped with sheet-iron bands, and a burner (No. 16, Fletcher). The opening at the top (protected when not in use by the cover shown) permits the heat to have full play upon the roasting-dish placed on it. The heat and flame pass from the burner through the furnace, and out and up the chimney-pipe. The funnel-shaped pipe over the cover, is to catch and draw the fumes up the chimney. When the burner is lighted,



a powerful draught ensues, carrying all odors and fumes at .once away. Both the pipe and hood are provided with dampers, controlled by small weights. The burner is connected to the gas-tap by stout $^1/_2$ inch rubber tubing. A cast-iron tripod supports one end of the furnace and keeps everything firm.

Next in regular order (supposing a sulphuret ore to be under treatment) is the middle furnace, for crucible-fusions. This, likewise, consists of a furnace and burner. The latter is a Fletcher No. 15, of the same construction, however, as the No. 16. The furnace proper is made in five parts, the central section (a cylinder of fire-clay); the bed-plate upon which it rests and which has an opening for the flame to pass through ; the cover (with handle attached) which also has an opening filled by a plug—all of fire-clay; and finally a plumbago lining. The rubber tube, chimney-connection and damper are like those of the other furnace.

Finally, at the right is shown the furnace for scorification and cupellation, which I have, I think fitly, designated as the "Monitor." Its form is almost that of the reverberatory furnace, the movable bricks, when in place, being the roof. Looking at it from another point of view, it may be considered as a muffle with the flame as well as the heat inside. Its exterior dimensions are as follows: length, 20 inches; width, 7 inches; and depth, 5 $^1/_2$ inches. In the interior, upon the bottom, are four little wedge-shaped bridges of fire-clay which are movable; and upon these rests a false bottom or floor, also movable. The latter corresponds to the muffle-bottom of an ordinary furnace, and upon it is done all the work. It is 3 $^1/_2$ inches wide by 7 $^1/_2$ inches long, and $^1/_2$ inch thick, and has a shoulder or bench running across its entire width on the end nearest the burner. The covering bricks, four in number, are each 7 inches long by 2 $^3/_4$ inches wide, and 1} inches high, with a slotted bridge for convenient handling. The connections are similar to those of the first-mentioned furnaces.

The 3-inch stove-pipes of all three furnaces are fitted into one long, horizontal pipe, which fits snugly into the chimney. The bench or table upon which rest the furnaces described, is made of pine, well-seasoned and firmly joined, to resist as much as possible the warping influence of heat, and to support the weight of the furnaces and table-tiles. In dimensions (not figuring on the top, which overlaps 1 inch all round), it is 4 feet 6 inches long, 1 foot 7 inches wide, and 2 feet 1 inch high, plus the thickness of the top which is 1 $^3/_4$ inches. A double coat of shellac varnish is its sole ornamentation. To the sides and ends of the table-top are firmly screwed four strips of band-iron, 2 $^1/_2$ | inches wide, and $^1/_8$ inch thick, and of such lengths as to alternately overlap at the angles, making smooth joints. The top of this sort of wall is $^3/_4$ inch above the bed of the table. Upon the latter are 114 fire-clay tiles, or rather clamps, such as are used to join house-tiles, and having the shape. Their average size is 3 $^1/_2$ inches by 3 inches across, and $1^3/_4$ inches high. They are so arranged on the table as to leave a series of six air-tubes or chambers running its entire length. The spaces between the tiles are filled with a mixture of plaster of Paris and Venetian red, rubbed up together with water. The latter color is also used for the tiles themselves and somewhat on the fire-clay portions of the furnaces. A $^{3}/_{8}$ inch gas-pipe, with proper taps and nozzles, is screwed to the front of the table.

I have gone somewhat minutely into detail in the above description, for the benefit of such as may care to duplicate the outfit.

The mariner of operating the furnaces is simple. As regards the roasting-furnace, it is necessary merely to shut off the dampers of the other furnaces, turn on and light the gas and regulate the heat to suit the particular ore. The control of the mixture of gas and air is effected by means of the milled handle at the burner. In using the crucible-furnace, remove cover, turn gas on full at tap, light, and regulate by milled handle. Crucibles containing charges that are to be heated gradually, can be placed in the furnace as soon as lighted; others, after the lapse of a few moments to allow the furnace to become thoroughly heated. Placing the charges in cold, I have made good fusions of refractory ores in twenty-five minutes from time of lighting. The furnace will take crucibles in size up to the Battersea " S' (4 $^{1}/_{4}$ inches across by 5 inches deep).

Finally, as to the " Monitor " furnace, I wish to say a word of explanation. It is not my intention to claim originality as regards this furnace, but merely superior applicability and decided improvements in form. It was Mr. Thomas Fletcher, of Warrington, England, to whom we are indebted for so many ingenious forms of apparatus for the utilization of illuminating gas as a medium of heat, who devised the original little furnace which I employed successfully in assaying for a year and a half. This is the one I now employ as a roasting-furnace, as shown in the cut. Its chief fault lay in the fact that but one scorifier or cupel could be operated at a time. This furnace had almost entirely escaped attention as an assay-furnaee, owing to its having been advertised mainly for melting small quantities of lead, copper, brass, etc In fact it had been withdrawn from the market when I took hold of it, with the idea of improving it so that it should be able to treat three or four or more scorifiers or cupels at once. With this object, the present furnace was finally constructed.

To manage it, remove the covering bricks, open the damper and shut those of the other furnaces, turn back the milled handle at the gas-entrance to the burner so as to allow a full flow of gas, turn gas on full at tap, light, and put back the bricks into place. In from twelve to twenty minutes the interior will be hot enough for work. The, bricks are then removed again, the charged scorifiers are placed on the false floor, the bricks are replaced, and the excess of gas is turned off at the burner. When the charges have melted, slide the bricks aside more or less—principally those nearest the burner—to admit air for oxidation. In cupellation, the gas is turned down more than in scorification.

The time of performing either scorification or cupellation varies according to the nature of the ore, charge, size of button, etc., but is about the same as that occupied in the use of a coke-furnace.

The consumption of gas is not far from 30 cubic feet per hour It is not intended or claimed that this furnace can take the place of one required to be run from ten to twelve hours per day; for that, of course, a solid fuel will be cheaper. But for short runs of from one to say four hours it is economical, as are also the others here described.

For small laboratories, therefore, the advantages of this, furnace are many: convenience of operating, since the assayer sees every step and stage of the operation, and so can tell when and where to change or improve; comfort in manipulation, since it does not heat. up the vicinity of the furnace and the room itself (quite a desideratum in the summer time); perfect control of the source of heat, so that a higher or tower temperature, a reducing or oxidizing effect may be produced in an instant; entire noiselessness (in which characteristic it is the superior of all blast assay-furnaces); saving of the time which, with furnaces employing coke, charcoal or coal, is spent in "bedding down," feeding, etc.; freedom from the annoyances of dust, ashes and smoke; and absence of waste. Finally, it possesses the advantages, which need not be dwelt upon, of simplicity of construction, durability and portability. Such simple tools as are required can easily be made from quarter-inch wire.

The complete plant, as illustrated, costs about $75.00. The furnaces are manufactured by the Buffalo Dental Manufacturing Company, of Buffalo, New York.

A BLAST-FURNACE WITH BOSH WATER-JACKET AND IRON TOP.

BY ARTHUR F. WENDT, NEW YORK CITY.

WITHIN the last few years the production of iron, and of the metals generally, by a given furnace-plant, has been largely increased, in many instances trebled. Iron-furnaces exceeding one hundred tons' capacity per diem are now the rule in new constructions. Copper and lead-furnaces smelting from 60 to 100 tons of ore per day are common. With this greatly augmented product, the life of furnace-linings has been diminished, and recourse has been had to various cooling devices for prolonging the life of such liuihgs. The object of this paper is to call the attention of the profession to an arrangement recently patented by the writer.

The common course of projecting water against the exterior of the brickwork of a furnace has been in a large measure abandoned by our most progressive managers. All have recognized the danger of this proceeding, especially when applied to the crucible of a furnace below the line of the tuyeres. Cast-iron water-jackets, with wrought-iron pipes for circulating the cooling-water, have replaced the cruder methods. In iron-smelting the use of such jackets has been confined to the crucible and the space around the tuyeres; and it has been the custom to support the jackets on the brickwork of the furnace. But the erosion of the brickwork below tuyere-jackets allows them to sag, and often displaces the alignment of the tuyeres and leads to other annoyances.

The principle of construction adopted by the writer to remedy this and other evils, is to use a thin fire-brick lining (not over nine inches) from the tuyeres up to the bosh, to back this lining with wrought-iron or steel water-jackets, *hung* from the mantel-ring, and thus to carry the whole weight of the furnace and its filling upon the supporting pillars. The crucible proper is lined with three or four thicknesses of fire-brick on the sides, and not less than forty-eight inches in the bottom. It is supported on independent pillars, and is practically an independent structure. It could even be placed on wheels and made removable, were there any adequate advantage to be gained by such an arrangement.

By reference to Plate I. a set-off in the lining will be seen below *e,e,* by reason of its increased thickness below the tuyere water-jacket.

The water-jackets ***e,e*** hang from the jackets *d,d,* and these are in turn hung from the mantle-ring.

The jackets *f,f*, encircling the crucible lining, rest ou the plate *g,* supported by the pillars *h.* An essential point of this construction is the annular space left between the jackets e,e and *f,f.* Through this the interior of the crucible can be reached, and the crucible-lining can be repaired without blowing out the furnace. It is immediately below the jacket *e,e* that the cutting action of the molten cinder is the greatest; and it is this space that can be most readily reached from the outside.

Inspection of Plate J. will show that the blast-pipe is carried very high, and the branches from it are built in two flanged sections. In case of a scaffold, the tuyeres can be instantly raised, and the furnace blown in at a higher level, through openings left for that purpose in the bosh water-jacket.

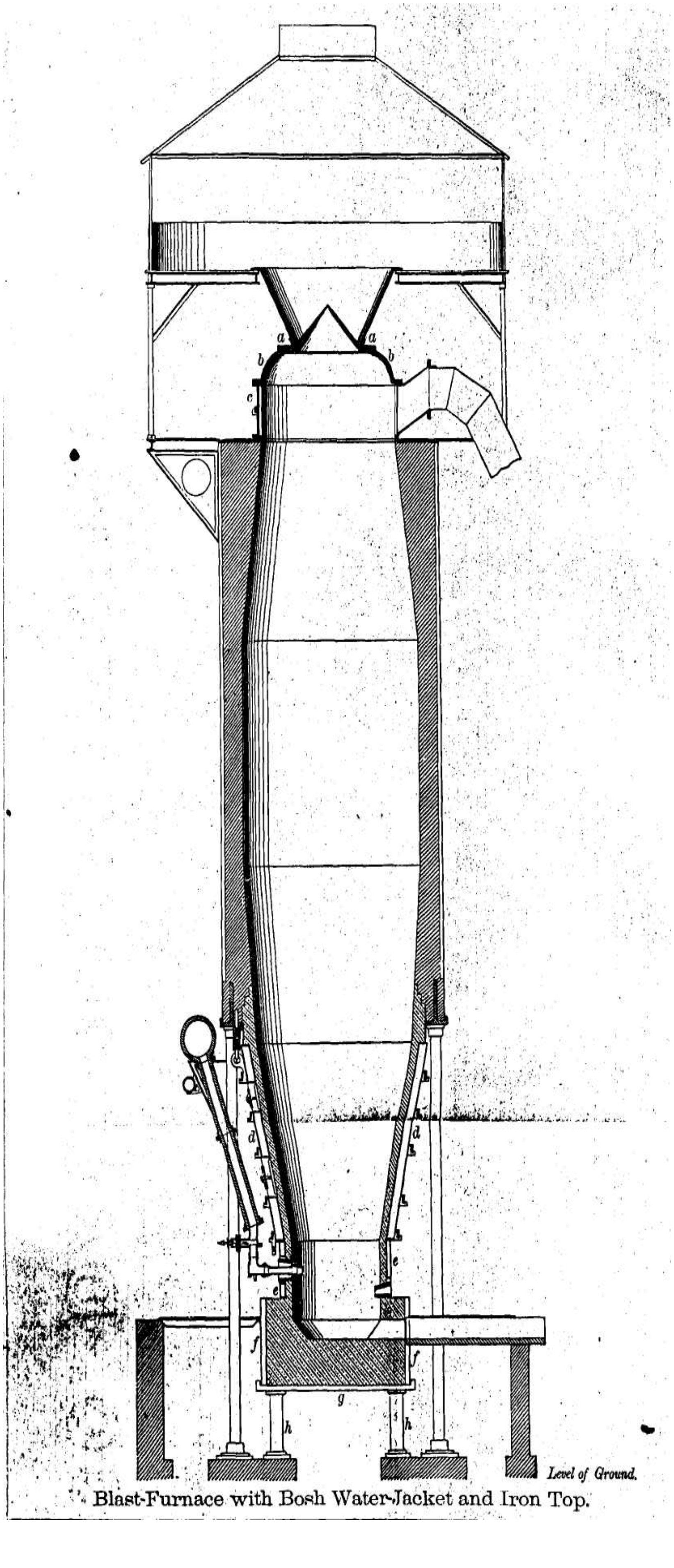
The level of the ground is some ten feet below the bottom of the crucible; and the level of the sand-beds, and the top of casting-house walls are carried to this height above the surrounding country.

From the bosh to the tunnel-head, the furnace presents no novelties. Above the brickwork of the tunnel-head, the construction is entirely of iron, and differs widely from that usually adopted.

There are two floors supported by brackets attached to the shell of the furnace. Resting on the lower floor .are the heavy iron columns c, supporting the dome 6,6. Closing the spaces between the columns are thin cast plates, firmly keyed to the columns. It is against these plates that the stock strikes, upon the lowering of the bell, thus effectually preventing the wear of the brick lining near the tunnel-head. Members of the profession will remember several instances where this wear has given trouble, and accidents have happened as a consequence.

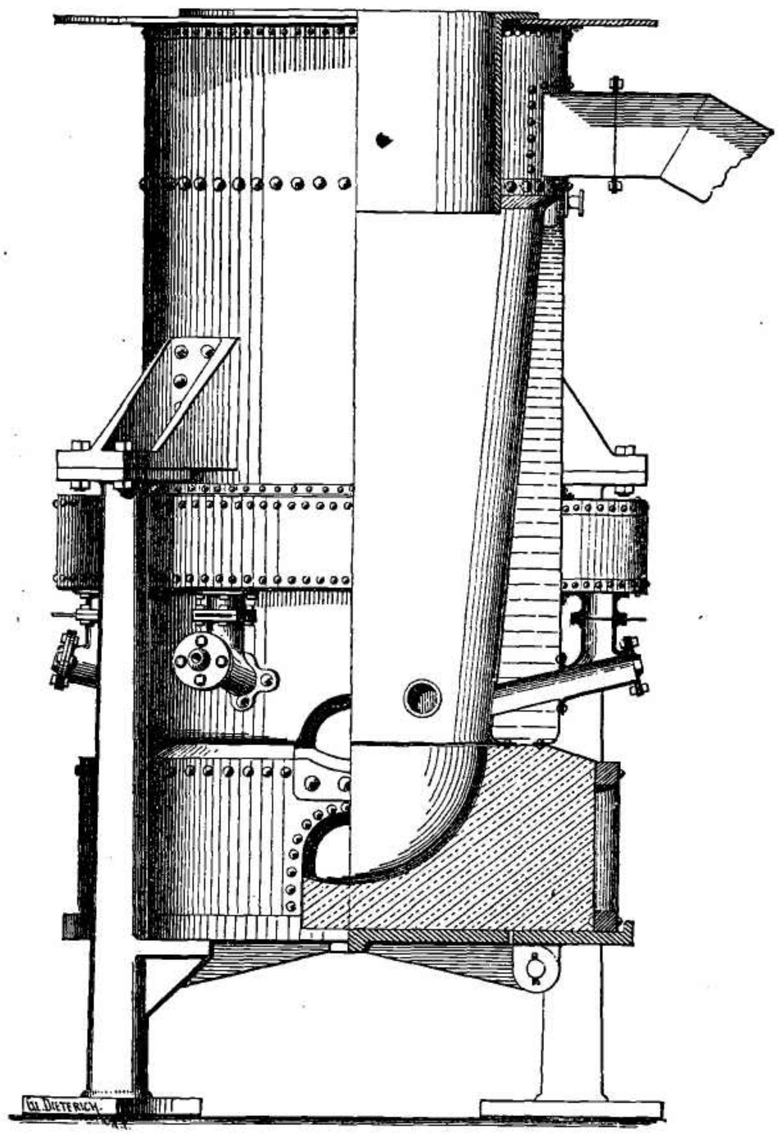
The charging-hopper hangs from the charging-floor, and its lower edge overlaps and rests on the circular angle-piece *a,a.* This angle-piece is turned true, and makes a gas-tight joint with the bell. It is coast in three or more flanged segments, which are bolted together and keyed fast to the top of the dome 6,6. In the event of the edge of the angle-piece chipping off or being otherwise destroyed, the segments can be readily removed and replaced by others.

Should the furnace be blown out, the plates c are removed, the hopper is filled with water, and a spray of water is kept on the dome. It is also advisable to charge some limestone during this operation,



Blast-Furnace with Bosh Water-Jacket and Iron Top.

PLATE II.



Water-Jacketed Copper-Smelter.

both to deaden the flame at the tunnel-head, and to facilitate the shovelling out of the last material remaining in the furnace. In smelting ores of iron, copper or lead, containing an appreciable amount of zinc, an iron top relieves all annoyance experienced from the accumulation of cadmia. The zinc condenses against the iron and can be removed without trouble.

Plate II. shows the general arrangement of a 36-inch water-jacket copper-smelter of the type now common throughout the West, arranged according to the writer's improvement. No lining whatever is used in the shell. The crucible is built up of fire-clay, rammed into place. The bottom of the furnace can be dropped, as is usual with iron-cupolas.

Lead-furnaces are constructed on the same general plan.

To iron-masters not acquainted with the practical operation of water-jackets, it might seem that by their use a large loss of heat is occasioned. But this cannot be the case, as a little reflection will readily prove. The bosh of an iron-furnace, especially that part immediately around the tuyeres, invariably cuts out, sometimes within a few days after going into blast, until the lining has become very thin, and the tendency of the heat to destroy the material is checked by the loss of heat by conduction and radiation from this material itself. Now whether this loss of heat is conditioned by the surrounding air or is controlled by a circulation of water, can make no difference in the fuel-consumption. To preserve a certain thickness of brick, a certain number of heat-units must be carried off".

The smelting process, however, goes on much more uniformly in a water-jacket, which preseryes the shape originally given to the interior, than in a furnace with 'thick walls cut into irregular shape by the heated stock and cinder. Thus an actual saving of fuel may ensue.

The principle of construction described can be readily applied to many existing furnaces, by raising them bodily and replacing the old-fashioned short pillars, under the inantel-ring, with long wrought-iron ones.

NOTE.—Since the writing of the foregoing paper, an iron-furnace to which the writer had applied the water-jacket has been blown out. The brickwork on the jacket is from six to nine inches thick, and the furnace has there preserved its shape. The bosh has a smooth surface, and no re-lining is required. Above the bosh the lining has been cut irregularly. Around the tuyeres no brick-lining remains ; and the furnace has been running on a slag-lining.

THE CONCEKTRATION OF IRON-ORES.

BY ARTHUR F. WENDT, NEW YORK CITY.

IN the manufacture of charcoal-blooms, washing or cleansing of the ore from adhering gangue has been practiced for many years. A sluice-box is even to-day used for that purpose in the Southern . Appalachian Mountains. For the Lake Champlain bloomaries hard magnetic ores are crushed with stamps and then sluiced or jigged in hand-jigs.

The stamps used in the Lake Champlain region are of the most primitive kind. They consist of a trip-hammer, dropping on a perforated cast-iron plate, through which the crushed ore escapes.

Only friable rock can thus be successfully treated. To render the "raw ore friable, a calcining or burning in piles on a bed of cordwood is resorted to. An expense of 35 cents per ton of crude rock treated is thus incurred. The crushed ore is shovelled or otherwise fed into jigs without previous sizing, except such as is incidental to crushing through the perforated bottom of the stamping-machine. In jigging this ore, it is allowed to pass through the bedding into the "hutch." The tailings are scraped off and wasted. They contain a large percentage of fine ore. In many instances, this is regained by subsequent sluicing.

Such was the condition of the industry, when the writer's attention was first called to it in 1882. No attempt had been made to introduce into this branch of ore-dressing the notable improvements adopted in concentrating the ores of other metals. The result of the writer's investigations was the building in 1382 of the " Crown Point Separator."

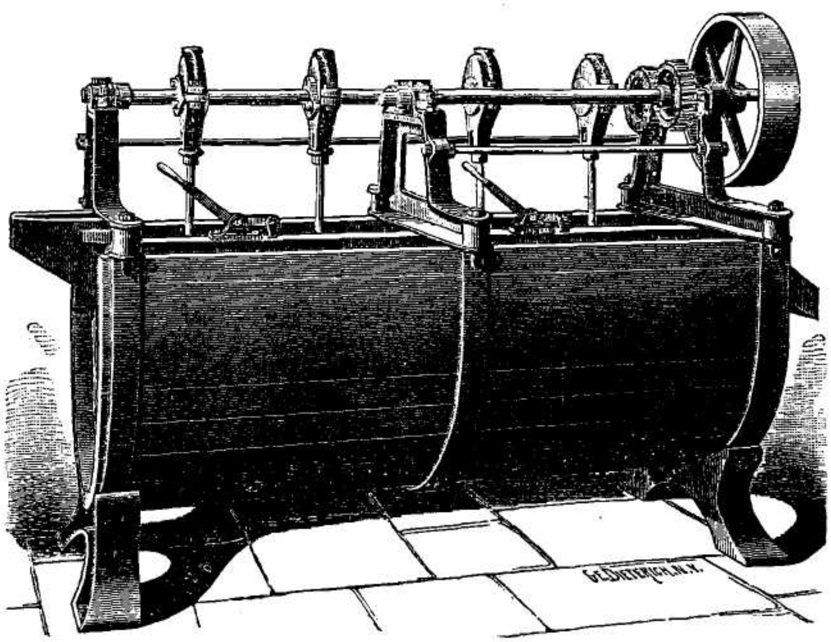
At the Crown Point Mines, N. Y., lean ore unfit for the blast-furnace (containing less than 33 1/3 per cent, of iron), was concentrated and used in the bloomary connected with the mines. The ore was burned here as elsewhere, and treated as described.

The plant designed by the writer for Crown Point, is nearly a counterpart of that since erected by Messrs. Copeland and Bacon, contractors, for the Theal mine, Putnam County, New York, which is illustrated by the accompanying plate. The only difference is in the support-of the crushers. At Crown Point this support is a wooden tower; at the Theal mine, masonry foundations are used.

By reference to the plate, the whole construction will be readily understood. Raw ore is dumped on the upper floor by an automatic skip. It is fed by hand into the 9 inch X 15 inch crusher, and thence passes by gravity through a 6 inch X 20 inch crusher, 16 inch X 36 inch rolls, and 12 inch X 24 inch rolls.

The whole operation is automatic. Screens are inserted between the different crushing machines, to remove any ore that will pass through a 1/8 inch mesh. The screens also serve to feed the various machines regularly, thus contributing, in a measure, to the rapid crushing.

A bucket-elevator raises the crushed ore to the sizing-screen, where grading into two sizes is effected. The coarse ore from 1/8 inch to 1/16



inch in diameter, is fed automatically to four jigs. The fine ore is fed to two jigs. From the moment the ore enters the large initial crusher until it is delivered, freed from adhering gangue, in any chosen receptacle, no manual labor whatever is employed.

A noteworthy feature of the plant, is the arrangement of the jigs. These, which have been patented by the writer, are illustrated in the accompanying cut They are of the usual type of plunger-jigs, the peculiarity being the means employed to vary at will the length of stroke of the plunger, and the relative speeds of this plunger on its down and np-stroke.

The desired result is secured by a combination of a pair of elliptic gear-wheels with two concentric eccentrics. As commonly used, the ratio of the short axis of the ellipse to the long axis, is such that the maximum speed of the down-stroke can be made from nine to sixteen times the minimum speed of the up-throw. The stroke of the plunger permits a variation at will up to four inches. There is no jar whatever in the motion. On the down-stroke the motion begins at a slow speed, increases rapidly and uniformly until the lowest point is reached, then gradually diminishes until the plunger reaches its highest point.

Thus the theoretical maximum efficiency is closely approximated. The ore and rock are lifted bodily on each down-stroke of the plunger, and drop according to gravity during the up-stroke, almost as if the particles were falling through a long stationary column of water instead of a succession of short columns. Excellent work has been done by these machines in every instance, even where the difference in gravity is not very marked.

The practical results of the Crown Point plant are as follows:

Ore treated in ten hours, 80 tons.
Percentage yield of ore in concentrations, 28 per cent.
Average per cent. of iron in concentrations, 65 per cent.

The power required is about 40 horse-power, and at Crown Point, where, for the major portion of the year, this power is furnished by water, the cost is considerably less than $1.00 per ton of dressed ore. A curious feature of the jigging is the elimination of phosphorus. At Crown Point this is not very marked, because the raw ore is extremely low in that impurity ; but at the Theal works, the results are striking. Thus, concentrations and tailings contained by analysis, respectively, 0.18 and 0.297 per cent. of phosphorus. Again, an average of a lot of raw rock, showed 0.18 per cent. and the concentrations therefrom 0.08 per cent. of phosphorus. This is practically converting a non-Bessemer into a Bessemer ore.

It might be doubted whether this process could be applied to iron ores other than magnetites, in which the ore occurs in grains of considerable size, but experiments have proved that there is no difficulty whatever with specular ores, although the degree of concentration is not equal to that of magnetites.

Thus a 100 pound sample of lean ore from the Penn Iron Company's mines in the Menominee range gave, when treated by this apparatus, 40 pounds concentrates, containing: .

Iron, 58.3 per cent.
Silica, 13.8 per cent.
Phosphorus, .024 per cent.

And 60 pounds tailings, containing:

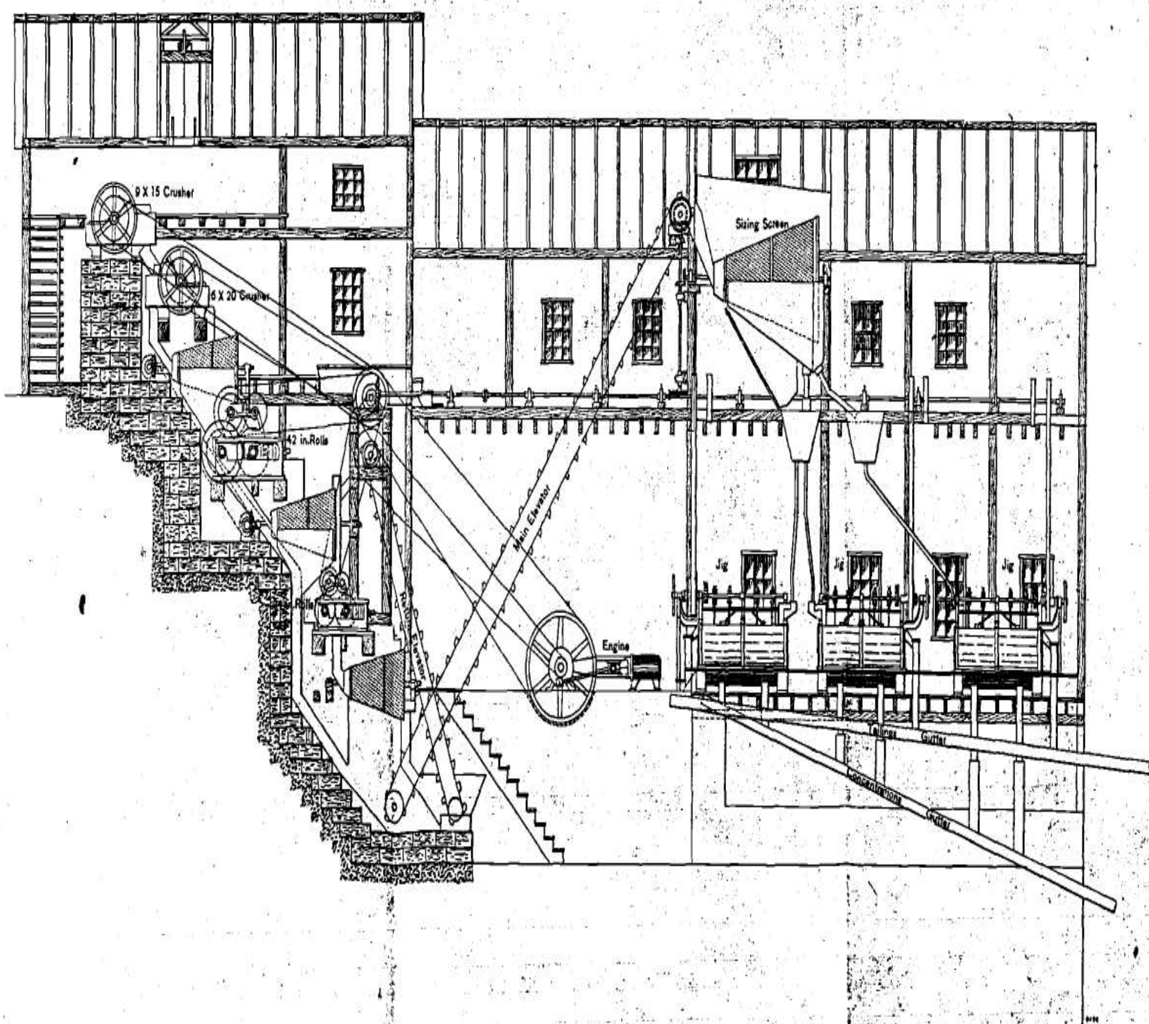
Iron, 24.2 per cent.
Silica, 55.5 per cent.
Phosphorus, .035 per cent.

Here the elimination of phosphorus may again be noted.

To the eye, the concentrates and tailings of specular ores look almost alike. Both are bright red, and the particles have the same shape. But an analysis proves the great difference as above. In conclusion, the writer ventures to predict that it will not be many years before most iron-mines will be equipped with dressing-plants to utilize low-grade ores.

There need be no fear of finding sale for the product. The bugbear of fine ore is rapidly disappearing from the minds of blast-furnace managers. Actual use has demonstrated that concentrated fine ore is reduced and changed into spongy, metallic iron, long before it reaches the hearth of a furnace, and that it does not run ahead of the charge. No trouble whatever has been experienced from its use as part burden of blast-furnaces.

For concentrated specular ores, a large use as fettling already exists; and all concentrated iron-ores are excellently adapted for the manufacture of blooms, or for any direct iron and steel process. Their use in an open-hearth steel-furnace, although never attempted, so far as the writer's knowledge goes, cannot but be eminently successful and profitable.



Concentrating-Works of the Theal Mine, Putnam Co., N. Y.

THE INFLUENCE OF ORGANIC MATTER AND IRONON THE *VOLUMETRI DETERMINATION OF MANGANESE.*

BY J. B. ACKINTOSH, NEW YORK CITY.

THE present note is intended as an addition to my previous communication on the volumetric determination of manganese, read at the Roanoke meeting,* it having been suggested that the circumstances under which my experiments had been conducted, were essentially different from those met with in the analysis of irons. The method used in these experiments is the same in all its details as that described in the paper referred to.

I have made seven experiments in all: two of these were in duplicate on half a gramme of a sample of spiegel dissolved in hydrochloric acid; one was on the same amount of spiegel with the addition of 25 c.c. of a standard solution of potassium permanganate; one was oh the same amount of spiegel with the addition of 35 c.c. permanganate and much organic matter, viz., one drop of castor-oil, two or three drops of coal-tar benzol and of gasolene (petroleum), about ten of alcohol, portions of starch and of sugar about the size of a small pea, and about half an inch of a common match cut into shavings. This organic matter was added to the manganese solution after the hydrochloric acid had been replaced by nitric, and the solution was heated until the wood-shavings had disappeared. The fifth experiment was made by dissolving half a gramme of spiegel alone in nitric acid; the sixth by dissolving half a gramme of spiegel in nitric acid with the addition of 25 c.c. potassium permanganate, some oxalic acid, half an inch of a match, one filter-paper 7 cm. in diameter, and two drops each of castor-oil and turpentine; and the seventh experiment by dissolving half a gramme of spiegel in hydrochloric acid and adding 35 c.c. permanganate, without however taking the precaution to evaporate off all the excess of hydrochloric acid.

Under these circumstances, one would expect that if organic matter exercises any influence on the determination, it would be plainly evident in the results obtained. But the accompanying table of results

* *Transactions,* vol. xii., p. 79.

shows that there is no such evidence, the slight differences obtained being easily accounted for as errors of manipulation.

No.	Spiegel used, grm.	$K_2Mn_2O_8$ used, c.c.	Other constituents present.	Oxidizing power in terms of $K_2Mn_2O_8$, c.c.	Deduct for Mn in spiegel, c.c.	Oxidizing power of precipitate from $K_2Mn_2O_8$ added, c.c.	Theoretical for MnO_2, c.c.	Percentage of theoretical.
1	0.5	....	.....	13.15	....	....	...	...
2	0.5	....	.....	13.15	....	....	...	...
3	0.5	25	.....	23.05	13.15	9.90	10 0	99.
4	0.5	35	organic mat.	26.90	13.15	13.75	14.0	98 2
5	0.5	....	.....	13.15	....	....	...	...
6	0.5	25	organic mat.	23.10	13.15	9.95	10.0	99.5
7	0.5	35	HCl	26.55	13.15	13.40	14.0	95.7

Experiment 3 shows that iron and the carbonaceous matter present in spiegel have no practical effect; experiments 4 and 6 show that extraneous organic matter has no effect; while experiment 7 shows that hydrochloric acid tends to make the results decidedly low. This is what we should expect; for the energetic oxidizing action of the nitric acid and potassium chlorate employed, is very apt to destroy all organic matter present, while we know that MnO_2 is decomposed by hydrochloric acid. Another cause of the slight lowness of the results is the formation of permanganate. Frequently the wash-water is tinted slightly pink.

It may be well to call attention to the fact that the differences between the observed and calculated values in Nos. 3, 4, and 6, correspond to errors of 0.43 per cent., 0.92 per cent., and 0.22 per cent, of the total amount of manganese present, including that in the spiegel, or to errors of 0.05 per cent., 0.12 per cent, and 0.025 per cent., if working on one gramme of spiegel or ferro-manganese, on the total amount of all the constituents present.

The low results obtained by some chemists may perhaps be explained on the supposition that the potassium chlorate used may be contaminated with potassium chloride, thus giving rise to the formation of free hydrochloric acid, which we see interferes with the accuracy of the process.

A MEXICAN CUPELLATION-HEARTH.

BY *W.* LAWRENCE AUSTIN, PH.D., SANTA BARBARA, CHIHUAHUA, MEXICO.

AT the Troy meeting of the Institute, in October, 1883, I presented a paper entitled "Smelting Notes from Chihuahua, Mexico,"* in which was briefly described a cupellation-hearth, commonly met with in the northern part of Mexico, called in the vernacular *un vaso.*

Since writing the paper I have had occasion to construct a hearth of this description for myself, using it, in conjunction with a water-

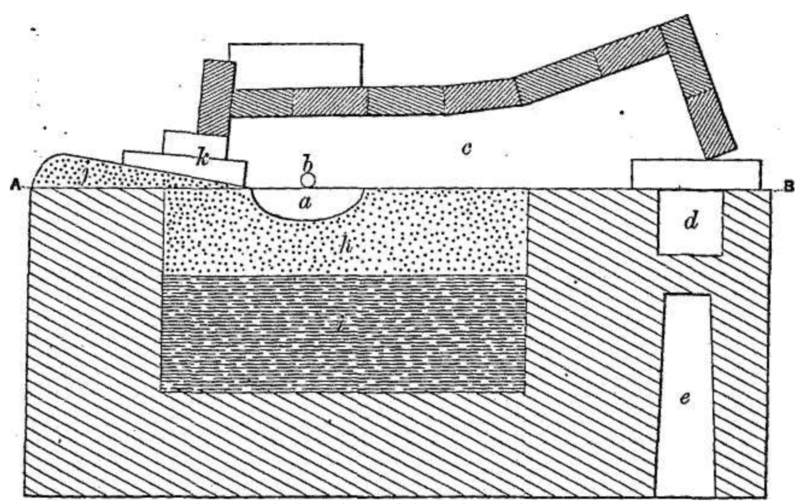


Fig. I. Vertical Section at right angles to Fig,3.

jacket, for the reduction of a very refractory ore in the form of concentrates ; and I now avail myself of this opportunity to qualify some of the statements made in the paper referred to. At the same time I wish to present some sketches which will enable anyone to run up a similar furnace within three days, should occasion demand

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* *Transactions,* vol. xii., p- 185.

it. As it is built entirely of common clay (the more refractory the better) and the ashes of scrub-oak taken from the ash-pit of the furnace itself, the materials necessary for its construction are available anywhere. Even the grate-bars of the fireplace are made of adobes cut in two. There are, scattered over the West, small deposits of refractory lead-silver ores, which, because of their rebellious nature or the isolation of the locality, do not admit of the ordinary smelting process, and are not amenable to amalgamation or any

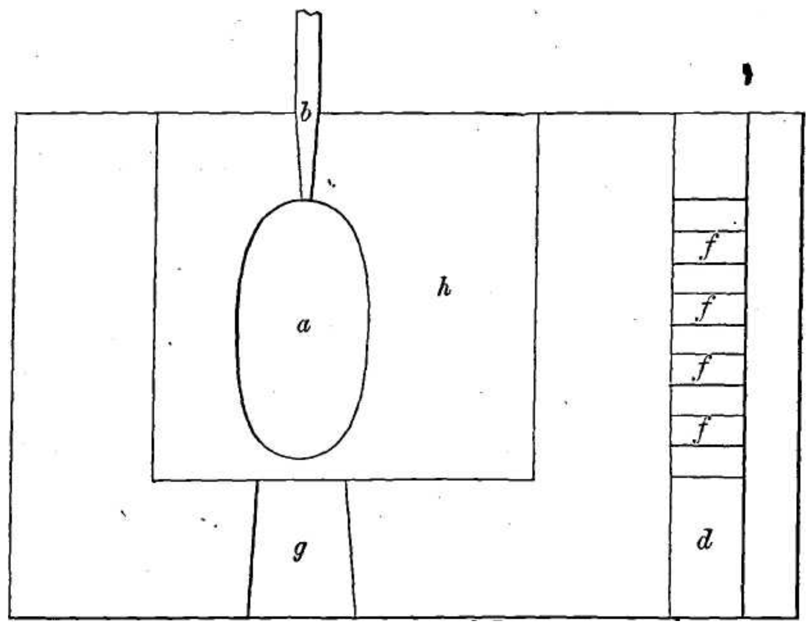


Fig.2. Plan on line A—B (Fig.I.)

other system of reduction commonly practiced; yet with the help of litharge, or, in other words, by performing a crucible assay on a large scale, these ores can be readily and cheaply beneficiated, even where iron and coke are unattainable. I am at the present time engaged in an operation of this description, and am producing fine silver from a mixture of galena, pyrites, and blende, using as fuel oak-charcoal, doing without the valuable fluxing-ores attainable in most smelting-camps, and depending wholly upon the litharge produced by the little *adobe* hearth I am about to describe. In doing this I am only imitating the common Mexican practice, which has been in use for a century or more.

In building the furnace which is the subject of the accompanying sketch, I made use of labor and materials as follows:

Cost of Constructing One Furnace.

300 adobes, @ $0.01, ...	$3 00
40 gallons clay,	
80gallonsasl.es, for test, ... nothing.	
One builder, 4 days, @ $1.20, ...	4 80
Two helpers, 4 days, @ $0.60, ...	4 80
Two boys, 4 days, @ $0.30, ...	2 40
Total	$15 00

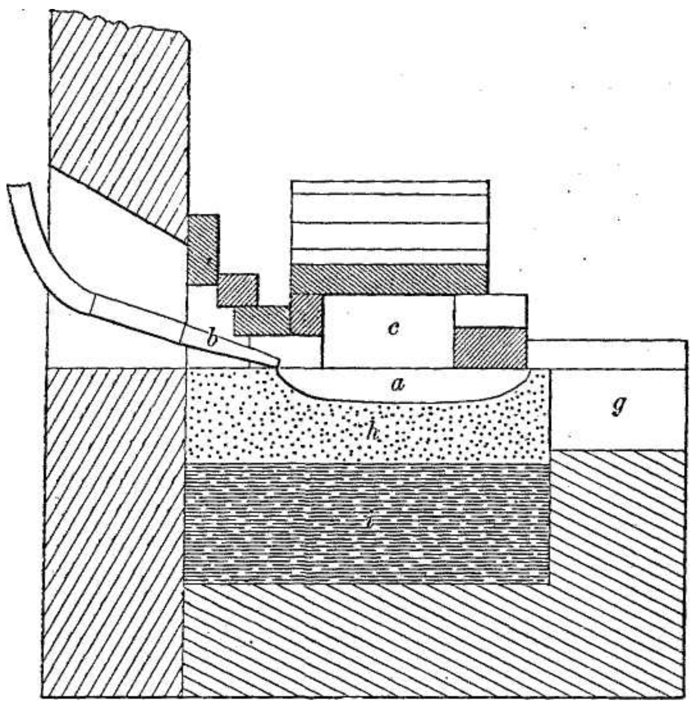


Fig.3. Vertical Section through b,a,g. (Fig.2.)

By comparison with my former figures these will be found somewhat in excess, a fact that arises from two causes: first, the inaccuracy of the statements upon which my calculations were based, and secondly, the fact that the natives of Mexico, from one of whom I obtained the figures referred to, are, in their own country, always able to get work done more cheaply than, a stranger can. This fact, by the way, it is well to bear in mind when forming estimates in that country, since the cheap operations of small proprietors often allure the inexperienced to commit grave errors of judgment. It will only be in rare instances that the profits of native proprietors can be augmented by handling large amounts of their ore with American machinery.

The Mexican is a good miner and a better metallurgist. It is well to examine closely the property he offers for sale, especially when it has a fine record and still cannot yield him sufficient for his simple wants.

But to return to our *vaso,* the difference between the figures given above and those of my former paper is so slight as not to merit comment were it not for the lesson it conveys.

Lead-ore, even when poor in silver, is very desirable in silver-lead smelting operations, and is sometimes paid for beyond its value. Again, the shipment of silver bars may, under certain conditions, be preferable to handling lead bullion. When a cupellation-hearth can be put up, a cheap lead-flux provided, and the advantages of the former method of shipment tested without incurring serious expense, it might, in some cases, be worth a trial. The Mexican *vaso* requires no expense for castings, no exorbitant freight-charges on the material for its construction ; in fact, it is simplicity itself, and answers very well for an experiment or where limited amounts of material are handled. In firing-up, care is necessary not to crack the test, but heat can be applied immediately after tamping-in. Eighteen hours later, the furnace is hot and ready for charging. Should the test be defective or worn out, chisel off the surface for six or eight inches, tamp it in again, and the furnace is ready for firing. In putting in the test, the whole amount of material (clay, 4 parts, and ashes 8 parts, by measure), after being thoroughly mixed and dampened so as to retain the form of the hand when pressed, is thrown in together and tamped solid with wooden poles 5 feet long and 3 inches in diameter, sharpened at one end to a point 1¼ inches square. The reason for putting the whole amount of material in at once is that by this means the whole is beaten into a compact mass ; whereas, by tamping in a little at a time, thin layers are formed, which easily peel off. After the whole is thoroughly pounded in, the test is cut out with a piece of hoop-iron. The accompanying diagrams, exhibiting cross-sections and plan of the furnace, are self-explanatory. The *adobes,* or sun-dried bricks used, are 18 inches X 9 inches X 4 inches, excepting those forming the roof of the canal leading from the fireplace and covering the test, which are 26 inches X 11 inches X 3½ inches. Extra care is necessary in their preparation, and they are dried in the shade to avoid sun-cracks. The capacity of a furnace of this description is something over one ton of lead-bullion in twenty-four hours, consuming less than half a cord of wood, and requiring the attendance of four men, two on a shift, whose collective wages amount to about $2.80 per ton.

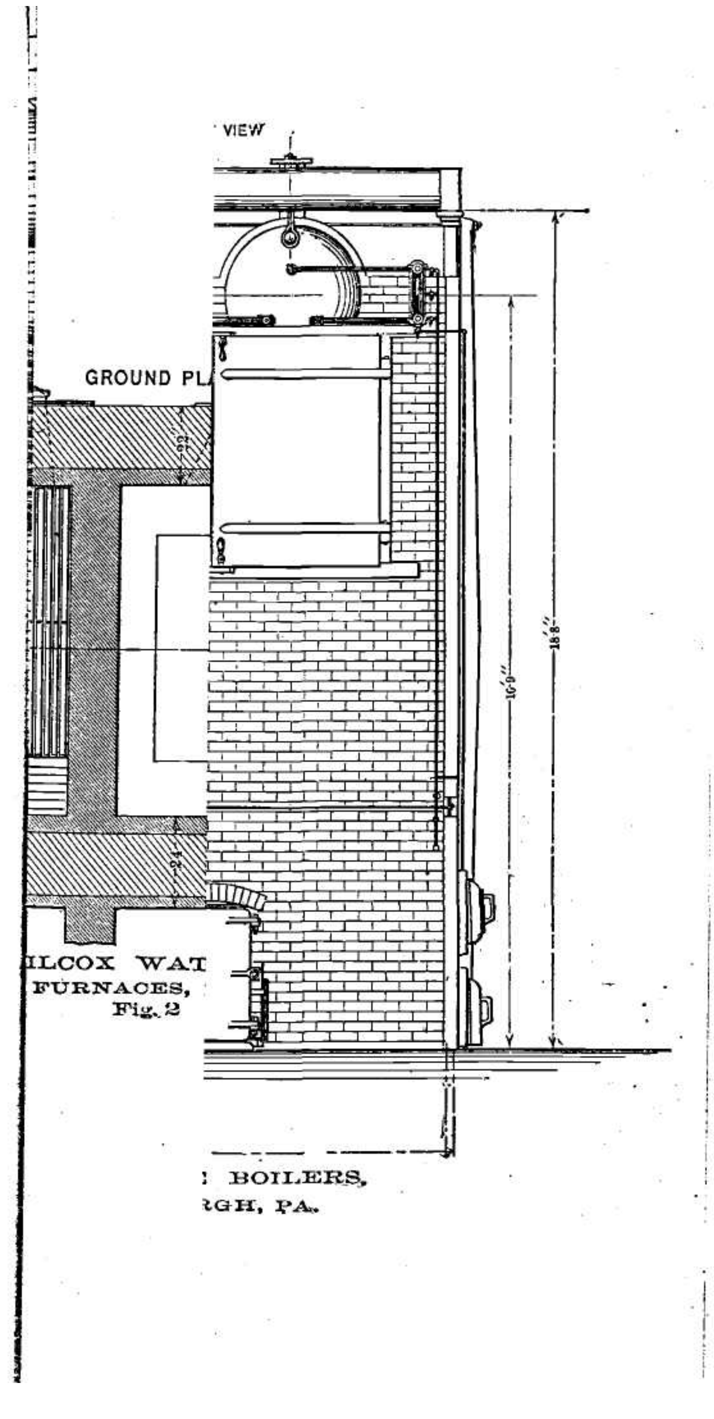
We have, therefore, in this apparatus, a fifteen-dollar furnace, built in three days, capable of reducing one ton of bullion to almost pure silver in twenty-four hours, at a cost of $6.30 per ton. The operation of the furnace is very simple. The bullion is placed on the inclined hearth at *k,* where the flame passing over the molten metal strikes and gradually melts it down. Blast is not put on until the test, which holds 300 pounds of lead, is filled, when its strength is so gauged as to cause slight ripples to play over the surface of the bath. The litharge is drawn off as it accumulates into a basin outside the furnace, where it solidifies and is lifted off in cakes. It is noticeable that no stack exists, yet the flame shoots fiercely out over the metal whenever a stick of wood is laid in the fireplace. Repairs on the test, made necessary by the corroding properties of the litharge, are attended to when the silver is taken out. An old test pounded up finely and mixed with wood-ashes furnishes the material for making such repairs. The silver is allowed to cool gradually in the furnace, and, when solid, is removed, and the cake is thrown into water.

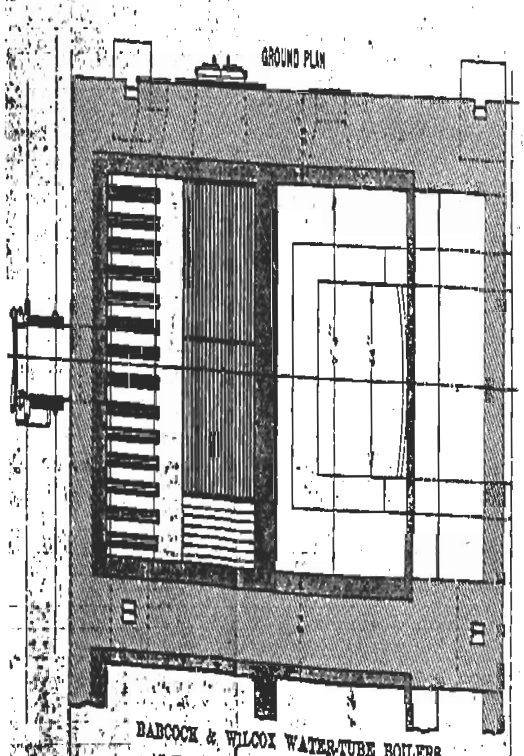
WATER-TUBE STEAM-BOILERS AT THE LUCY FURNACES, PITTSBURGH, PA.

BY WILLIAM KENT, M.E., NEW YORK CITY.

I DESIRE to place on record in our *Transactions* a recent innovation in blast-furnace practice, namely, the introduction at the Lucy Furnaces, in Pittsburgh, of four water-tube steam-boilers, of the Babcock and Wilcox pattern, aggregating 832 horse-power, builder's rating, or 9,568 square feet of heating-surface, utilizing the waste gases of the furnaces as fuel. The boilers are set in two batteries, each of 416 horse-power, and each battery occupying a ground-space of 22 feet 7 inches by 20 feet 4 inches. The accompanying drawing shows a side-elevation and a partial ground-plan of the boilers and setting. The boilers are the regular design of the Babcock and Wilcox Company; but the setting is a novel one, designed by the superintendent of the furnaces, Mr. Julian Kennedy, a member of the Institute. As shown in the drawing, the boilers are raised about five feet above what would be their ordinary position if fired with coal, to permit the introduction under each of a tall combustion-chamber, about 7 feet 6 inches square by 10 feet high. This chamber is divided into two portions, a front, and a rear, by a perforated wall and by a number of tiles set on edge, reaching from the top of this wall to the front wall of the boiler. The gas is conveyed to the boilers through an underground flue, 5 feet by 3 feet, and is introduced into the combustion-chamber under each of the four boilers through a Witherow and Gordon gas burner. The gas striking the hot perforated wall, and the tiles overhead, and passing through them, and the proper amount of air being admitted, part through the burner, and part through small flues in the front wall of the boiler (not shown in the drawing) by which it is heated before admission, thorough combustion is insured. A small fire of coal is kept burning on the grate as a precaution to secure the relighting of the gas in case of the possible interruption of its supply. The heating-surface of the boiler is divided into two portions, front and rear, by a transverse division-wall as shown in the drawing The heated gases of combustion pass up through the front portion of the heating-surface, and down through the rear, and enter a flue leading to the chimney. Four side cleaning-doors are attached to each boiler, through which the dust deposited from the gases is easily cleaned from the tubes by means of a steam-jet.

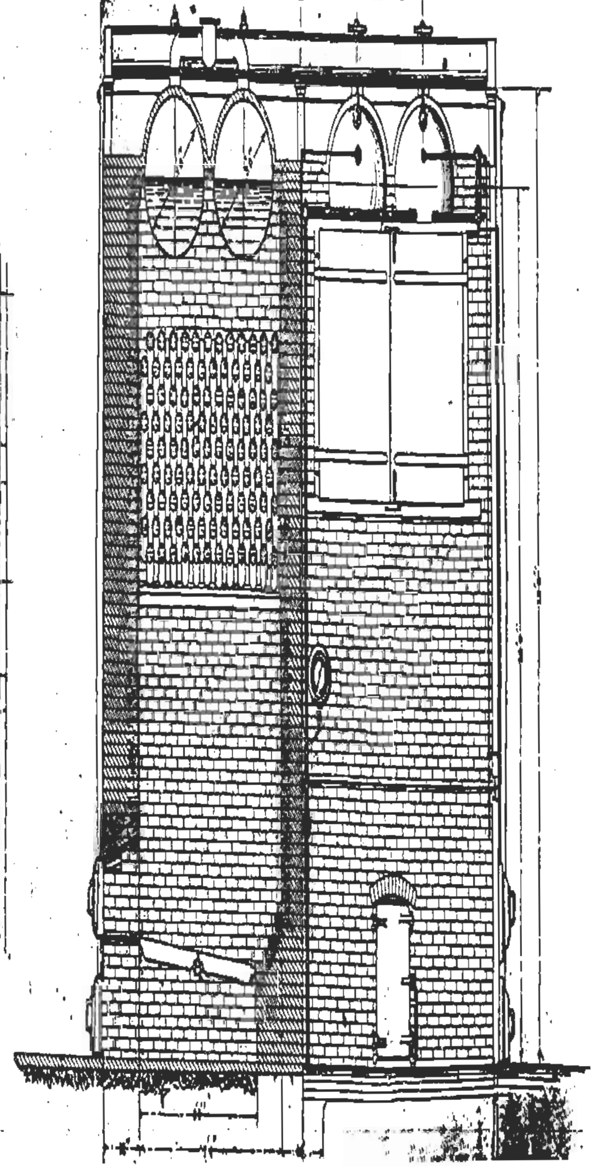
The boilers have now been running two months with great satisfaction to all concerned. Without mentioning the general advantages of water-tube boilers, which are now well known, I may remark that they are especially adapted to replace the cylinder and two-flue boilers ordinarily used at blast-furnaces, on account of their occupying less than one-third of the ground-space, and being actually cheaper in first cost for an equal amount of heating-surface.

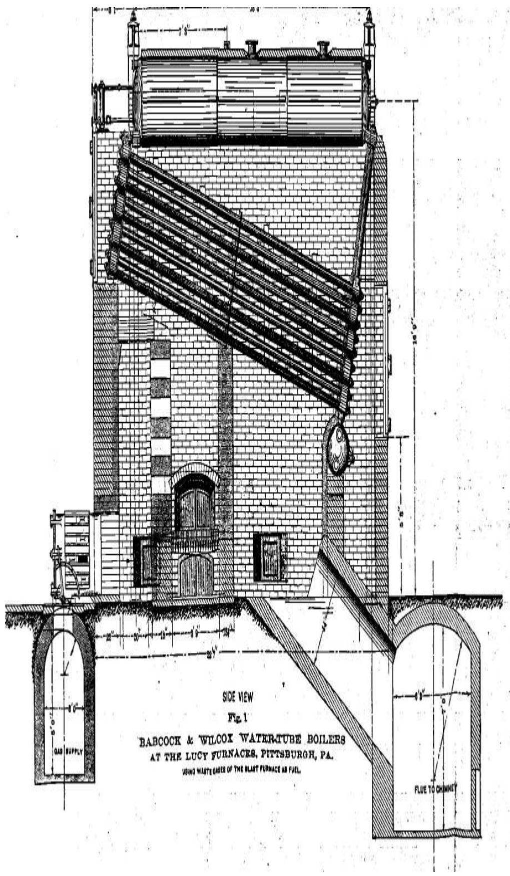

VIEW
GROUND PL
22
24
16'9"
18'8"
ILCOX WAT
FURNACES,
Fig. 2
BOILERS,
RGH, PA.



BABCOCK & WILCOX WATER-TUBE BOILERS,
AT THE LUCY FURNACES, PITTSBURGH, PA.
Fig. 2

CROSS SECTION Fig. 3 FRONT VIEW

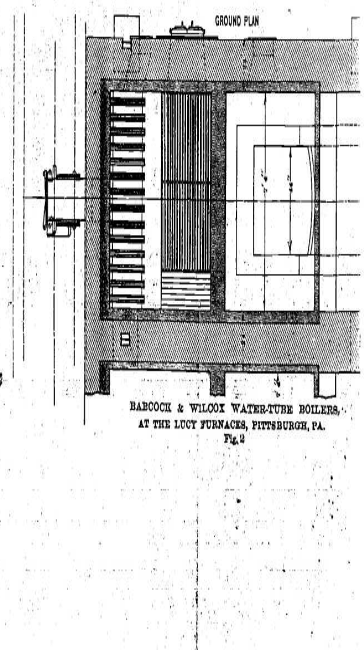




SIDE VIEW

Fig. 1

BABCOCK & WILCOX WATER-TUBE BOILERS
AT THE LUCY FURNACES, PITTSBURGH, PA.
USING WASTE GASES OF THE BLAST FURNACE AS FUEL.



GROUND PLAN

BABCOCK & WILCOX WATER-TUBE BOILERS,
AT THE LUCY FURNACES, PITTSBURGH, PA.
Fig. 2

RUSSELL'S IMPROVED PROCESS FOR THE LIXIVIATION OF SILVER-ORES.

WITH CRITICAL REMARKS ON OTHER METHODS OF COPPER, SILVER, AND GOLD EXTRACTION

BY C. A. STETEFELDT, NEW YORK CITY.

FOR the convenience of those who do not care to enter into the details of this long essay, I begin with a summary of the most important results it presents.

The extraction of silver by the lixiviation-process from ores which have been subjected to a chloridizing-roasting, is based upon the fact that silver chloride is easily soluble in solutions of sodium or calcium hyposulphite, and that silver is precipitated from such solutions by an alkaline sulphide, with regeneration of the hyposulphite salts. In case the ore contains lead a large portion of the latter is also dissolved, lead sulphate being soluble in hyposulphite solutions. If, at the same time, copper is present, the sulphides precipitated from the solution, contain silver, copper, and lead, a combination of metals not desirable for subsequent treatment.

Mr. E. H. Russell, of Park City, Utah, is the inventor and the patentee in the United States and several foreign countries of a new lixiviation-process, based upon the chemical facts discussed in this paper. Mr. Russell has discovered that lead can be completely separated from a sodium hyposulphite solution, as lead carbonate, by sodium carbonate or purified soda-ash, without precipitating any copper or silver. After decanting the solution from the lead carbonate, silver and copper are obtained from it in the usual way. This method of separating lead prohibits the use of calcium poly-sulphide as a precipitant for the sulphides, because any calcium entering the regenerated lixiviation-solution would also be precipitated as a carbonate with the lead by soda-ash. Hence, a sodium sulphide must be employed. A full investigation has demonstrated that this is by no means detrimental. Sodium sulphide and hyposulphite are more advantageously used in the lixiviation-process than the corresponding calcium-salts.

Another defect in the lixiviation-process consisted in the necessity of a very perfect chlorination of the silver in the ore, because silver in any other combination, or in the metallic state, would be only imperfectly extracted by sodium or calcium hyposulphite.

Mr. Russell discovered, that a solution of a double salt of cuprous hyposulphite and sodium hyposulphite, formed by mixing sodium hyposulphite with copper sulphate, exerted a most energetic dissolving and decomposing action upon metallic silver, silver sulphide, and its combinations with antimony and arsenic. Hence, if a charge of ore is first lixiviated with ordinary sodium hyposulphite solution to dissolve the silver chloride, and, subsequently, with cuprous hyposulphite, —this solvent is called the extra-solution,—an additional amount of silver is extracted which would have been lost in the tailings by working according to the old method alone.

This process can also be introduced with profit to extract silver from ores without roasting, or after they have been subjected to an oxidizing-roasting.

The sulphides of silver and copper, obtained as precipitates in the lixiviation-process, are dissolved by nitrated sulphuric acid, the escaping nitric oxide being reconverted to nitric and nitrous acid according to well-known chemical principles. From the solution cement-silver is precipitated by metallic copper, and copper sulphate results by crystallization. A part of the latter is again needed for preparing the extra-solution. Having thus briefly and generally stated the substance of Mr. Russell's discoveries, I now proceed to consider the subject in detail.

Mr. Russell, being in charge of the assay-office at the Ontario Mill, Utah, has carried out a series of experiments, the results of which have ltd to his improved process for lixiviating silver-ores. These researches are so thorough and extensive, they cover so much untrodden ground, and have brought to light such novel and interesting facts, that they must command general attention, not only for the sake of their practical- importance, but also for their purely scientific value. Having procured for Mr. Russell the support of Mr. R. C. Chambers, the General Manager of the Ontario Silver Mining Company, in testing the practical value of his discoveries by experiments on a large scale, and having followed the progress of his work with ever-increasing interest, I have prepared the results of his investigations for publication.

I propose to describe Russell's process principally from a scientific, and not from a technical standpoint, leaving a description of the plant and the manipulations, and a full consideration of all economic questions, as the subject of a paper to be published hereafter.

In the lixiviation of silver-ores by means of a hyposulphite solution, which process was first proposed by Professor John Percy, two difficulties have heretofore been met with which have rendered the process inapplicable in many cases. These are: 1st. The difficulty of producing bullion free from lead. 2d. The necessity of a very perfect chloridizing-roasting, since the hyposulphite solution acts only imperfectly upon metallic silver and such of its combinations as have not been transformed into the chloride by the roasting process.

In the amalgamation of roasted silver-ores, silver-bullion almost entirely free from lead is produced if certain precautions are taken, even in case the ore contains a large percentage of lead-minerals. If native silver occurs in the ore, which is not entirely converted into chloride by roasting, this silver amalgamates readily. Silver-compounds, too, which are not converted into chloride, are decomposed to a certain extent, and the silver is amalgamated, especially if the roasted ore contains soluble copper-salts. Hence, a larger percentage of silver is in many cases extracted by amalgamation than that shown to be present as chloride, according to the customary chlorination-tests.

To make lixiviation applicable in all cases, was the object of Russell's researches; how well he has succeeded, will be demonstrated in the following pages.

The solubility of a substance in a liquid may be considered as a function of temperature, concentration of the liquid, and time of reaction, other conditions being equal. In regard to the solubility of certain combinations of silver, and other metals, in a solution of sodium hyposulphite, we may state here at once that temperature enters in so far as an important factor, as moderately warm solutions, say from 25° to 50° C, act more energetically, and dissolve in less time, than colder ones. A much higher temperature of the solution, however, must be avoided.

In making chlorination-tests of roasted silver-ores, with a sodium hyposulphite solution, it has been generally assumed that the silver extracted is all in the form of chloride. This is not correct. The solution reacts, more or less, upon metallic silver, and also upon many silver-combinations other than chloride, especially if the roasted ore contains a considerable amount of soluble copper-salts. The silver bromide and iodide do not interest us here.

In the following investigations on solubility it might have been of interest if, in every case, a series of experiments had been conducted with the view to arrive quickly and surely at saturation-points by using less solution, and a large surplus of the substance to be dissolved.

I do not think, however, that my general conclusions, drawn from these researches, would be affected by such additional information. This has been verified in special cases. I also wish to say, that if others should repeat similar experiments, they should not be astonished at finding numerical results differing, more or less, from those recorded here. They will, undoubtedly, arrive at the same general conclusions as those presented in this paper.

I. The Reactions of a Sodium Hyposulphite Solution.

Silver forms with the hyposulphites of sodium, potassium, and calcium two series of double salts. The one has the formula $2RS_2O_3$ + Ag2S2O3 + 3aq., and the other, RS_2O3 + Ag2S2O3 + 2aq.

Of these double salts the former are easily soluble in water, and the latter much less so.

§ 1. *Solubility of metallic Silver.*

[In all the following experiments the metric system is used.] 0.500 gm. cement-silver were treated cold (at about 15° C) for forty eight hours with 1000 c.c. of solutions, containing respectively 10, 25, 50, 100, 150, 200, and 250 gm.Na_2S_2O3 + 5aq. The result was that the 1 per cent, solution dissolved as much silver as the 25 per cent, solution, namely, 0.030 gm. Solutions of intermediate strength gave figures somewhat higher or lower. This shows that the dissolving energy of the solution is not increased by concentration, a peculiarity which will be met with frequently in subsequent experiments. In repeating this experiment at a temperature of 50° C, the solubility of the silver was materially increased. The 20 per cent., 15 per cent., and 5 per cent, solutions dissolved 0.100 gm. silver each, and the others somewhat less.

§ 2. *Solubility of Metallic Gold.* '

0.050 gm. gold-leaf were treated for forty-eight hours with 1000 c.c. of solutions of different concentration, as in § 1. In every instance about 0.002 gm. gold were dissolved, the deviations from this quantity being exceedingly slight. No differing results were obtained with cement-gold.

§ 3. *Solubility of Silver Sulphide.*

No silver was dissolved after exposing 2 gm. Ag_2S to hyposulphite solutions of different concentration for twenty-four hours.

§ 4. Solubility of Gold Sulphide.

Gold sulphide is decomposed by a solution of sodium hyposulphite. For energetic action, heating to 50° or 60° C. is necessary. In treating 2 gm. Au_2S_3 for twenty-four hours cold, 0.066 gm. gold were dissolved; while at a temperature of 65° C, 0.117 gm. gold went into solution in two hours. An alkaline sulphide again precipitates Au_2S_3 from this solution.

§ 5. *Solubility of Silver Arsenate.*

Silver arsenate was prepared which contained, by fire-assay, 67.75 per cent, silver. This corresponds nearly with the formula Ag_3As0_4. 1-gm. of this salt treated with 500 c.c. of a 5 per cent, sodium hyposulphite solution, without heating, showed, after twenty hours, only a residue of 0.003 gm. undissolved.

§ 6. Solubility of Silver Antimonate.

Silver antimonate was prepared which contained, by fire-assay, 36.46 per cent, silver. This corresponds with the formula $AgSbO_3$. In treating 1 gr. under the same conditions as in § 5, 44 per cent., or 0.160 gm. of the silver went into solution, and a residue of 0.177 gm. was left undissolved. The composition of the latter was not ascertained.

§ 7. Solubility of Cuprous Chloride.

Cuprous chloride, Cu_2Cl2 is dissolved by sodium hyposulphite with the formation of double-salts, the nature of which will be fully considered in subsequent paragraphs.

§ 8. Solubility of Lead Sulphate.

Lead forms a sodium hyposulphite double-salt of the formula $2Na2S2O3,PbS_2O_3$, without water. The solubility of lead sulphate in sodium hyposulphite is characteristic, on account of its being principally a function of the concentration of the solution. If the same quantity of sodium hyposulphite is dissolved in varying quantities of water, the solubility of the lead sulphate increases materially with the concentration of the solution. The following figures, deduced from a series of Mr. Russell's experiments, will illustrate this.

Concentration of the solution in $Na_{2\ S2O3}$ + 5aq.	Amount of $PbSO_4$ dissolved for one part of $Na2S_20_3$ + 5aq.
5 per cent.	0.080
6.6 "	0.102
10 "	0.131
20 "	0.194
25 "	0.226

This peculiarity is very favorable for working on a large scale, where hyposulphite solutions of low concentration are used, and the quantity of lead sulphate dissolved is thus brought to a minimum.

The solubility of lead sulphate increases materially with the temperature of the solution. In exposing 20 gm. $PbSO_4$ to 1000 c.c. of a 5 per cent, sodium hyposulphite solution for one hour, 0.048 parts of $PbSO_4$ per unit of $Na_2S_2O_3 +$ 5aq. were dissolved at 21 degrees C., while the solubility-coefficient at 49 degrees C. was 0.095.

§ 9. *Solubility of Calcium Sulphate.*

The solubility of calcium sulphate or gypsum per unit of sodium hyposulphite, is principally a function of the concentration of the solution. The more dilute solutions are relatively better solvents than more concentrated ones. The following figures are deduced from a series of Mr. Russell's experiments. The solubility of calcium sulphate is decreased by elevating the temperature of the sodium hyposulphite solution. The experiments below were made at about 18° C.

Concentration of the solution in $Na_2S_2O_3 + 5aq.$	Amount of $CaSO_4$ dissolved for one part $Na_2S_2O_3 + 5aq.$
5 per cent.	0.157
6.6 "	0.143
10 "	0.119
20 "	0.117

The solubility of gypsum in calcium hyposulphite is somewhat less than in the sodium-salt.

§ 10. *Solubility of Silver Chloride.*

In dissolving AgCl by sodium hyposulphite, both double-salts mentioned at the beginning of this chapter are formed.

Two methods can be used in determining the solvent energy of sodium hyposulphite for silver chloride.

1st. By exposing freshly precipitated AgCl to the solution.

2d. By adding $AgNO_3$ to a hyposulphite solution which contains sodium chloride. In this case the AgCl is dissolved " in statu nascendi," and as soon as saturation has taken place the solution becomes turbid.

If, in the second method, a silver-solution of known standard is taken from a graduated burette, the result is sufficiently accurate for practical purposes, to ascertain the strength of a lixiviation-solution in hyposulphite. The exact end of the reaction, however, is not plainly visible.

The first method gives somewhat varying results if a large surplus of AgCl is used, and left exposed to the solution for a long time. Then the less soluble double salt $Ag_2S_2O_3 + Na_2S_2O_3 +$ 2aq. is formed. By using solutions of more than 10 per cent, concentration, the AgCl hardens into lumps, because in such cases the quantity of water present is not sufficient to dissolve the argentic double-salts. For solutions of lower concentration, the solvent energy is almost entirely a function of concentration, and increases in proportion to the quantity of sodium hyposulphite present. Temperature does not influence results materially.

Mr. Russell's determinations, by the first method, give an average coefficient of 0.301 Ag, or 0.400 AgCl, for one part of $Na_2S_2O_3$ + 5aq.

By the second method the coefficient is 0.365 Ag, or 0.485 AgCl, for one part + 5aq. The latter figures are to be considered as the more correct ones.

It is of considerable interest to know to what degree the solubility of AgCl is influenced, if other soluble salts are mixed with the solution, or if the latter has been saturated with salts not very soluble in water, but soluble in sodium hyposulphite. The principal combinations which in tin's respect play an important part in the lixiviation-process, are the sulphates of lead, calcium and sodium, the caustic alkalies and alkaline earths; and these alone we shall consider.

Influence of Lead Sulphate.—If lead sulphate has been dissolved in a sodium hyposulphite solution, and the latter is tested for its solvent energy for silver chloride, by the first method, the results show a marked decrease. It is not astonishing that this should be so, because a part of the sodium hyposulphite is consumed in the formation of the lead-salt. Assuming that this has the formula $2Na_2S_2O_3, PbS_2O_3$, and calculating the amount of sodium hyposulphite necessary in its formation, we find that the dissolving energy of the solution for silver chloride has been less reduced than should be expected, taking Mr. Russell's value of 0.400 for the solubility of silver chloride as a basis for calculation. From Mr. Russell's experiments I have deduced the following table:

Solution contains for one part $Na_2S_2O_3 + 5aq.$ dissolved parts of $PbSO_4$	Decrease of dissolving energy for AgCl.	Decrease expected by the formation of $2Na_2S_2O_3, PbS_2O_3$.
0.045 parts.	8.6 per cent.	11.0 per cent.
0.054 "	11.2 "	13.2 "
0.059 "	12.6 "	14.4 "
0.086 "	15.4 "	21.0 "
0.107 "	23.8 "	26.2 "

Influence of Calcium Sulphate.—In testing the solubility of silver chloride in a sodium hyposulphite solution saturated with gypsum, no marked decrease of solvent energy was clearly established. The reason is obvious. A double-salt of sodium and calcium hyposulphite is formed, and sodium sulphate. Any decrease in solvent energy would, most likely, be produced by the presence of the last-named salt.

The same results were obtained in saturating a calcium hyposulphite solution with gypsum.

Influence of Sodium Sulphate.—The presence of this salt depresses the solvent energy of sodium hyposulphite for silver chloride. In experimenting with solutions containing 1½ per cent, of $Na_2S_2O_3$ + 5aq., their solvent energy was diminished 6 per cent, by addition of 2 per cent, of sodium sulphate, and 8 per cent, by addition of 5 per cent, of this salt.

The solvent energy of potassium hyposulphite is, however, increased by sodium sulphate. This, no doubt, is based upon the formation of potassium sulphate and sodium hyposulphite, which latter is a much better solvent for silver chloride than the potassium-salt, as will be found in § 26.

Influence of Caustic Alkalies and Alkaline Earths. — Mr. Russell found that the presence of a very slight quantity of a caustic alkali or an alkaline earth in a hyposulphite solution has a very deleterious effect on the solubility of silver chloride and other silver combinations. This is not the case with carbonates of the alkalies. The presence of one-tenth of one per cent, of caustic soda is sufficient to depress the results in working on a large scale from 6 to 17 per cent., if extra-solution is used, and as much as 30 per cent, if ordinary solution alone is used. If tailings from such defective lixiviation are subsequently treated in the laboratory with more concentrated sodium hyposulphite solutions, in some cases only a small percentage of the silver can be extracted. The same effect is produced by caustic lime. In adding one-half of one per cent, of caustic lime to a sodium hyposulphite solution, the percentage of silver extracted from Ontario ore was depressed from 11 to 24 per cent. These facts seem to have been overlooked so far.

A sample of roasted Ontario ore, which yielded by lixiviation-tests with ordinary solution 86.5 per cent., and with extra-solution 93 per cent, of its silver, was first leached with water, and then treated for thirty-six hours with sodium hyposulphite solutions of 2½ per cent, concentration, to which various amounts of caustic soda had been added.

Per cent. of caustic soda added.	Per cent. of the silver extracted.
0.2	6.5
0.5	3.7
1.0	4.8
5.0	5.9

We note here that, after the maximum effect has been produced, an increase of caustic soda is actually beneficial. A sodium hyposulphite solution of $2\frac{1}{2}$ per cent, concentration, saturated with caustic lime, extracted from the same ore 60 per cent, of its silver. In case lixiviation-tests are made without first leaching with water, the effect of caustics is materially lessened by their action upon sulphates and chlorides of copper, zinc, and manganese.

From numerous experiments carried out by Mr. Russell, it appears that the effect of caustic soda is generally not so pronounced as in the example given above. The character of the ore seems to have an influence on the results. More concentrated hyposulphite solutions lessen the effect; hence lixiviation-tests in the laboratory will extract more silver from the tailings resulting from such defective lixiviation. It can easily be seen that caustics may be introduced into a lixiviation-solution, namely, by the alkaline sulphides used as precipitants for the silver. It seems difficult to prepare these alkaline sulphides in such a manner that they are entirely free from caustics, which applies more to the sodium than to the calcium preparation. If lead is precipitated as $PbCO_3$ by soda-ash, or as basic hydroxide by caustic lime, this is another source of introducing caustics, namely, if the soda-ash contains caustic soda, or if a surplus of caustic lime has been added. Caustic lime also decomposes sodium sulphate with formation of gypsum and caustic soda. This will be further discussed in the following paragraph.

If caustic soda is present in the lixiviation-solution, Mr. Russell counteracts its injurious effect by making the solution slightly acid with sulphuric acid. The deleterious effect of caustic alkali and alkaline earths in amalgamation is well known, and is one of several parallels we meet in both processes.

§ 11. *Solubility of the Carbonates of Silver, Copper, Lead and other Metals.*

Mr. Russell has discovered a reaction of which I have found no previous record, namely, that $PbCO_3$ is insoluble in a sodium hyposulphite solution, while the carbonates of silver and copper are soluble, which latter fact was known. Hence, if Na_2CO_3 is added to a hyposulphite solution containing lead, silver and copper, $PbCO_3$ alone is precipitated. If a solution of pure $PbSO_4$ in sodium hyposulphite is so treated, the precipitation of the lead is so complete, that H_2S gives no reaction in the filtrate. Upon these reactions is based the separation of the lead from silver and copper in Russell's lixiviation-process. In effecting this on a large scale, it is most economical to use the commercial soda-ash. The latter, if manufactured by the old process, contains more or less Na_2S, and precipitates Ag_2S with the $PbCO_3$, whereby a product results rich in silver. In order to purify the soda-ash, Mr. Russell makes use of the fact that $CuCO_3$ is soluble in a hyposulphite solution, and C11S is not. He dissolves the soda-ash in water containing about 1½ per cent. $Na_2S_2O_3 + 5aq.$, and then adds a solution of copper sulphate. Copper sulphide is precipitated, and the soda-ash so purified yields a lead carbonate retaining a trace of silver only. But the soda-ash may also contain caustic soda. The latter, if present in a hyposulphite solution, has an injurious effect in extracting silver by lixiviation. In order to remove it, the soda-ash solution is first boiled with sulphur, whereby sodium polysulphide and hyposulphite are formed, and then the sodium polysulphide is decomposed by copper sulphate as stated above. The carbonates of iron, manganese and zinc, and also of calcium, share with the lead the peculiarity of being insoluble in a hyposulphite solution. In well-roasted ores only traces of iron salts exist, and these, as well as the chlorides and sulphates of zinc and manganese, are removed by the wash-water. Hence, none of these carbonates are precipitated with the $PbCO$.

If lead is to be precipitated by this process, the use of calcium hyposulphite is not admissible, neither can a calcium sulphide be used for the precipitation of the silver, as will be fully discussed below.

The last-mentioned experiment led Mr. Russell to investigate the properties of a hyposulphite solution to which copper sulphate has been added. He calls this the "Extra-Solution" to distinguish it from the ordinary hyposulphite solution, without copper. The discovery of the reactions of this extra-solution constitutes, in its practical application, Mr. Russell's second and most important improvement in the lixiviation of silver-ores.

Before entering on the last-named subject, some further remarks about Russell's method of separating lead will be in order. In Kerl's *Metallurgy,* edition 1865, vol. iv., page 299, occurs the following passage: “In order to extract silver and gold from ores Kiss roasts them with salt, lixiviates the roasted ore with calcium hyposulphite, and precipitates from the solution gold and silver by calcium sulphide. . . . . Alkalies *(Alkalien)* separate silver and gold from the calcium hyposulphite double-salts contained in the solution either not at all or only in case the lime itself is precipitated, while lead, zinc and antimony are precipitated at once.”

The meaning of this passage is in some respects obscure. That Kiss did not use this method for the separation of lead becomes evident from the fact that the sulphides he obtained in this process contained 18.8 per cent, of lead sulphide. Neither is there anything definitely expressed, if Kiss meant by *Alkalien* caustic alkalies or carbonates of alkalies *(kohlensaure Alkalien).* Whoever reads without prejudice the quoted passage, and what follows in Kerl's Metallur*gy* , must acknowledge that Kiss was not aware that a perfect and practical separation of lead could be accomplished by sodium carbonate from a sodium hyposulphite solution. All that can be said is, that Russell's discovery might be anticipated from the remarks of Kiss. Between anticipation, however, and the perfection of a method for practical ends, there is a great difference.

The Separation of Lead by Cau*stic Lime.*—From the Walker Lake Bullet*in* of April 30th, 1884, it appears that at the Mount Cory mill, Nevada, caustic lime is used as precipitant for lead from the lixiviation-solution. In this case the lead is obtained as basic hydroxide, together with gypsum and such impurities of the caustic lime as do not enter into the reaction. Cheapness and the possibility of using calcium pentasulphide for the precipitation of silver and copper are claimed as the advantages of this method. It does not follow that because a method is apparently cheap it is the best. [That the cheapness of calcium pentasulphide is a delusion, will be discussed later.] Its disadvantages are easily perceptible.

1st. It is difficult, indeed impossible, to notice the end of the reaction without calling some other reagent into requisition. The use of a solution of caustic lime in water is not permissible on account of its dilute character, hence caustic milk of lime, or slaked lime, must be added at random, and, the reagent itself being in the form of a precipitate, the end of the reaction cannot be observed by addition of a sufficient quantity of the reagent.

2d. If a surplus of lime has been used, hydroxide of lead will be redissolved, it being soluble in caustics. Hence, no complete separation of the lead can be effected.

3d. The lead precipitate with lime being very impure, is of less commercial value than the lead carbonate in Russell's process.

4th. I doubt whether the lead hydroxide can be obtained as free from silver and copper as Russell's lead carbonate.

5th. If a surplus of caustic lime has been added to the lixiviation-solution, and, after precipitating the sulphides, the caustic lime is not neutralized by an acid, such lixiviation-solution will not be a good solvent for silver, as demonstrated in § 10. A lixiviation-solution of 2 per cent. concentration in sodium hyposulphite dissolves 50 per cent.

more calcium hydrate than pure water does. Even if no surplus of caustic lime has been added, the solution may become caustic by the formation of caustic soda.

II, The Extra-Solution.

If solutions of alkaline hyposulphites are mixed with salts of cupric oxide, hyposulphite double salts, containing the alkali and cuprous oxide, are formed. If the solutions are not too dilute, these double salts separate in the form of canary-yellow precipitates.

The latter, under certain conditions, turn black in consequence of the formation of copper sulphide. By treating them with boiling water, the cuprous hyposulphite is completely decomposed into a sulphide. Dilute acids do not decompose these double salts at ordinary temperature, but do so very quickly upon heating. Some of these double salts are very little soluble in water, but dissolve readily in aqueous hyposulphite. The latter solutions are quite permanent, even if heated to 85° C.

The potassium-salt has, according to Rammelsberg, the formula $K_2S_2O_3,Cu_2S_2O_3 + 2aq$. Lenz obtained a sodium double salt of the formula $2Na_2S_2O_3,3Cu_2S_2O_3 + 5aq$. If solutions of sodium hyposulphite and copper sulphate are mixed, the reactions are expressed by the equation:

$$\text{(No. 1.)} \quad 11Na_2S_2O_3 + 6CuSO_4 = 2Na_2S_2O_3,3Cu_2S_2O_3 + 6Na_2SO_4 + 3Na_2S_4O_6,$$

leaving out the water-equivalents. It is a reaction similar to the one which takes place if sodium hyposulphite is treated with iodine, as far as the formation of sodium tetrathionate is concerned, viz.:

$$2Na_2S_2O_3 + 2I = 2NaI + Na_2S_4O_6.$$

Some writers state that in equation No. 1 no sodium tetrathionate is formed, but free sulphuric acid and sulphur; and that the former again reacts upon the hyposulphites, and precipitates sulphur and copper sulphide. In preparing the precipitate according to the above equation, and dissolving it again in aqueous sodium hyposulphite, not a trace of free sulphur or copper sulphide was discovered.

The solutions of the cuprous hyposulphite double salts are peculiar on account of the energetic decomposing action they exert upon most silver-combinations and silver-minerals. That upon silver sulphide has been especially investigated. If the silver sulphide has been freshly precipitated, the reaction is practically instantaneous. In all cases an argentic hyposulphite double salt is formed, which goes into solution, and copper sulphide is precipitated in case the silver was combined with sulphur.

We have here an interesting parallel with the action of cuprous chloride on silver sulphide, and various silver-minerals, upon which the process of raw amalgamation is principally based. But there is this difference, that cuprous hyposulphite acts very energetically, even in dilute solutions, while the cuprous chloride must be used rather concentrated to decompose most silver-minerals, except the sulphide, whereby it becomes too expensive for practical operations, and also produces a silver-bullion of low fineness. The following investigations form one of the most interesting and important contributions to the hydro-metallurgy of silver.

Before entering into a discussion of the reactions of the cuprous hyposulphite double salts, it will be important to know something more about the peculiarities of the sodium-salts. The formation of 3($2Na_2S_2O_3$, 5aq., which we will call the two-thirds salt, has already been indicated. From Mr. Russell's experiments, however, it may be assumed that there are two other salts, namely, $Na_2S_2O_3,Cu_2S_2O_3 + 2aq.$ (the $\frac{1}{1}$ salt), and $2Na_2S_2O_3,Cu_2S_2O_3 +$ 3aq. (the $\frac{2}{1}$ salt), the formation of which are expressed by the equations:

$$\text{(No. 2.)} \qquad 4Na_2S_2O_3 + 2CuSO_4 = Na_2S_2O_3,Cu_2S_2O_3 + 2Na_2SO_4 + Na_2S_4O_6.$$

$$\text{(No. 3.)} \qquad 5Na_2S_2O_3 + 2CuSO_4 = 2Na_2S_2O_3,Cu_2S_2O_3 + 2Na_2SO_4 + Na_2S_4O_6.$$

L $Cu_2S_2O_3 + aq.$ d also a double salt of the formula $3Na_2S_2O_3,$

If we consider that the atomic weight of $CuSO_4 + 5aq. = 249.5,$ and that of $Na_2S_2O_3 + 5aq. = 248,$ it will be seen that for satisfying the conditions of equation No. 2, two parts of sodium hyposulphite to one part of copper sulphate are required, and that the conditions of the first equation are produced by a slight excess of copper sulphate, and those of the equation No. 3, by a somewhat greater excess of sodium hyposulphite than the second equation calls for. From this it follows that by mixing the reagents about in the proportion of two to one, all these double salts may be formed, but that an increased amount of copper sulphate will principally, or only, produce the $\frac{2}{3}$ salt.

If concentrated solutions of the reagents are mixed, the cuprous hyposulphite double salts soon commence to precipitate as a crystalline powder, and continue to do so, until finally the solution contains very little cuprous hyposulphite. The more concentrated the solutions are the more rapid and complete is the separation. This shows that these double salts are almost insoluble in concentrated solutions of sodium sulphate [and tetrathionate]. If the clear solution is decanted from the precipitate the latter can be more or less redissolved by water, especially if warm. A diluted sodium hyposulphite solution, however, is a much better solvent than pure water. In case the reagents have been mixed as concentrated solutions, in the proportions expressed by equation No. 1, namely, 9 parts sodium hyposulphite to 5 parts copper sulphate, the clear liquid above the precipitate is almost free from copper and sodium hyposulphite. The yellow precipitate contains 33.7 per cent, copper, corresponding with $\frac{2}{3}$e formula of the salts of Lenz, which calls for 33.9 per cent, copper.

This salt [$2Na_2S_2O_3,3Cu_2S_2O_3 + 5aq.$] is very little soluble in water; 1 part requires 352 parts of water for solution at ordinary temperature. In aqueous sodium hyposulphite, it dissolves freely, as the figures below demonstrate:

100 c.c.	of a	5	per cent.	solution	dissolve	12.28 gm.
"	"	$7\frac{1}{2}$	"	"	"	17.46 "
"	"	10	"	"	"	22.54 "

This gives 2.46 gm., 2.32 gm., and 2.25 gm. of $2Na_2S_2O_3,3Cu_2S_2O_3+$ 5aq. per gm. of $Na_2S_2O_3 +$ 5aq. respectively.

In calculating the atomic weights, I find that it takes nearly 2 equivalents of sodium hyposulphite to dissolve 1 equivalent of the $\frac{2}{3}$ salt of Lenz. Hence a double salt of the formula $4Na_2S_2O_3,3Cu_2S_2O_3+x$ aq. must be assumed to exist in the solution.

Mr. Russell found that the § salt can be kept moist, or dried at a temperature of about 40° C. without decomposing. In attempting to get it dry at a much higher temperature rapid decomposition took place. The solution of the $\frac{2}{3}$ salt in aqueous hyposulphite is quite permanent, and can be heated to 70° or 85° C. without decomposing. At higher temperature it turns dark and copper sulphide commences to separate. As soon as decomposition has been started it increases rapidly on account of the formation of free sulphuric acid.

Extra-solutions prepared from calcium hyposulphite are about equal in effect to those in which the sodium-salt has been used. The potassium cuprous hyposulphite, however, acts with much less energy.

III. The Reactions of the Extra-solution.

§ 12. *Solubility of Metallic Silver in Extra-solution.*

This subject is of considerable practical importance, and Mr. Russell has furnished me with ample material, the publication of which, in detail, would be more confusing than interesting. After eliminating a few conflicting statements, and making allowance for slight errors, unavoidable in such experiments, I have formulated the following laws from the results:

1st. If the same quantities of sodium hyposulphite and copper sulphate are dissolved in varying quantities of water, the dissolving energy of the solution is not materially increased with its concentration. In the experiments made, the concentration of the solutions varied between 2 per cent, and 20 per cent, in $Na_2S_2O_3 + 5aq.$, and from 1 per cent, to 10 per cent, in $CuSO_4 + 5aq.$

2d. If, to a hyposulphite solution of constant strength, variable quantities of copper sulphate are added, the dissolving energy of the solution is not increased by concentration in copper, after so much copper sulphate has been added that its weight is about one-half that of the sodium hyposulphite.

3d. An extra-solution at 50° C. acts more energetically than the same solution at ordinary temperature, say 15° C, but the difference is much less than in treating metallic silver with ordinary solution.

4th. The best effect, under equal conditions, obtained with extra-solution on metallic silver, is about nine times as great as with ordinary solution, if both are used cold; and only about three and a half times as great if the solutions are heated to 50° C.

§ 13. *Solubility of Metallic Gold in Extra-solution.*

A series of experiments was made as in § 2, and the results were substantially the same.

The dissolving energy of a hyposulphite solution upon metallic gold is not increased by the addition of a copper-salt.

§ 14. *Solubility of Silver Sulphide in Extra-solution.*

I have already stated that in decomposing Ag_2S by extra-solution copper sulphide is formed. Mr. Russell failed to get accurate results in determining the amount of copper so precipitated, for reasons previously stated. The copper found was always more or less in excess of the theoretical quantity called for. This is caused by the precipitation of a cuprous hyposulphite double salt from more concentrated solutions. Hence, the detailed results of these experiments have no special interest. In summing up Mr. Russell's numerous experiments on the decomposition of Ag_2S by extra-solution, I find the results correspond more or less with the laws established in § 12, on the solubility of metallic silver. The second law is established beyond a doubt. The effect, in every case, is a maximum, when the solutions contain for 1 part copper sulphate about 2 parts of sodium hyposulphite.

It will be interesting to illustrate this by a few examples. In all the following experiments 2 gm. sulphides with 0.860 gm. silver were treated, which had been obtained in the lixiviation-process, and were, principally, a mixture of Ag_2S and CuS.

The extra-solution measured in each case 1000 c.c, and all samples were treated under exactly the same conditions.

Extra-solution with:	$Na_2S_2O_3 + 5aq.$ gm.	$CuSO_4 + 5aq.$ gm.	Silver dissolved: gm.	per cent. of 0.860 gm.
	250	50	0.533	62
	200	"	0.662	77
	150	"	0.731	85
Maximum effect.	100	"	0.791	92
	50	"	0.705	82
	25	"	0.602	70
	10	"	0.455	53
	250	10	0.206	24
	200	"	0.206	24
	150	"	0.198	23
	100	"	0.318	37
	50	"	0.499	58
Maximum effect.	25	"	0.662	77
	10	"	0.473	55

In comparing the effect of standard extra-solutions (I give this name to the solution which has for 1 part copper sulphate about 2 parts sodium hyposulphite) of different concentration, we find that the more dilute solutions act with much more energy than concentrated ones, considering the quantity of reagents they contain.

Averaging a number of experiments, 1000 c.c. of a standard extra-solution with 1 per cent. $CuSO_4 + 5aq.$ dissolved 0.645 gm. silver, while a solution with 5 per cent. $CuSO_4 + 5aq.$ dissolved 0.808 gm. silver only, although the latter contained five times the amount of reagents. Their relation is considerably modified when a large surplus of Ag_2S is used, as will be seen from another series of experiments in which 20 gm. pure silver sulphide were treated with 1000 c.c. of extra-solution.

Extra-solution with:	$Na_2S_2O_3 + 5aq.$ gm.	$CuSO_4 + 5aq.$ gm.	Silver dissolved: gm.	per cent. of 4.710 gm.
	250	50	1.900	40
	200	"	1.911	40½
	150	"	3.870	82
Maximum effect.	100	"	4.710	100
	50	"	3.225	68
	25	"	1.845	39
	10	"	0.663	14
	250	10	0.314	6½
	200	"	0.312	6½
	150	"	0.384	8
	100	"	0.670	14
	50	"	1.514	32
Maximum effect.	25	"	1.880	40
	10	"	0.593	12

The rationale of all the results recorded in this paragraph, and in § 12, becomes evident when we consider what has been stated in regard to the properties of the sodium cuprous hyposulphite double salts. If extra-solutions are prepared, as was done in these experiments, a large portion of the cuprous hyposulphite must at once separate in minute crystals, even if their formation is not immediately perceptible. It is only the solution which reacts and not the precipitate. The more concentrated the solutions are the more rapidly will the formation of the precipitate take place. Hence the comparatively better effect of dilute solutions. An excess of copper sulphate above the standard proportions favors the formation and precipitation of the least soluble $\frac{2}{3}$ salt, and the solution becomes at once weak. On the other hand, if there is a considerable excess of sodium hyposulphite the solubility of the most soluble double salt seems to decrease materially, and also in this case the solution will hold Jess of the reagent. For these and other reasons it is more profitable to prepare the extra-solution by forming the precipitate of the $\frac{2}{3}$ salt first, and then dissolving it in a dilute sodium hyposulphite solution.

The effect of such solutions on Ag_2S is as follows, namely:

Saturated solution of the $\frac{2}{3}$ salt in aqueous sodium hypo-sulphite of	Silver dissolved per gm. of the $\frac{2}{3}$ salt of Lenz.
5 per cent. concentration.	0.137 gm.
7½ " "	0.115 "
10 " "	0.113 "

A solution of the $\frac{2}{3}$ salt in water dissolved only 0.022 gm. silver per gm. of this salt.

It seems to me that the most effective solution must be one which contains so much sodium hyposulphite that the double salt $2Na_2S_2O_3$, $Cu_2S_2O_3$ is formed. In this instance, if copper is replaced by silver, the most soluble argentic double salt, $2Na_2S_2O_3, Ag_2S_2O_3$ will be the result of the reaction. The aqueous solution *of* the $\frac{2}{3}$ salt has such a low solubility-coefficient for silver because in this case argentic double salts are formed that are not easily soluble.

§ 15. *Solubility of Gold Sulphide in Extra-solution.*

Au_2S_3 is readily decomposed by the extra-solution. In investigating this subject, Mr. Russell obtained rather irregular figures. It seems that the temperature at which the Au_2S_3 is precipitated by H_2S, and various other conditions, influence the result. In the following experiments, 0.500 gm. gold were dissolved in aqua regia, and precipitated with H_2S. The Au_2S_3 was treated with 1000 c.c. of a standard extra-solution containing $1\frac{1}{2}$ percent. $CuSO_4 +$ 5aq. After one hour 0.460 gm. Gold had gone into solution ; after an hour and a half another sample showed nearly all the gold, namely 0.482 gm., dissolved. In this case, too, copper sulphide is precipitated.

In another series of experiments 1.333 gm. gold were, in each case, converted into Au_2S_3, and treated with extra-solutions of varying concentration, and at different temperatures. The solution acts best at a moderate temperature, and heating it seems to be of no benefit, The maximum effect of the standard extra-solution was not clearly established, but an injurious effect was observed by an increase of copper sulphate.

§ 16. *Solubility of Silver Arsenate and Antimonate in Extra-solution.*

The extra-solution produces no effect on Ag_3AsO_4 differing in any way from that recorded in § 5. The same is to be said about silver antimonate.

How the extra-solution acts on silver-minerals will be found in a subsequent paragraph.

§17. *The Effect of Extra-solution on Roasted Silver-Ores.*

We now arrive at the most important part of the experiments, so far as their practical value is concerned, namely, the effect of the extra-solution in extracting silver from roasted ores. Since March, 1882, Mr. Russell has made daily, all chlorination-tests (they should be more properly called lixiviation-tests) of the Ontario mill-samples, both with the ordinary and the extra-solution, and compared the results with those obtained by amalgamation.

The Method Used in making the Lixiviation-tests.—Mr; Russell states : " The amount of ore used is ½ assay-ton. To this, in a beaker-glass, is added 25 gm. $Na_2S_2O_3 + 5aq.$, and 5 gm. $CuSO_4 + 5aq$-, previously dissolved in water. The whole is then diluted to 500 c.c. with cold water, and heated on a sand-bath to 50° C. After one hour the residue is filtered off, dried, assayed, and the percentage of silver lixiviated is calculated. This constitutes my new method of lixiviation-assay. Along with these I always make assays by the old method, that is with ordinary hyposulphite solution. I have found that a longer time of exposure than one hour does not produce materially differing results. It is important to filter the solutions warm and not allow them to get cold."

It may be asked why the standard extra-solution is not used for these tests. The reason is that silver chloride is more easily dissolved in ordinary solution, and that only a small percentage of silver is present in another form, and requires the cuprous hyposulphite for its solution. *Lixiviation-tests at the Ontario Mill.*—The ore is roasted with salt, in two Stetefeldt furnaces, each having a capacity of 30 tons in 24 hours. After discharging the ore from the furnaces, it is piled up on the cooling-floor, and left for 12 hours undisturbed. It is then cooled with a spray of water, and loaded into cars for charging the pans. From these cars the samples are taken to which reference is made below. The percentage of silver extracted from the roasted ore by amalgamation, is calculated from the silver remaining in the tailings, by comparing their value with the value of the roasted ore after leaching out its soluble salts with water.

Monthly Averages of Lixiviation-tests, and Percentage of Silver extracted by Amalgamation at the Ontario Mill-

Samples taken:	Lixiviation-test with: Ordinary solution. Per cent.	Lixiviation-test with: Extra-solution. Per cent.	Silver extracted by amalgamation. Per cent.
March, 1882,	84.6	92.0	89.6
April, "	87.6	91.3	89.9
May, "	88.5	92.9	92.1
June, "	87.5	93.1	91.5
July, "	91.2	93.0	91.8
August, "	89.8	92.5	90.6
October, "	87.3	92.7	89.7
November, 1882,	89.2	93.1	90.4
December, "	88.5	92.9	89.2
March, April, 1883,	87.3	92.7	89.7
Averages,	88.1	92 6	90.4
Differences,	4.5		2.2

The Effect of the Extra-solution on Ontario Ore if not well chloridized.—Much more pronounced becomes the difference between the dissolving energy of the two solutions if ore is lixiviated which does not show a high chlorination by the ordinary method. Experience has established the fact that for Ontario ore, and all ores with a large percentage of sulphurets, especially zinc-blende, considerable time is required to complete the chlorination of the silver. This is effected by leaving the ore in a red-hot state for several hours. There are ores which do not necessarily require this treatment, but in all cases the effect is more or less beneficial. If samples of Ontario ore are taken immediately after a charge has been drawn from the furnace, the percentage of the silver chloridized is very low, especially, if the ore has been roasted at a moderate temperature. The dust seems to make an exception to this rule, ■ but, in fact, it does not, if we consider that it remains in the dust-chambers for a long time before it is discharged.

Samples of Ontario Ore Lixiviated immediately after Discharging from the Furnace.

From where discharged:	Lixiviation-test with: Ordinary solution. Per cent.	Extra-solution. Per cent.	Differences: Per cent.
Shaft,	60.7	86.1	25.4
Return-flue,	61.8	84.2	22.4
Dust-chambers,	90.7	93.3	2.6
Shaft,	65.2	93.2	28.0
Return-flue,	60.7	91.8	31.1
Dust-chambers,	80.0	91.4	11.4
Shaft,	60.5	90.0	29.5
Shaft,	65.4	93.9	28.5

These results are very important. It is most likely that by conducting the roasting process in a different manner from that now found most advantageous for amalgamation, still better results by lixiviation could be obtained than under present conditions.

Lixiviation-tests with Ore from the Bertrand Mine, Nevada.—The ore, which is not of high grade, is roasted in revolving cylinder-furnaces, a modification of the Bruckner furnace, for the purpose of lixiviation. The chlorinations, shortly after starting the mill, were very variable. For analysis of the ore, and working results, see Professor T. Egleston's paper, "Leaching of Gold and Silver Ores in the West" (*Transactions* of the Institute, 1883, vol. xii., p. 40).

Lixiviation-test made with:		Difference:
Ordinary solution.	Extra-solution.	
Per cent.	Per cent.	Per cent.
48.3	68.9	20.6
44.7	63.4	18.7
44.4	61.2	16.8
39.6	54.7	15.1
83.5	88.2	4.7
85.5	90.0	4.5
89.7	91.4	1.7

In 49 samples tested the average difference was 10.1 per cent.

Lixiviation-tests made with Roasted Ores from Various Mills.

Furnace Used.	Name of Mill.	Ordinary Solution.	Extra-solution.	Difference.
Howell, . . .	Alice, Montana, . . .	90.0 p. ct.	93.7 p. ct.	3.7 p. ct.
"	" "	73.7 "	89.2 "	15.5 "
"	" "	86.0 "	92.0 "	6.0 "
Bruckner, . .	Custer, Idaho, ...	88.3 "	91.5 "	3.2 "
Stetefeldt, . .	Lexington, Montana, .	92.4 "	93.6 "	1.2 "
Stetefeldt, . .	Manhattan, Austin, . .	94.1 "	94.6 "	0.5 "
Howell, . . .	Black Warrior, Arizona,	94.0 "	95.2 "	1.2 "
Bruckner, . .	Bertrand, Nevada, Mt. Cory Ore, ...	89.5 "	95.1 "	5.6 "

It remains to be stated that the difference in the percentage of silver extracted by ordinary and extra-solution is dependent on various circumstances, namely:

1st. On the character of the ore.

2d. On the fineness to which the ore has been pulverized. The difference decreases with the fineness of the ore.

3d. On the method of roasting. The difference decreases if the roasted ore, after discharging it from furnaces working on the continuous principle, is left red-hot for several hours on the cooling-floor.

4th. On the percentage of salt used in roasting. The difference decreases by increasing the percentage of salt. Whenever the chlorination of the silver has been carried to a very high percentage, it is but natural that the results of lixiviation with the two solutions cannot differ very much. Hence, it will be necessary to investigate in every special case how much profit can be derived from the use of the extra-solution.

In the examples given above it should be considered that in all cases, except the last one, the ore had been crushed by stamps through a No. 30 or No, 40 screen for the purpose of amalgamation. Only in the last case the ore was crushed by rolls and sifted through a No. 20 screen.

Results with Tailings.—In a former paper " On the Lexington Mill," I have drawn attention to the fact that the tailings, resulting from the amalgamation of roasted silver-ores, carry a large percentage of their silver in a form soluble in ordinary hyposulphite solution. From such tailings a much larger percentage of silver is extracted by extra-solution. I consider this of great importance for many localities where tailings have accumulated, which, heretofore, could not be worked with a profit.

Lixiviation-tests made with Tailings from Various Mills.

Name of mill.	Silver extracted by: Ordinary solution. Per cent.	Extra-solution. Per cent.	Difference. Per cent.
Sierra Grande, New Mexico,	61.1	70.2	9.1
Black Warrior, Arizona,	57.5	62.5	5.0
Bertrand, Nevada,	7.2	59.8	52.6
Raymond and Ely, Nevada,	30.4	42.4	12.0
Custer, Idaho,	17.0	31.0	14.0
Belmont, Nevada,	22.8	28.0	5.2
Manhattan, Nevada,	23.6	25.3	1.7

§18. *The Reaction of Extra-solution on Silver-Minerals.*

Most interesting are the results which Mr. Russell has obtained in lixiviating silver-ores without previous roasting. Their importance can hardly be over-estimated, since thereby an entirely new field is opened to the lixiviation-process. It is most likely that in many cases, where raw amalgamation is practiced with profit, lixiviation can take its place. There is, however, one class of oxidized ores to which, it seems to me, the process cannot be applied. If a considerable portion of the silver occurs with lead carbonate, the extra-solution will not extract this part of the silver on account of the insolubility of lead carbonate in hyposulphite solutions. This also seems to be the case with silver-bearing lead antimonate, judging from a sample from the Bertrand Mine.

The ores in the tabulated statement below belong mostly to the so-called " base ores;" still the percentage of silver extracted is, in many cases; remarkably high.

From this table it appears that, of the sulphuret-ores, those are principally affected by extra-solution which carry the silver in the form of native silver, silver sulphuret, and the group of antimonial and arsenical sulphurets, like pyrargyrite, stephanite, and polybasite. Being especially familiar with the ores from the Lexington, Manhattan, and Ontario mines, I think a comparison of results will be interesting. The

Name of Mine.	Process by which ores are worked at present.	Silver per ton of ore. oz.	Lixiviation-test with: Ordinary Solution.	Lixiviation-test with: Extra-solution.	Difference.	Character of Ore.
Lexington, Montana,	Roasting and amalgamation.	54.0	26.0 p. ct.	68.5 p. ct.	42.5 p. ct.	Native silver, silver bearing pyrites of iron, zinc-blende, galena, pyrites of copper.
Manhattan, Nevada,	Roasting and amalgamation.	164.8	8.3 p. ct.	57.2 p. ct.	48.9 p. ct.	Group of antimonial and arsenical sulphurets of silver, fahl-ore, zinc-blende, galena, pyrites of iron and copper.
Ontario, Utah,	Roasting and amalgamation.	90.8	7.0 p. ct.	31.9 p. ct.	24.9 p. ct.	Fahl-ore, native silver, zinc-blende, not much pyrites of iron and copper, galena.
Mount Cory, Nevada,	Roasting and lixiviation.	54.0 42.5	39.6 p. ct. 16.0 p. ct.	63.0 p. ct. 40.0 p. ct.	23.4 p. ct. 24.0 p. ct.	The same minerals as in Ontario ore, but less base and somewhat decomposed.
Custer, Idaho,	Roasting and amalgamation.	30.8	27.8 p. ct.	72.8 p. ct.	45.0 p. ct.	Principally stephanite, pyrites of iron, etc.
Ramshorn, Idaho,	Smelting.	89.6	34.4 p. ct.	50.5 p. ct.	16.1 p. ct.	Principally iron carbonate, some lead minerals, pyrites of copper, copper-silver glance.
Jesus Maria, Parral, Mexico,	Roasting and amalgamation, or lixiviation.	71.2	16.0 p. ct.	54.5 p. ct.	38.5 p. ct.	Principally pyrites of iron, some galena and zinc-blende, no precious silver min. visible.
Mines near Durango, Mexico,	Patio process.	58.0 14.8 32.8 19.2	2.0 p. ct. 16.9 p. ct. 8.0 p. ct. 34.9 p. ct.	39.8 p. ct. 51.4 p. ct. 65.3 p. ct. 70.4 p. ct.	37.8 p. ct. 34.5 p. ct. 57.3 p. ct. 35.5 p. ct.	Completely oxidized, no sulphurets visible. Below water-level the ore contains galena. The oxidized ore, most likely, contains lead, sulphate, and carbonate.
Bertrand, Nevada,	Roasting and lixiviation.	24.0	8.0 p. ct.	11.8 p. ct.	3.8 p. ct.	Principally lead antimonate.
Tombstone, Arizona,	Raw amalg'n. Battery sands.	52.8	70.5 p. ct.	81.1 p. ct.	10.6 p. ct.	Oxidized or free-milling ores, with more or less silver chloride and lead sulphate and carbonate.
	Sands from tailings beds	9.2	60.9 p. ct.	70.0 p. ct.	9.1 p. ct.	
	Slimes from tailings beds.	17.2	81.4 p. ct.	81.4 p. ct.	none.	
Sierra Grande, New Mexico,	Tailings from raw amalga'n, concentrated.	67.6	61.1 p. ct.	70.2 p. ct.	9.1 p. ct.	Oxidized or free-milling ores, with silver chloride and lead sulphate and carbonate.
Sombretillo, Sonora, Mexico,	?	86.4	75.0 p. ct.	84.0 p. ct.	9.0 p. ct.	Gangue composed of about 30 p. c. quartz and 70 p.c. carbonate of lime and magnesia. Silver, most likely, present as chloride.
Ore from dump of Chrysolite, Leadville, Colorado,		8.0	24.0 p. ct.	40.0 p. ct.	16.0 p. ct.	Silver combined with lead sulphate and carb., Also silver chloride.

Lexington ore is the basest of the three, and any one seeing this ore in bulk would not suppose that a lixiviation-process could extract 68.5 per cent, of its silver without roasting. Much of its silver occurs native, and the principal portion of it is combined with iron pyrites as silver sulphide. Then comes the ore from the Manhattan mines. Native silver here is rare. The principal silver-bearing minerals are ruby-silver, stephanite, and polybasite. Ontario ore shows the lowest result. Native silver occurs, bg? to much less extent than at the Lexington. About 88 per cent, of its silver is found as fahl-ore, and this mineral seems to be more refractory in contact with the extra-solution.

The battery-sample from Tombstone is of interest, because it shows that Russell's process will extract from such ores a higher percentage than raw amalgamation. In the last annual report of the Tombstone Mill and Mining Company, the yield of silver by raw amalgamation, is given as 76 per cent, of the assay value. From tests made with Tombstone and Sierra Grande tailings, it appears that most of the silver which escaped amalgamation can be extracted by lixiviation. Hence, a combination of both processes may be advantageous in some cases.

The ore samples in the preceding table were all pulverized so as to pass either through a No. 30 or a No. 40 screen. The following figures show the influence of finer crushing.

Sample of Oxidized Ore from the 200-foot Level of the Ontario Mine. Value, 48.8 *ounces Silver per ton.*

	Pulverized so as to pass. No. screen.	Lixiviation-test with: Ordinary solution. Per cent.	Lixiviation-test with: Extra-solution. Per cent.
	20	50.0	60.0
	30	50.0	65.2
	40	52.0	65 6
	50	52.5	66.4
	60	53.3	67.0
	70	54.0	74.6
	80	55.0	75.5
t Difference between No. 20 and No. 80 screens, .		5.0	15.5

Sample of Oxidized Ore from the 4.00-foot Level of the Ontario Mine. Value 100.0 *ounces Silver per ton.*

	Pulverized so as to pass. No. screen.	Lixiviation-test with: Ordinary solution. Per cent.	Lixiviation-test with: Extra-solution. Per cent.
	40	46.4	72.4
	50	46.6	74.6
	60	48.0	75.4
	70	55.0	78.0
	80	55.2	78.4
	90	——	79.8
Difference between No. 40 and No. 90 screens, .		8.8	7.4

Sample of Ore from . the Yedras "Mine, Mexico. Value, 33.6 *ounces Silver per ion.*

	Pulverized so as to pass. No. screen.	Lixiviation-test with: Ordinary solution. Per cent.	Extra-solution. Per cent.
	40	45.3	50.6
	60	45.3	58.4
	90	45.3	64.3
Difference between No. 40 and No. 90 screens, .		none	13.7

From these results it appears that fine crushing is essential to extract a high percentage of the silver. The same is necessary in raw amalgamation with chemicals, where the ore is finely ground in the pan after a more or less coarse crushing in the battery. In both cases the particles of - the silver-minerals, on account of their density, are not penetrated by the solution, and the reaction takes place on the surface only. It is quite different with roasted ores. Crushing through a No. 20 or No. 30 screen is, in most cases, sufficient for good roasting, whereby the particles of ore are left in a porous condition. It is well known that the expense and difficulty of crushing increases materially with the fineness. The same is the case with lixiviation considered from a mechanical standpoint. Hence, it may be, in many cases, more profitable to crush the ore as coarse as possible, and first roast it before extracting the silver by lixiviation. With well appointed mechanical , furnaces, of large capacity, the expense of roasting, so far as labor and fuel are concerned, is slight. The cost of the salt is, in chloridizing-roasting, generally the principal item of expense. That it is possible in some cases to save this, will be shown in the following paragraph.

Recent investigations have demonstrated that what I have said above about the influence of fine crushing in raw lixiviation does not hold good as a general rule. On the contrary, Mr. Russell found that in the greater number of cases crushing through No. 120, No. 30, and even No. 20 screen produces no great difference in the percentage of silver extracted by extra-solution.

I have finally to record a curious fact lately noticed by Mr. Russell. In a few cases the extra-solution actually extracted less silver than the ordinary solution. But if the raw ore was first treated with ordinary solution, and subsequently with extra-solution, the latter extracted an additional amount of silver. Hence, it is always best to apply the two solutions in succession. In the table below I give another series of lixiviation-tests, made with ores from a great number of mines. The solvents used were extra-solution, ordinary solution, caustic ammonia, and concentrated brine:

Name of Mine.	Value of ore, ounces silver per ton.	Per cent. of the silver extracted by lixiviation with: Extra-solution.	Ordinary solution.	Caustic ammonia.	Concentrated brine.
Grand Central, Arizona, .	43.2	93.7	86.6	48.2	50.5
Horn-Silver, Utah, ...	184 0	90.7	81.6	74.2	56.6
Price River, Utah, ...	25.0	87.2	77.6	13.6	42.5
Sombretillo, Mexico, . . .	80.4	84.0	75.1	6.7	3.4
Tombstone, Arizona, . . .	52.8	81.1	70.5	30.7	27.3
Silver Reef, Utah, . . .	45.0	77.8	50.7	20.0	36 9
Gray Rock, Montana, . .	19.0	73.4	47.4	10.9	19.0
Custer, Idaho, ...	30.8	72.8	27.8	27.5	17.3
Pearsall, Colorado, . . .	100.8	68.3	36.6	6.8	36.8
Tybo, Nevada, ...	20.0	58.0	30.0	0.0	8.0
Ramshorn, Idaho, . . .	89.6	50.5	34.4	2.2	11.8
Silver Spring, Montana, .	62.8	49.0	4.4	20.0	15.7
Highland Chief, ...	51.2	48.1	31.5	17.6	13.2

It will be proper to refer here to the fact that lixiviation of raw ores has been practiced before, especially at the Old Telegraph mine, Utah. In the latter case the ore contained silver chloride and lead-minerals. These were concentrated after lixiviation. In attempting to concentrate the ore at once the silver chloride was lost. There is no doubt that the extra-solution would have extracted a much higher percentage of the silver. This system maybe used to advantage in many cases where the character of the ore is such that a large percentage of the silver is lost by direct concentration, and this silver is in a form soluble in extra-solution.

§ 19. *The Treatment of Silver-ores by Lixiviation after they have been Subjected to an Oxidizing-Roasting.*

Many of the western silver-mines in the United States carry oxidized, or so-called " free ores," in their upper levels, which change, in depth, to sulphuret or " base ores." The Free ores are, in most cases, reduced by raw amalgamation, while the base ores require chloridizing-roasting. One of the most notable examples—showing a very marked difference between the two classes of ore—was observed at the Ontario mine. In its upper levels an exceedingly free-milling ore was found, which changed, in depth, to an unusually base ore. Before the mine had a mill of its own, the free ores were reduced at the McHenry and Marsac mills. In both cases the ore was crushed wet by stamps, and amalgamated in pans by the Washoe process. From 13 to 18 per cent, of the silver remained in the tailings, and, besides, a considerable percentage of the silver accumulated in slimes. When the Ontario Mill was built the mine still contained a considerable reserve of free-milling ore. But it was considered expedient to construct at once the whole battery of 40 stamps for dry crushing, and to connect 20 stamps only with a Stetefeldt furnace, for the reduction of the base ores, leaving the other 20 stamps for crushing the free ores, without roasting, go long as the supply should last. The crushing was done through a No. 40 screen. In panning a pulp-sample of the free ore no sulphurets could be seen. It contained native silver, silver chloride, and silver-bearing lead sulphate and carbonate. A chlorination-test with ordinary hyposulphite solution would not extract more than from 25 to 50 per cent, of the silver. The results of amalgamation were somewhat better than those obtained previously by wet crushing, and loss of silver in slimes was avoided.

At that time, the " Kroencke" process attracted some attention on the Pacific coast, and I concluded to try it, in a modified form, in pan-amalgamation, adopting the following *modus operandi:*

The pans were charged with so much salt that its weight amounted to 8 per cent, of the ore, and the quantity of water reduced to a minimum in order to get as concentrated a brine as possible. The addition of the quicksilver took place immediately after charging, together with so much granulated zinc (which had been previously amalgamated by bringing it in contact with quicksilver and dilute sulphuric acid), that its weight represented somewhat less than three-tenths of the quantity of silver in a charge of 3000 pounds of ore. In this way the pans were kept running, without grinding, for two hours, at a temperature of about 70° to 80° C. Then we added 4 pounds of copper sulphate to the charge, and amalgamated six hours longer. The results were most surprising, as will be seen below. We obtained bullion 980 fine, proving that only a part of the copper from the copper sulphate entered the amalgam. Another great advantage was shown, namely, that no solid amalgam adhered to the muller, or any part of the pan, but that it was completely discharged into the settler, thus doing away with the unhealthy cleaning of the pans from solid amalgam. Besides, the time of running the pans was reduced from twelve hours to eight hours.

Results of Working "Free Ores" by the "Kroencke" Process at the Ontario Mill.

Month.	Average value of Ore. Ounces.	Average value of Tailings. Ounces.	Silver left in tailings. Per cent.
April, 1877,	64.75	4.76	7.3
May, 1877,	74.32	5.65	7.6
June, 1877,	78.23	6.03	7.7

The brilliant results so obtained induced me to make the following experiments I roasted the base ore from the Ontario Mine (its character is described in § 18) by simply oxidizing it, and then treated it by amalgamation in the same manner as the free ore. The results, however, did not show a higher yield of the silver than from 70 to 80 per cent., and as no saving in the cost of reduction could be effected by this process, further experiments were abandoned.

In view of the energetic reactions of Mr. Russell's extra-solution, I considered it of interest to carry out some experiments in the same direction, namely, to roast without salt, and then extract the silver by Russell's process. These experiments were, at first, made on a small scale only, that is, by roasting samples in a muffle.

The following table contains the results of Mr. Russell's whole series of experiments. In each case a sample of 500 gm. was roasted.

Ore from	Temperature.	Time, hours.	Per cent. of silver extracted with: Ordinary Solution.	Extra-solution.	Per cent. of silver lost in roasting.
Ontario Mine.	Cherry-red.	½	31.1	55.8	2.2
		1	28.6	40.0	8.8
		1½	19.3	28.9	10.4
		2	17.0	26.9	11.0
		2½	17.3	23.0	13.4
		3	14.1	11.0	17.6
Ontario Mine.	Dark red.	½	44.2	64.5	0.7
		1	35.1	44.5	7.0
		1½	31.0	34.8	7.1
		2	24.6	26.4	8.7
		2½	23.8	26.8	8.3
		3	37.4(?)	32.3	8.3
Ramshorn Mine.	Dark red.	½	13.4	17.4	2.3
		1	7.7	11.6	5.0
		1½	7.0	7.6	5.3
		2	6.6	7.7	5.4
		2½	3.9	5.5	5.8
		3	2.9	2.9	5.8
Manhattan Mine.	Dark red.	½	10.0	22.2	4.8
		1	5.0	18.1	6.5
		1½	8.0	13.0	12.4
		2	2.6	....	13.0
		2½	1.0	2.0	14.0
		3	....	....	14.8
Lexington Mine.	Dark red.	½	17.6	32.5	3.2
		1	6.2	12.0	3.7
		1½	6.6	6.6	4.0
		2	1.2	4.7	4.3
		2½	2.0	5.5	4.6
		3	....	....	4.8

Ore from	Temperature.	Time, hours.	Per cent. of silver extracted with: Ordinary Solution.	Extra-solution.	Per cent. of silver lost in roasting.
Bertrand Mine.	Dark red.	½	1.0	6.0	From 4.3 to 5.7 p. ct.
		1	....	3.7	
		1½	....	....	
		2	1.3	2.0	
		2½	2.4	1.7	
		3	1.6	1.3	
Custer Mine.	Dark red.	½	27.0	31.5	From 1 to 2.1 p. ct.
		1	22.5	29.8	
		1½	26.0	30.0	
		2	21.0	29.8	
		2½	29.0	28.4	
		3	19.0	25.0	

(A description of the ores is given in § 18.)

In reviewing tin's table it is, in the first place, evident that the ores become less fit for the lixiviation-process the longer they have been roasted. The two Ontario samples, roasted at different temperatures, further show the injurious effect of high heat. If we compare the lixiviation-tests in the above table with those in § 18, made with raw ore and extra-solution, we find that in all cases, excepting the Ontario ore, the roasting proved to be decidedly detrimental. Concerning the loss of silver, experienced in muffle-roasting, Mr. Russell's figures are entirely in accordance with Plattner's observations on this subject. The loss of silver, other conditions being equal, is a function of temperature, time, and character of the ore. How very marked the influence of time is, these experiments plainly indicate. Hence, the instantaneous roasting, as it is done in a Stetefeldt furnace, must reduce that influence to a minimum.

In another series of experiments, Mr. Russell discovered a fact which is not stated by Plattner, namely, that in cliloridizing-roasting the loss of silver is materially diminished by an increase of the percentage of salt mixed with the ore.

The curious fact, that in oxidizing-roasting of silver ores, the percentage of silver extracted by hyposulphite solutions decreases the more the roasting is prolonged, led to the question : What will be the result if the roasting is done in the shortest possible time, namely, in a Stetefeldt furnace ? This experiment was carried out by Mr. Russell at the Ontario Mill. After cleaning out the chloridized ore from the hoppers of the shaft and flue, the feeding of the salt was suspended for two hours. Samples of raw ore, taken every half hour from the feeder, showed the pulp to contain only a fraction of 1 per cent, in salt, the latter being derived from pulp lodged in the troughs of the conveyor-screws. The roasting was conducted at a very high temperature, and with an abundant supply of air for oxidation. Samples of roasted ore were taken from the top of the pile in the shaft and flue, and lixiviated.

Sample from:	Silver extracted with: Ordinary solution. Per cent.	Extra-solution. Per cent.
Shaft,	12.8	55.9
Shaft,	19.0	58.6
Shaft,	28.8	55.6
Flue,	14.4	45.5
Flue,	39.9	67.3
Flue,	25.0	37.0

At the expiration of two hours, the ore was discharged from the shaft and flue, allowed to remain in a pile on the cooling-floor for twelve hours, and carefully sampled. Below are the results of lixiviation.

Silver extracted by lixiviation with:	Ore from: Shaft. Per cent.	Flue. Per cent.
Water,	17.5	4.9
Water and H_2SO_4,	16.3	5.2
Ordinary solution,	86.0	62.4
Extra-solution,	89.7	69.2

These results are so interesting and important, and so contrary to accepted metallurgical principles, that it was considered expedient to repeat the experiments.

The following five experiments were made with Ontario ore which carried an unusually large percentage of zinc-blende. As in the previous case, a fraction of one per cent, of salt (from three-tenths to six-tenths) remained in the ore. If we call the amount of fire generally used in chloridizing-roasting at the Ontario Mill " normal," this condition was only maintained in experiment No. 4. In all other cases extra fire was used, especially in Nos. 1, 2, and 3. The final results, that is, after the ore has remained on the cooling-floor, indicate that this extra fire is beneficial. In experiment No. 3 the admission of air was materially reduced, and the temperature was highest. The initial result in this case is the lowest of all, but the increase in per cent, of silver extracted, after the ore has remained on the cooling-floor, is by far the highest, and the final result the best. When the ore in experiment

No. 4 was discharged it was not red-hot. Although the initial result is much better than in No. 3, the gain by remaining on the cooling-floor is less than one-half of No. 3. Outside of the lixiviation-tests recorded below, Mr. Russell also treated the roasted ore with caustic ammonia and concentrated brine. But without first going into an investigation of" the solubility of silver-compounds in these reagents the results have little interest.

Table of Experiments.

Samples taken from inside of shaft and flue.	Experiment				
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Value of raw ore, oz. per ton, .	74.8	83.2	82.4	102.8	79.5
Value of roasted ore, shaft, oz.,	66.	68.	62.	92.	72.
Value of roasted ore, flue, oz., .	94.	84.	84.	108.	91.
Per cent. of salts soluble in water, ... shaft.	6.5	3.0	3.5	3.2	4.2
Per cent. of salts soluble in water, flue.	2.0	1.5	1.5	5.0	2.1
Per cent. of salts soluble in sodium hyposulph. shaft.	14.0	7.5	9.5	10.7	9.3
Per cent. of salts soluble in sodium hyposulph. flue.	9.0	5.0	6.5	7.0	6.0
Per ct. of silver extracted by leaching with water shaft.	5.2	5.3	5.8	4.8	5.6
Per ct. of silver extracted by leaching with water flue.	12.0	. . .	. . .	4.0	. . .
Per cent. of silver extracted by ordinary sol. shaft.	30.9	20.9	31.5	23.0	27.5
Per cent. of silver extracted by ordinary sol. flue.	29.0	26.9	15.0	25.2	18.8
Per cent. of silver extracted by extra-solution. shaft.	66.5	60.6	50.0	59.6	66.7
Per cent. of silver extracted by extra-solution. flue.	61.6	70.9	45.5	66.3	67.8
Samples taken after the ore has remained 16 hrs. on cooling floor.	**Composition of charge, about, parts.**				
	3 shaft, 2 flue.	3 shaft, 2 flue.	Shaft only.	4 shaft, 1 flue.	Shaft only.
Per ct. of salts soluble in water.	8.5	5.0	6.7	5.5	5.5
Per ct. of salts sol. in sod. hypos.	13.2	9.5	12.7	11.0	10.0
Per ct. silver extracted by water.	2.0	. . .	12.6	6.8	10.0
Per cent. of silver, ordinary sol.	74.2	64.8	83.4	35.3	73.7
Per ct of silver, extra-solution.	84.0	80.0	85.8	77.6	81.9
Increase of per cent. in silver extracted by extra-solution as compared with the samples taken from inside of shaft and flue, considering the composition of charge.	19.5	15.3	35.8	16.7	15.2
Per cent. of silver extracted by lixiviating 2 tons, ...	85.0	72.1	85.7	74.4	80.6

The first question which presents itself in reviewing this interesting table is: In what condition does the silver exist in the roasted ore ? The silver soluble in water is undoubtedly present as silver sulphate. From the fact that a large percentage of silver is extracted by ordinary solution, especially considering the final results, it follows that the principal part of the silver must be in a combination equally soluble in ordinary and extra-solution. As such, we have found the arsenates and antimo-nates of silver. Nearly all the silver in Ontario ore occurs as fahl-ore, and from it these combinations are derived. Some silver, it is fair to presume, is present in metallic form, and this is easily soluble in extra-solution. Silver sulphide as such does not occur in the ore, and supposing it to be present, is so easily oxidized that it can hardly exist after roasting.

The solubility-tests of roasted ore in water, show a marked difference between shaft and flue. In chloridizing-roasting, the formation of sulphates takes place principally in the flue. The salt converts the sulphates of copper and zinc completely into chlorides in the shaft, but not in the flue. The larger percentage of sulphates formed in oxidizing-roasting in the shaft of the Stetefeldt furnace, must be due to the greater coarseness of the ore which is here deposited. It will be seen from the difference in value of the roasted ore in the shaft and flue, that the latter contains much more silver-bearing mineral, and that in consequence more sulphates might be expected in this portion of the ore. After the roasted ore has remained red-hot for a considerable time on the cooling-floor, the quantity of salts soluble in water and sodium hyposulphite has materially increased. The sulphates of copper, zinc and manganese react most energetically on the silver, increasing the quantity of silver sulphate, antimonate and arsenate, and thus converting it into combinations soluble in hyposulphite solutions.

I can not end this discussion without pointing out the practical importance of these experiments. If it is possible to extract silver by lixiviation without using salt in roasting, we not only save the expense of the salt, but also the cost of drying and crushing it, and of the plant needed for these purposes. For localities where salt is very costly, and the ores are of low grade, a decrease in the yield of silver, of several per cent, would still leave a balance in favor of oxidizing-roasting.

From the facts recorded about the influence of time in muffle-roasting, it apppears that a momentary roasting is an essential condition to the success of the process. It seems difficult to convince the majority of metallurgists of the advantages, and even of the possibility, of this method.

I will state here, that it is a common practice in silver-mills to be penurious in the use of salt in chloridizing-roasting, and the ordinary so-called "mill-man," rarely takes pains to experiment on this important subject.

No general rules can be given, and only actual tests fully decide the question. The following series of tests, made with Ontario ore, plainly show the effect of an increase in the percentage of salt.

Ontario Ore roasted with:	Silver chloridized:
2 per cent. salt.	44.5 per cent.
4 " "	52.0 "
6 " "	60.4 "
8 " "	76.0 "
10 " "	82.8 "
12 " "	88.4 "
14 " "	90.9 "
16 " "	93.0 "

§ 20. *Extra-solution with Cuprous Chloride.*

In § 7 we have seen that cuprous chloride is dissolved by sodium hyposulphite. In the reaction taking place, expressed for instance by the equation:

$$2Na_2S_2O_3 + Cu_2Cl_2 = Na_2S_2O_3,Cu_2S_2O_3 + 2NaCl,$$

the same double-salt is formed as the one we discussed in the preparation of the extra-solution with copper sulphate in equation No. 2. In comparing the above formula with that of equation No. 2, it is easily seen that with Cu_2Cl_2, only half the quantity of sodium hyposulphite is required as with copper sulphate, to produce standard extra-solution of equal strength. Hence, it might be considered economy to use cuprous chloride in the preparation of the extra-solution. But the difficulty and expenseof first preparing cuprous chloride make this impracticable. The question has, however, an important bearing in another respect. If a silver-ore which contains copper is subjected to a chloridizing-roasting, more or less copper sulphate and cuprous chloride will be formed. In former publications I have pointed out a curious fact which was observed in analyzing samples of Ontario ore roasted in the Stetefeldt furnace. The ore from the shaft contained 0.16 per cent, copper in the form of cuprous chloride, and only a trace of sulphate; the ore roasted by the auxiliary fire in the flue and dust-chambers, contained only a trace of cuprous chloride, but 0.30 per cent, copper in the form of sulphate. In the lixiviation-process, a leaching with water being imperative before the hyposulphite solution can be applied, it is the insoluble cuprous chloride only which remains in the ore, and even a part of this is dissolved by the wash-water, especially if the roasted ore contains undecomposed salt. From this it follows that the extra-solution formed by the cuprons chloride in contact with ordinary solution can only be very weak, and that its effect can not be very pronounced.

§ 21. *The Extraction of Silver from Copper-matte.*

The Ziervogel process is, theoretically, the most simple and advantageous for the extraction of silver from copper-matte. But in practice we find its application rather limited. It is adopted in its greatest perfection at the works of the " Mansfelder Kupferschieferbauende Gewerkschaft," in Germany. But even here many charges have to be returned for a second roasting, whenever they contain above 0.023 per cent, of silver. In England the Ziervogel process has been used to extract the largest portion of the silver from copper-matte, followed by a roasting of the residues with salt, and lixiviation of the silver chloride by Augustin's method. In the United States, the Ziervogel process is in operation in Colorado, but with rich mattes desilverization of the residues is by no means so perfect as is desirable. If we inquire into the conditions essential for a successful working of this process, we find the following requirements must be fulfilled:

1st. Absence in the copper-matte of such sulphides as in roasting change to sulphates, and are liable to sinter: $PbSO_4$.

2d. Absence of such sulphides as, after oxidation, and in contact with Ag_2S and Ag_2SO_4, are liable to form silver salts insoluble in water: Ag_3AsO_4 and $AgSbO_3$.

3d. Absence in the matte of metallic copper, the silver-contents of which would be lost.

4th. Roasting furnaces of such construction must be used, that a complete combustion of -the gases takes place, and the possibility of the formation of cuprous oxide is excluded.

5th. Complete control of the temperature, so that the $CuSO_4$ can be decomposed without affecting the Ag_2SO_4.

6th. A very careful roasting is essential, commencing at a low temperature, which is gradually raised and increased, so as to decompose the $CuSO_4$ only. This requires skilled laborers who are trained especially for the work.

When Mr. Russell had discovered the peculiar reactions of his extra-solution, it became at once evident to me that the Ziervogel process could be used to advantage in many cases where it is inapplicable now, and also that a less delicate management of the roasting-process might still lead to satisfactory results. To effect this, it would only be necessary, first, to lixiviate with hot water, and then, without removing the charge from the tanks, to apply the extra-solution. Any metallic silver, Ag_2S, Ag_3AsO_4 and $AgSbO_3$ must then go into solution, and only such silver-combinations would be lost as are inclosed in sintered and melted particles of the charge.

The experiments so far made are only few, but indicate the probability of success. Mr. Russell experimented principally on roasted matte from Colorado, with the following results:

The roasted copper-matte contained 511.5 oz. of silver per ton.

There were extracted of the silver:

By lixiviation with hot water,		87.5	per cent.
" "	made acid with H_2SO_4,	89.0	"
" "	and subsequently with	90.3	"
" "	ordinary hypos. sol.	90.5	"
" "	and subsequently with	95.4	"
" "	extra-solution as per § 17.	95.7	"

Consequently in this case, 6.55 per cent., or 33.5 oz., more silver per ton were extracted by a subsequent leaching with extra-solution than by lixiviation with acid water alone.

The same matte was treated raw, with ordinary and extra-solution, with the following results :

Silver extracted with ordinary solution,	0.4	per cent.
" " extra-solution,	5.2	"

The fineness to which the matte had been pulverized, is not stated. But it is evident that the percentage of silver extracted depends on the surface exposed, the copper-matte being a homogeneous and dense product which the solution cannot penetrate. Mr. Russell produced some copper-matte by melting Ontario bullion-skimmings with sulphur. From this matte (silver-value not stated), one sample was pulverized so as to pass through a No. 60 screen, and another one through a No. 90 screen, and both were lixiviated, with these results:

	Lixiviated with: Ordinary solution. Per cent.	Lixiviated with: Extra-solution. Per cent.
Sample, No. 60 screen	1.0	17.0
" No. 90 "	4.0	21.0

of the silver extracted.

It seems to me that the experiment of roasting copper-matte in a Stetefeldt furnace, and then leaching first with water, and, subse quently, with Russell's standard extra-solution, has sufficient probability of success to attract the attention of metallurgists.

§ 22. *The Extraction of Gold from Silver-ores which have been Subjected to a Chloridizing-roasting.*

We frequently find, on this continent, silver-ores which contain more or less gold. Leaving out the famous Comstock, where the sharp practice of certain " rings " found it most advantageous, and still does so, never to attack any metallurgical problem with intelligence, I will cite examples only which have come directly under my personal observation. Such are, the mines in Ophir Cañon and Ione, Nevada, and the mines in the vicinity of Butte City, Montana. In all these cases the ores were, and are at present, reduced by amalgamation after having been subjected to a chloridizing-roasting. The Nevada mines mentioned have been abandoned long ago, and there are no statistics, to any extent, on hand, nor were they ever kept, so far as the percentage of gold extracted was concerned. The silver-bars produced were from ½ to 2 thousandths fine in gold. In the case of the Murphy mine, Ophir Cañon, I know from personal observation, that not more than 25 per cent, of the gold was extracted by amalgamation. The ore was roasted in reverberatory furnaces. The same ore roasted in the experimental Stetefeldt furnace, erected at the Murphy Mill in 1868, yielded by amalgamation 80 per cent, of the gold.

In May, 1870, 48 tons of ore, from the Gould and Curry Mine, were worked at the Auburn Mill, Reno, Nevada, by chloridizing-roasting in a Stetefeldt furnace, and amalgamation. From Mr. J. J. Dunne, the superintendent of the mill, I obtained the following statement: " The assay value of the ore was §566.56 in silver, and §211.70 in gold per ton. The actual yield in the bullion was 90.34 per cent, of the silver, and 62.7 per cent, of the gold." The tailings were subsequently reworked.

Prof. W. P. Blake's report on the Alice Mine, Butte, Montana, November, 1881, contains statistics about the percentage of gold extracted in the Alice Mill, from January 1st to August 6th, 1879. From an average of 194 assays it appears that the roasted ore contained §7.07 gold per ton. The percentage of soluble salts in the roasted ore is given in this report, elsewhere, at 11 per cent. This would give to the roasted ore, after washing out the soluble salts, a value of §7.94 per ton in gold. As the average value of the tailings, we find §3.53 per ton in gold. Consequently the percentage of gold left in the tailings is 44.4 per cent.

. The ore was roasted in a Howell furnace.

More complete and interesting statistics I have from Mr. A. Wartenweiler, superintendent of the Lexington Mill, Butte City, Montana. The ore from the Lexington mine contains from 42 to 52 oz. silver, and from 0.7 to 0.9 oz. gold per ton. It is roasted in Stetefeldt furnaces, and amalgamated. The following table will be of interest:

		Percentage of Silver and Gold remaining in tailings.	
Month.	Furnace.	Silver per cent.	Gold per cent.
December, 1882, . . .	No. 1.	10.0	42.3
"	No. 2.	11.8	42.6
January, 1883, . . .	No. 1.	9.9	38.7
"	No. 2.	10.8	42.5
February, ...	No. 1.	7.4	38.7
"	No. 2.	8 5	42.0
March, ...	No. 1.	7.8	36.9
"	No. 2.	8.9	42.3
April, ...	No. 1.	6.1	45.7
"	No. 2.	6.5	46.5
May, ...	No. 1.	5.5	43.8
"	No. 2.	5.3	46.4

This table shows a somewhat irregular relation between the percentage of silver and gold remaining in the tailings, but it seems that, with a more perfect extraction of the silver, the yield in gold decreases. Summing up all my personal experience in the amalgamation of gold-bearing silver-ores, I have come to the following conclusions:

The percentage of gold extracted by amalgamation decreases with the increase of temperature at which the roasting is conducted, and with the time consumed in roasting, or the time during which the charge is kept red-hot after being withdrawn from the roasting furnace.

If we inquire in what condition the gold is found in the roasted ore, and, especially, why it does not amalgamate to a higher percentage, we may just as well confess that we do not know. There is a monochloride of gold, AuCl, which has some stability above a temperature of 185° C., at which the terchloride decomposes, and which, as a sodium double salt, is said to exist at a dark red heat, according to Plattner and Kiss. We know that the monochloride of gold is insoluble in water, and the sodium double salt formed in roasting may share the same property. It is further asserted that this monochloride of gold is not decomposed by quicksilver, but I can not find a record of any experiments to prove this fact. Finally, we know that the monochloride of gold is soluble in sodium and calcium hyposulphite solutions, while metallic gold is comparatively little affected by sodium hyposulphite, as we have seen in § 2.

According to the above statements, the gold, present as a monochlo-* ride, would be lost in amalgamation, but extracted by lixiviation with a hyposulphite solution. Hence, if the same ore should be treated by amalgamation, and show an extraction of the gold of 60 per cent., for instance, we should expect to obtain not much more than 40 per cent, by lixiviation. But this does not agree with the facts, as will be seen later on. Indeed, there is a large field open for investigation, and it seems that our best metallurgists are either disinclined to publish their researches, or they consider work of this kind financially unprofitable. The shameful fact must be recorded that men of Mr. Russell's type are not sufficiently appreciated by the class of men generally in charge of mining operations in this country.

Any attempts to improve the extraction of the gold, in pan-amalgamation, by chemicals, for instance, chloride of lime, and mercuric chloride, have utterly failed to produce better results. The Designolle process pure, however, has not yet been tried, and it may be that by 'barrel-amalgamation, and addition of mercuric chloride, after the silver has been reduced, a better yield of gold can be obtained.

We will now critically review the principal lixiviation-processes which have been successfully used for beneficiating gold-bearing silver-ores. In all cases the ore is first roasted with salt, and then washed with water.

The Kiss Process.—The ore is lixiviated with calcium hyposulphite. The percentage of gold extracted depends upon the temperature at which the roasting is conducted. A dark-red heat must only be used, so that the formation of monochloride is favored, and that of metallic gold, as much as possible, avoided.

We here run the risk of effecting an incomplete chlorination of the silver, and if the ore contains copper, so much cuprous chloride may be formed and left undecomposed, that bullion of very low fineness will result.

The Patera and Roeszner Process.—The ore is lixiviated with a cold solution of brine which has been saturated with chlorine gas. G. Kuestel states, that ores, treated by this process in Hungary, yielded 98.9 per cent, of the silver, and nearly all the gold. Even with such a good record the method seems to me inapplicable on a large scale, and for ores rich in silver. The solubility of silver chloride, in cold brine, is slight, and the handling of large quantities of solutions, saturated with chlorine, must be an insufferable annoyance. Roeszner modifies the process by first lixiviating with hot brine, to dissolve the silver chloride, and then extracts the gold with a cold solution of salt, saturated with chlorine.

Hofmann's Process.—O. Hofmann first extracts the silver chloride and a part of the gold with a hyposulphite solution, and then the rest of the gold by the Plattner process. Results with concentrations from the Tarshish Mine, California, showed a saving of 96 percent, of the silver, and 95 per cent, of the gold.

The value of the concentrations was from $250 to $1700 per ton, over 40 per cent, of it being gold. The operations were conducted on a small scale and with great care and skill.

There is one great objection to this method, namely, the drying of .the residues after the silver has been extracted, which is imperative, because the chlorine gas cannot penetrate the charge if it is wet. For ores low in gold-value, so much additional handling would be too expensive. The Mears process could, in such a case, be used to much better advantage, as no drying of the residues is needed. Why is it, I may ask, that we hear very little about this process, so excellent on theoretical grounds? Have its technical difficulties been found unsurmountable, or has it died from sheer inanity? If we inquire as to other combinations of known methods, which are feasible, and deserve to be tried, we may state them as follows:

After lixiviation with hyposulphite solution the residues are to be treated for gold.

1st. *By the Designolle Process.*—The experience with this process is, however, that it requires as delicate a roasting as the Plattner.

2d. *By the Hears Process.*—This has been already indicated. A great advantage of the Mears process is that it succeeds where the old method of Plattner has failed to give satisfactory results.

3d. *By Lixiviating with Bromine Water.*—With the present low price of bromine, the last named combination is deserving of special consideration.

For the sake of completeness we will extend the discussion to copper-matte, containing silver and gold. The smelting-works in the vicinity of Butte City, Montana, are producing very large quantities of such mattes, and the out-put is constantly increasing and throwing the production of the Colorado works entirely in the shade. To separate the precious metals from such mattes by the sulphuric acid process, and manufacture copper sulphate from the solution, as is done on a comparatively small scale, in Freiberg, Germany, and elsewhere, is not to be thought of, the copper-vitriol not being salable in large quantities.

In Schemnitz, Hungary, the residues from the Ziervogel process have been treated by the Plattner chlorination process, but I am not aware that this has been repeated in other localities.

The Swansea Process.—It is to be presumed that such a skilled metallurgist as Mr. Richard Pearce went carefully over the whole field, when he introduced this method of separating the gold from copper-matte, at the works of the Boston and Colorado Smelting Company, at Argo, Colorado. This process is based upon the fact that gold has a much greater affinity for copper than silver, which was already known at Oker, at the time when the precious metals were extracted from copper, by the old-fashioned " Saiger" process. The mode of operation is as follows : The residues from the Ziervogel process are melted in a reverberatory furnace, with pyritic ores. The concentrated copper matte so produced, is roasted for " black copper," which, in falling to the bottom of the hearth, collects the gold, and also precipitates impurities of the matte, such as Sb,As and Pb. At a certain stage of the process, and after the charge has been brought to a high temperature, the furnace is tapped, and the metallic bottoms are separated from the matte. By repeating the operation, more gold can be extracted from the matte. It lies in the nature of this process that the separation of the gold can not be complete, and the concentrated copper matte, after a second treatment, contains about ¼ oz. gold per ton.

Considering the richness of the Argo matte, the percentage of gold extracted is extremely high. The disadvantages of this method are, that it is expensive in fuel and repairs of furnaces, and that the furnace-hearth is liable to absorb considerable quantities of the precious metal. Formerly in use at Vivian's works, Swansea, it has been replaced there by Hartmann's process, to which reference is made below.

The Electrolytic Process.—In Europe the tendency is, at present, very much in favor of the electrolytic process. The complete separation of the precious metals, and the great purity of the electrolytic copper, provided the process is conducted with the necessary precautions, are strong arguments in its favor. First successfully introduced in England, it has been in operation for several years, on the continent, especially in Germany. The principal works there are those at Hamburg, Oker, and near Eisleben. The details of the process are everywhere guarded with the utmost secrecy, and admission to the works is generally refused. No literature of any value, from a technical standpoint, exists. Professor Hampe, of Clausthal, so well known to metallurgists through his researches on copper, after investigating the electrolytic process in a most thorough manner, bad written an exhaustive treatise, bearing on all practical questions. Its publication was officially suppressed. Such bureaucratic folly still exists in Prussia! If officers of the Government are allowed to act in such a mysterious way—this takes us back to the times of the alchemists—we cannot expect that a firm in Hamburg should be more liberal. This spirit of narrow-minded illiberality is fast gaining ground in the metallurgical works of Germany, and wherever the student goes he is no more received with the cordial frankness of former times. Even the Ziervogel extraction-works of the Mansfeld company are now closed to visitors, simply because the general manager was, at some time, refused admittance to silver extraction-works in Swansea. But are there, in fact, such awful secrets about the electrolytic process as this policy would indicate? And is it surrounded with such enormous technical difficulties as all the managers of European works seem to imply? My answer is in the negative. That these gentlemen have finally achieved a great success, after a long series of blunders, nobody will deny. But it seems to me they would have reached their goal much sooner, if they had paid a little more attention to well-established laws of electricity. That the working of copper-matte, by this process, proved to be a failure might have been anticipated beforehand. The notion that any copper, no matter how impure, could be treated by it with economy might also have been condemned in advance. The electrolytic process permits the use of currents of low intensity only. With increased differences in the composition of the electrodes, the difference in their electric potential also increases, and a marked polarization of the current must be the result. But perhaps of still greater importance is the durability of the copper solution into which the electrodes are immersed. Certain impurities concentrate in this solution more and more, and are finally precipitated on the cathode. The peculiarity of arsenic to precipitate the sooner on the cathode, the lower the electric current is in intensity, was also known to physicists before it made itself felt in electrolytic works. That the process does not offer great technical difficulties, or require an experience of several years, has been demonstrated by its successful introduction at the metallurgical works of Mr. Balbach, Newark, N. J. The plant, of 800 pounds daily capacity, is by no means a model of construction, but it works well and with profit. Mr. Balbach claims no secrets, and admits with pleasure everybody belonging to the profession.

There is no doubt that the electrolytic process offers many advantages compared with other processes, both in economy and perfection, but the large capital required for the plant and buildings, the extensive area covered by the latter, and the enormous quantities of metal in rotation are a bar to its introduction on a' large scale. In this country, especially, capitalists are not inclined to invest so much money for such purposes. Hence, it is a question if it can compete with those processes which are based upon the regeneration of sulphuric acid, and require a comparatively inexpensive plant.

To those who are interested in electro-metallurgy, I recommend the reading of Martin Kiliani's papers, published in *the Berg- und Hüttenmanmsche Zeitung,* Nos. 21, 22, 32, 34, and 36 of 1883. Although Kiliani's experiments were all carried out on a small scale, they have great practical value, and his original researches give more information than all the books taken together that pretend to treat the subject of electro-metallurgy.

An important patent application has recently been filed by Dr. Moebius. His improvements apply especially to the parting and refining of high grade bullion. By ingenious devices he has completely overcome the influence of polarization.

We have still to consider two processes in which sulphuric acid is regenerated:

The Hunt and Douglas Process.—The Hunt and Douglas process has been described in the *Transactions* of the Institute, 1881. The matte is roasted, and the oxide of copper dissolved by dilute sulphuric acid in the presence of a soluble chloride. Gold, silver chloride, lead sulphate, and oxide of iron and antimony, remain as insoluble residues. The copper is precipitated from the warm solution as cuprous chloride by sulphurous acid, and the sulphuric acid regenerated. In decomposing the cuprous chloride, after separating it from the acid solution, by iron, ferrous chloride is formed, to be used again for chloridizing the copper of subsequent charges.

In conducting the sulphurous acid through the copper-solution, care must be taken to have the gas practically free from an excess of air. Otherwise more sulphuric acid will be formed than cuprous chloride, the latter absorbing oxygen rapidly, and becoming reconverted to cupric chloride.

This process has, so far, not been introduced to work copper-matte on a large scale, and nothing has been published about its technical difficulties, or its economy. From a theoretical stand-point it is very promising, especially for mattes containing antimony and arsenic. The cuprous chloride produced by this process is perfectly pure.

Hartmann's Process.—Another process for treating copper-matte, based upon the regeneration of sulphuric acid, is in operation at Vivian's works, Swansea. The roasted matte is dissolved in sulphuric acid, as is done in Freiberg, the gold and silver remaining in the insoluble residue. From the solution copper is precipitated by sulphuretted hydrogen, and the sulphuric acid regenerated. Sulphuretted hydrogen is gained by passing sulphurous acid from a roasting-kiln, together with steam, through a column of hot coal. The gas ascends a tower through which the copper-solution is showered. Any loss in sulphuric acid is made good by copper sulphate contained in the roasted matte. The precipitate of copper sulphide is oxidized by a patented process—details not known to me—said to dispense with the use of fuel, and then reduced to copper in a reverberatory furnace. It is claimed that from very impure matte a copper of superior quality is obtained. This seems to me somewhat doubtful. To remove all arsenic from a copper-matte by roasting is not possible. Arsenates, formed in roasting, are soluble in sulphuric acid. It is true, arsenic is precipitated from a solution by sulphuretted hydrogen before copper. But a separation in this way seems to me, practically, difficult to accomplish.

This and the former process have very much in common in their manipulations. The principal difference consists in the final treatment of the copper precipitate. It would be premature to give a decided opinion as to which of them deserves preference.

After writing the above I received the following information from Mr. John Williams regarding Hartmann's process : " This process has been in operation at least two years. Thousands of tons of matte from Montana, and all parts of the world, have been treated, and ' best selected' copper made therefrom. Mr. Hartmann states that as to impurities, namely, arsenic, antimony, and bismuth, the two latter do not go into solution with the dilute sulphuric acid used; and that any arsenic is easily removed in the final melting and refining. For one ton of copper about three tons of coal are consumed, including the refining of the precious metals."

EXPERIMENTS ON THE EXTRACTION OF GOLD FROM SILVER-ORES WHICH HAVE BEEN SUBJECTED TO A CHLORIDIZING-ROASTING.

a. Extraction of the Gold by Lixiviation with Hyposulphite Solutions. —Considering the comparatively low percentage of gold extracted by amalgamation, it was of practical importance to ascertain, in the first place, if Russell's process would yield a larger amount of gold, and if it could enter, successfully, into competition with amalgamation also in this respect.

We find it stated in treatises on metallurgy that calcium hyposulphite is a more energetic solvent for gold than the sodium salt, and, in copying this statement, metallurgical writers have gone so far as to assert that sodium hyposulphite does not extract any gold at all. Professor T. Egleston, in his paper, "Leaching of Gold and Silver Ores in the West," *Transactions,* 1883, vol. xii., p. 41, says, the use of hyposulphite of calcium "has a great advantage in the treatment of ores containing even a very small quantity of gold, as the hyposulphite of lime dissolves nearly the whole of the gold, and allows of its being extracted, while the hyposulphite of' soda does not." That there is no possibility of misunderstanding this sentence, becomes evident in quoting another passage from the same paper. " The leaching process is also applicable to ores containing both gold and silver, for when hyposulphite of soda is used, after the ores have been leached for silver, the tails can be treated by Plattner's process, and the gold and silver both recovered in a state of high bullion, so that a parting process would not be necessary, and when hyposulphite of lime is used, they are recovered together." Professor Egleston's authority for this statement is not given. Nor does it seem to me that there is any scientific foundation for it, the double salt of $3Na_2S_2O_3 + Au_2S_2O_3 +$ 4aq., being as easily soluble as the calcium double-salt. To settle this question I induced Mr. Russell to carry out some comparative experiments with ore from the Lexington, Montana, and from the Custer, Idaho. For the sake of completeness Mr. Russell also used solutions of potassium and magnesium hyposulphites. In all cases the solutions were of 2 per cent, concentration, and the figures below represent the averages of six tests.

	Ounces gold remaining in tailings after lixiviating with the hyposulphite of:			
Sample from:	Sodium.	Potassium.	Calcium.	Magnesium.
Lexington Mill, . .	0.333	0.316	0.326	0.366
Lexington Mill, . .	0.308	0.320	0.313	0.366
Custer Mill, . .	0.280	0.350	0.362	0.280

These figures prove conclusively that the superiority of a calcium hyposulphite solution for the extraction of gold from roasted silver ores is a fable.

As far as the percentage of gold is concerned, which is extracted by lixiviation with hyposulphite solutions, Mr. Russell made a great number of tests with ore from the Lexington Mill. The results varied between 60 and 70 per cent, of the gold extracted. The statistics of the Lexington Mill show that by amalgamation the yield is only from 53.5 to 63.1 per cent. Hence, lixiviation is also in this respect superior to amalgamation. Mr. Clark worked ore from the Alice Mine, Montana, at the Bertrand Mill, and reports a larger yield in gold than that obtained by amalgamation at the Alice Mill.

In lixiviating Custer ore the results were less favorable compared with amalgamation. I have no doubt, however, that in this instance also superior results may be obtained by modifying the treatment of the ore in roasting.

b. Extraction of Gold by the Sulphides of the Alkaline Metals, and by Extra-solution.—The solubility of gold sulphide in extra-solution, and the fact that it is also dissolved by the sulphides of the alkaline metals, led to experiments in extracting gold by these reagents. My idea was to treat the residues of gold-bearing silver-ores, after the extraction of the silver, and a part of the gold, by Russell's process, with sodium sulphide solution (or with CaS_5), and convert the gold into a sulphide, and then react upon it with extra-solution. A part of the gold would be dissolved by sodium sulphide, and another part by sodium hyposulphite.

Mr. Russell's first object was to ascertain the solubility of metallic gold in a sodium sulphide solution. For this purpose he utilized the solution prepared for the precipitation of silver in his lixiviation process. It contains about 24 per cent, of sodium polysulphide, and also sodium hyposulphite, resulting from its preparation by boiling caustic soda with sulphur. In carrying out the experiments, 25 milligrammes of pure gold-leaf were left in contact with solutions of different concentration for three and a half hours on the sand-bath, and the gold dissolved was determined.

25 milligr. gold-leaf, and 50 c.c. sodium polysulphide solution.	Water added, c.c.	The solution contains in sodium polysulphide, per cent.	Gold dissolved, milligr.
1, ...	10	20	19.8
2, ...	25	16	17.2
3, ...	50	12	6.0
4, ...	75	9½	2.6
5, ...	100	8	1.0

The more dilute solutions dissolved only fractions of a milligramme of gold. In experiments 1 and 2 the solutions had become very concentrated by evaporation on the sand-bath. The whole series shows that the solvent energy of the solution is principally a function of concentration.

In treating, by the method indicated above, samples of roasted ore from the Lexington Mill, which contained 0.8 ounce gold per ton, Mr. Russell succeeded in producing tailings with only from 0.09 to 0.05

ounce gold per ton. This sample had an unusually low chlorination of the silver, and in repeating the experiment with ore of normal chlorination the results were less favorable, but still much better than by amalgamation. A sample of roasted copper-matte from Argo was also tested by this process. It contained 5.4 ounces gold per ton. Of this 3.65 ounces were extracted, namely, 2.55 ounces by sodium sulphide, and 1.1 ounce by extra-solution. Further experiments established the fact that the sodium sulphide solution has to be rather concentrated, and must be used warm to be effective. For this reason, and on account of the difficulty of separating the gold from the sodium sulphide solution, I do not consider this method of practical value, and it has not received further attention. The idea of extracting gold by a solution of an alkaline polysulphide is not claimed to be new.

IV. WORKING OX A LARGE SCALE.

Mr. Russell has not been content with mere laboratory-experiments, but has tested his process on a large scale. The experimental plant at the Ontario Mill is capable of lixiviating a charge of 3 tons in one tank. More than 100 charges of Ontario ore have been worked up to date. In these experiments the following facts have been ascertained.

§ 23. *Preliminary Leaching with Water.*

It is just as effective and more judicious to leach the roasted ore with cold, and not with hot water, prior to turning on the hyposulphite solution. Hot water will dissolve a larger percentage of AgCl, this being more soluble in hot than in cold brine. The first wash-water which contains copper, and some silver, is conducted to tanks filled with scrap-iron, where the copper, and with it most of the silver, is precipitated. Mr. Russell has determined in ten charges (of 2 tons each) the total amount of silver dissolved by the wash-water, and the amount recovered with cement-copper.

Total amount of silver dissolved per ton, ...	0.39 oz.
Amount of silver recovered with copper, ...	0.28 "
Amount of silver lost, ...	0.11 "

These figures will, no doubt, vary in other localities, where more or less salt remains undecomposed in the roasted ore, and acts as the principal solvent for the chloride of silver.

§ 24. *The Extra-solution.*

After leaching with water the AgCl in the charge is first extracted with an ordinary hyposulphite solution, containing from 1¼ to 1½ per I cent, of the commercial $Na_2S_2O_3 + 5aq$. This solution is made slightly acid with sulphuric acid, provided it contains caustic soda. After most of the silver chloride is dissolved the extra-solution is turned on, to act upon the silver not present as chloride. This method of lixiviating has the best effect. Mr. Russell found that the extra-solution is a much poorer solvent for silver chloride than ordinary hyposulphite solution. The solubility of silver chloride rapidly decreases with an increase of copper sulphate added to the solution. That this should be the case follows from the reactions taking place in the formation of cuprous hyposulphite.

The extra-solution is made up by adding to a measured quantity of ordinary solution so much copper sulphate dissolved in the smallest quantity of water, that a standard extra-solution is formed. By allowing the extra-solution to sink through the charge, and pumping it up again, all particles of ore are brought in contact with it.

The peculiarity of the extra-solution, if prepared as indicated above, to part with a precipitate of a cuprous hyposulphite double-salt after some time, makes it desirable to obtain this solution in a more permanent form. This can be done by dissolving 18 parts sodium hyposulphite and 10 parts copper sulphate, each in a small quantity of water, mixing the solutions, allowing the precipitate of $2Na_2S_2O_3,3Cu_2S_2O_3 +$ 6aq. to separate completely, decanting the clear solution of sodium sulphate and tetrathionate, and redissolving the precipitate, after washing it, in a pure sodium hyposulphite solution of from 1 per cent, to 1½ per cent, concentration. This extra-solution of constant strength is used for several ore-charges in succession, until the cuprous hyposulphite is nearly exhausted, before it is turned into the precipitating tanks. Here the silver is best precipitated by sodium sulphide from which any sodium sulphate, which this reagent may contain, has been removed by calcium sulphide. (As to the reaction here taking place, I refer to § 26.) The pure regenerated solution of sodium hyposulphite is then utilized again for dissolving a fresh charge of $2Na_2S_2O_3,3Cu_2S_2O_3$ + 5aq. By this method a much better effect from the same quantity of copper sulphate is obtained than by the one first described.

It will be seen in § 28 that, in working on a large scale, a larger percentage of silver is extracted than is shown to be soluble by laboratory tests. This is undoubtedly due to the prolonged time of the reaction, and to the use of ordinary and extra-solution in succession.

§ 25. *The Precipitation of $PbCO_3$.*

An extra series of tanks has to be provided for the precipitation of the lead. The soda-ash solution is purified as stated in § 11. The $PbCO_3$ settles in less than one hour, leaving a perfectly clear solution to be decanted into the silver precipitating-tanks. Whenever the precipitate has accumulated in sufficient quantity, it is collected by means of a filter-press. The value of the lead carbonate will, in many localities, pay for the soda-ash used in precipitating it. Besides, we should consider that the lead would otherwise have to be precipitated as sulphide by sodium sulphide. As this reagent is more costly than soda-ash, whatever is realized for the lead is clear profit. The great advantage, however, is the absence of lead in the sulphides of silver and copper precipitated from the lixiviation-solution.

§ 26. §26. The *Precipitation of Ag2S and CuS.*

In Russell's process silver and copper have to be precipitated from the hyposulphite solution by a sodium sulphide. Calcium sulphide cannot be used, because any lime entering the lixiviation-solution would be precipitated with lead as carbonate in effecting the separation of the lead, as shown in § 25. Calcium sulphide having been generally introduced in lixiviation-works as a precipitant for silver, it might be argued that the necessity of abandoning this practice is a point not in favor of Russell's process for separating lead. Hence, it is a question of importance, to which hitherto metallurgists have paid little attention, to examine carefully if there are any tenable reasons for this preference, or if the practice is merely based upon a prejudice. In fact, the issue is a double one: 1st. Is calcium sulphide preferable as a precipitant for silver? 2d. Is a calcium hyposulphite lixiviation-solution superior to one of the sodium salt? The continual use of calcium sulphide gradually converts the original sodium hyposulphite solution into one of calcium hyposulphite.

In considering the first question the following points are involved :

A. The preparation of the sulphide solutions, and their composition.

B. Their action and value as precipitants.

A. Preparation of Calcium and Sodium Sulphide Solutions, and their Composition.

In preparing calcium sulphide, caustic lime is boiled in water with an excess of sulphur, so that the polysulphides CaS_4 and CaS_5 are formed. This excess of sulphur is necessary, because the lower calcium sulphides are not easily soluble in water, and this solution must be used rather concentrated. From the slight solubility of calcium hydrate in water it follows that this process must require considerable time. Sodium hydrate, on the contrary, is very easily soluble in water, and the sodium monosulphide, and all of the polysulphides being equally so, the process must be completed very rapidly. In preparing, for instance, both solutions with the same amount of sulphur, and under otherwise equal conditions, the sodium solution precipitated, after six hours' boiling, seven and one-half times as much silver as the calcium solution. Continuing the boiling for seventy-two hours, the calcium solution had reached its maximum of precipitating energy, but precipitated only 0.76 as much silver as the sodium solution after six hours' boiling. This demonstrates the wastefulness of the calcium-process in sulphur and time.

Another question, however, is of equal, if not of greater importance. The reactions taking place in boiling a caustic alkali with sulphur are expressed by the formula:

$$3RH_2O_2 + (2+2x)S = 2RS_x + RS_2O_3 + 3H_2O.$$

That is to say: For two equivalents of the alkaline sulphide, one equivalent of a hyposulphite salt is formed. Now, let us consider the peculiarities of solutions at boiling-point, containing calcium or sodium hyposulphite. A solution of sodium hyposulphite can be heated to 100° C. without much injury—it decomposes very slowly. A solution of calcium hyposulphite, on the contrary, decomposes rapidly into gypsum and sulphur if heated above 60° C From this it follows that in preparing the calcium-solution most of the calcium- hyposulphite formed is again decomposed, and that in its place calcium sulphate is obtained. In order to test the correctness of this reasoning, Mr. Russell determined the quantity of calcium hyposulphite formed in the preparation of calcium sulphide. The method used was the following: To the solution of calcium sulphide freshly precipitated silver chloride was gradually added, until the former was completely decomposed, and the silver chloride ceased to be discolored. Then more silver chloride was added, and the solution left for twenty-four hours. Its filtrate, upon being tested with sodium sulphide, showed a very small quantity only, and in some cases no silver at all dissolved, depending on the time of boiling in preparing the calcium sulphide solution. A large quantity of calcium sulphate, however, was found in the residue of the original solution. It will be seen that here again a portion of the sulphur is completely wasted, which, with sodium sulphide, appears as hyposulphite. The calcium sulphide solution can only contain the hyposulphite salt after it has been exposed to the oxidizing influence of the air. For an exact determination of the hyposulphite a volumetric method with iodine must be used. The one selected by Mr. Russell is, however, sufficient for practical purposes as it copies the conditions of the process on a large scale..

It is evident that in the lixiviation-process, a certain quantity of hyposulphite must be lost, namely in the wash-water, which has to be precipitated by itself, and is too dilute to be mixed with the normal solution, and also by decomposition in contact with the atmosphere. This loss has to be made good, otherwise the solution would get weaker, and finally refuse to dissolve any silver. If a sodium sulphide solution, to be used for precipitating the silver, has been prepared as stated above, it contains a considerable quantity of sodium hyposulphite. For each part of silver precipitated, 0.574 parts $Na_2S_2O_3 + 5aq.$, and for each part of copper, 1.968 parts $Na_2S_2O_3 + 5aq.$, are added to the lixiviation-solution. Hence, in working high-grade ores, and especially if much copper is present, the lixiviation-solution actually becomes more concentrated with continued use. The same reasoning does not hold good if freshly prepared calcium sulphide is used as the precipitant, according to what is stated below.

That a solution of calcium sulphide oxidizes rapidly at ordinary temperature, with formation of hyposulphite, is established by practical experience. Mr. Ottokar Hofmann, who used calcium sulphide as precipitant, at the Silver King mill, Arizona, states to me that the original sodium hyposulphite solution was used over a year and a half, and that it increased in strength and volume, making it necessary to run a part of it to waste. In this case a large amount of copper and lead was precipitated with the silver.

At La Dura, Sonora, Mexico, the lixiviation-solution was allowed to flow into the river by the stupidity of a laborer. A new supply of sodium hyposulphite could not have been obtained in less than ninety days, and in this dilemma, Mr. Hofmann proceeded to manufacture a new solution from the calcium hyposulphite contained in the sulphide. The lixiviation wash-water, containing the base metals, was precipitated with calcium sulphide, and the operation repeated until a calcium hyposulphite solution of sufficient strength had been obtained to resume operations. I am sure this process would not have been successful with freshly prepared calcium sulphide, and that sodium sulphide would have answered the purpose much better.

While these facts show that a calcium sulphide solution, unless freshly prepared, is by no means deficient in hyposulphite, they do not contradiet any of the arguments offered in favor of the sodium sulphide. Sodium sulphide, proving to be superior in many respects, can be economically prepared by several methods, namely:

1st. By reducing sodium sulphate, at a high temperature, with carbon.

$$Na_2SO_4 + 2C = Na_2S + 2CO_2.$$

The disadvantages of this method are that the solution contains no hyposulphite, and that Na_2S in contact with air changes to hyposulphite with formation of caustic soda. The latter finally absorbs carbonic acid, and changes to a carbonate.

$$2Na_2S + H_2O + 4O = Na_2S_2O_3 + 2NaHO.$$

In order to utilize such a solution in the lixiviation-process it would be desirable to boil it with sulphur, and then expose it to the air. The oxidation of a solution of Na_2S_2 produces $Na_2S_2O_3$ only, while the higher polysulphides decompose in the same manner, but with precipitation of free sulphur.

2d. By melting sodium carbonate with sulphur.

Carbonic acid is liberated, and sodium polysulphides and hyposulphite are formed. If the temperature is raised too high, the hyposulphite is changed to sulphate.

3d. By boiling a solution of caustic soda with sulphur.

The reactions which take place in this case are expressed by the general formula introduced previously.

The choice of method will depend on local circumstances, namely, cost of chemicals, freight, etc. As the most simple in execution, the third method recommends itself, and where freights are high, it will also be the most economical. Regarding such a solution, it becomes a question of importance to have it so constituted that it produces a maximum effect with the smallest quantity of reagents consumed in its preparation. Mr. Russell has investigated the subject, and his results are very interesting and surprising.

If one of the heavy metals is precipitated by an alkaline polysulphide, RS_x, one equivalent of the latter precipitates not more than one equivalent of the former, $(x-1)S$ being liberated as free sulphur. It seems, however, that there are exceptions to this rule, if the heavy metal exists in the form of a hyposulphite salt, and the alkaline polysulphide has been prepared in a certain way, and is of a peculiar molecular constitution.

If sodium polysulphide is obtained by boiling caustic soda with sulphur, the equation:

$$6NaHO + 2(x+1)S = Na_2S_2O_3 + 2Na_2S_x + 3H_2O$$

shows that for 100 parts of caustic soda used, the sodium polysulphide solution can not precipitate more than 180 parts of silver as Ag_2S, according to the theory stated first above. Hence 100 parts of commercial caustic soda, containing, say, 87 per cent. $NaHO$, the remainder being sodium carbonate and sulphate, would have a maximum precipitating energy of 156.6. parts of silver only. In preparing sodium sulphide from caustic soda of such quality, Mr. Russell found that its precipitating energy for silver out of a hyposulphite solution was in many cases far in excess of the theoretical limit, depending upon the original concentration of the solution in caustic soda. I will illustrate this by selecting a few examples from numerous experiments.

Solutions prepared by heating 1000 c.c. water and:			Silver precipitated per	
	Caustic soda.	Sulphur.	100 Caustic soda.	100 Sulphur.
No. 1.	400 gm.	400 gm.	95 gm.	95 gm.
" 2.	150 "	150 "	108 "	108 "
" 3.	100 "	100 "	151 "	151 "
" 4.	50 "	100 "	174 "	87 "
" 5.	25 "	30 "	245 "	204 "
" 6.	20 "	15 "	250 "	333 "
" 7.	20 "	20 "	282 "	282 "
" 8.	20 "	30 "	282 "	188 "

The commercial caustic soda here used contains 87 per cent. NaHO.

For a better understanding regarding consumption and effect of sulphur, I will state that for the formation of different polysulphides, the following quantities of sulphur would be required :

100 caustic soda of 87 per cent. require	46.4	sulphur to form	Na_2S
" " " "	69.6	" "	Na_2S_2
" " " "	92.8	" "	Na_2S_3
" " " "	116.0	" "	Na_2S_4
" " " "	139.2	" "	Na_2S_5

The results of experiments No. 4 to No. 8 show that a great deal more silver has been precipitated than the generally accepted theory demands. This fact can only be explained by assuming the following reaction to take place:

$$x\,Ag_2S_2O_3 + Na_2S_x + (x-1)H_2O = x\,Ag_2S + Na_2S_2O_3 + (x-1)SH_2O_4 + (x-1)S.$$

The free sulphuric acid formed produces a secondary effect, which may be:

1st. To neutralize sodium carbonate, or free caustic soda, if such be present.

2d. To decompose sodium polysulphide with formation of H_2S and Na_2SO_4.

The former would precipitate more silver from $Ag_2S_2O_3$, and set S_2O_2 free. This acid, however, does not exist in a free state, and unless it combines *in statu nascendi* with caustic soda, provided such be present, it will decompose into $SO_2 + S$. The following equation will illustrate the final result for $x = 3$:

$$5Ag_2S_2O_3 + 3Na_2S_3 = 5Ag_2S + Na_2S_2O_3 + 2Na_2SO_4 + 2SO_2 + 8S.$$

In such cases the effect would be 261 silver precipitated per 100 caustic soda of 87 per cent. If, however, we assume that a part of the free sulphuric acid was consumed in neutralizing sodium carbonate or caustic soda, then the precipitating coefficient of the solution would be very much increased.

The question presents itself: Is there any economy in using a sodium sulphide solution of this character ?

A considerable loss in hyposulphite is indicated by the reaction which, in this case, decomposes more hyposulphite than it regenerates. If this loss had to be made good by adding fresh quantities of the salt to the lixiviation-solution, then there would be no economy at all in using such a precipitant. Even by allowing hyposulphite to be formed, purposely, by oxidation of the sodium sulphide solution, no advantage would be gained. The new reaction could be utilized in part, with a profit, only in cases where the character of the ore is such, that the lixiviation-solution gains considerably in hyposulphite with an ordinary precipitant.

Mr. Russell preserved a number of sodium sulphide solutions, obtained in his experiments, for five weeks in glass bottles, excluded from contact with air. Upon testing their precipitating-capacity again, he found that a decided change had taken place. Some of the solutions had increased in strength, others had decreased in a more or less marked degree. The increase was noted with the concentrated solutions, the decrease with the more diluted ones. This shows that a molecular change must have taken place in the composition of the sodium polysulphides.

Solutions of calcium polysulphides of different concentration, and prepared in different ways, kept five weeks as noted above, had degenerated in every instance to such an extent that the old solutions precipitated only ½ to 1/3 as much silver as they did originally when fresh. Here again we meet with another proof of the superiority of the sodium sulphide solution.

Since writing the above Mr. Russell has sent me a tabular statement containing the results of 238 experiments on the preparation of sodium and calcium sulphide, of which 188 refer to the former, and 50 to the latter. These experiments have demonstrated, beyond doubt, the best *modus operandi* for sodium sulphide to be as follows, namely : The caustic soda is dissolved in an iron tank, in its own weight of water. The solution should not fill more than one-fourth of the tank. Considerable heat is evolved, and in case the solution has not by itself reached a temperature of about 80 degrees C. (this can easily be effected by using warm water), it is brought to 80 or 90 degrees C. by a fire underneath the tank. For 100 parts of caustic soda, 66 parts of pulverized sulphur are now gradually added. The temperature of the solution soon rises to about 145 degrees C, and it foams up to two or three times its volume. In about five minutes the sulphur has dissolved, and the reaction is completed. Upon cooling the mass solidifies; hence it is necessary to ladle it out, and either dissolve it at once or cast it into moulds, and preserve the cakes. If the sodium sulphide is dissolved, not in water, but in lixiviation-solution, no dilution of the latter takes place in precipitating the silver. From the consumption of sulphur it follows that the sodium sulphide is principally Na_2S_2 a combination to be considered as the most desirable one. Solutions so prepared show remarkably high precipitating coefficients, both for caustic soda and sulphur, ranging from 184 to 230 parts of silver for 100 parts of caustic soda, and from 275 to 345 parts of silver for 100 parts of sulphur. In the preparation of calcium polysulphide, the best coefficients were from' 98 to 132 parts of silver precipitated by 100 parts of sulphur consumed, and that with freshly made solutions. Considering how much the latter deteriorate, after some time, it is safe to assume that the precipitation of silver by calcium polysulphide requires about three times as much sulphur as is needed with properly prepared sodium sulphide. This item, the convenience of making sodium sulphide, and the loss in hyposulphite caused by boiling caustic lime with sulphur, more than compensate the extra expense for caustic soda.

B. Calcium and Sodium Sulphides compared as Precipitants for Silver.

G. Kuestel states—and this has been copied by others—that in using calcium polysulphide, the sulphides precipitate quicker, and settle better than with a sodium polysulphide. This statement is not confirmed, but contradicted by Russell's experiments. In working on a large scale, the sulphides precipitated by sodium monosulphide, or polysulphide, settled without difficulty, and in a short time, and the effect of calcium sulphide did not show itself to be superior in any respect. On the contrary, sodium monosulphide proved to be infinitely better than calcium pentasulphide. Indeed it is not possible to advance theoretical reasons to support the superiority of calcium polysulphide. Using the pentasulphide, which is mostly obtained, four equivalents of sulphur are wasted, and appear as free sulphur in precipitating the lixiviation-solution. To regain this free sulphur either by distilling the sulphides in an iron retort, or by boiling them with caustic lime, as has been proposed, seems to me objectionable, and not profitable. The distilling process would leave the sulphides in a condition requiring pulverizing for subsequent treatment, and the operation needs an expensive plant, and is costly. In boiling the sulphides with caustic lime, we run the risk of having impurities of the lime, and insoluble calcium monosulphide, and sulphate, with the sulphides, whereby their treatment becomes more difficult. A much better method would be to boil the sulphides with an excess of caustic soda. The solution, so obtained, could be treated with more sulphur, and converted into a normal solution for precipitating.

Another point against the use of calcium sulphide is the fact that gypsum is precipitated with the sulphides, whereby their subsequent treatment becomes more troublesome.

Mr. Russell found that calcium sulphate is, practically, "insoluble in a solution of calcium sulphide." (And also in sodium sulphide.) Hence no gypsum can enter the lixiviation-solution from this source directly. If to a calcium sulphide solution a soluble sulphate is added, for instance that of sodium, a precipitate of gypsum appears immediately; and if to a sodium hyposulphite solution, containing sodium sulphate, or any other sulphate, calcium sulphide is added, gypsum is formed which, in part, remains in solution, and, in part, is thrown down with the sulphides.

The fact that calcium sulphate is insoluble in a sodium sulphide solution can be turned to a practical account in removing from the latter any sodium sulphate it may contain. It is only necessary to add gradually a solution of calcium sulphide, as long as a precipitate appears. In preparing sodium sulphide from caustic soda, the amount of sulphate formed is trifling; but the commercial caustic soda may contain an appreciable percentage of sulphate beforehand.

I now turn to the question: In what respect, if in any, differ the calcium and sodium hyposulphite solutions regarding their efficiency in lixiviation? The points to be considered are: a. The deterioration of the solutions after prolonged use. b. Their dissolving energy for extracting silver. c. Their dissolving energy for extracting gold, in case gold-bearing silver-ores are lixiviated.

The last subject has already been treated in a former paragraph on gold-extraction especially.

a. The Deterioration of the Lixiviation-solution after Prolonged Use.

If a hyposulphite solution is left to itself for a longtime, it deteriorates in a marked degree. It takes up oxygen from the air, and sulphates are formed. Mr. Russell interrupted on two occasions his lixiviation-experiments, on a large scale, for some time, and determined the deterioration of the sodium hyposulphite solution.

Solution not used for twenty-six days.

100 c.c. dissolved, ... 0.485 gm. silver as AgCl.

After twenty-six days, ...………...0.458 gm. " "

Deterioration,................................. ………….5.5 per cent.

Solution not used for thirty-five days.

100 e.e. dissolved, ...…………….. 0.447 gm. silver as AgCl.

After thirty-five days,……………………………..0.369 gm. " "

Deterioration,………………………………………17.4 per cent.

This result is interesting, because it shows that the decomposition of the solution is not merely a function of time. I am inclined to believe that, outside of difference in temperature, the condition of the atmosphere has a marked influence, most likely its contents in ozone.

In order to test the relative deterioration of solutions of calcium and sodium hyposulphite, Mr. Russell has carried out the following experiments.

Hyposulphite solutions of different concentration were exposed in soup-plates to the atmosphere for seven days at a temperature of from 20 to 22 degrees C, and the solutions brought to their original volume at the expiration of that time. The relation of the depth of the solution to the diameter of the plate was about 1 to 8. A re-determination of the solvent energy of these solutions for silver chloride gave the following average results, namely: The sodium hyposulphite solutions had deteriorated 1 4/10 per cent. The calcium hyposulphite solutions had deteriorated 16 1/19 per cent.

About the deterioration of a calcium hyposulphite lixiviation-solution, Mr. G. Kuestel says: "If the solution of hyposulphite of lime is not properly managed, for instance, by introducing the solution on the ore without leaching it first with water, augmenting by these means salt and sulphate of soda in the solution of hyposulphite of lime, this solution refuses to dissolve the silver as well as it did in the beginning, and requires then to be renewed, which is expensive and troublesome. To revive a solution of this description, it is sufficient, when the vat is charged, to spread wood-ashes over the entire surface of the ore, two or three inches deep, and then admit the solution. It will then act like a new solution."

No explanation is given of the reactions taking place, and effecting the regeneration of the solution. The only effective agent in the wood-ashes must be potassium carbonate.

How can this remove "salt and sulphate of soda"? The potassium carbonate would cause a precipitate of calcium carbonate, and change calcium hyposulphite, and gypsum dissolved in the latter, to the respective potassium salts. How is this to improve the 'solution when, as we will see further on, potassium hyposulphite is a much poorer solvent for silver chloride than the calcium salt? That a solution of calcium hyposulphite, if saturated with gypsum, is not thereby materially affected in solvent energy, we have noted before.

If the wood-ashes really have the beneficial effect which Mr. Kuestel claims (I have had no occasion to verify his statement), then the reaction still lacks explanation.

b. The Solvent Energy of various Hyposulphite Solutions for Silver Chloride.

Mr. Russell prepared solutions of 1½ per cent. concentration from the hyposulphites of sodium, potassium and calcium, and treated with them freshly precipitated silver chloride under equal conditions. I present the results of these experiments as follows, calling the solvent energy of sodium hyposulphite 100.

Name of salt:	Solvent energy for silver chloride:
Sodium hyposulphite,	100
Potassium "	70
Calcium "	91.5

This shows plainly the inferior effect of the calcium-salt. That of potassium hyposulphite is comparatively low, and does not seem to have been investigated before. It finds a parallel in the inferior solubility of silver chloride in potassium chloride solutions as compared with those of sodium chloride.

§ 27. *Treatment of the Sulphides.*

Samples of sulphides, obtained from Ontario ore by Russell's process, if treated by the ordinary method (namely, roasting and melting), yielded, in one case, bullion 874 fine, and, for 100 parts of bullion, 62 parts matte, assaying 2720 oz. silver per ton, and 24 per cent. copper. In another case, bullion 876 fine was produced, and, for 100 parts bullion, 76 parts matte were obtained, assaying 3308 oz. silver per ton, and 27 per cent. copper. A more complete roasting would have diminished the percentage of matte, but produced bullion of inferior fineness. It can not be denied that the handling of the sulphides is a weak point in the lixiviation-process. In roasting such rich products, a mechanical loss, and a loss in silver by volatilization, cannot be avoided. The by-pro-duct of rich copper-matte, even if reduced in value by melting with scrap-iron, is also a very undesirable feature. If oxidizing-roasting is carried too far, the material becomes more difficult to fuse, and the loss in silver, by volatilization, increases. In case the sulphides contain lead the bullion has to be cupelled, and if much copper is present, more lead must be added to produce fine bullion. That also in this process a loss of silver occurs is well known. Besides, litharge with copper is not a desirable by-product. Finally it should be taken into consideration that the hearth of the reverberatory furnace, in which the sulphides are roasted, gradually absorbs a large amount of silver. Mr. Clark, superintendent of the Bertrand mill, informs me that he recovered from the hearth of such a furnace over §6000 in silver, but that this by no means accounted for all the silver lost. To avoid all these difficulties, and to produce at the same time fine silver, gain the copper as a valuable by-product, and part the gold, if it be present, I have proposed the following process.*

The sulphides, collected by means of a filter-press,—Dehne's or Johnson's construction,—are dissolved, without previous drying, in sulphuric acid with addition of sodium nitrate. No heating is necessary, the reaction being quite violent. If any gold is present it remains un-dissolved, together with some silver chloride, the chlorine being derived from impure sulphuric acid and nitrc. The lead having been

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* United States patent granted to C. A. Stetefeldt.

previously separated by the method described in § 25, no lead sulphate can be formed. The sulphur gathers mostly in globules, and can be used again in the preparation of sodium sulphide. After complete decomposition has taken place, the solution is drawn into a tank, and the silver precipitated by metallic copper. The cement-copper gained from the wash-water (see § 23) can be utilized for this purpose, and its silver extracted at the same time. It is preferable first to melt this copper, refine it, and cast it into plates of proper form. From the solution copper sulphate is obtained. The acid mother-solution is used again for dissolving sulphides. A portion of the copper sulphate is utilized in preparing the extra-solution.

In effecting the oxidation of the sulphides by nitric acid, set free from nitre by sulphuric acid, nitric oxide escapes. When the latter comes in contact with air and moisture, nitrous and nitric acid are regenerated, which are again ready to part with oxygen. This reaction, upon which the manufacture of sulphuric acid is based, can be utilized also in this case. It is only necessary to dissolve the sulphides in a closed vessel, and conduct the escaping nitric oxide to a coke-tower, into* which air is admitted below, and a spray of water or sulphuric acid from above. The nitrated solution, thus obtained, is passed through the tower again until it attains a proper concentration, and is then used for dissolving fresh charges of sulphides. Of course, a portion of the nitric acid will be lost, and has to be made good by fresh supplies of nitre.

In case the process of regenerating nitric acid is used, the best *modus operands* will be as follows :

The first charges are dissolved with sulphuric acid of 66° B. and nitre, and the escaping nitric oxide, with a surplus of air, is conducted to a coke-tower in which concentrated sulphuric acid is nitrated. In working with concentrated acids iron vessels can be used throughout, the nitric acid having the tendency to make the iron more passive. The solution is drawn into a tank No. 1, where it is diluted to 58° B., and heated to about 110° C. It is kept at this temperature until perfectly clear, and is then drawn into a tank No. 2, surrounded by cold water, where it is cooled rapidly. Here the silver sulphate crystallizes, and also copper sulphate, whenever the solution has reached a sufficient concentration in the latter salt. The residue in tank No. 1 will consist, principally, of gold (if such is present in the ore), some silver chloride, lead sulphate (if the lead has not been completely precipitated previously), and sulphur globules, and may also contain some undecomposed sulphides. It is allowed to accumulate, and is worked by itself. After the sulphates in tank No. 2 have been completely strained from the acid mother-solution, they are taken to a lead tank No. 3. Sufficient water is added to dissolve the copper sulphate, and the solution is boiled with metallic copper until the silver sulphate is reduced. The reduction of silver sulphate is better accomplished by scrap sheet-iron (Lautenthal, Germany), or by ferrous sulphate (San Francisco, Cal.). I propose to use metallic copper in order to gain a maximum of copper sulphate. The copper-solution is crystallized in tank No. 4, and the cement-silver is washed until it is sweet. The mother-solution from tank No. 4 is used, in place of water, for boiling and dissolving the sulphates in tank No. 3. We now return to the acid solution from tank No. 2. This is mixed with sufficient sulphuric acid of 66° B. to make good the loss incurred in the formation of the sulphates, and after passing through thecoke-tower to be nitrated, is used for dissolving a fresh charge of sulphides. In order to avoid a loss of nitric acid as much as possible it is best to charge the dissolving-vessel with more sulphides than the nitrated acid is able to oxidize. The excess of sulphuric acid will keep the silver sulphate dissolved, if the solution is sufficiently hot, and the latter can be clarified in part, in the dissolving-vessel, before it is drawn into tank No. 1. Operating in the way indicated no further dilution of the solution in tank No. 1 is necessary or desirable. Whenever the residue in the clarifying tank No. 1 has accumulated in sufficient quantity, it is returned to the dissolving-vessel, and treated with an excess of nitrated sulphuric acid. It will then consist, principally, of gold, silver chloride, and perhaps of lead sulphate. Both of the latter can be extracted by a solution of sodium hyposulphite, and the gold can be refined by cupellation with lead.

It will be seen that this process, if successfully executed, is not any more complicated or expensive than that of refining silver bullion in bars. On the contrary, the solution of the sulphides is more easily and rapidly effected, and no sulphuric acid is wasted.

A boiling of the sulphides with caustic soda, prior to their treatment by the process described, might be advantageous. The largest portion of the sulphur would, in this way, be extracted as sodium sulphide. It would not be necessary to filter or wash the sulphides before this first treatment—more or less lixiviation-solution in the sodium sulphide not being detrimental. Filtering and washing would take place after the boiling with caustic soda. Where freight is high it may be more economical to use concentrated nitric acid in place of nitre.

§ 28. *The practical Results obtained at the Ontario Mill.*

I give below the results of 20 working-tests with the Russell process, made with ore-charges of two tons each.

	Lixiviation-test with: ordinary solution, per cent.	extra-solution, per cent.	Silver extracted from the charge, per cent.
	89.5	91.8	92.1
	91.9	92.7	94.8
	88.8	93.1	94.6
	87.4	92.6	92.6
	88.5	92.4	91.9
	90.3	92.6	93.5
	91.1	93.1	94.1
	89.4	92.8	92.9
	85.3	91.9	91.8
	86.2	91.3	91.5
	90.3	91.9	91.9
	93.7	94.7	94.5
	89.3	92.7	92.4
	83.1	91.8	91.1
	89.4	90.9	91.3
	86.4	90.3	91.5
	887	93.1	93.6
	87.6	91.5	92.2
	88.6	92.2	92.5
Averages:	88.6	92.2	92.6

Seven charges of Ontario ore, lixiviated subsequently, gave results as follows, viz.:

	Lixiviation-test with: ordinary solution, per cent.	extra-solution, per cent.	Silver extracted from the charge, per cent.
	91.2	93.7	94.4
	88.4	91.4	92.6
	86.9	94.9	95.3
	88.4	93.7	93.7
	90.1	93.7	93.9
	93.6	95.2	95.1
	91.4	95.0	95.7
Averages:	90.0	93.9	94.4

From charges lixiviated recently as high as 97 per cent. of the silver has been extracted.

Mr. Russell further states : "I have made 12 working-testsduring the past winter with the temperature of the hyposulphite solution near the freezing-point of water, in order to determine whether the solution would require to be warmed in cold weather. For these tests I selected ore which had a comparatively low chlorination. The results of these tests averaged 7 per cent. above the chlorination-assay with ordinary solution. These experiments, with a cold solution, constitute a very severe test of the process."

It is more advantageous, however, to use solutions which are moderately warm.

§ 29. *The By-Products.*

From one ton of Ontario ore about 5 to 8 pounds of $PbCO_3$ were obtained, if a 1 1/4 per cent. hyposulphite solution was used. The wash-water (see § 23) yielded about 3 ½ pounds of cement-copper per ton of ore. It contained 130 oz. silver per ton, more or less.

If the sulphides are treated by the wet process, more than one-half of this copper could be used in the precipitation of cement-silver. The remainder may be treated in different ways. It could, for instance, be dissolved by the same process as proposed for the sulphides in § 27, or it could be oxidized by heating in a reverberatory furnace, and the oxide of copper extracted by dilute sulphuric acid, leaving the silver as au insoluble residue. About 3 pounds more copper, or its equivalent in $CuSO_4 + 5aq.$, would result from the sulphides per ton of Ontario ore.

A part of this copper comes from the copper in the extra-solution, and is thus kept in constant circulation.

§ 30. *Economy of the Process.*

To my professional colleagues it is hardly necessary to point out the economy of Russell's process. Without entering into detailed calculations, I will only point out the principal items which are in favor of lixiviation, as compared with amalgamation.

1st. In amalgamation the fineness to which the ore has to be crushed is determined by the capacity of the settler to work off coarse sands without loss of quicksilver. It is not practicable to use a coarser screen than No. 30 if the crushing is done by stamps. This is almost equivalent to sifting through a No. 40 revolving screen if the crushing is done by rolls. In lixiviation, pulverizing as coarse as possible is desirable. The limit of coarseness is determined by the roasting process. It depends upon the character of the ore, and, principally, upon the manner in which the silver-bearing minerals are distributed in the gangue.

2d. The original cost of the lixiviation-plant is much lower than that of pans and settlers. A further saving is effected by a reduction in size of the engine and boilers.

3d. In amalgamation the pans and settlers consume not less than 1⅓ horse-power per ton of ore. The power for pumping solutions, etc., in the lixiviation-process, is merely nominal.

4th. In large mills the quantity of quicksilver in rotation represents a capital of from §30,000 to $40,000, while the stock of chemicals required for lixiviation does not cost more than one-tenth of this amount.

5th. With Russell's improvements the percentage of silver extracted by lixiviation is much higher than by amalgamation.

6th: Lixiviation by Russell's process requires a less careful chloridizing-roasting. That in many cases the salt may be dispensed with, is indicated by Ontario experiments.

7th. The value of the lost quicksilver, and cost in wear and tear of the pans and settlers, amounts to more than that of the chemicals consumed in the lixiviation-process.

8th. The lixiviation-process permits the extraction of copper and lead as valuable by-products.

9th. The sulphides from the lixiviation-process can be much more easily converted into fine bars, and the gold parted, than this can be done with the bullion obtained in amalgamation.

10th. Amalgamation is invariably injurious to the laborer's health.

11th. In case gold-bearing silver-ores have been roasted with salt, lixiviation extracts, in most cases, more gold than amalgamation.

If we take, finally, into consideration: first, the great reduction in the cost of crushing silver-ores dry by the successful introduction of Krom's steel rolls in place of stamps; second, the possibility of lixiviating with profit some classes of silver-ores after they have been subjected to an oxidizing-roasting only; third, the possibility of lixiviating many so-called "free-milling" ores without previous roasting, including tailings resulting from amalgamation of roasted or raw silver-ores; we may expect a revolution in the reduction of silver-ores, and a cheapening of the process, rarely witnessed in the history of metallurgy.

Mr. Russell's researches are not yet ended. Much ground, still a " terra incognita," remains to be explored. What has* been accomplished is of such importance, and so interesting, that it is expedient no longer to withhold it from publication.

In conclusion I will state that this paper conveys no idea of the amount of work performed by Mr. Russell. Many of his experiments failed to produce results of practical importance, and are ignored here so as not to overload this essay with too much detail. If I have succeeded in presenting the ample material at my disposal in a comprehensive and intelligible form, I shall feel gratified.

APPENDIX No. 1.

NOTES ON THE CONSTRUCTION OF THE LIXIVIATION-PLANT.

1. *Lixiviation-Tanks.*

Where a sharp quartz-sand is obtainable, and Portland cement is not too expensive, I would suggest to build up the lixiviation-tanks of béton, reinforced with wrought-T iron, such as architects use in the construction of floors in buildings. Such tanks could be made very large and rectangular, and, if placed on a solid foundation, would never leak, wear out, or absorb any solution. They could be protected against wear in shoveling out the tailings, by a lattice-work of wood. If common bricks, taken hot from the kilns, are immersed in coal-tar, they also form a suitable material for the construction of lixiviation-tanks. Asphaltum-mortar is used for building up the walls. Finally, I propose the use of asphaltic concrete for building up bottom and sides of the tanks. Besides, all floors of the lixiviation-building should be covered with asphaltic concrete.

2. *Pipes for Conducting Solutions.*

By heating iron gas-pipes, and immersing them in asphaltum-varnish, they receive a hard coating, which resists for a long time even the action of acid copper solutions. All joints are made with the aid of asphaltum-varnish. Cocks are to be as much as possible avoided. Solutions from tanks are drawn by a piece of rubber hose, entering the tank at the bottom, and ending below the level of the solution, kept in position by a swimmer. By raising the hose out of the solution the flow of the liquid ceases at once. Any precipitate accumulated at the bottom of the tank is thus left undisturbed. The solution is admitted to any lixi.viation-tank by a rubber hose connected with the solution pipe. By raising the end of the hose above the level of the solution in the supply-tank, the flow is at once stopped. Pinch-cocks are used merely to regulate the quantity of the solution running out.

3. *Rassing of the Solution to a Higher Level.*

For this purpose plunger-pumps, lined with hard lead, are recommended. They should be driven by steam-power, be provided with a loose pulley, and either with cone-pulleys, or with movable eccentrics, to regulate the number or length of strokes, and thus the quantity of solution pumped. It is of great advantage to allow the lixiviation-solution, especially the extra-solution, to sink constantly through the charge.

4. *Precipitation of Lead Carbonate and of the Sulphides.*

In works of large capacity, stirring of the solutions by hand is laborious and imperfect. Mechanical stirrers, with up-and-down movement, can easily be arranged.

5. *Heating of the Solutions.*

We have seen that the extra-solution, and also the ordinary solution, acts with greater energy at an elevated temperature. Hence, during cold weather, heating of the solutions may become necessary in order to shorten the time of lixiviation and obtain maximum results. A worm of lead pipe, through which steam circulates, would be the most convenient apparatus for this purpose. The distilled water could be returned to the boilers, and no steam need to be wasted by escaping uncondensed.

6. *Filtering of the Lead Carbonate and of the Sulphides.*

Centrifugal machines have been proposed, but since the introduction of the filter-press, the latter most decidedly deserves the preference. The precipitates can be completely washed out, and are obtained as slightly moist cakes. The solutions in which the precipitates are suspended, can enter the press in any condition whatsoever.

7. *Plant for the Treatment of the Sulphides.*

If the humid process is used, the plant required has already been outlined. The cement-silver, after being compressed into cakes, is melted in a small reverberatory furnace with gas-producer. I have intraduced such a furnace at the Lexington Mill, Montana, for melting retort-bullion. Mr, A. Wartenweiler, the superintendent of the mill, writes as follows: "When we are ready to melt, the furnace is fired up at 4 o'clock A. M. Ten bars (of about 1800 oz. each) are run out at 9 A.M., when the furnace is immediately recharged, and about 11 A.M.

the second batch of bars is cast. For the first lot we consume one-half of a cord of wood, and the second takes only one-quarter of a cord, the furnace being already heated. It was originally intended to burn charcoal in the gas-producer, but I found that wood did the work just as well, in fact, better, and much cheaper.

"If the metal is hot, and has been well stirred before tapping the furnace, the bars are very uniform in fineness, and samples taken in various ways seldom differ any in fineness from the granulated sample obtained while the metal runs into the moulds."

8. *System of Continuous Lixiviation.*

In conclusion, I wish to propose a system of lixiviation which may be of value in some instances. If low-grade ores are treated, the hyposulphite solution has not taken up as much silver as it is capable of dissolving, and the work of precipitating the sulphides is thereby unnecessarily augmented. By passing the solution from tank to tank it could be completely saturated, and, in my opinion, a charge could be finished in lass time, and with better results. I will further illustrate this by an example. Suppose the plant consists of six tanks, one being charged every six hours, which gives a working-time for each charge of thirty-six hours. One tank of the six is always in the act of being discharged and recharged, and the lixiviation-solution circulates only through five tanks. The fresh hyposulphite solution enters the tank which is to be discharged next, and runs, saturated with silver, from the tank charged last, to the precipitating vats. In case the ore is very coarse, and filters freely, the tanks can be placed on a platform of steps with a drop from 6 inches to a foot, and one pump will suffice to raise the solution from the lowest to the highest tank. With fine ores, requiring filtering by the suction of a water-column, a pump has to be provided for each tank. The water-column, however, may be dispensed with, the pump itself creating the suction. In this manner the solution is kept in constant motion and circulation, sinking through the ore-charges, and leaving the last tank ready for precipitation. *As* the tank to be discharged next receives the fresh solution, the action of the latter, on the remaining portion of soluble silver in the ore, must be most energetic.

APPENDIX No. 2.

Historical, Notes.

Mr. Ottokar Hofmann deserves the credit of having been the first to introduce the lixiviation-process on this continent. He has furnished me with the following data. The process was introduced :

1868. La Dura, Sonora, Mexico.

1869. Trinidad, Sonora, Mexico.

1869. San Marcial, Sonora, Mexico.

1871. Las Bronzas, Sonora, Mexico.

In all these places Mr. Hofniann was active himself.

Other localities in Mexico where the process has been or is still in operation are:

La Barranca, Sonora.

Promontorio, near Alamos, Sonora.

Cosihuiriachic, Chihuahua,

Mines near Parral, Durango.

Triunfo, Lower California.

Las Yedras, Sinaloa.

Alameda and Tirito, Sonora.

In the United States lixiviation was first introduced by Mr. G. Kuestel, in 1874, at Melrose, near Alameda, California. The works were built to do custom-work, and the supply of ore being limited and irregular, they did not prove a financial success, and had to be abandoned.

1877. At Galena, Nevada, ores containing zinc-blende and galena were concentrated by Krom's dry system. The galena-concentrations were sold to smelting-works, and the silver-bearing zinc-blende treated by lixiviation. The mine has been abandoned.

1878. O. Hofmann works concentrations containing $250 silver and §25 gold per ton at the Advance Mill, Monitor, California, where 85 per cent. of the gold has been extracted by simple lixiviation.

1879. Introduced at the Tarshish Mine, Monitor, California, by O. Hofmann. The results have been already stated. Both of the last-named works had only a short existence.

1880. First successful introduction, on a large scale, at the Silver King Mill, Arizona, by 0. Hofmann. Average of ore $196.92 per ton ; percentage of silver extracted 89.2 per cent.

1882. Lixiviation-works of 60-ton capacity are constructed at the Bertrand Mine, Geddcs, Nevada. Krom's rolls are successfully introduced for pulverizing the ore. For results I refer to Professor Egleston's paper quoted previously.

1883. A lixiviation-mill has been built for the Mt. Cory Mine, Nevada, with Krom's rolls.

At the Old Telegraph Mine, Utah, chloride of silver has been extracted by lixiviation from oxidized lead-ores without roasting. The residues' were subsequently concentrated for lead-minerals.

APPENDIX No. 3.

A COMPARISON BETWEEN KROM'S ROLLS AND THE STAMP-BATTERY.

The successful introduction of Krom's rolls in the Bertrand lixiviation-mill, Nevada, is of such importance that it deserves notice here. In comparing stamps and rolls we have to consider : 1st. The physical difference of the pulp produced. 2d. The question of economy, namely : a. In regard to original cost of constructing the plant. *b*. The wear and tear of each machine, and consumption of fuel.

1. *The Physical Difference of the Pulp Produced.*

I refer here to the well-known fact, that if pulp produced by rolls or by stamps is sifted through the same size of screen, the ore-particles from the former are more uniform in size, and contain much less impalpable dust than those from the latter. It has been found that for chloridizing-roasting great fineness of the ore is entirely unnecessary— provided the silver minerals are not too finely impregnated in the gangue. In the lixiviation-process great fineness of the ore interferes with rapid filtration. From this it follows that ore pulverized by rolls is in the most favorable condition as far as the mechanical part of lixiviation is concerned.

2. *The Question of Economy.*

A discussion of this subject, which is complete and thorough, and compares the efficiency of rolls and stamps under varying conditions, is not possible at present, because the available statistics concerning Krom's rolls are confined to those from the Bertrand Mill. Sufficient evidence, however, has accumulated to prove the superiority of the rolls beyond any doubt. Their introduction in the Mt. Cory Mill, Nevada, will soon bring additional proof. It seems to me that the application of rolls is most favorable in cases where silver is extracted by lixiviation, and the character of the ore permits comparatively coarse crushing without interfering with good roasting.

A comparison between rolls and stamps will be made from the following premises: I assume that the crushing capacity of two sets of Krom's 26-inch rolls is equal to that of a 30-stamp battery with stamps of 850 pounds, dropping from 7 inches to 8 inches ninety-four times per minute. Mr. Clark, superintendent of the Bertrand Mill, states that he can crush, with two sets of rolls, 100 tons of ore in twenty-four hours to such a fineness that all will pass through a No. 16 wire-screen, consuming not over 4 cords of wood for power. The ore has a quartz gangue, and is by no means an easy crushing ore. The fuel required for running 30 stamps is about 6 cords of wood in twenty-four hours. For some remote locality in the West the following prices *are* assumed, namely : Freight at 3 cents per pound; lumber at §50 per thousand feet; wood at $6 per cord; wages of carpenters at §4.50, and of millwrights at $6. Certain items of construction will be about equal, namely : conveyors, elevators, revolving screens, and dust-chambers. Revolving screens are also used in connection with a well-appointed battery in order to separate coarse material resulting from the breakage of battery-screens. The building, however, for rolls will be much smaller than that for the battery, and a saving of not less than §1500 will be effected in its construction. Finally, the rolls requiring less power, a saving of at least $1250 will be made in providing and setting up engine and boilers in a mill with rolls.

Cod of Erecting a 30-stamp Battery.—The plant, including hard-wood screen-frames and guides, wooden pulleys on cam-shafts, Tullock's feeders with iron hoppers, and all necessary bolts, weighs 90,(500 pounds, and costs in Chicago §5850, according to a statement of Messrs. Fraser and Chalmers. The framework takes about 36,000 feet of lumber, and the expense of setting up the battery is estimated at $4000. Hence, total cost of constructing a 30-stamp battery is:

Plant at foundry,	$5,850 00
Freight,	2,718 00
Lumber,	1,800 00
Cost of setting up,	4,000 00
	$14,368 00

To this has to be added in order to compare with rolls:

Extra cost of building, ...	1,500 00
Extra cost of engine and boilers, ...	1,250 00
Total, ...	$17,118 00

Cost of Erecting two sets of Krom's 26-inch Rolls.—The amount of lumber required for setting up the rolls alone is merely nominal. From this it follows that also the labor of placing the rolls must be trifling. The weight of one set of 26-inch rolls is 12,000 pounds, and the cost in New York is $2250. There is only one self-feeder required, and its weight is estimated at 2000 pounds, cost $200.

From these figures we deduce the following:

Plant at foundry, ...	$4,700 00
Freight, ...	780 00
Cost of setting up, including lumber, ...	700 00
Total, ...	$6,180 00
Difference in favor of rolls:	$10,938 00*

Wear and Tear of Stamps and Krom's Rolls.—In comparing the wear and tear of stamps and rolls we cannot very well express it per ton of ore crushed, because the capacity of the pulverizing machinery is a function of the hardness of the ore, and of the fineness of the pulp produced. A much correcter method will be to take the figures per running time of twenty-four hours. Making estimates from this standpoint it is supposed that the wear and tear in running the machinery at full capacity is a nearly constant quantity, while the capacity is variable as stated above. That this assumption is correct for practical purposes has become evident to me by a comparison of the battery-statistics from the Manhattan and Ontario mills. The conditions in these mills are by no means the same. There is a difference in the character of the ore; the Manhattan uses No. 50, and the Ontario No. 30 screens; the Manhattan stamps weigh 1000 pounds, those at the Ontario 850 pounds; Ontario stamps drop 92 times per minute, those at the Manhattan about 100 times; still, in comparing the wear and tear per actual horse-power expended, the figures are very nearly the same. Hence, my argument does not lack the support of practical experience. The wear of rolls is principally confined to the steel tires, that of the batten' to a great number of parts. With rolls

* In both estimates elevators, conveyors, and revolving screens are not included, as stated previously.

the steel tires can be consumed to within less than ½ inch of their thickness, while with stamps, the shoes and dies have to be exchanged after only two-thirds, or less, of their weight has been worn, leaving other parts out of consideration. Another point should not be overlooked. The complicated construction of the battery causes considerable expense in skilled labor for repairs, which, in the case of rolls, is merely nominal. Advocates of the battery have argued that its great advantage is the continuance of its operation if one battery of five stamps gets out of order, while both sets, or three sets of rolls, as the case may be, have to be stopped it" repairs are needed for one set. But it is just the solid construction of Krom's rolls which reduces stoppages from this cause to a minimum. The system of elevators, screens, hoppers and conveyors, if properly constructed, will get out of order very rarely. How often it is necessary to hang up stamps for repairs is too well known to require any statistical proof.

Wear and Tear of Krom's Rolls.--As to statistics of wear and tear of Krom's rolls I am confined, at present, to those from the Bertrand Mill. Mr. R. D. Clark states that two sets of steel tires crushed in round figures 20,000 tons of ore.

As stated previously, the full capacity of the rolls is, in twenty-four hours, 100 tons, the ore being sifted through a No. 16 screen. In the beginning, however, the ore was crushed much finer, namely, so as to pass a No. 20 screen, and the daily capacity of the rolls was much less. Taking this into consideration, the actual wearing capacity of the tires cannot be estimated at less than 250 working days. The cost of this wear is as follows :

Two sets of steel tires at New York,	$764 00
Freight on 3264 pounds, at 3 cents,	98 00
Total,	$862 00
Wear and tear per twenty-four hours:	
In steel tires,	3 45
In other parts, screens, supplies and lubricants,	1 75*
Wages for repairs,	1 25*
Total,	$6 45

Wear and Tear of Stamps.--I have been favored with correct statistics from three of the most prominent mills in the West, namely, the Manhattan, Nevada; the Ontario, Utah ; the Lexington, Montana. Taking into consideration the somewhat abnormal conditions at the

* These figures will, no doubt, be considered too high by Mr. Krom and Mr. Clark. I consider it safer, however, to provide a limit for accidents.

Manhattan Mill, in so far as the weight of stamps there is 1000 pounds, and the number of drops is greater than in either of the other mills, causing a more frequent breakage of stems and cam-shafts; further, that the statistics from the Lexington Mill are those from the first year's run, where certain breakages are reduced to a minimum ; finally, that freight in these localities, on account of direct railroad-communications, is slightly less than I have assumed in my premises, I arrive, by making such allowances, at the following figures for wear and tear of a 30-stamp battery per twenty-four hours running time:

In all parts subjected to wear and breakage, supplies, screens, and lubricants,*	$11 50
Wages for repairs, ...	5 50
Total, ...	$17 00
Wear and tear of rolls, ...	6 45
Difference in favor of rolls, ...	$10 55

Interest and Amortisation.--In comparing the expense of running rolls and stamps, interest and amortisation on the excess of capital required in the original construction of the plant for stamps cannot be neglected. Considering the short life of most silver-mines in this country, this item should not be taken at a lower rate than 15 per cent. per annum. If we take the running time of a mill at three hundred and fifty days in the year, and consider that a mill with stamps will cost $10,938 more than one with rolls, the interest and amortisation amount to $4.68 per day.

Summary.--From the above we find the following daily saving in a mill with two sets of Krom's 26-inch rolls as compared with 30 stamps:

Wear and tear, and repairs, ...	$10 55
Interest and amortisation, ...	4 68
Fuel, 2 cords of wood, at $6, ...	12 00
Total, ...	$27 23

If no great accuracy can be claimed for this estimate, it is the best winch can be given at present.

Mr. Krom, supported by Mr. Clark, claims that two sets of rolls will crush more ore than 30 stamps. Others will consider my estimate too much in favor of the rolls. Time will establish the correctness or fallacy of these views.

* Of this amount, the wear and tear of shoes and dies represents only 40 per cent.: tappets, bosses, cams, stems, cam-shafts, flanges, and boxes, 3S per cent.; and screens, lubricants, screen-frames, battery-guides, and carpenters' and machinists' supplies, 22 per cent.

MOLLING STEEL INGOTS WITH THEIR OWN INITIAL HEAT.

BY JOHN GJERS, MIDDLESBROUGH, ENGLAND, MEMBER OF THE BRITISH IRON AND STEEL INSTITUTE.

BEING on a visit to your great and prosperous country, and having been favored with an invitation to attend this meeting of your Institute, the author has been requested by your Secretary to give a short account of his invention of the "soaking-pit," which he has great pleasure in doing.

The object of the soaking-pit is the rolling of steel ingots with their own initial heat, that is, to supply the missing link in that chain of metallurgical operations which Sir Henry Bessemer began in 1857, when he proved how it was possible to produce malleable iron or steel direct from the fluid cast-iron out of the blast-furnace, without any further direct use of fuel.

The great Bessemer invention has revolutionized iron and steel-making throughout the world; but it stopped short at producing the ingot, which, it was found, had afterwards to be heated in a furnace to enable it to be rolled or hammered; and it is only lately, twenty-five years after Mr. Bessemer's announcement, that the author of this paper has been able to show that furnacing can be dispensed with, and that it is practicable to roll a steel ingot into say a bloom, a rail, or a billet, with its own initial heat.

It has no doubt suggested itself to many that there ought to be heat enough in the ingot just cast, for the purpose of rolling; and from time to time attempts have been made to utilize this heat; but such attempts always ending in failure, it became a settled opinion in the trade that it could not be done--an opinion which the author is aware that your late lamented countryman, Mr. Holley, than whom there was none more conversant with Bessemer steel-making, also entertained.

But settled opinions sometimes prove to be great fallacies. As an instance, it is not many years since the opinion prevailed in the trade that steel ingots could not be rolled successfully, that is, so as to make good rails, unless they were first allowed to get quite cold, and afterwards heated. No greater boon was ever conferred on the steel-maker, than when the custom began to take the ingots as hot as possible to the furnaces. The fact is, steel does not improve by strong or repeated heating. On the contrary, the less heating it has the better. A steel ingot is often permanently injured in the heating-furnace ; and many of the defects in steel rails are traceable to that cause.

You are aware that the present practice of Bessemer steel-making is to take the fluid cast-iron direct from the blast-furnace, or to take remelted metal from the cupola, and blow it in the converter into steel. The steel is cast into moulds, and the ingots produced are either very strongly heated in a furnace and rolled direct into maybe several lengths of rails; or the ingot, somewhat less heated in a first heating-furnace, is rolled into a bloom 7 or 8 inches square, which is cut up in lengths for single rails, such cut-up pieces being afterwards given a second slight heat, or what is called wash-heat, and then rolled out into rails. Without going into the merits of the two modes of operation, the author will only point out that the latter is the mode most in favor in this country. In this case, the soaking-pits would supersede the first heating only; but wherever the machinery is strong enough to roll off several lengths of rails from one heat in a furnace, it is also capable of rolling off from the soaking-pits (if properly arranged) with no heating at all. .

It has been ascertained by direct experiment made for the author by the well-known analytical chemist, Mr. Stead, of Middlesbrough, England, that the margin of heat is ample; that is, if the heat-units in an ingot brought in a furnace to the highest heat for rolling be represented by 100, then the heat in fluid steel is 150; so that one-third of the total heat in the fluid steel, as it is poured into the ingot-mould, may be lost, and yet there would be sufficient left for rolling purposes.

Some of this heat passes into the mould and some is lost by radiation on its passage from the mould to the soaking-pit; but in actual practice there is no need to lose so much as one-third. Hence, the soaking-pit system, by observing certain conditions, can be made almost universally applicable. The operation of soaking is carried out by placing the ingot, as early as possible after it has been stripped of its mould, in previously heated cells of brickwork, or other heat-absorbing sufficiently refractory material, arranged so that the least possible amount of heat shall be able to escape. The plan most easily carried out, and the one which gives by far the best results in practice, is that of underground single vertical soaking-pits, arranged in nests of any required number of pits. After the brickwork in these pits has once got thoroughly heated, the operation of preparing ingots for rolling can go on continuously.

Three main conditions for success, which must be as far as possible attended to, are:

1. To strip the ingot as early as possible.
2. To remove the ingot with the least possible delay into the soaking-pit.
3. To carry on the operation of placing fresh ingots in the pits at a sufficient rate of speed.

In this country, where the blows of the Bessemer converter succeed' each other very rapidly, the first two conditions need be less strictly complied with ; since, if the ingots come on faster, there is less margin of heat required in each ingot. But if the margin be sufficient, then this excess of heat from each ingot, after the brickwork is once thoroughly heated, continuously passes into the brickwork constituting and surrounding the pits, and tends to keep the pits always at a high temperature. The brickwork surrounding the ingot being as hot as the ingot itself, or nearly so, it follows that very little heat can escape from the surface of the ingot, and that the excessive internal heat will work to the surface and heat it, thus tending to distribute the heat equally through the ingot. As soon as the ingot on the surface becomes hot enough (and HO longer time should be allowed in the pits than is necessary), it should be taken to the rolls. There is always the assurance in favor of the machinery, that whatever the surface-heat, the ingot is always hotter inside, which is the reverse of what happens when an ingot is heated from a comparatively cold state in a furnace.

Thus continually every ingot brings into the pits some excess of heat, which tends to keep them always at a high temperature, such heat dissipating but slowly in the underground arrangement, since, after the ground gets saturated with heat, it can only escape principally upwards. After a time no inconvenience is felt from occasional stoppages; and if the top-plate be covered with 3 or 4 inches of sand or ashes on Saturday, there will be no difficulty in starting with the first blow on Monday morning.

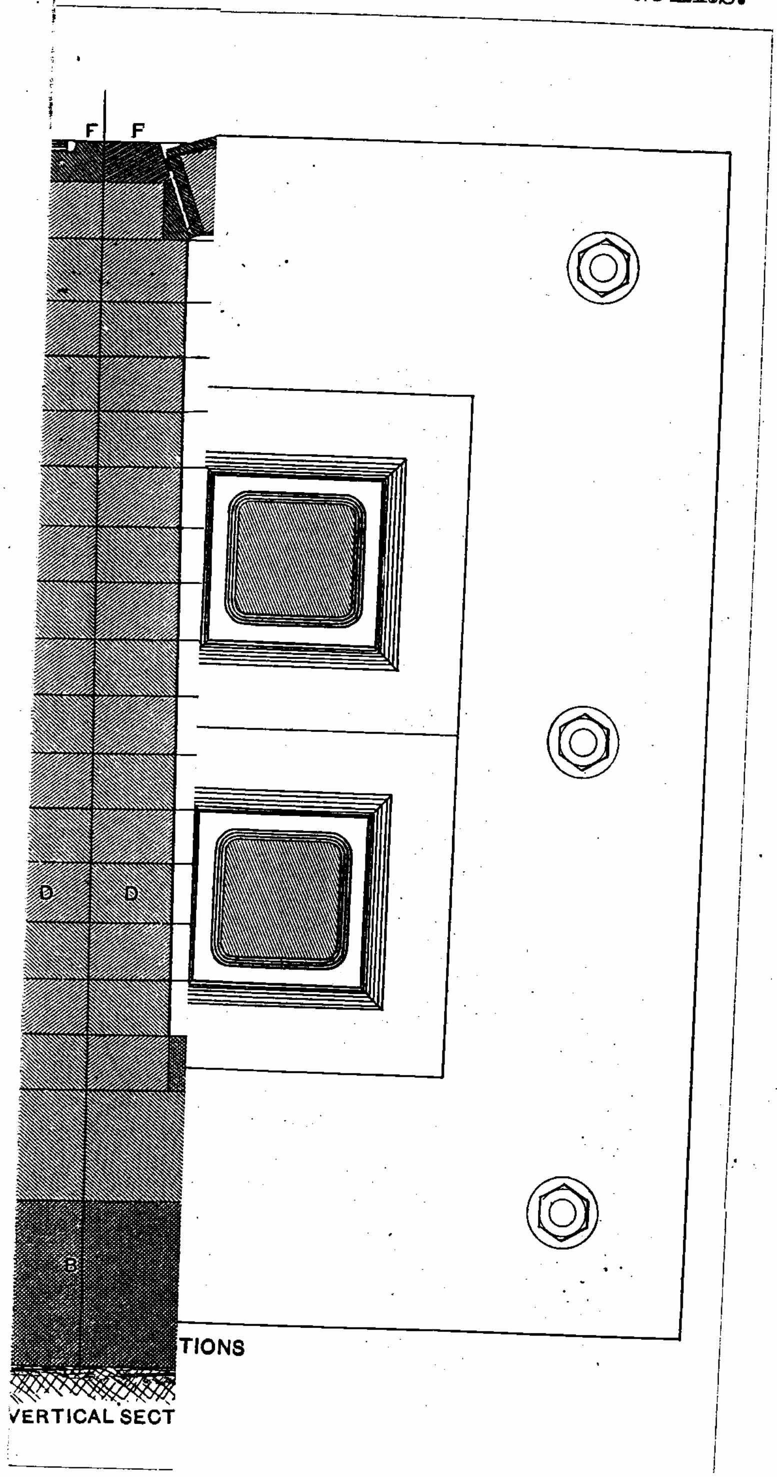
In the accompanying Plate, Fig. 1 shows the sectional elevation, and Pig. 2 the plan of a set of four soaking-pits. These pits are built in a mass of brickwork ion a concrete foundation *B.* The ingots C *C* stand upright in the pits. Each pit is provided with a separate lining, *D,* which should be of the best hard-burnt firebrick, the remainder of the brickwork being of an inferior kind. *F* is a cast-iron plate to cover each pit, fitting loosely within the large plate *E* which is held down by foundation bolts.

One pit is shown with an arrangement of double covers, *G G,* which may be lifted by hand; the other pit shows an arrangement of brick cover, H, which must be lifted by the crane or by a lever on a pair of wheels. This brick cover is preferable whenever rolling off direct into rails is intended, or the margin of heat from the Bessemer operation is small. The cast-iron or steel covers, as shown, have, however, proved themselves sufficient whenever blooming only was intended.

The ingots are placed in the pits and taken out by an ordinary hydraulic ingot-crane and suitable tongs. One such crane, and a set of four men and a boy on each shift, can readily deal with say two hundred 20-cwt. ingots per twelve hours, or, say 2000 tons a week. In the case of heavier ingots, a considerably larger, and in case of very small ingots a smaller, tonnage would be put through. For such standard output, about eight pits would do the work.

The author's paper on this subject, read at the Vienna meeting of the British Iron and Steel Institute, in September, 1882 (*Journal Iron and Steel Institute,* 1882, ii., p. 565), was accompanied with a diagram, showing an outline plan and elevation of a Bessemer plant conveniently arranged for working on the soaking-pit system. Referring to that paper for details, I will simply say here that the ingots are taken from the casting-pit by means of two ingot-cranes, and delivered to a third crane, which transfers them from the ingot-cranes to the soaking-pits. The latter are commanded also by a fourth crane, which transfers the prepared ingots to the blooming-mill. By thus placing the blooming-mill near the Bessemer plaint, and handling the ingots with the cranes only, a good deal of labor would be saved; and there would be no difficulty in getting the ingots from the soaking-pits hot enough to roll off straight into rails.

But, besides the saving of coal, labor, and cost of repairs to furnaces, there is another economy in the soaking-pits, viz., the saving of steel. The loss of steel by absolute waste in the heating-furnace varies very much in different works. In England and on the continent of Europe, the loss in first heating is seldom leas than 2 ½ per cent. in the ingot after it has left the blooming-rolls, and 1 ½ per cent. on the bloom in wash-heating after it has left the finishing-rolls.


F
F
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VERTICAL SECT

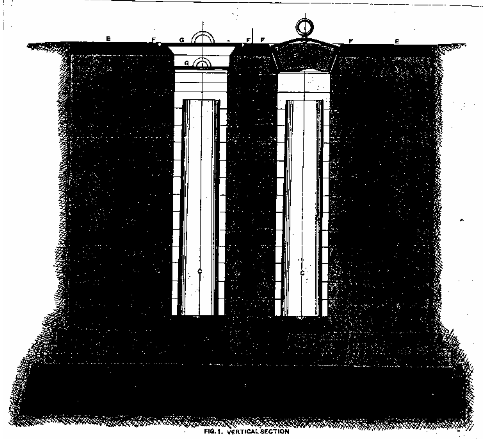


FIG. 1. VERTICAL SECTION

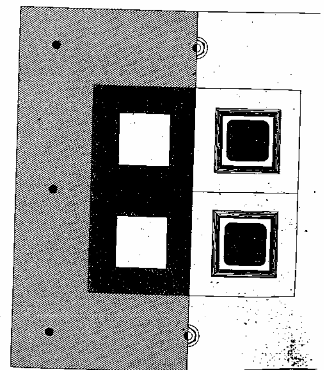


FIG. 2. HORIZONTAL SECTIONS

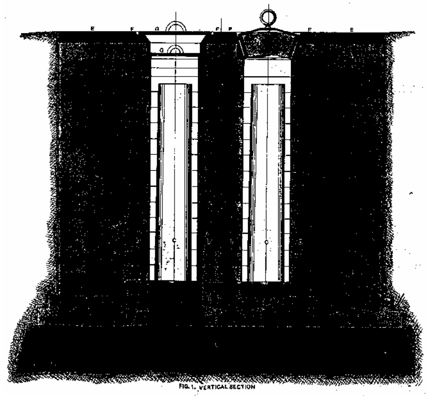


FIG. 1. VERTICAL SECTION

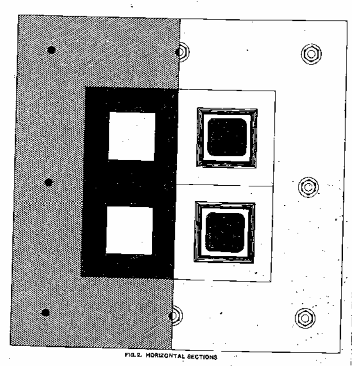


FIG. 2. HORIZONTAL SECTIONS

Numerous experiments have been made by actually weighing the ingot after it left the mould, and the bloom after it left the blooming-rolls; and it has been proved that the loss with the pits is ½ per cent., or a saving of about 2 per cent. in yield of blooms. This may not hold good in all cases in this country, where the ingots always are of large size; but the saving will be an important one. It arises from the fact that the ingot, when in the pit, is entirely excluded from free oxygen. Not only does the cover exclude the atmosphere, but during the soaking operation a considerable quantity of gas exudes from the steel and fills the pit, completely protecting the ingot. By analysis this gas has been shown to be composed entirely of hydrogen, nitrogen, and carbonic oxide, so that the ingot soaks in a perfectly non-oxidizing medium.

In cases where rails have been rolled off direct from the soaking-pit, the loss has been something less than 1 per cent., under favorable circumstances as low as ¾ per cent; while in England it has been shown that the loss in rolling off in one heat from the furnace is often 3 per cent., and never less than 2 ½ per cent.

The soaking pit process has long since passed the experimental stage, and is now in continuous operation in four Bessemer works in England, two of which roll off direct without any furnacing whatever. The system is just about being started at the largest open-hearth works in Scotland. It has also been in continuous work for some months at two large Bessemer works on the continent; and a third is just starting, as also an open-hearth plant. The author wishes to point out that smaller open-hearth works cannot make use of the process to the full extent of rolling or hammering direct from the pits, on account of the long space of time between their casts; but they may derive great advantage from allowing one cast of ingots to remain in pits well covered until the next cast follows, thus gaining ample time for the chemical and other tests.

Although the ingot, in such a case, may not come out hot enough to go into the rolls, still it will come out at a red heat; and a comparatively slight heating in a furnace, with corresponding smaller waste, will make it fit for rolling. This applies especially to hard steel.

To the Bessemer plants of this country the system is peculiarly adapted, on account of the fast and regular working which prevails. In starting new pits, the author prefers first to dry them thoroughly, and expel all steam from the brickwork by inserting moderately hot ingots. When the pits are dry the insertion of very hot ingots should begin, and be repeated, say, every half hour until the brickwork in the pits gets up to a red heat. After a few hours, the ingots will come out hot enough to roll. Until the pits get very hot, the ingots may not have to remain in them more than fifteen to twenty minutes; afterwards, when the pits get hotter, they will have to stay a longer time, depending upon the initial heat of the ingot.

RECENT IMPROVEMENTS IN COPPER-SMELTING.

BY FREDERICK H. MODOWELL, NEW YORK CITY.

NOTWITHSTANDING the rapidly increasing use of copper, due to the extension of its applications within the last few years, the fact of its continued steady decline in price stands prominently forward. Nor have we far to look for the cause. The opening up of the vast copper-deposits of our Western States and territories is the metallurgical event of the last five years.

We must not forget, in looking at the new field, the changed conditions under which the metallurgist must work, as compared with the previous history of copper-smelting. Until quite recently, the copper-plants of the country were few in number; and the concentration of industry implied in this circumstance, allowed many practices which must be considered as inapplicable to the conditions offered at the many mines which have of late become such important factors in our copper-production. Thus the old style of smelting the ore for matte in brick furnaces, involving great expense and time in their construction, while deservedly losing repute even in its old strongholds, in comparison with water-jacketed smelters, is still in some cases adhered to. But to put up such furnaces at Western mines would be out of the question. The large and continual need of brick for relining and repairs acts as an effectual bar, when such furnaces come into competition' with the light, portable, and easily managed water-jacketed smelters of improved types.

It is owing to the present unusual activity, manifested in the opening up of new copper-properties and the erection of plants for working them, that any improvement in furnace-construction is of especial interest and importance. The method in which processes are copied without variation in the rapid growth of metallurgical interests, has already been strikingly exemplified in the history of our gold and silver extraction-works; and it is desirable that, in what may be considered the inception of copper-smelting at the West, no false practice or unimproved plant should be allowed to "set the fashion " for succeeding usage.

It is in this spirit that we draw the attention of the Institute to an improvement in water-jacketed smelting-furnaees, which has not as yet been brought definitely before its notice.

This improvement, which we owe to Mr. J. B. F. Herreshoff, the superintendent of the works of Messrs. G. H. Nichols & Co., of New York, is the subject of a patent granted to him, and concerns what has long been a troublesome feature of furnaces with removable wells, namely, the cutting away by the molten slag of the connection between the furnace and the well. By a simple device this is here entirely obviated; and while, we believe, no claim is made of originality in connection with the rest of the furnace, still the selection of the details has been made with such care, and the results obtained have been so encouraging, that where so many works are in process of construction, and so many questions are showered on metallurgists as to the plant best fitted for the work in view, we think it best to describe the furnace as a whole, paying, however, special attention to the slag-connection, when we come to speak of it in its order.

The furnace described is known as a 100-ton smelter, and is of the pattern used during the last three years at the Laurel Hill Works of Messrs. Nichols & Co., for smelting the cinders resulting from the burning of low-grade copper-bearing iron pyrites. With such material, it has smelted as high as -17,000 pounds of charge per day, exclusive of coke, which latter bore the ratio of 1: 7 to the charge itself. In looking at such a figure, however, the adverse conditions, as regards ordinary copper-smelting, under which the run was made, must be remembered. Thus, the copper-smelting being subsidiary to the manufacture of sulphuric acid, for which the pyrites is used, no chance is afforded of mixing different qualities of copper-bearing materials together for the purpose of making a fusible slag, since but one kind of ore is used for making the acid. The only addition found practicable was the addition of sand, to supply the deficiency of silica in the ore. When it is remembered that the fusibility of polybasic silicates is much greater than that of ferrous silicate alone, the effect of being able to utilize a varied mixture of ore is at once apparent, as increasing the amount we are able to charge in a given time.

Another point of even greater influence in determining capacity is the mechanical condition of the cinder as used at the works. It is broken to small lumps (the size *of* an egg, for instance) in order thoroughly to burn out the sulphur in the kilns ; and, being exceedingly friable, by the time it is put in the furnace, after much handling, both in and out of the kilns, it is in much too fine a condition for the best results as regards rapidity of fusion, since by filling the spaces between the lumps, the fine material causes the blast to seek passages of least resistance and thus to be imperfectly utilized. We are therefore safe in saying that the run above cited can be exceeded under the more favorable conditions of ordinary smelting.

The drawings designed to accompany this paper are so clear as to details, that it has been thought best to allow them to explain themselves, while the leading features of the furnace are enumerated without much alphabetical or numerical reference to the plates.

The furnace proper consists of a double shell of boiler-plate steel, circular in section, and 10 feet in height; the iuner diameter of the shell at the base being 4 feet, while at the top the diameter is 5 feet and 6 inches. The water space between the shells is 2 inches. They are connected at the bottom by rivets passing through a ring of wrought iron, 4 inches in diameter and placed between them. The connection at the top is made by turning over the inner shell for about 4 inches, where it laps over a similar but not so deep turn of the outer shell. These are then riveted together.

The furnace-bottom is in the form of a very shallow basin of cast-iron, bolted on to the ring connecting the inner and outer shells of the water-jacket.

This water-jacket rests on columns 2 feet, 6 inches high, and is thus raised sufficiently from the floor to allow easy manipulation of the well, without placing anything below the level of the ground; while all danger due to overheating of the bottom-plate is overcome by the free radiation thus allowed from its surface.

The columns are four in number, and so spaced that they do not interfere with the removal of the well or its subsequent adjustment.

By a glance at the drawings, it will be seen that the columns are placed, not directly underneath the jacket, but with their inner margin touching the outer shell of the jacket, to which they are secured by strong irons, of the requisite angle for giving a broad bearing both on the head of the column and on the wall of the shell. By this means, the bottom is entirely removable. The center of the bottom-basin is thickened and flattened on the outside, to allow of a support which can at any time be removed. The air is supplied to the tuyeres by means of an air-box reaching around the furnace, except for about one-sixth of its circumference, where its jutting over the well would be inconvenient. This air-box is 20 inches high and 4 inches through, and receives its own air from a *No,* 5 Root's Positive Blower. The tuyeres are in reality water-jacketed ; since they are formed by a ring of 2 inches internal diameter, bolted between the shells of the jacket, and are not prolonged within the interior. The passage for air thus formed, communicates directly on the one hand with the interior of the furnace, and on the other with the air-box. Opposite each tuyere, in the outer wall of the air-box, is placed a removable cover, furnished with a glass for inspecting the interior of the furnace. When necessary, the cover can be taken off and a bar inserted in the opening. The interior diameter of the furnace at the tuyeres is 4 feet, 3 inches. A small opening, which can easily be made water-tight, is conveniently placed near the bottom of the outside shell, for the removal of sediment from bad waters. The feature of the furnace, however, is the ease with which an old well can be removed, repaired and run back, or if, as may be advisable, two wells are used, a new one can be immediately substituted for the old. The principle upon which this is done, consists in making the slag, which has been of great trouble in cutting out connections through its corrosive and mechanical action, itself form the connection between the well and the furnace. It can readily be seen that if the slag-hole in the furnace be made to correspond to the opening through which the slag flows into the well, and the well, which is placed on wheels, be run up so as to touch the furnace, the bulk of the slag will run into the well while a part will trickle down between the furnace-front and the back of the well. If this be solidified while trickling through, and can be kept cool enough to resist penetration by the molten slag continually flowing, it is evident that we have made a tight connection by means of the slag, which heretofore has been the great destroyer of connections between the furnace and removable wells. This cooling of the slag is effectually done by means of a water-jacketed back to the part of the well in the immediate vicinity of the slag-hole. The slag is thus brought into contact with two surfaces kept constantly cool, and any tendency to leak between the walls is prevented.

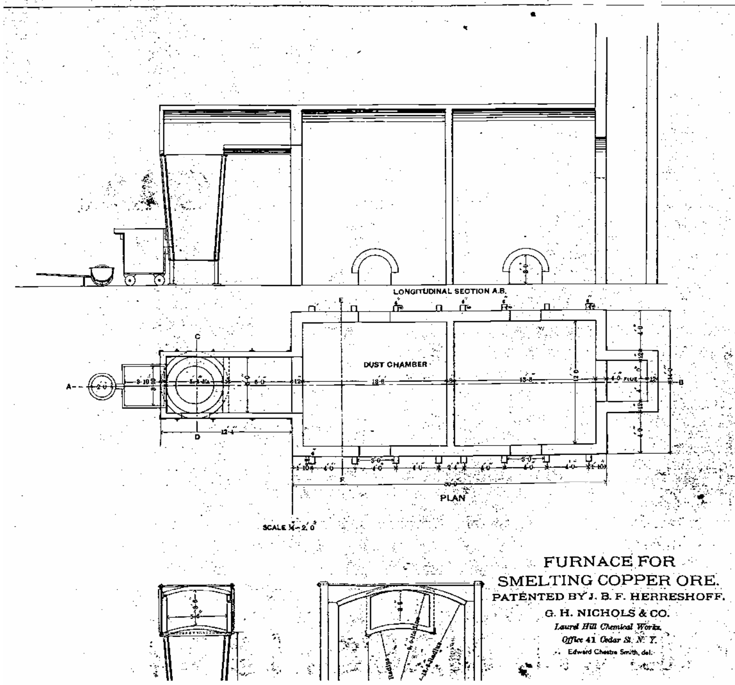
It is believed that the manner of using movable wells is tolerably familiar to the members of the Institute. If not, a look at the elevation of the furnace will sufficiently explain the mode. Apart from the preservation of the connection between the furnace and the well, the water-jacketed slag-inlet is the best preventive of the cutting-out and enlargement of the inlet itself.

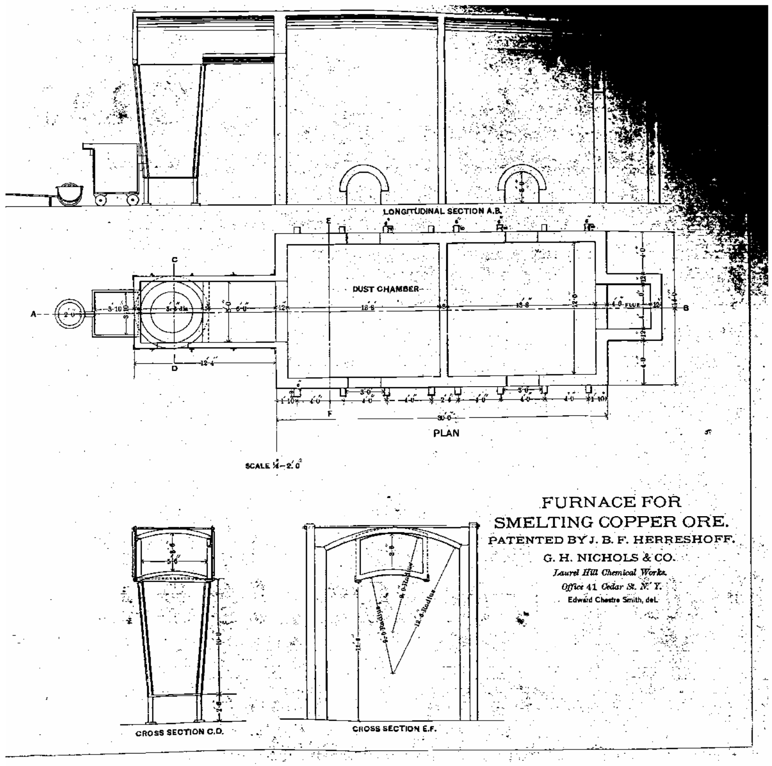
The lower front of the furnace, where the well comes into contact with it, is flattened to correspond with the back of the well, which is itself provided with a wedge-shaped iron, to make the small water-jacket parallel to the furnace-front, which, owing to its conical shape,-recedes towards the base of the shell. The well is of such height that the slag before flowing out rises above the inlet-hole in the well, and thus cuts off any fumes which might be blown out by the blast-pressure. The lip, over which the slag is constantly flowing, and which, formed at first from a mixture prepared to withstand its action, was rapidly worn away, is now made of iron with a small stream of water constantly flowing through. The arrangement gives no trouble, while the lip itself shows no wear after many months. The matte is tapped from the side of the well, when nearly filled, and allowed to run into a series of iron moulds.

The charging-door is situated just above the shell, where the flue, as shown in the drawing, bends over the furnace. For works where the ore can be charged free from dust, such a flue and dust-chambers can be dispensed with. They are necessary at the works of Messrs. Nichols & Co., for reasons given above. In case no flue is required, the furnace can be finished off by simply placing above the water-jacket a continuation of thin iron plate with a lining sufficiently thick to prevent the burning-out of the iron.

The furnace, as thus made, forms in our opinion a cheap, convenient and compact type of furnace for copper-smelting; while, as is apparent, its use is not restricted to that metal. Indeed, it is especially applicable to lead; and its use in that direction will probably be not behind its advantages as a copper-smelter for treating our western ores.

The old style of lead-furnace, with the pocket for the reception of the molten metal communicating directly with the hearth of the furnace, which is sunk far below the level of the tuyeres, is familiar to all. In such a furnace, the slag must be tapped intermittently, since no provision is made for trapping the blast in case the slag-opening be not closed. In any case of irregular working, with formation of deposits in the bed of the furnace, it is practically impossible to get at them without removal of the water-jacket above, since they are far below the level of the blast and cannot be fused out. Recognizing this, it has been the practice to make the water-jacket in sections or removable.


LONGITUDINAL SECTION A.B.
DUST CHAMBER
PLAN
SCALE ¼"–2'0"
FURNACE FOR
SMELTING COPPER ORE.
PATENTED BY J. B. F. HERRESHOFF.
G. H. NICHOLS & CO.
Laurel Hill Chemical Works.
Office 41 Cedar St. N. Y.
Edward Chestre Smith, del.


LONGITUDINAL SECTION A.B.
DUST CHAMBER
FLUE
PLAN
CROSS SECTION C.D.
CROSS SECTION E.F.
FURNACE FOR
SMELTING COPPER ORE.
PATENTED BY J. B. F. HERRESHOFF.
G. H. NICHOLS & CO.
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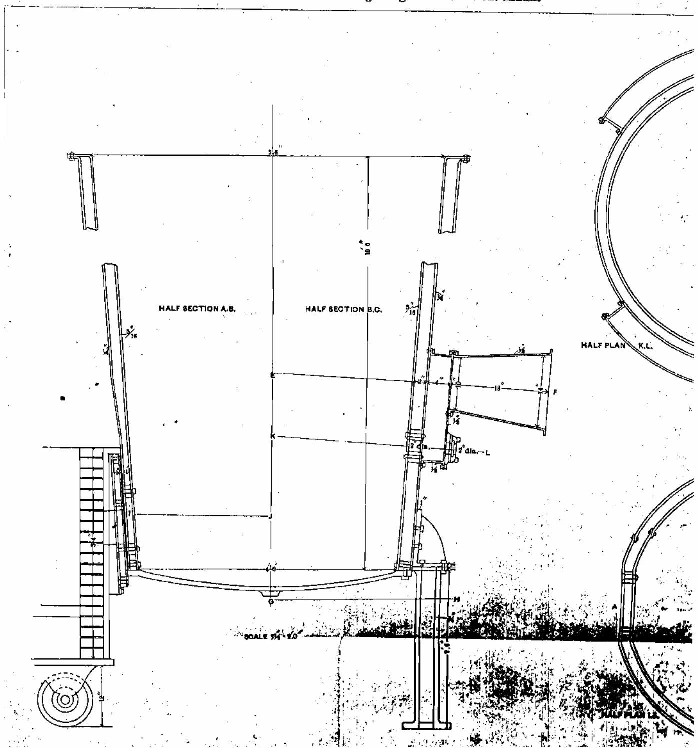
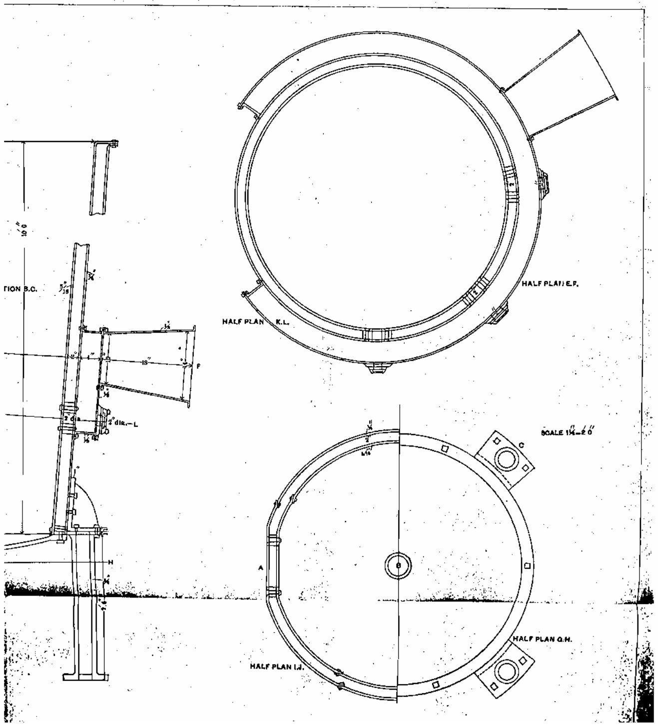

HALF SECTION A.B.
HALF SECTION B.C.
HALF PLAN K.L.
SCALE


TION B.C.
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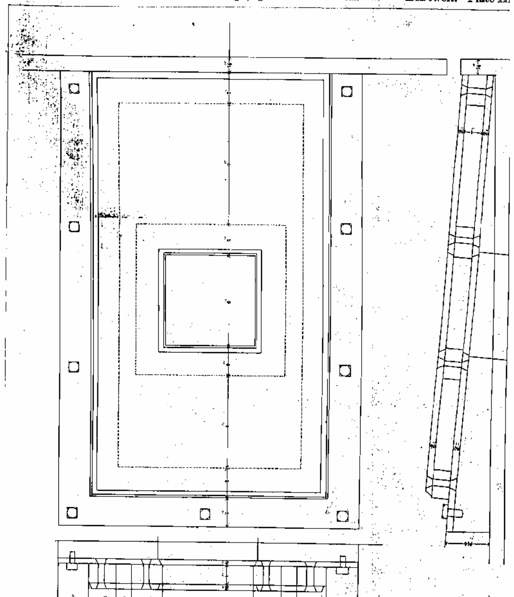
HALF PLAN G.H.
HALF PLAN I.J.



DETAIL OF WATER-JACKETED SLAG CONNECTION.

FURNACE FOR
SMELTING COPPER ORE.
PATENTED BY J. B. F. HERRESHOFF.

G. H. NICHOLS & CO.
Laurel Hill Chemical Works.
Office 41 Cedar St. N. Y.
Edward Chester Smith, del.

Such difficulties are, however, overcome by a modification of the furnace already described for copper-smelting. To use it as a lead-smelter, it is only necessary to make the water-jacket 5 feet, 6 inches in height, and continue the furnace above in brick, and also to provide the, pocket, fitting it to the side of the well, instead of directly to the furnace. The advantages of this arrangement are obvious. The flow of slag is constant, since the deleterious lead-fumes are stopped as soon as the slag-level reaehes above the slag-outlet of the furnace. The hearth of the furnace is but a small distance below the tuyeres, rendering easy the removal of any obstruction by using more fuel and blast. Such obstructions are, however, not so likely to occur as where the molten materials get below the zone of burning fuel.

The well in this case takes the place of the deep basin in the furnace ; and when any trouble occurs, the difference between changing a well which, with this furnace, is the work of a few minutes, and removing the water-jacket and then working out an obstruction sunk in a deep basin, can be appreciated.

These points may be considered of sufficient importance without enumerating minor advantages. As a combination-furnace, applicable to lead and copper-smelting, it seems to possess some advantages over any furnace designed for either purpose. I am indebted to Mr. J. B. F. Herreshoff, Superintendent, and to Mr. Lucius Pitkin, chemist of Messrs. G. H. Nichols & Co.'s Works, for opportunities to thoroughly investigate the subject of this paper, and I desire, in this connection, to thank them for their courtesy.

THE WOLF SAFETY-LAMP.

BY EUGENE B. WILSON, DRIFTON, PA.

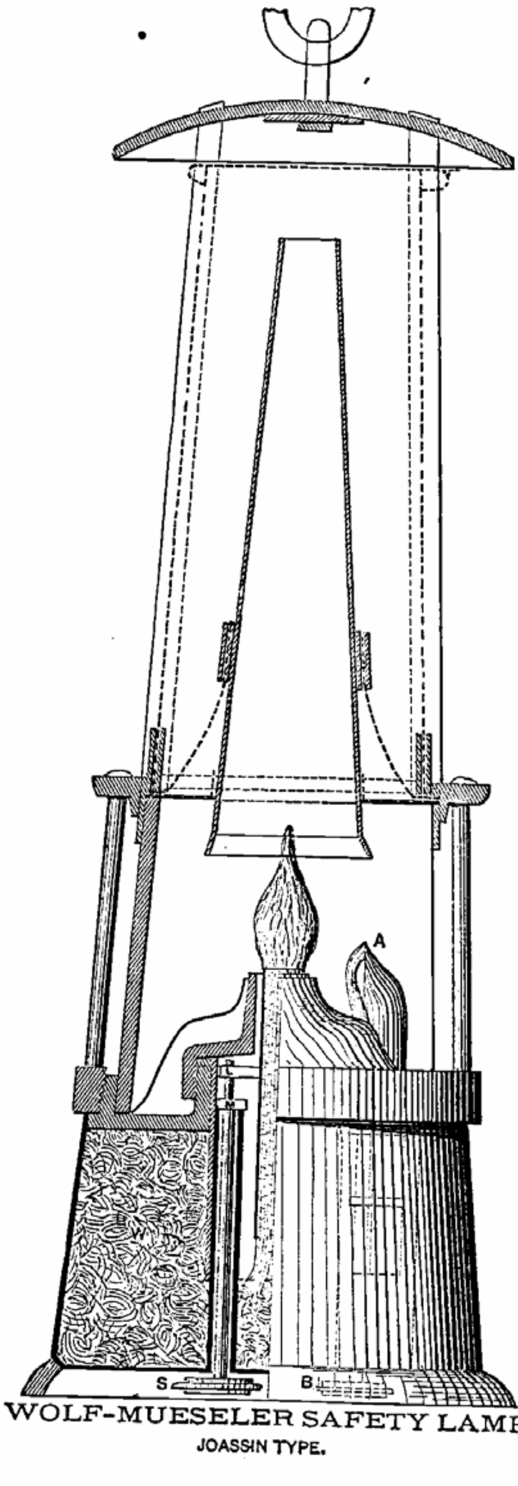
THE development of coal-mines has kept pace with the facilities at command for ventilating and lighting. In fact, it was formerly customary to leave unworked those mines, or portions of mines, in which naked lights could not be used without danger. Attention was then turned to the ventilation ; but even with improved ventilation, the naked light was often unsafe. The new era in coal-mining dates, we may say, as far back as 1815, when Sir H. Davy and Mr. George Stephenson discovered the principle of the safety-lamp. Since then many improvements have been added to their lamps, but until recently, none can be said to have given entire satisfaction; and even now the question of more light is being agitated.

The difficulties to be overcome by improvers were many. Attention was first directed to the locks, with the view of making them more secure, and of preventing the miners from picking them to light their pipes, or from relighting the lamps in the mines in case they had been extinguished—such a proceeding being, of course, highly perilous in fiery mines. The improvement of locks was not found, however, to be perfectly effectual, since the miner could, by the aid of his picker, raise the wick of the lamp to such a height as to draw the flame through the gauze and thus light his pipe. Legislation then made the act of smoking in fiery mines a criminal offense; but even this did not put an entire stop to it, nor could it be guarded against, since the pickers were indispensable in order to raise and trim the wicks. On the other hand, could all the miners have been convinced that in drawing the flame through the gauze, they put in jeopardy their own as well as the lives of others in the colliery, and thus persuaded to cease from the practice voluntarily, still the danger would not be entirely removed ; for we have it from no less an authority than Mr. Darlington, that sparks may fly off from the lamp when the picker is used, and that one spark would be sufficient to cause an explosion.

The next attempt was to invent a lamp which would not pass the flame through the gauze when moved rapidly. The Boty lamp, on being immersed in an atmosphere highly charged with fire-damp, becomes extinguished. But the miner thus finds himself in an unenviable position, since he cannot relight his lamp, and must, consequently, remain in the dark or grope his way back to the fire-boss to have his light unlocked and relighted—a dangerous undertaking at best.

What was needed was a lamp, the lock of which could not be tampered with; the wick of which could not be raised ; one which did not require a picker, and could be extinguished or lighted at pleasure without opening.

Such a lamp is the invention of Mr. Wolf, of Zwickau, Saxony. A friend of the writer brought one of them from Germany last fall, and it has been greatly admired for its simplicity, efficiency and safety. The accompanying drawing shows Wolf's improvement as attached to the Mueseler lamp, which was considered by the Belgium Commission of 1868 to be the best, and the use of which was again made obligatory by a royal decree in Belgium in 1876, as it had been



WOLF-MUESELER SAFETY LAMP,
JOASSIN TYPE.

also in 1864, before the Commission reëxamined the question. The Mueseler lamp is, like the Clanny, a modification of the Davy in which a glass cylinder is interposed between the wire-gauze cylinder and the body of the lamp, so that the light of the flame is not diminished by the wire. The Mueseler lamp has, however, also a sheet-iron chimney inside the gauze, which is said to cause the light to be extinguished when placed in a strong draft or an oblique position. The Mueseler lamp burns vegetable oil. The Wolf lamp, on the other hand, burns benzine, which is less expensive, gives a brighter and more uniform light, and does not deposit soot. The consequence is, that a much finer wire-gauze can be used, with great increase in safety; and the miner does not need to pick his flame or clean his lamp during the shift, the wick being made of mineral wool. The opening of the lamp is prevented by a lock which is operated by a magnet; and as it is not necessary to open the lamp to relight it, all legitimate occasion for doing so in the mine is removed.

The body of the lamp, W, which contains the benzine, is packed with mineral wool, to prevent spilling. Thus held, the benzine is itself no source of danger. The flame may be made larger or smaller, to a limited and not dangerous extent, by the screw S, working in the collar M. The arrangement for lighting is not clearly shown in the drawing. It is similar to that which is so commonly sold by tobacconists for lighting cigars, consisting of a tape, carrying at intervals small percussion-wafers. The dotted lines between A and B indicate, in a general way, the position in the lamp of this arrangement. The button B operates both the feed of the tape upward (bringing a fresh percussion-cap to the point of ignition A) and, by means of a spring not shown, the tripping of the lever which explodes the cap. This lever is shown in the drawing in contact with the tape-holder at A, as it would be just after the explosion of the cap.

In the latest edition of Serlo's *Leitfaden zur Bergbaukunde* (Berlin, 1884), vol. ii., p. 453, the above-mentioned advantages of the Wolf lamp are enumerated (but no drawing is given); and it is added that the lamp is said to go out when dangerous proportions of fire-damp are present, and also to burn in "bad air," long after oil-lamps have gone out It certainly seems to the writer to be the nearest approach to a perfect safety-lamp which we have at present. There is, of course, yet room for invention. We want more light, and better instrumental means of warning when fire-damp is present.

THE CAUCA MINING DISTRICT, U. S. OF COLOMBIA, S. A.

BY JOHN HAYS HAMMOND, NEW YORK CITY.

THE following notes are descriptive of a country as yet in its infancy as regards the advancement made in mining operations. Its inaccessibility and other militating circumstances have retarded progress in that direction. With the completion of the railroad, how under construction, having the city of Cali as its objective point, with the concomitant civilizing and developing consequences, it is certain that the slopes of the Cordilleras will prove to be a South American Eldorado. Deposits of coal, copper, and minerals other than those of the precious metals are known to exist in quantities which, under more favorable conditions of accessibility, etc., could be profitably mined. The Government of the United States of Colombia, I think, is disposed to encourage and foster mining enterprises. Articles designed for mining are admitted free of duty; the permanency of the government is, at least, as well assured as that of Mexico (which is not noted for its immutability), and a more sincerely friendly sentiment towards Americans prevails in the United States of Colombia than in Mexico. This paper is confined to a description of the property of the Cauca company's mines, and is intended rather as a preliminary notice than as an exhaustive report. The Cauca mining district is reached by the following route: New York to Aspinwall; to Panama; to Buenaventura, a port on the west coast of the United States of Colombia, distant thirty-six hours from Panama by steamer; to Cali in the State of Cauca. The State of Cauca is bounded on the north by the Atlantic Ocean, on the northwest by the State of Panama, on the northeast by the States of Bolivar and Antioquia, on the east by Brazil and Venzuela, on the south by the Republic of Ecuador, and on the west by the Pacific Ocean. It has a territory of 41,443 square miles, which is about one-tenth of the entire territory of the United States of Colombia. Its population, including the 50,000 savage Indians of the Caquetá (some of whom are cannibals), is nearly 450,000 souls, or about one-sixth of the population of the Colombian republic. Of these, one-fifth are whites (Spanish South Americans), two-fifths mixed, two-fifths negroes and Indians. The climate of the country varies in its different parts. Along the coast are fevers of the most malignant types, but the interior and more elevated portions are exceptionally healthful. There are two dry and two wet seasons, alternating, designated respectively *verano* and *vierno.* To the dry season or *verano,* belong the months of January, February, March, July, August, and September, while the other months are included in the *vierno* or the wet season.

Cali is a city of some 13,000 inhabitants, situated in the beautiful, fertile, and salubrious valley of the Canca, a valley included between the western and middle ranges of the Cordilleras of the Andes. It is about 70 miles distant in a southeasterly direction from the port of Buenaventura, and at an altitude of 3400 feet above the sea-level. The city of Cali is reached by means of a railroad to its present terminus, Cordova, twelve miles from Buenaventura, and from there by an excellent horseback-road to the foot of the Western Cordilleras, whence a good but somewhat steep road, crossing the mountains at an altitude of 6000 feet, leads to Cali. The mines of the Cauca Mining Company are embraced in a large tract of land, covering some 400 square miles, and situated about 40 miles to the south of Cali. The situation of the company's mining property is in many respects most favorable. The climate in that section is one of rare salubrity; the heat Hue to the close proximity—about two degrees north latitude-—-to the equator, is tempered by the high altitude of some 4500 to 5000 feet above sea-level. Water and fuel are everywhere abundant; provisions are plentiful and cheap; and labor, though at present somewhat scarce, could, in the event of the inauguration of mining, be obtained from neighboring districts. Experienced Spanish-American miners from the adjoining mining States of Antioqua and Tolima, at from one to two dollars per day, with negroes, or preferably Indians, for from 50 to 75 cents per day, could make up the complement of mining laborers, were an enterprise to be initiated upon this property.

At present mining is carried on in a most primitive manner. Negro women are the miners of the country; their implements of mining are restricted to the crowbar and the *almocqfré.* The *almocafré* is the vade-mecum of the prospectors of the Cauca country. It is to them what the pick and shovel are to the prospectors of our country. This tool is a blade of steel from 8 to 20 inches in length and from 4 to 8 inches wide. The blade is bent and the end pointed, somewhat resembling in form a pruning-knife. It has a handle about a foot long. Picks, shovels, and powder are almost entirely unknown. *Parahuelas* of the Mexican pattern take the place of wheelbarrows. The *batea* replaces the miner's pan of our own country, and, in fact, is the only method known to the people for extracting gold. Mercury is rarely used.

With reference to its geographical position, the property may be divided into the "Ensalvado" and the "Cauca" mines.

ENSALVADO MINING PROPERTY.

The Ensalvado property, lying to the west of the River Cauca, consists of two classes of mining property, different with respect to their geological character. To the first class belong the auriferous quartz-veins, having an approximately parallel easterly and westerly trend through the granite, which almost invariably constitutes the country-rock of this district. The developments upon these veins, consisting of but a few feet of shafts or tunnels, are too small to permit any predication as to the persistency of the gold-tenor of the ore in its distribution along the strike and dip of the veins. That the fissures are "permanent," or that the veins are what are generally designated " true fissure-veins," is well evidenced by abundant indications, characteristic of that class of deposits. But it must be observed that the continuity of the fissures is not to be confounded with the continuity of the gold-tenor. The latter can only be ascertained by actual explorations on the veins, especially in a mineral district of undetermined character in this regard.

Attending the working of the veins are many economical advantages. Water and wood are everywhere abundant; the topographical features of the country admit in many places the exploitation of the mines by means of tunnels, whereby is obviated the erection or maintenance of an expensive plant for the extraction of the ore; and whereby also, water under high pressure may be utilized for mill-power, effecting a saving in the cost of milling-plant and in the subsequent treatment of the ore. Unfortunately, the veins are narrow, and the extraction of the ore would, in most instances, necessitate the removal of a large volume of the inclosing non-metalliferous granite country-rock. This rock, though more or less soft near the surface, owing to the superficial decomposition, will be found compact and hard when but little depth shall have been attained; and the expense incurred in its removal must needs be very considerable. The ore of the veins consists of a quartz gangue, carrying free gold and chiefly auriferous iron and arsenical pyrites. In some of the veins the ore is much decomposed, while in others the matrix is hard and the ore but little altered.

The following description of the Mamindomingo and Felipe veins, extracted from my report to the Cauca Mining Company, will suffice as a description of the character of the ore of the veins of the Ensalvado property. The Mamindomingo vein lies about a third of a mile to the east of the company's house. The vein has an easterly and westerly course, namely, bearing eight degrees only south of west—and a dip to the south. The fissure is well defined, and is 5 feet in width from wall to wall. The central portion of the fissure is filled by "horse" matter (*caballo),* while nearer the foot-wall and hanging-wall occur lenticular bunches of ore. A tunnel running upon the vein a distance of 24 feet is the extent of developments upon this vein, as, indeed, it is the most expensive work as yet made upon any of the veins. The aggregate width of the bunches of ore (assaying about §25 gold per ton) is 18 to 24 inches, chiefly auriferous arsenical pyrites, iron pyrites, occasionally copper pyrites, and some free gold. There is but very little gangue in the ore; the auriferous mineral portions being in a highly concentrated state. Were the ore susceptible of any considerable further artificial concentration,—with its present gold-tenor,—the vein would have a very different aspect as regards its prospective value. This ore cannot be beneficiated by free milling, but must be treated in part by the so-called chlorination process. This process involves the preliminary roasting of the ore and its subsequent treatment by chlorine gas—expensive operations where salt and other chemicals employed have to be transported any great distance. The vein may be worthy of more extensive explorations, such as the continuance of the present tunnel some 50 feet further (and more if the vein improve), and the sinking of two or three winzes, at points along the tunnel, to a depth of from 20 to 100 feet, depending upon the character assumed by the vein as work progresses.

The Felipé vein lies about a hundred yards to the west of the company's house, and is probably a continuation of the Mamindomingo vein above described ; the vein has an easterly and westerly strike or course, and is exposed by a small shaft about 10 feet deep. The vein in the shaft varies from 7 to 13 inches, all of which is mineralized quartz. Assays show §33.91 in gold per ton.

A large part of the gold-tenor of this ore is contained in the auriferous sulphurets. This ore is susceptible of considerable further concentration; and in the event of the favorable development of the vein justifying the erection of a milling-plant for the treatment of this ore, such portion of the gold as is free could be obtained by amalgamation, while the sulphurets containing the other portion of the gold could be concentrated, and the concentrates beneficiated by Plattner's chlorination process above referred to. Where the determining-conditions make smelting possible, this process may be more economical than is the chlorination process. The scarcity of lead, as far as my observations extended, would, under the existing conditions, make the smelting of these concentrates impracticable.

The *Lomas* belong to the second geological division of the Ensol-vado gold deposits. The genesis of this class of deposits is one not less of economical importance than of scientific interest. In a few parts of California I have examined deposits of this character, though of a very limited extent as compared with those of the En-solvado property. These *Lomas* show evidences of past great activity in mining, many hundred of acres having been washed away during the years prior to the emancipation of the negro slaves. Ditches in some instances many miles in length were made by the "ancients" —the old Spaniards and their descendants—to convey water to the different points for the washing (not hydraulicking in the present comprehension of the term) of the auriferous material. This fact, coupled with the extensive excavations made, has been adduced as a proof of the feasibility of the application of the hydraulic process for the working of these deposits.

This is an opinion widely entertained throughout that section ; but the fallacy of this argument may be shown by a consideration of the economical conditions prevalent at the time this work was accom-plished. Under the regime of the ancients it was customary to compel the slaves to devote five days per week in mining for the benefit of their masters, and one day to obtain gold to pay for their own maintenance. In this way labor was obtained almost absolutely gratis. And as this was the sole item of expense incurred, the fact that this system of working did pay the slave owners, is no criterion of the profitable character of an enterprise conducted upon a system rendered far more expensive by the changed conditions now existing between the employer and employed.

The consideration of the geological features of the *Lomas* will facilitate the comprehension of the economical aspects of the subject. Traversing the granite formation in a general easterly and westerly direction are numerous *hilos* or small veins of gold-bearing quartz.

Owing to the energetic action of atmospheric agencies there has not only been a decomposition of the gangue of the veins but a liberation, through a well-known chemical reaction, of the gold from its mineral combinations. Along the outeroppings of these decomposed veins (called *veneros)* rich prospects are often found ; and from these points, and in close proximity thereto, by far the greater portion of the gold-bearing product has been derived. The same process of decomposition has effected the disaggregation of the country-rock. Along the planes of jointing and other crevices in the weathered granite, gold is sometimes found in considerable quantities. This gold has been unquestionably derived from the neighboring gold-veins, and has been transported from this source by means of water. Nothing of the nature of fluviatile deposition was anywhere discernible, as far as my investigation extended. On the contrary, unequivocal evidence of the origin of the formation, as above indicated, was observed. Obviously the hydraulic process would not be applicable to such points as these. The gold is almost entirely limited in its distribution, economically considered, at least, to points not many feet remote from the decomposed veins. The veins are not numerous enough along any possible line of attack of the deposits, nor are they decomposed to sufficient depth, to admit of the profitable hydraulicking of the hills in their entirety. Below the zone of decomposition in the veins, the quartz is too compact to permit the use of this process. Likewise, where the process of weathering has not been penetrated, the granite will, of course, be found hard and compact. I have made many careful tests by means of the well-known California cradle (one of which I constructed for that purpose), and also by the pan and *batea*. The resulting gold from each separate experiment was cleaned and weighed, and the yield per cubic yard was estimated. The yield of the *Lomas* examined by me was from a small part of a cent to 6 and 8 cents per cubic yard, depending upon the points from which samples were selected as above explained. Knowing the *raison d'etre* of the rich spots, it was not difficult to predict with considerable accuracy the result of the tests. There are some advantageous circumstances that would attend the hydraulicking of these deposits, where other conditions allow of its working. Water could be brought under sufficient pressure for hydraulicking by the construction of a few miles of ditches. There is abundant dump for the piping-off of the tailings; and the question, how to dispose of the debris, so perplexing at our California hydraulic mines, would never, or not for many years at least, affect the prosecution of the enterprise here. The *Lamas* cover many square miles (some 250 or more), and there may be some points where there exists a more favorable occurrence of the gold, which, combined with the advantageous considerations just referred to, would admit of the successful prosecution of the hydraulic industry, perhaps in an appropriately modified form. As far as my observations extended, such a site was not encountered.

The Cauca River Mines

belong to the second geographical division of the mining property considered in this report. These mines lie immediately in and along the banks of the Cauca River. Much gold has been obtained and is still extracted from this source. The deposits in question belong to the *Playas,* or alluvion deposits of the River Cauca. These are the results of the deposition by the River Cauca during a period when it assumed larger proportions than at present. The *Playas* are contiguous to the present channel of the Cauca. The deposits are obscured to a great extent by vegetation, and as yet are opened up for inspection at but a few points. There are many square miles of these auriferous alluvions, but owing to the very limited period of my visit to this property, I made an examination of but one point, which was represented to have yielded a large quantity of gold when worked in former years. The inundation of the excavations prevented the further working of these deposits. With the cradle I tested considerable quantities of gravel from different points about the old pits. My tests showed the top-gravel to carry from 10 to 50 cents per cubic yard. These rasults were obtained from points several feet above the bed-rock. Unfortunately the bottom of the pit was covered by water, which prevented the sampling of points nearer the bed-rock. Careful sampling and tests made by Messrs. Rahmer and Masse, who carried on the work after my departure, gave much better results than those obtained by me as above indicated. They were enabled to obtain samples within a few feet of the bed-rock. The gravel from the depth reached by them gave from four to ten dollars per cubic yard, showing very great richness at that level. I have no doubt as to the accuracy of these results; but their sampling was unfortunately necessarily confined to a very limited area. The great disadvantages accompanying the working of these deposits are their flat character and the inferior position of the bed-rock with reference to the water level of the Cauca River. This unfavorable location necessitates the draining of the pits or excavations by means of pumps, and also requires considerable manual labor in the extraction and washing of the auriferous gravel; but there is very little superincumbent material that would not defray a considerable portion of the expense incurred in its removal; and this is a feature of considerable economical importance.

Notwithstanding these disadvantages, if the above experiments made by Messrs. Rahmer and Masse for the determination of the gold-tenor of the gravel are not misleading, these *Playas* are certainly worthy of a thorough exploration. The bed-rock has never been explored; and it is from points immediately overlying the bed-rock that the best yield of the gravel is to be anticipated.

NOTE ON PATCHING PLATINUM CRUCIBLES.

BY H. J. SEAMAN, CATASAUQUA, PA.

THE cost of keeping platinum ware in repair becomes such an important item in laboratories where much fusion-work is done, that a method of saving in this direction may not prove unacceptable to at least some of the members of the Institute.

Some two years since I had the misfortune to puncture an almost new Bishop crucible. As an experiment I endeavored to patch it, and with such success that it is still in constant use.

This may be accomplished in the following manner : The crucible and patch, which should be of stout foil, are rubbed bright with silica, or rotten-stone; a light platinum wire, welded to a corner of the patch, and the whole treated for several hours with hot concentrated hydrochloric acid; after which they are thoroughly washed with distilled water and dried.

The head of an ordinary iron rivet, 4 inches by 5/8 inches, is rounded off by hammering to somewhat the shape of the crucible. This is sunk 2 inches in a block of hard wood, and firmly wedged in place. This serves for an anvil. The hammer is an ordinary cast-iron toy, 1 ½ inches long, and 3/8 inches in face, mounted on a 1/4 inch iron rod, 10 inches long.

A gas-blowpipe is fixed in a horizontal position, and the strongest heat obtainable with it directed upon the rivet head; this soon attains a bright-red heat, and the crucible is now dropped over it. The patch, by means of the thin platinum wire, is now held over the point of operation ; a few taps of the hammer serve to fix it to the crucible. The wire is now nipped off, and the patch firmly united to the crucible by continued tapping with the hammer, steadying the crucible with a platinum spatula or wire. The metal should be maintained at as nearly a white heat as possible throughout the operation. With care the metal may be so perfectly united as scarcely to show the outline of the patch. After the operation the crucible will be found very much out of shape, but it may easily be brought, back by tapping with a hammer over the rounded horn of a small anvil.

I am at present using three patched crucibles; one, previously mentioned, has been in use about two years; has served for at least two hundred fusions since patching, and is still in good order. Another, which developed an extensive crack in the bottom, was repaired by a circular patch a trifle smaller than the bottom. The third has a patch on the side near the bottom. These have all done good work.

I am in the habit also of welding my platinum triangles, thereby making them light, strong, and durable.

DISCUSSION OF MR. P. G. SALOM'S PAPER ON "PHYSICAL AND CHEMICAL TESTS OF STEEL FOB BOILER AND SHIP-PLATE FOR THE UNITED STATES GOVERNMENT CRUISERS,"

(Paper read at the Cincinnati Meeting, February, 1884. See vol. xii.)

WILLIAM KENT, New York City: I regret that I have not had the time since the Cincinnati meeting to make as complete a study of Mr. Salom's paper as I wished. I regard it as one of the most important papers that have been presented on this subject, and worthy of complete study. I started out, on the limited time I had, on a system of study which I would recommend to any one else who has leisure to complete the investigation. I took the original report presented at the Cincinnati meeting, and selected from it such tests as had the analyses reported along with the physical tests, giving the amounts of carbon, phosphorus, manganese, etc., taking only those in which all these elements are given..

Whenever there were two or three of these tests, I took the average of them. I. thus made a new table, from which I attempted to learn the influence of carbon, phosphorus, silicon, and manganese. I have failed so far to learn the influence of either of these elements, with the exception of carbon.

A new table was formed, in which these steels are divided into several classes, based on the percentages of carbon from .10 to .20, and for each class the maximum and minimum tensile strength and the average tensile strength was shown. The variation between the maximum and minimum is greatest at .20 carbon, where it is 14,000 lbs. tensile strength per square inch on the same carbon, one steel having 59,000 lbs., the other 73,000 Ibs. There is a large variation also at .15 carbon, nearly 12,000 Ibs. The following is the table thus prepared from Mr. Salom's data :

Tensile Strength, Pounds per Square Inch.					
Carbon.	No. of Tests.	Highest.	Lowest.	Average.	Average by Plotting.
.10	1			53,010	53,000
.11	3	56,400	52,185	54,495	55,200
.12	4	58,850	56,550	57,558	57,000
.13	13	60,600	52,750	57,988	58,600
.14	16	66,150	55,590	60,410	60,000
.15	23	68,200	56,605	61,647	61,300
.16	19	66,300	57,750	61,726	62,400
.17	11	66,200	57,875	62,572	63,600
.18	3	65,950	60,495	63,732	64,700
.19	6	71,700	62,500	66,826	65,700
.20	3	73,300	59,015	66,588	66,600

The figures in the last column are obtained by plotting those in the fifth column, and drawing a regular curve through their positions as plotted. They may be considered as the most probable average tensile strengths of boiler-plate steels of .10 to .20 carbon when tested in eight-inch parallel specimens.

Referring to these figures, it will be seen that there is a gradual increase of tensile strength with increase of carbon. This, of course, is nothing new; it has long been known.

When we come to study the effect of manganese and phosphorus, the figures would lead to the same conclusion as that reached by Mr. Salom, viz.: that the strength does not seem to greatly depend on the percentage of phosphorus and manganese within the limits of the analyses of the paper, although, of course, it would if these limits were widened. In order to study the effect of these other elements, I took a sheet of cross-section paper and plotted the results ; but, from a study of the plotted figures, I have not been able, so far, to find out what relation phosphorus, silicon, and manganese have to tensile strength.

Mr. Salom expresses his opinion on page 665, that "phosphorus is not the terrible *bête noir* it has been considered; it has had to bear the burden of many sins wrongfully ascribed to it." I would hesitate to take this strong position in regard to phosphorus, in view of the general consent of those who have investigated its effects during the last twenty years, that phosphorus *is* the *bête noir* of steel. While employed a few years ago in the steel-business, my duty was to learn all I could about steel. While, in tests with the testing-machine, some of the figures I got would lead to the same conclusion as Mr. Salom's, that phosphorus is not bad, others showed the contrary; and we never would sell a piece of steel as locomotive fire-box steel if it contained more than .04 of 1 per cent. of phosphorus, while some of his contains .075. And the reason we came, to that conclusion was this: that, getting all the information we could from railroads and other consumers who used steel in locomotive fire-boxes, we found that one or two brands, which had the preference from the fact that they lasted longer in such service,—not being apt to crack while being riveted, or while the boiler was cooling in the round-house,—were invariably found to be low in phosphorus; also, that the steels which had a bad reputation were high in phosphorus. And I consider that the final and crucial test of steel is actual service, and there *is* no more severe service than in locomotive fire-boxes. ' The ordinary tests, chemical, physical, testing by a blacksmith or on a machine,—tests of a few minutes,—fail to tell us all that there is in the steel. The final test is putting that steel in a locomotive fire-box, and running it over a long period of years, as the Pennsylvania Railroad Company has done (fifteen or twenty).

As far as I can learn, the reason of a great, many bad reports concerning steel, especially reports from Europe, where the German locomotive engineers abandoned the use of steel on account of its unreliability, was that the steel was irregular, and that was due chiefly to its being too variable in phosphorus. As far as I have yet been able to find, phosphorus is a very injurious element in steel and should be kept down. This is very important commercially to the steel-manufacturers, because the lower they make the phosphorus in the steel the more expensive it is. It is to their interest, in view of the first cost of manufacture, not to try to get the phosphorus too low. But the experience of the best firms has been that it paid to get the phosphorus as low as possible, and then charge a higher price for the steel, and get a reputation for general satisfaction given by the steel in use.

Mr. Salom says also: "The average amount of carbon is .15, which I regard as being from .03 to .05 too high for the best boiler-plate." My own experience is different. I prefer .15 to .18 carbon, provided it is low in phosphorus, very low,—.04 per cent or less,—so that its tensile strength and ductility would be about the same as .10 carbon with about .08 phosphorus. This is to be preferred on account of facility of manufacture. When you are trying to make .10 carbon steel, you run the risk of making a considerable proportion of .07 carbon, which frequently causes trouble on account of red-shortness and a great deal of waste; but if you make .18 or .15 your percentage, you may vary from .15 down to .12, and yet all the steel can go into service somewhere, and none of it need be red-short.

I recently had occasion to make the specifications for a large contract for steel boiler-plate. It was to go into a service which was not as severe as that of locomotive fire-boxes, and in which a second quality of steel would answer. I specified that it should not have over .08 per cent, phosphorus, and should have between 55,000 and 65,000 lbs. tensile strength and 20 per cent, elongation in 8 inches. I considered the 25 per cent, elongation of the government specifications rather too severe, causing the rejection of good steel, and I believe that 20 per cent, is all that is necessary. I also specified that the steel should stand a bending test both before and after being plunged in water.

There is perhaps one reason why I have not been able to deduce from Mr. Salom's tests the real effect of phosphorus, silicon, and manganese, and that is because the pieces of steel were not annealed. Of course, in practice and commerce we do not want the steel annealed. It should be ready to go into boiler-plate as it conies from the rolls, but for scientific investigation it would have been well to bring all these steels to a uniform condition. The steels as rolled are not in a uniform condition. Some are finished hotter than others. It is possible easily with a given piece of steel to make a difference of 10,000 lbs. tensile strength by a little delay during rolling, which prevents the steel being finished quite as hot in one case as another. I would suggest that in future investigations of the influence of carbon, silicon, phosphorus, and manganese upon the physical qualities of boiler-plate and other steels, duplicates of all the test-specimens be brought as nearly as possible to the same physical condition by uniform annealing.

ALBERT F. HILL, New York City: There is one point in Mr. Salom's paper to which I want to call the attention of the Institute, and it is a point which is very important to a large number of our members. It is the fact that "The original specifications, as regards the *manner* of testing, were so impracticable (when their severity was taken into consideration)," that . . . " in order to simplify and expedite the amount of testing that had to be done, the Naval Advisory Board was induced, after considerable discussion, to alter the specifications, so as to test each heat, instead of each lot of twenty plates," etc. Now this is a very serious matter. The specifications form the basis upon which the steel-manufacturer makes his bid. To make later specifications after the letting, and for the benefit of the contractor, is a manifest injustice. It is unjust to the bidders who are not successful. It is unjust to those who stayed away from the competition on account of the immense expense involved in the testing.

There is at this time a committee of this Institute engaged in devising means to unite the different engineering societies upon uniform standards of test-pieces. I have no idea of foreshadowing the work of that committee (in fact I have no means of doing so); but I believe that it will ultimately result in establishing standard specifications for the mode of testing. It is a well-known fact that government specifications especially are not only unnecessarily and unreasonably severe, but that they are unreasonably enforced. Any steel-manufacturer who has had occasion to fill government contracts well knows that the inspection is not only unreasonably and unnecessarily severe, but that it results, in nine cases out of ten, in the government getting worse steel than the maker would have dared to offer, and in the rejection of material that it would have been advantageous to accept, in many cases. For instance, in a bridge-works not a hundred miles from Pittsburgh, some government work was to be inspected, and the inspector that was sent there was absolutely the laughing-stock of the whole mill; nevertheless he did the inspection and occasioned about an equal amount of damage to the makers and to the government. [Laughter.]

I do not know any way out of this except by uniting upon a standard mode of testing. It is impossible to unite upon a standard form of test-piece that shall cover all the requirements of the constructing engineer. But it is not impossible to prescribe a mode of testing which shall give a very fair indication of the material which has been furnished to the constructing engineer.

I have been very strongly impressed with some of the apparent anomalies in the results of the tests in this paper. Mr. Salom has endeavored to explain them entirely upon the basis of the chemical composition of the steel. I think that not sufficient attention was paid in the paper or in the investigation of the steel to the changes that may have resulted from the treatment the steel received after it left the casting-department, namely, in the mill and in the shop. I am satisfied that chemical changes take effect in the rolling and in the heating; and in order to decide whether the change was entirely due to the original composition of the steel or to the treatment of the steel subsequent to its being cast in the ingot, it would have been necessary to make a further analysis of the finished plates. And that brings me to the last point in Mr. Salom's paper, in which he expresses the hope that the chemical test will ultimately supersede entirely the physical test. I hope the day is very far distant when the constructing engineer will be bold enough to accept material on the indorsement of the chemist. I think it would be very unfortunate. I do not think that the chemical analysis of a piece of steel will give either to the constructor or to the general public the confidence in the quality of the materialin its physical qualitiesthat the physical test will give. A statement of the amount of creatine contained in a beefsteak may be correct and a proper amount; but if the steak is *tough,* to know the exact amount of creatine it contains is no satisfaction. [Laughter.] On the other hand, if too much weight is given to the chemical composition, it will induce the constructing engineer to prescribe formulæ for the steel-maker. Now, I admit that the constructing engineer has got a perfect right to say what he wants; but it is the prerogative of the manufacturer to say how he will make it. The manufacturer ought not to be influenced by any formula that is contained in the specifications. It is not fair. The engineer has no right to say " you must make steel by a certain formula, and then it must have certain physical qualities ;" because this is impossible. The constructing engineer has nothing to do with the chemical composition. All he wants to know is that the steel possesses certain physical qualities, and these qualities are to be determined by physical testing. A good bending-test would be better than all the chemical tests that the manufacturer coùld furnish him. And it is unfair to expect the manfacturer to make steel according to a formula of which he does not approve, and then insist that it shall be satisfactory. The manufacturer knows by experience what chemical formula to take for his own works, for the stock he is using, and for his method of manufacture, in order to meet the requirements of the constructing engineer; and it will be a very serious matter if any attempts are made on the part of these constructing engineers, whether in the Ordnance Department, or in the Naval Department, or in civil practice, to prescribe formulæ to the steel-maker. It would be not only a dangerous precedent, but at the same time would make the manufacture of metal for structural purposes much more difficult.

CHARLES A. MARSHALL, Johnstown, Pa.: I wish, first of all, to disclaim any intention of criticizing the steel Mr. Salom has made. He has given us tests of first- class steel, and shows a good record as regards both grade and quality. I make this disclaimer because I am connected with another steel-works which has also furnished a large quantity (over 1200 tons) of steel which was rolled into angles, bars, and bulb-beams for the same steel cruisers. By the courtesy of Mr. P. E. Chapin, General Manager of the Cambria Iron Company, I am enabled to present test-records of this steel for the examination of such as are interested to see them.

I cannot present such interesting chemical records as the paper under discussion contains, for the reason that such continuous and extended analyzing of the product is not at our works deemed necessary for the working of the furnaces; yet I need handly say the amount of chemical work done at the Cambria Works is probably not exceeded at any other steel-works laboratory in the country. Should the management of our works adopt Mr. Salom's proposed plan of dealing with consumers on a basis of chemical specifications and guaranteed analyses of material (which would have to be made even if not always called for), it is certain that a large increase of laboratory-force would be needed. But before finishing with this part of the subject, upon which I have more to say, let me take up the specifications for steel for cruisers as originally put forth. I shall endeavor to point out two features which have been proved by experience to be wrong or unnecessary.

First, the testing of a plate taken at random from every lot of twenty is both wrong and needless. By arrangement of the Phœnix Iron Company (which rolled the steel into finished shapes) and the Cambria Iron Company with the Naval Advisory Board, it was fixed that each heat should be tested at the Cambria Works, and this arrangement has given satisfaction to all parties. Mr. Salom has pointed out that it is wrong to condemn nineteen possibly good plates for one bad one. To make so many tensile tests is needless, first, since by marking heat-numbers upon blooms and finished pieces, as is our practice, if at any time a heat should be thrown out after being rolled, through haste to fill order or delays in testing, it can all readily be selected and laid aside; and secondly (basing the assertion on experience at the Cambria Works, where Pernot furnaces are used), there is not nearly so much range in physical qualities in different parts of the same heat of good open-hearth steel as there is in the qualities of test-pieces of absolutely the same composition and original quality, caused by the variations in their preparation, unless great care be taken and a uniform standard adopted.

This requirement for tensile testing of one plate in a lot, or every plate, is a relic of the ancient and barbarous English custom of testing plates at the ship-yard. I believe it stands, in one shape or another, on underwriters' and admiralty specifications to-day; but it is to be hoped, for the peace and prosperity of both the steel-makers and the ship-builders of Great Britain, that it is a dead letter. In taking advantage of what is good that our English friends can show us, by all means let us abandon what is bad ; and this cnstom, with its related requirements, is unquestionably bad.

The next feature in the specifications which is needless, is the great amount of time required to make tests. From seventeen to twenty-three minutes is taken for a single test where one-half or one-third of this time would be ample. I have never been able to discover any useful purpose in the five minutes that "initial strain" is kept on the specimen. I am inclined to think, also, that applying straius by increments at stated intervals, as required, will not give so uniform results as applying strain gradually at stated speed of ram or screw, which can generally be regulated with sufficient accuracy. This may account partly for the Variable relation between elongation and reduction of area spoken of by Mr. Salom. Upon •the point of time, I present tests of two heats of our steel, similar to that made for cruisers, with statement of speed and times from passing elastic limit to breaking. Specimens are alike throughout, being $\frac{7}{16}''$ thick and planed to $1\frac{1}{4}''$ width.

Heat No.	Elastic Limit lbs. per sq. inch.	Ult. Strength lbs. per sq. inch.	Elongat'n. Per cent. in 8".	Reduction. Per cent.	Time.	Total Time of Test.
5017	42,080	65,150	24.8	47.1	3 m. 10 sec.	Say 7 minutes.
5017	41,930	65,550	25.6	47.1	" "	" "
5018	38,450	61,830	27 2	50.3	3 m. 30 sec.	Say 7½ minutes.
5018	37,870	61,670	28.5	50.0	3 m. 40 sec.	" "
5017	42,070	66,450	26.6	46.8	14 m.	22 minutes.
5017	42,400	66,530	26.2	49.3	13 m.	23 "
5018	38,280	62,410	28.7	52.0	11 m.	19½ "
5018	39,000	62,000	26.3	48.8	10 m.	17½ "

The speed of screw was throughout about f inch per minute. In the first four tests, the pulling was continuous after passing the elastic limit; the last four were tested in accordance with the requirements of the Naval Advisory Board. A strain of 30,000 pounds per square inch was left on for five minutes, elastic limit taken, and subsequent strain applied in increments at half-minute intervals.

I would also quote the mean results of some experiments presented by Mr. William Denny to the Institution of Naval Architects in 1880.:

HARD STEEL.	Ult. Stren. per sq. in. lbs.	Elongation on 8 in.	Time.
Mean of six experiments, plate ¼" thick,	91,011	11.96	1 m. 30 sec.
" " from same plate,	89,286	11.48	11 m. 50 sec.
SOFT STEEL.			
Mean of two experiments, plate ½" thick,	65,296	23.55	1 m. 30 sec.
" " from same plate,	64,176	23.55	4 m. 43 sec.
" " "	64,736	22.7	13 m. 11 sec.

It will be seen that the variations are exceedingly small, and my tests seem to contradict the English ones. I think the speed of the first four tests given was slower than necessary for such soft material ; the harder the material, the slower the speed should be; but I have had good results with this speed on spring-steels of 140,000 pounds per square inch ultimate strength.

Regarding the conditions of acceptance and quenching-tests required by the government specifications, I would only say that they were rigidly carried out at our works and also at the Phœnix Works-by officers of the navy; and that, while the requirements are stringent and leave little or nothing to judgment, that is characteristic of all government work. They who call for closely inspected selected material must pay a little extra for it; and that ends the matter. Quenching-tests, as I am informed by one of the naval officers who inspected our steel, were an efficient check upon burnt material, an appreciable though small percentage of finished material being thrown out for this cause. This is a point which chemical specifications would not reach. No heat was ever wholly or in large part lost after passing tests at our works.

It is true, as Mr. Salom says, that an error in measurement of $\frac{1}{100}$ inch affects results two per cent, on a piece ½ inch thick. The remedy is not to make such errors. The one-thousandth part of an inch is not difficult to measure with a micrometer-screw.

MR. SALOM : My remark had reference to the variations of thickness in the same plate.

MR. HILL : I have never seen a half-inch plate rolled correct to the one-thousandth of an inch.

MR. MARSHALL : No; not to the one-thousandth ; but you must Lave seen them rolled to the one-hundredth and better.

MR. HILL : There might be, even then, differences amounting to five-thousandths.

MR. MARSHALL : I should consider a specimen varying one-hundredth of an inch in thickness as a defective one, which should not be. tested.

Further, as to the bold prophecy that chemical specifications and tests are going to supersede physical ones, I would respectfully submit that the tendency is in the opposite direction, and for excellent reasons. First, steel-buyers are not steel-makers, as a rule. The steel-maker must have the chemical and metallurgical knowledge to produce steel that will answer certain physical ends. The engineer can readily trace the analogy between his requirements in practice and the behavior of a test-piece under a simple and known strain, but he cannot, or at least certainly ought not to be expected to, translate from the science of statics or dynamics into that of chemistry or the still more complex science of metallurgy. The projectors of a structure or buyers of boilers and machinery are, generally speaking, men who could still less than engineers be expected to say from looking at the analysis of a piece of steel what its qualities should be. And when I say *should be* I have said all that any one can say. What the qualities *are* can be determined only by putting the material to actual test. By Mr. Salom's proposed plan, it would be first put to the test in the completed structure—a somewhat costly experiment in case of failure.

Secondly, it is extremely doubtful if the completest analyses of steel will ever alone account for the differences in behavior of steels made by even the same process. To illustrate, I note in Mr. Salom's table of tests the following :

Heat No.	Thickn's of Specimen.	Ultimate Strength.	Reduct. of Area.	Elongation.	C. P. Mn.
640	½ in.	58,400	49.0	27.8	.13 .049 .30
640	"	59,600	51.8	28.3	
575	$\frac{9}{16}$ in.	60,000	57.3	25.8	.13 .042 .30
575	"	58,700	61.	27.3	
637	½ in.	53,400	56.3	28.	.13 .049 .31
637	"	52,000	50.2	27.5	

With almost identical analyses, the very slight differences all in favor of No. 637 being the harder, it has ultimate strength 10½ to 11 per cent, below the others. It would not be difficult to find other similar cases, but this is a point which has been repeatedly discussed; and I do not wish to consume the time of the Institute needlessly.

It is gratifying to note from Mr. Salom's remarks about rails that he has set his face towards homogeneous steel. Homogeneous, uniform steel is what the steel-user and the engineer want to be assured of every time. Homogeneity is the quality which the testing-machine will not show without an excessive amount of testing. To produce such steel is alike to the advantage of consumer and producer. Let the engineering and manufacturing public become convinced that only homogeneous heats are produced, and the very simple process of testing a sample or two from each heat will serve to grade the steel, insure its quality and put the whole matter of adaptability and uniformity in the largest lot of steel beyond question, and this without requiring every one who has to buy a few tons of steel to study up the whole subject of metallurgy in order to know whether the chemical guarantee offered him by the steel-maker accords with the requirements he has in mind.

I should like to say a word with regard to the question of hard vs. soft structural steel. Mr. Salom has given us his opinion—that the steel which was rejected for being too soft is better material than that accepted. I would suggest that he allow those more directly interested in the structures to be made of his steel to say what grade of steel they want. The first users of steel for structural purposes very generally chose steel of a high strength, thinking thereby to effect greater economy of material, and, in some cases at least, partial failures resulted, owing principally to two causes. First, in the state of the art of steel-manufacture and the lack of efficient testing and inspection in those times, the steel was faulty in spots and irregular in its qualities, comparing one heat with another. This increased the dangers arising from the second cause, namely, that builders did not know how to treat the new material properly. Nevertheless, high steel had to bear the burden of blame for failures; and a reaction set in, as the result of which the strength of steel used is considerably less than at first. The superb ductility and reliability of mild steel attracted engineers; and many adopted grades, the ductility of which is greatly in excess of that of the iron formerly used for the same purposes. To illustrate, I quote figures given by Mr. Kirkaldy (having no suitable American tests at hand) of average results from three grades of iron plate, and, in comparison with them, the average of the steel made by the Cambria Iron Company for cruisers:

MATERIAL.	Thickness. Inches.	Mean Ult. Resistance. lbs. per sq. in.	Mean Reduct. of Area. Per cent.	Mean Elongation. Per cent.
Iron "ship-plates,"	$\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$	49,504	5.4	5.7
Iron boiler-plates, ordinary quality, ...	$\frac{1}{2}$, $\frac{3}{4}$, $\frac{5}{8}$	47,375	13.07	9.6
Yorkshire wrought-iron plate, .	$\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$	47,712	20.6	16.7
Cambria open-hearth steel, . .	$\frac{7}{16}$	65,843	47.18	25.32

These figures speak loudly. The steel plates have fully one-third greater strength than the *best* English iron (not to speak of the ordinary "boiler" and "ship" plates), one-half more ultimate elongation, and over twice as much reduction of area at fracture.

Now, if elongation and reduction of area represent the reliability of the material under strain, or its capability of passing safely through trying circumstances, as I take it they do (except for the fact that nicks, bruises, or surface-cracks injure the mild steel slightly more than they do the iron), why do we need such a vast excess of these qualities? Factors of safety, so called, remain about the same. Have not our iron bridges and ships, when carefully and honestly built, been safe structures?

If the great difference is really required, it must be to allow for ignorant working; and at this day shops ought not to be ignorant about the treatment of steel. Bridge-builders in this country have not yielded to the downward pressure toward mild steel so much as ship-builders, who seem to have followed pretty closely foreign practice. The bridge engineers seem latterly to have required about the same ultimate elongation in steel as in iron, and then have taken advantage of the higher strength thus obtained, which seems to me logical, though I am not yet clear that higher steel might not be safely used in many cases. And in justice to steel and steel-makers, it must be allowed, that with and by reason of the system of submitting steel to tests, uniform and satisfactory material has been and can always be obtained, whereas when specifications for an elongation equal to that now deemed desirable in steel are attempted with iron trouble is very likely to follow. In this I speak only of equal percentages of elongation; in the qualities indicated by free bending and reduction of area at fracture, the steel still has a large advantage.

I do not agree with Mr. Hill, if I understand him correctly, that a standard form and size of test-piece is impracticable or unnecessary. It seems to me that a standard can be devised for the purpose of grading steel by its physical characteristics, and that when such a standard shall have been adopted, to speak of steel of a certain tensile strength and certain elongation, etc., will have a definite meaning, and these points can be guaranteed without circumlocution or evasion.

I can speak with certainty of the Cambria Works; and it is probably within the mark to say that at any steel-works where testing is carried on regularly, as with us, the difficulties arising from differing ideas of buyers are recognized; and that a standard form and size of test-specimen for grading steel will be welcomed by all, if it be practical and cheap.

With regard to size and form of test-specimens, I am making a few tests for our own benefit in comparison of plain-rolled round and square test-pieces, and regret they are not far enough advanced to present results. I find but small differences in elastic limit and ultimate strength between rounds and squares of the same sectional area. The rounds generally have the advantage over squares in elongation and reduction of area, both in point of amount and uniformity with the same material; but the advantage is more marked in the case of hard material. Thus, while a rolled square test-piece might answer well as a standard for soft materials, I at present favor a round of not too small size, since with hard materials squares give results less uniform, and sometimes misleading.

MR. HILL : In defence of what I have said, I will take the case of an engineer testing steel eye-bars, whether they be round bars or flat bars. The tendency of bridge-constructing engineers of late years has been to reduce the thickness of eye-bars and widen them out correspondingly. If we have two eye-bars made from the same material, one an inch thick and four inches wide, and the other one-half inch thick and eight inches wide (both eye-bars thus having the same section), the results of testing will be inevitably very different. To establish, therefore, a bar-test of any standard size would not contribute very much to the assurance that the material is exactly what you want.

It is the same also in boiler-plate tests. Make a boiler-plate test standard, and apply it to steels ¼, 5/16, 3/8 inch thick, and you will find that your specimens will not be reliable as to the quality of the material that you have. But if instead of prescribing a uniform shape or size of test-piece, you say it shall bear a certain ratio between thickness of plate and width of plate, then you can always get the same result. And that is what I mean by saying that it is better to establish a *mode* of specifying or a mode of testing rather than a design for a test-piece.

MR. MARSHALL: I fully agree with Mr. Hill in the idea that the mode of testing should be specified more clearly than it has been. I think we ought to have a standard mode. The point I was making was, that we want a standard size for grading *steel*,—not for grading plates only, or bars only, or any other shapes only, but for the steel. We want to be able to know what results an ingot has given in one form ; then we will be able to calculate from that up to every variety of such forms as we may want to use, by a system of test which each works can make for itself, or which might be made by committees.

MR. KENT: I think great confusion will result if too many different forms of test-pieces are selected. As Mr. Marshall said, what is wanted in the steel-works is some method of grading the quality of steel itself, and not of a particular shape, whether 12 inches wide or half an inch wide, which the bridge-engineer may need in construction. It is the business of the engineer who designs the bridge to know what change will occur in the strength of steel by changing its dimensions. But we should have some standard form of test-piece for the grading of steel at the works. I think it is the practice now in some works—and a very good practice—to cast with each heat a 4-inch ingot, or, better, a 5-inch ingot, and draw that down to a ¾-inch round bar as the standard test-piece for grading the steel. If the steel is to be used for boilers, the test-ingot may be rolled to a certain thickness of plate, from which the standard test-piece for boiler-plate may be made. By casting such test-ingots, and rolling them to standard shapes for tests, we would obtain a regular test-record as well as a chemical record of every heat,—so much carbon, phosphorus, manganese, etc., and what the standard test specimen of steel showed in tensile strength, in elongation, reduction of area, etc. If the engineer buys a steel that shows, say 60,000 lbs. tensile strength and 28 per cent, elongation in the test-piece of standard form, and then puts it into eye-bars of various dimensions, it is his look-out to know how the steel will be changed by being put into that form. Engineers who design various forms of eye-bars are taking the risk of the changes in tensile strength due to changes of shape from the standard.

W. F. DURFEE, Bridgeport, Conn.: I desire to call attention to possible structural defects in high-carbon steel not to be detected by chemical analysis. If you take an ingot, say fourteen inches square, of pretty high-carbon steel, put it in a very hot furnace and then stand close to the furnace, you will very likely hear in a few minutes or seconds a sound much like the striking of that steel with another body of iron. If you know what that sound indicates, you will know that there is trouble ahead. If you do not know, when you take the ingot out and attempt to either forge or roll it, the character of the trouble will usually become manifest. That sound indicates that the too rapid superficial healing has actually ruptured that ingot-, and ruptures of that kind do not often show themselves upon the outside of the ingot while it is being heated. I have seen ingots worked with such defects, and some ingots actually put into finished shape and the defects not seen. Fortunately they were discovered by subsequent tests.

Now it does not make any difference how much knowledge you have of the carbon in such a piece of steel as that; yon are going to get a bad result inevitably. Nor does it make any difference how many ingot-tests you have taken of steel subsequently submitted to that kind of heating. That particular steel that has suffered such careless work is bound to fail when it comes into use.

It has been my fortune to witness some so-called testing operations upon long bars, which were conducted as follows: A heavy cylindrical bar, somewhat more than thirty feet long, was subjected to tensile strain in a powerful testing-machine. This bar was not supported at its center, but only at its ends by the clamps which secured it in the machine; consequently the bar was subject to a cross-strain from its own weight, which in this case acted precisely as though the bar were built into a wall at each end, the metal on the top of the bar at its ends being elongated, and that at the bottom compressed, while at the middle point of the bar the reverse action took place. Bars subjected to longitudinal strain under the above conditions may fail, whereas if they had been properly supported and the strain applied fairly the test would have told a different story.

MR. HILL : In testing heavy bars horizontally for tension, we counterweight them in the center ; but where they are not counterweighted, the strain is one of shearing and not of tension.

MR. DURFEE : I do not say that the proper precaution is universally neglected, but I have seen exactly what I have described.

MR. HILL : It was certainly not a fair test.

WILLIAM H. MOERIS, Philadelphia, Pa.: In a paragraph on page 669, which perhaps is the key to a considerable part of the . regular manipulation of testing steel-plates, Mr. Salom says:

"It is to be regretted that we could not anneal the test-pieces without annealing the plates, as this would have removed all variations in the results, due to differences of mechanical treatment, and perhaps would have prevented anomalous results. So much has been written on the treatment of steel, that it would be out of place for me in this paper to do more than mention, in a general way, that many of the failures which manufacturers experience with steel plates are due to the improper manner in which they handle them. Moreover, it is certain that steel plates, after having been flanged and punched, ought to be annealed."

It seems to me that the tendency has been a step backward, that plates, after being rolled, ought to be annealed before they are tested, as, if I mistake not, was the practice when we first commenced rolling steel plates in this country. The rolling of plates is a much severer test of the quality of the metal than the rolling of any other section of iron that has been devised, because there is no edging possible. On the contrary, the tendency is to widen out the plate, and, besides that, it is necessary to widen out the ingot to get it to the proper width that you are to make the plate, so that the spreading of the grain or fibre is both ways; whereas, in the rolling of a bar or a bloom, or any other section, there is a tendency to edge it up. Now this widening is a great strain on the quality of the material. Moreover, it is alrnqst impossible that the large mass of which the plate is composed should be uniformly heated; and even if you start with a uniformly hot ingot, before the plate is finished it will be colder on the end, and perhaps colder on one side or both sides, than it is in the middle.

It seems to me that plates ought to be annealed before they are worked to insure uniformity. And I think that this would correct a considerable part of the irregularity we find in the testing.

P. G. SALOM, Thurlow, Pa.: I would like to say a few words in regard to the criticisms passed on my paper.

Mr. Kent's method of analysis would be, if completed, very interesting; but I doubt whether we would ever arrive at the exact truth by such a method. Some years ago I had occasion to study Dr. Dudley's tables, by the laborious method of least squares, on the effect of phosphorus, silicon, manganese, and carbon. The results I give below ; but, since we do not have all the chemical reasons for the physical results, the values are not correct.

Consider $\frac{1}{100}$ of 1 per cent, of each of the five substances, iron, carbon, phosphorus, manganese, and silicon, respectively, as a unit of that substance, and let

$$\left.\begin{array}{l} u = \text{influence of a unit of iron,} \\ v = \quad \text{"} \quad \text{"} \quad \text{carbon,} \\ x = \quad \text{"} \quad \text{"} \quad \text{phosphorus,} \\ y = \quad \text{"} \quad \text{"} \quad \text{manganese,} \\ z = \quad \text{"} \quad \text{"} \quad \text{silicon,} \end{array}\right\} \text{ on the } \left\{\begin{array}{c} \text{tensile strength,} \\ \text{elastic limit, and} \\ \text{elongation-per-} \\ \text{centage succes-} \\ \text{sively.} \end{array}\right.$$

Then, by making 64 equations only of Dr. Dudley's analyses (taking iron by difference), and physical tests of the steel, and solving these 64 equations for the five unknown quantities by the method of least squares, in three different series of equations, we get the following values for u, v, x, y, and z;

	Elongation.	Tensile Strength.	Elastic Limit.
u,	+ .284	+ .022	+ .009
v,	— 30.36	+ .235	— 2.9
x,	— 68.31	+ 1.326	+ 5.05
y,	+ 2.607	+ 1.085	+ 1.394
z,	+ 1.	+ 2.347	+ 2.157

The only values we can place much reliance upon in this table are the two strongly negative values of carbon and phosphorus on elongation.

Now, as regards the influence of phosphorus, I think I am perfectly justified in taking the position that phosphorus, up to the amount of 0.075 per cent., is not injurious to the physical qualities of soft steel. I have seen a piece of boiler-plate, containing 0.3 per cent, of phosphorus, that not only flanged well, but bent double when cold.

MR. KENT: Would you put it into the fire-box of a locomotive?

MR. SALOM : I am not speaking of that. I cannot say how it would act there, and do not think any one can, as it has not been tried. But the effects most people attribute to phosphorus are certainly absent in that case.

DR, RAYMOND : How much carbon did the piece contain ?

MR. SALOM : I do not know. It was a piece of basic steel, made by the Pennsylvania Steel Company, and on exhibition at their office in Philadelphia. I did not analyze it myself, but was told that their chemist said it was remarkable, because it contained 0.3 per cent, of phosphorus. He had made repeated analyses to be sure he was right, being himself as much surprised as others.

In regard to the proper amount of carbon, Mr. Kent is certainly wrong. He falls into the error that you can have high carbon if the phosphorus is low, and get the same effect as low carbon and higher phosphorus.

MR. KENT : I have found that very strongly.

MR. SALOM : I do not, in my tests ; and, further, I have made a very careful examination of Dr. Dudley's tables in this respect, and find no-such relation. On the contrary, some of his highest phosphorus rails are lowest in tensile strength, which is what I should expect. The difference of phosphorus in Dr. Dudley's tests, taking both good and bad rails, or fast-wearing and slow-wearing rails, is only a little over 0.02 per cent. The slow-wearing rails were .07, and the fast-wearing .09. Now, it is absolutely incomprehensible that that small amount of phosphorus should influence in a marked degree the wear of those rails, and especially when we find a large number of individual cases where the phosphorus is double, and the results are good. And yet Dr. Dudley regarded phosphorus as the most potent factor in the law of wear.

In reply to Mr. Hill's remarks, that not sufficient attention was paid in the paper or in the investigation of the steel to the changes that may have resulted from the treatment the steel received after it left the casting department, namely, in the mill and in the shop, I would say, that the greater part of the paper and investigation has been devoted entirely to these points. Heating and rolling have little or no influence on chemical composition. The carbon sometimes changes a few points (two or three hundredths at the most), but there would not be any other chemical changes, except superficial oxidation.

I knew that my remarks on chemical specifications would be the subject of criticism, especially from constructing engineers, whose prerogative it sometimes is to build gigantic structures, to show how they will *not* work. Now it seems to me the most rational method would be to find, if possible, the reason of the matter before beginning operations. Chemistry will do this. It tells us why a certain metal has so much tensile strength and elongation,--that is, if all the conditions are known,--which proviso I was careful to insert.

In regard to Mr. Hill's beefsteak metaphor I would say, that his knowledge of organic chemistry must be very limited if he does not know that it is just as possible to recognize tough and tender steak without using his teeth as it is to recognize good and bad steel without a testing-machine. To argue that we cannot depend on the physical properties of steel from its chemical composition, owing to the injuries it may receive from mechanical treatment, is equivalent to saying a thing is bad when it is spoiled. Of course it is quite possible to spoil the best steel that was ever made in heating and rolling, just as it is possible to spoil anything else; but it does not take a testing-machine to tell us when this has been done. No one is better acquainted with the facts than the workmen in the mill.

Moreover, the physical test is open to the same objections as the chemical test; since no matter how many tests you may make from the same metal, as the plate, angle, or bar, those tests are necessarily local; and the conclusion as to physical properties of such a plate, angle, or bar is based on the assumption that it is without flaws or defects of any kind. I repeat, therefore, that, given a good method for determining oxide of iron, we can predict with certainty the physical properties of ordinary steel.

This controversy arose some years ago when Dr. Dudley was bold enough to prescribe a chemical formula for steel rails, and although there was a great storm at the time, rail-men have generally come to the conclusion that steel rails of *about* the composition that he suggested are the best that can be made. If we should make a chemical specification for boiler-plate we certainly could not go very far wrong. I have analyzed samples of most of the boiler-plate made in this country (the celebrated Otis steel which is generally acknowledged to be the best, and others); and I find in the best of them an astonishing degree of uniformity in their chemical composition. They are all about the same in carbon--from .10 to .15, rarely over .15--low in phosphorus, and with as little manganese as possible, to permit of working well in the mill.

I have a few more tests that I would like to present, that have been made since my paper was written.

1. *The Effect of Annealing.*

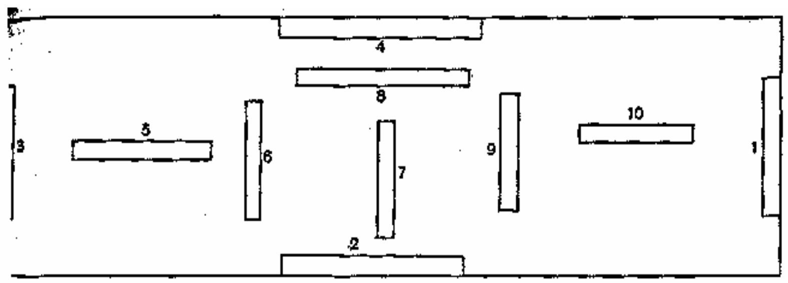
There was a little trouble in working some of the boiler-plates which had passed inspection. This we had anticipated, owing to the fact that the specifications called for the tensile strength, 60,000 lbs. on an 8-inch section, whereas 60,000 and below is generally required on a 1-inch section; and we had discovered that this involved a difference of from 5,000 to 10,000 lbs. to the square inch. The Advisory Board permitted the plates to be annealed; and the result was that after annealing none of the plates would stand the requirements, all being too low in tensile strength. I give the results below.

The letters refer to plates from the same heat.

Original Heat Tests.				Test of Annealed Plates.			
Heat No.	Tensile Strength. Lbs.	Reduction of Area. Per cent.	Elongation. Per cent.	Heat No.	Tensile Strength. Lbs.	Reduction of Area. Per cent.	Elongation. Per cent.
678. . .	61,000	54.5	30	678 M .	53,000	63.7	29.5
" . . .	59,400	58	30.6	" " .	52,750	61.7	30.7
				678 W .	53,500	57.7	29.3
				" " .	52,600	63.3	28.7
671. . .	61,600	58	30	671 O .	54,000	64	27
" . . .	62,400	53	25.9	" " .	53,000	66	27.2
				671 P .	53,170	58	29.8
				" " .	52,700	61.5	29.8
				671 Q .	56,400	64.3	28.4
				" " .	54,130	62	32.1
673. . .	60,400	58	32	673 R .	54,400	62.9	32.5
" . . .	60,500	60	28.5	" " .	55,000	60.7	28.7
				673 T .	57,400	64.2	30.7
				" " .	53,600	61.3	31
				673 U .	53,900	62.3	28.3
				" " .	53,500	60.8	30.7
675. . .	60,500	60	31.2	675 S .	54,970	62	28.4
" . . .	58,900	59	28.3	" " .	54,640	61.2	27.6
				675 X .	53,000	65	30.5
				" " .	54,300	61	29.8

2. *The Effect of Different Sections.*

To show the influence of different sections of test-pieces on elongation and tensile strength, the Advisory Board purchased one of the annealed plates, and at their request the following tests were made, the test-pieces being cut from the plate according to the annexed diagram.



The plate (No. 678, W.) was 222 inches × 78 inches × $\frac{5}{8}$ inch, and the test-pieces were about 0.6 inch wide and 0.67 thick.

No.	8 in. section, loads applied at intervals.		1 in. section; load applied at intervals.		1 in. section; continuous application of loads.		
	Tensile Strength. Lbs.	Elongation. Per cent.	Tensile Strength. Lbs.	Elongation. Per cent.	Tensile Strength. Lbs.	Elongation. Per cent.	Reduction of Area. Per cent.
1	57,300	29	59,500	27.5	66,500	26	42
2	57,300	31	60,200	25	64,200	31	58
3	52,790	30	60,200	32	67,200	28	45
4	52,100	31	64,000	27.5	68,700	34	51
5	54,780	27.5	65,450	29	69,800	26	42
6	55.350	29	65,000	27.5	69,100	31	44
7	57,500	26	64,000	25.5	67,300	31	46
8	52,880	26.5	64,000	31	65,900	31	47
9	54,910	27.5	63.000	26.3	66,200	31	42
10	55,500	30	62,000	30	67,400	31	49

The second and third columns show tensile strength and elongation in an 8-inch section and the 4th and 5th columns show the same in a 1-inch section, all tests being made with the usual intervals between application of loads. The 6th, 7th and 8th columns show tensile strength, elongation and reduction of area on a 1-inch section, with continuous application of loads.

3. *The Influence of Time.*

Some further tests in regard to the influence of time gave the following results:

Heat No.		Tensile Strength. Lbs.	Elongation in 8 in. Per cent.	Reduction of Area. Per cent.	
Longitudinal	705,	59,500	26	53	Time pull.
"	"	59,300	28	53	" "
"	"	60,000	24	48	Fast "
"	"	59,700	24.6	58	" "
Transverse	"	59,100	22 3	53	Time "
"	"	58,900	24	53	" "
"	"	59,600	22	50	Fast "
"	"	59,100	21.5	46	" "

4. *The Effect of Different Lengths.*

To show the effect on test-pieces of different lengths between the shoulders the following tests were made, all taken from the same plate (No. 678, W.), 24 pieces being cut longitudinally in section of plate marked 10 (see diagram), the approximate size of test-pieces being 1 X 0.65 inch.

No.	Length between Shoulders. Inches.	Tensile Strength. Lbs.	Elongation. Per cent.	No.	Length between Shoulders. Inches.	Tensile Strength. Lbs.	Elongation. Per cent.
1	1	63,300	41	13	5	56,300	32.5
2	1	62,800	40	14	5	56,590	33
3	1½	56,660	49	15	6	55,700	29
4	1½	56,660	49	16	6	55,700	30
5	2	56,400	42	17	7	56,000	28.5
6	2	56,800	46	18	7	56,500	28.5
7	2½	56,200	40	19	8	55,200	27.4
8	2½	56,200	40	20	8	55,200	28.4
9	3	56,400	38	21	9	56,000	28
10	3	56,400	38	22	9	55,950	25
11	4	56,300	34	23	10	54,750	27.8
12	4	56,100	35	24	10	54,750	27

These results show that the lengths between shoulders have but little influence on tensile strength, except in the 1-inch section, and this is owing to the shape of the test-piece, which was reamed out with curves, thus, *X*, instead of angular shoulders.

THE ESTIMATION, OF PHOSPHORUS IN IRON AND STEEL.

BY BYRON W. CHEEVER, UNIVERSITY OF MICHI0AN,ANN ARBOR.

WHILE engaged in experimenting with the usual methods for estimating phosphorus in iron and steel, it occurred to me that potassium chlorate might be used to oxidize the carbon, and thus avoid the tedious and vexatious evaporations necessary for successfully carrying out the usual methods.

After many trials, the following plan was adopted :

Take, for analysis, of Bessemer or other low-carbon steels, from 3 to 5 grammes; of crucible steel, 10 grammes; of pig-iron, 1 to 5 grammes, according to the percentage of phosphorus supposed to be present. • Of iron, high in phosphorus (1 per cent.), take 1 gramme.

Place in a No. 4 evaporating dish the amount of iron or steel decided upon, cover with a funnel which will just fit inside the dish, and then add gradually HNO_3 (1.20 specific gravity), using 12 c.c. of acid for each gramme of steel or iron taken. (A larger quantity of acid will be required for small samples.) When the full amount of acid has been added, and the violent action has ceased, place the evaporating dish on a sand-bath, add 10 c.c. HNO3 (1.40 specific gravity), and boil till the bulk of the solution is reduced about one-half. Then add 10 c.c. HNO_3 (1.40 specific gravity), continue the boiling, and add from time to time, during the next 15 minutes, small portions of pulverized $KC1O_3$ till about 2 grammes have been added. (If the solution shows signs of going dry, more strong acid must be added.) This will precipitate the manganese, with some iron. Sometimes it happens that the manganese does not come down readily, and more $KC1O_3$ or further concentration, or both, will be required.

The process is not complete till the manganese is precipitated, which may be known by the appearance of a dark, mirror-like deposit on the dish, at the edge of the solution.

Boil the solution 5 minutes after the last addition of $KG1O_3$, and then add cautiously (to prevent sudden explosions) 5 c.c. strong HC1. This will dissolve the precipitated manganese and iron.

Continue the boiling till the chlorine is all expelled, adding from time to time HNO_3 (1.40 specific gravity) to prevent the solution from evaporating to dryness.

Now, add an equal bulk of water to the solution, and boil from 5 to 10 minutes, cool, and filter into a flask. This filtration may be omitted, if, as is generally the case with low-silicon steels, there is no residue. Place the flask under the hydrant, till the solution is perfectly cold; then add gradually strong ammonia, with constant stirring, till the solution is changed into a pasty mass, and the ammonia is in slight excess; cool ; add cautiously HNO_3 (1.40specific gravity.) till this mass is nearly dissolved; boil moderately, and add HNO_3, a little at a time, till the solution has a straw-color. If the solution has a red tinge, iron will be thrown down with the phospho-molybdate precipitate, which can only be removed by re-precipitation, and with a loss of phosphorus.

Cool the solution to 60° C., and add 60 c.c. of molybdate solution ; place the flask on an iron plate heated to 60° C. (not more), and let it stand one hour.

By cooling the solution, before adding the molybdate solution, and not raising the heat above 60° C., the phospho-molybdate precipitate is obtained free from molybdic acid, and also, if the above precautions have been observed, from iron, and will contain only a part of the silica, the whole of the silica being thrown down only by high heat and long standing. Filter and wash the precipitate (keeping as much of it in the flask as possible) with an acid solution of ammonium nitrate (made as follows: water, 1 litre; $NH4NO_3$, 100 grammes; HXO_3, of 1.40 specific gravity, 15 c.c.); wash till the wash-water will not give a red color with potassium thiocyanate.

Place the flask, which contains the bulk of the precipitate, under the funnel, and dissolve the precipitate of phospho-molybdate on the filter with a 3 per cent. solution of ammonia. The filter should remain perfectly white, or only slightly tinged with red on the upper edge. If much colored with iron, run through the filter into the ammoniacal solution enough dilute nitric acid to dissolve this oxide of iron, and render the solution slightly acid ; then add 5 c.c. molybdate solution, heat the flask to 80° C., let it stand 15 minutes, or till the precipitate subsides ; filter and wash as before. This will give a phospho-molybdate precipitate free from iron. Dissolve this precipitate with a 3 per cent, solution of ammonia, as above.

To the ammoniacal solution of phospho-molybdate add 5 e.c. strong HC1, or enough to render the solution decidedly acid ; dissolve the precipitate thus formed with ammonia, adding it gradually, so that the last drop-will just disperse the yellow color, leaving the solution cloudy, and with a peculiar sweet smell. Boil the solution 10 minutes; then set it aside till the silica becomes flocculent (about 10 minutes); remove the separated silica by filtering through a small close filter--or better, through the filter from which the phospho-molybdate precipitate has been dissolved, for the silica is not so liable to pass through that as through a new filter.

By repeated tests I have been unable to find phosphorus in the separated silica when iron was not present, but have always found it when the silica contained iron. To the filtrate add 5 c.c. of ammonia; cool; and then add gradually 15 c.c. of magnesia mixture, keeping the solution in constant motion ; cork the flask and shake violently for two or three minutes; set it aside for three hours; filter and wash with ammonia-water (3 parts of water, 1 part of ammonia) till the wash-water, acidulated with nitric acid, gives no precipitate with silver nitrate.

Place the moist filter with its precipitate in a platinum crucible; cover, and apply a strong heat till the filter is thoroughly charred; remove the cover; turn the crucible on its side, and ignite till the filter is white; then place the crucible in the upright position ; cover, and heat five minutes with the blast. This will volatilize the greater part of the molybdic acid, which is nearly always present with the ammonio-magnesium phosphate. The determination may be made in six hours. The results in Table No. 1 were obtained by students working in the laboratory, and by myself. A., B., C. and D. are students. E. is myself.

The sample was a piece of steel rail, about 8 inches long; and the drillings were made from time to time as wanted : which may account in part for the rather wide difference in some of the results. The amount taken for each determination was either 3 or 5 grammes.

The sulphuric acid and nitric acid processes, socalled, are described in the *Transactions* of the Institute, vol. page 330. The nitric acid and potassium chlorate process, mentioned in the table, is the one just described.

Table No. 1.

Chemist.	Sulphuric Acid Process. Phosphorus, per cent.	Nitric Acid Process. Phosphorus, per cent.	Nitric Acid and Potassium Chlorate Process. Phosphorus, per cent.
A.	0.128	0.1303	0.132 0.132 0.133 0.1331
B.			0.1274 0.1293 0.1274 0.1365
C.	0.1276 0.1276	0.1292 0.1245	0.1273 0.1283
D.			0.130
E.	0.1337	0.1294 0.1290 0.1296	0.1355 0.1332 0.1330 0.1274 0.1266
Average, . .	0.1292	0.1286	0.1308

The following table gives results obtained from another sample:

Table No. 2.

Nitric Acid Process. Phosphorus, per cent.	Nitric Acid and Potassium Chlorate Process. Phosphorus, per cent.
0.1048 0.1120 0.1034 0.1118	0.1185 0.1151

The attempt was made to estimate manganese in the same sample and at the same time with the phosphorus; but the manganese precipitated by the potassium chlorate was found to carry phosphorus, which necessitated its re-solution, as above described, by adding HC1.

On testing the magnesium pyrophosphate for impurities, I obtained a reaction which, if other tests are not made for iron, may lead to the conclusion that iron is present when it is not. This reaction was obtained by dissolving the magnesium pyrophosphate with HC1, and then adding thiocyanate, which gave a red color, resembling in every respect that produced by iron. This color I have found to be due to the molybdic acid, which has been reduced by the ignition, and which is always present in greater or less quantity in the magnesium precipitate.

THE SEGREGATION OF IMPUBITIES IN BESSEMER STEEL INGOTS ON COOLING.

BY PROFESSOR BYRON W. CHEEVER, UNIVERSITY OF ICHIGAN ANN
ARBOR, MICHIGAN.

IN the *Journal of the Iron and Steel Institute* for 1881 (vol. ii., page 379), will be found an article upon this subject. The analyses there reported were of samples taken from an ingot made especially rich in impurities and then cast in a sand-mould in order to give the elements a better chance to redistribute themselves, on account of the steel solidifying more slowly than when cast in an iron mould. Wishing to ascertain how much, if any, segregation takes place when the steel is cast in the ordinary way, I placed the subject in the hands of Mr. W. J. Olcott, a graduate of the Michigan University, who has carefully collected and analyzed samples taken from different parts of ingots and billets.

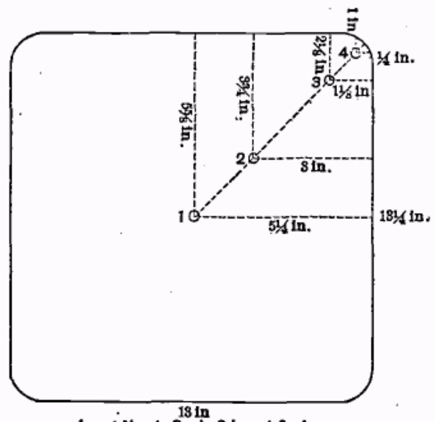
In this undertaking he found himself somewhat embarrassed on account of being distant from steel-works, and therefore unable to supervise the selection of samples.

He found, however, a competent and willing aid in the person of E. F. Wood, M.E., chemist of the Pittsburgh Bessemer Steel Company, Limited, who has spared no pains in collecting the desired samples and furnishing drawings and descriptions of the ingots from which the samples were taken.

The following are the results obtained:

Ingot No. 1.

This ingot was about 5 feet long and 13 X'13¼ inches at the point of fracture, which was 2 feet from the bottom. The samples were taken from points 1, 2, 3, and 4, as shown by the following cat:



Ingot No. 1. Scale 2 in.=1 foot.

End view of fracture, showing drill-holes.

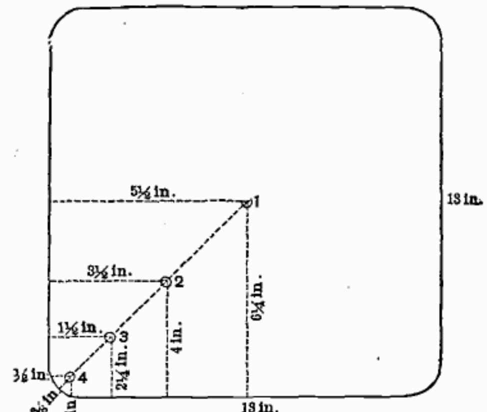
The holes were 1¼ inches in diameter, drilled with a twist-drill. The ingot was badly honeycombed.

Results of Analysis.

	1	2	3	4
Silicon, . . .	.0269	.0195	.0093	.0279
Phosphorus, .	.0966	.0966	.100	.0966
Sulphur, . . .	.022	.013	.005	.029
C. Carbon, . .	.49	.42	.37	.45

Ingot No. 2.

This ingot was 4 feet 6 inches long and 13 X 13 inches at the point of fracture, which was 2 feet 6 inches from the bottom. It was a soft ingot. The sample holes, 1, 2, 3, and 4, as shown by the following cut, were 1¼ inches in diameter. All measurements are to the edge of the hole, and not the centre.



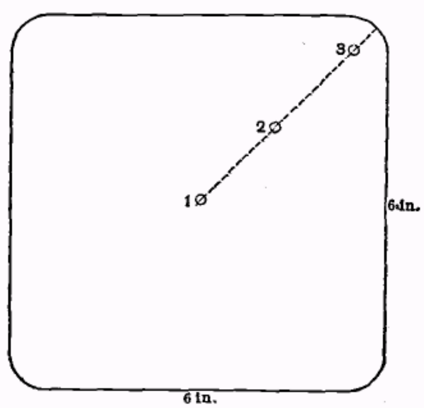
Ingot No. 2. Scale 2 in.=1 foot.

End view of fracture, showing drill-holes.

Results of Analysis.

	1	2	3	4
Silicon, . . .	.015	.008	.003	.013
Phosphorus, .	.197	.131	.082	.086
Sulphur, . . .	.078	.059	.029	.023
C. Carbon, . .	.10	.10	.10	.09

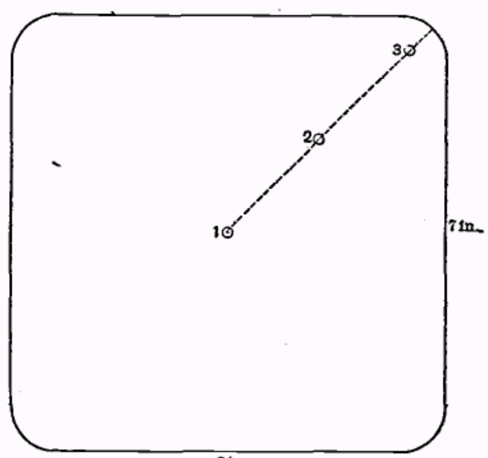
Billets.



Billet No. 1. Scale 4in.=1 foot

Results of Analysis.

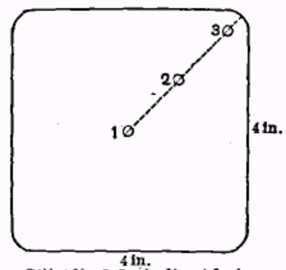
	1	2	3
Silicon, . . .	.016	.015	.015
Phosphorus, .	.075	.074	.081
Sulphur, . . .	.026	.027	.028
C. Carbon, . .	.21	.23	.20



Billet No. 2. Scale 4 in. = 1 foot

Results of Analysis.

	1	2	3
Silicon, . . .	.04	.037	.039
Phosphorus, .	.085	.089	.089
Sulphur, . . .	.037	.036	.038
C. Carbon, . .	.40	.40	.42



Billet No. 3. Scale 4 in. = 1 foot

Results of Analysis.

	1	2	3
Silicon, . . .	.016	.015	.015
Phosphorus, .	.075	.076	.073
Sulphur, . . .	.026	.025	.024
C. Carbon, . .	.39	.40	.40

On examining the foregoing analyses it will be seen that there is a tendency on the part of some of the impurities to separate from the cooling mass and concentrate in that part of the ingot which remains fluid the longest.

This concentration, however, is so slight, in the ordinary ingot, as not to be manifest in the billet.

The fact that segregation does take place calls for some attention on the part of the manufacturer of large steel castings, on account of the large percentage of silicon present and the slow cooling of such castings, which gives the impurities a better chance to concentrate.

It is evident that the more rapidly the fluid steel is cooled the less the segregation. Therefore the steel should be cooled as rapidly as is consistent with good work, in order to secure in the casting as perfect uniformity as possible.

THE HYDRAULIC CEMENT WORKS OF THE UTICA CEMENT COMPANY, LA SALLE, ILL.

BY HENRY C. FREEMAN, C.E., E.M., ALTO PASS, ILL.

DURING the early period of the construction of the Illinois and Michigan Canal, about 1838, in excavating for the canal, where the present town of Utica stands, hydraulic limestone was discovered, and its value was recognized. A kiln for calcining and a mill for grinding were erected, and the cement was used in the construction of the locks of the canal.

This property was subsequently bought by the present owner, Mr. James Clark, and the work has been contiuned to the present time in much the same primitive manner as it was begun. The bed is exposed in the Illinois River valley by stripping off a few feet of the covering rock. It is from 4 feet to 6 feet 9 inches thick, and nearly level, dipping gently to the northeast.

The Utica Cement Company's establishment, which is two miles west of Utica and two miles east of La Salle, was an outgrowth of the Illinois geological survey. The writer was in charge of the district which included La Salle county, and, in working out the details of the geology of that county, discovered, below the Utica bed, another workable hydraulic limestone, which makes its appearance in the northern bluff of the Illinois River valley, rising above the water level at the point where the company's works are established. This cement group, of which there are several thin beds, lies just below the St. Peter's sandstone, with a few feet intermediate of trausition-rock, which appears to represent the Calciferous, and is exhibited in place, in concretionary form, at the top of the bluff. The hydraulic beds are very regular, and the one worked by the company is 10 feet thick; or, speaking more definitely, there are two beds, separated by 18 inches of sandstone, lying about two feet above the bottom, and the two beds are worked as one, the sandstone being first cut out and removed, to prevent mixture.

In 1869 I was invited to join with a company, and to take charge of and develop the property. The Utica Cement Company was organized, and work was commenced in the autumn of that year. , The entire plant was constructed under my personal supervision, and from original designs of my own.

A canyon 100 feet deep, with nearly vertical walls, very narrow where it opened to the canal and railroad in the Illinois valley, afforded the best place for opening the mine; and by building very "compactly, with careful planning, there was sufficient room for the plant, close to the mine-entrance.

The rock is obtained entirely by mining underground. Tunnels are driven in the cement-rock, and the interior plan is much the same as a coal-mine, laid off in rooms with walls between, connected with the main tunnels or entrances by cross-entries. The rooms are worked 45 feet wide, with 15-feet walls between, the main tunnel having side-walls 25 feet thick. The mining has all been done with pneumatic drills, and I understand the set of drills in use are the same with which the work was started, excepting one, which has been worn out and broken up. My connection with the work terminated five years after its commencement, the work being then complete.

After some experimental work, the plan settled upon for mining was to cut out the sandstone and remove it; then blow down the upper or main mass of the cement-rock; and, lastly, raise the two feet of cement-rock below the sandstone. But all the drilling for the face of either a tunnel or a room was done before a shot was fired. The method of working a room and tunnel was the same, and by preference the tunnel was driven wide—about 20 feet—as a Matter of economy, excepting at the entrance, which was kept narrow, that it might be readily closed against severe winter weather, and also to lessen the action of frost on the roof.

The drilling commenced anywhere in the face, after the drillers became skillful; but the system indicated a beginning always in the center of the face, a few inches above the sandstone,—one, two, or three drills occupying the face of a room together. Usually it was divided between two. Two holes were drilled, 2½ feet apart, about 2½ feet deep, and directed obliquely downward and forward, converging so that the two holes would be about 4 to 6 inches apart at the bottom, and terminate in the sandstone near the base. Two more holes, 4½ or 5 feet deep, were drilled like the first pair, starting 3 inches horizontally from them, and converging as before, A third pair of holes, 3 inches from the second pair, went in 7 feet, and sometimes a fourth pair were put in 9 feet in the same manner. These .holes were always blasted in pairs, and in the order given, the first pair making a wedge-shaped opening, which the second and third pair deepened to the regular depth of breast, which was usually 7 feet for the standard. Occasionally 9 feet, and in a few instances 11 feet depth of breast, was taken out by having extra long drill-points. The rest of the drilling was one hole for each 2½ or 3 feet of horizontal distance of sandstone, until the side-walls were reached. A few holes, properly distributed, to bring down the mass above, and a few to tear *up* the bottom bed to the floor, completed the drilling. As it was necessary to have a clean parting at the floor and roof, the bottom and top holes were drilled with special reference to this object.

In the early period of the work, the men at the drills were paid by the day; but, as soon as safe data had been collected upon which to base contracts, the drillers were brought under that system, and paid for the actual measure of the holes drilled, provided they were properly drilled as to depth, position, direction, and number. Any excess, deficiency, or error of direction for the holes, was charged against the driller's credit, and became his loss. The result of a few months' judicious discipline of this kind, together with careful instruction, was, that the drillers learned to do their work so that no failures followed in blasting, no hand-drilling was required, and the walls were kept to a line.

As the result of this systematic training, I was enabled, in a few months, to dispense with steam-engineers for the drills—who at that time were paid S3 per day often hours, and had helpers at §1.75—and gradually brought in a new set who had never run engines, selected from the ambitious and careful men among the better class of laborers. During the employment of the steam-engineers, who were generally railroad men, of unsettled habits and fixed prejudices, it was rare to get 100 feet of holes per day per drill, the general distance ranging down to 80 feet; but, soon after the new trained men came in, this was increased to 160 feet and upwards, occasionally reaching 200 feet. By paying, during a few mouths, a bonus for the best and largest amount of work done per month, we were greatly assisted in bringing the monthly average to a standard maximum. All dill-sharpening was at the driller's cost. In order to insure carefulness, all breakages were charged to the driller; and, to prevent waste, all the oil was charged. To insure regularity of time, half the cost of the power used to compress the air was charged to the drillers, of whom there were six. Thus, if one drill was idle, the five had to pay the share of the idle one. By this arrangement the drillers were kept from dropping out at will, and disarranging the order of work; and when one or more wanted to stop, it was arranged beforehand among themselves, and permission was obtained from the office. In this way an orderly system of work was introduced, permitting a complete control. The important men in the system learned by experience how much the cost of work was increased by disturbance of its regularity; and the gradual reduction of cost at last considerably exceeded 50 per cent.

Every day, record was made of each division of labor throughout the establishment, charging each classification of work with its quota of labor, even to the fractions of a day per man ; and the aggregation of the daily details balanced the gross amount of labor. The foreman of each gang furnished daily the distribution of labor under his charge. Once a month, this was consolidated on one sheet. The cost of each division of labor and of each kind of material consumed was thus known each month; and if any essential variation was observed, it was immediately investigated, whether it increased or lessened cost. To make this complete, involved taking a monthly account of stock of finished and unfinished work, which was easily done. This system was established at a period when labor was very difficult to handle, and made especially so at that place by local surroundings and circumstances.

The blasting was all done by a set of men who did nothing else. The common laborers followed, broke the rock to proper size, loaded the cars and run them out to the nearest main entry. As already remarked, the sandstone was blasted out and removed before the cement-rock was disturbed. Black powder was used. Nitroglycerine and dualin were both tried without success. It was an essential condition that the rock should not be broken too small for proper calcining, as the draft of the kilns would be obstructed by too large a percentage of fine rock. These stronger explosives shattered the rock too much, producing excessive waste.

The Burleigh drill was used. In the beginning of the work, the "tunnel carriage" which the manufacturers sent out with the drill was employed. It was an unwieldy affair, requiring nine men to move it about, though two (the driller and his helper) were sufficient to use it. The unsuitableness of this carriage led me to design a totally different one adapted to our work. The accompanying drawings and description exhibit this carriage, which is still in use.

As it was not patented, it is free for public use. This carriage suited the work perfectly. • It is also adapted for any tunnel-work of ordinary width for a railroad, and down to seven or eight feet wide, by making the carriage specially for narrow work. This carriage, with its drill (weighing together one ton), was handled very easily, either on or off the tracks, by the two men who did the drilling, a pinch-bar being used to shift it into position.

In the accompanying plate, Fig. 1 is a side view, with one end shown partly in section. The drill (not shown in the drawing) is clamped to the long horizontal bar in the usual way. This bar moves up and down freely between the guide-posts of the carriage, being suspended at each end by a chain. A lever working in the ratchet winds or unwinds the chain at each end. The two stanchions shown in position support the drill when in action, and are themselves supported against the floor and roof, and made secure by the long jackscrews in the bottom. A wooden cap is usually laid on top next the roof. On the floor is an iron plate for the screw-head.

Sets of clamps at each end of the drill-bar inclose the two stanchions; and a short jackscrew in each end of the drill-bar is forced out against the stanchion. The drill-bar is then independent of the carriage, and the chain may be slackened.

A is an end view of the drill-bar looking downward. It shows the lugs that serve as guides on the posts, and the attachment of the clamps, bolted on. A short jackscrew is omitted in the figure.

B exhibits half of the bottom-frame, showing method of framing and attachment of the posts.

The frame is of seasoned white oak, the stanchions of Norway pine. For a ten-feet ceiling an eight-feet stanchion is a convenient length. They are eight inches square.

Fig. 2 is an end view of the carriage, with the stanchions omitted and the clamps thrown open.

T rails were used; but as it was inexpedient to have a track close to the face, the flange of the wheel was broadened, so that the wheel had two treads, the lesser diameter to run on the rail, and the greater to run on the rock-floor. The construction of the track was unlike the common practice. Four by six-inch oak scantling, 14 feet long, was framed together by tongue and mortise, the six-inch face flat, with three cross-pieces secured with wooden pins. These 14-feet sections were kept in stock, with a few half-lengths. It is a very convenient method for mine-tracks with light rail. The rail has a full bearing its whole length, and a lighter rail can be used.

The high price of iron at that time made this an important piece of economy.

The plant consisted, besides the drills referred to, of the necessary yard and mine-tracks and a railroad-connection ; a house containing a sixty horse-power Babcock & Wilcox boiler and two Burleigh compressors, each of power to drive three tunnel-drills, and connected with the necessary air and water-pipes distributed through the mine; a blacksmith shop; four kilns for ealcining the rock, two of 1000 barrels capacity each, and two of 500 barrels capacity each ; a mill-building of stone, three stories high (total height, 65 feet), with a one-story wing, also of stone, for boilers and engine; a receiving-house, which is an open building, to which the calcined rock is transferred from the kilns; a warehouse for storage, one story high, 37 by 100 feet, with cellar for empty barrels; a house for the superintendent, and a village on the bluff, with an artesian well for water-supply; and the machinery, referred to more in detail below.

The large kilns are oval, and the smaller ones round,—all are perpetual kilns. The large ones have eight furnaces, four on each side, and below each furnace is a gate for drawing at the lower level, high enough above the ground to draw into a car. The round kilns have four furnaces each, but only one gate to each kiln for drawing. The kilns are 45½ feet high, finished on the top with T rail tracks, so that the mine-cars deliver their load of two tons each into the kiln. These reach the top of the kiln by an inclined plane. The space between the draw-gates and the bottom of the furnace is a chamber sufficiently large to cool the calcined rock to a proper degree for handling in wooden cars. Drawing is done usually every two hours,—filling with fresh rock once in twenty-four hours. The time required for calcining is about four days, or ninety-six hours. When and how much to draw, is determined by the fireman from the apparent condition of the rock at the back of the furnace. Firing is done in shifts of twelve hours, one fireman attending one large kiln or two small ones. Another man does the drawing.

The kilns are lined with fire-brick, backed with common rubble masonry. The outside is an iron shell of No. 12 to No. 16 iron, the space between being filled with sand or ashes. This is the construction from the top of the furnace to top of kiln. Below the iron shell is solid brick-work, 7 feet high, containing the furnaces. This is banded with four sheet-iron bands. All below is heavy stone masonry, including the cooling chambers.

From the kilns the calcined rock goes into the receiving-house, about 100 feet long, at an elevation, reached by an inclined plane, sufficient to draw from it through side-gates on each side into a car. From this car the rock is dumped into a hopper over a crusher in the yard at the ground-level. As the calcined rock runs into the car it is inspected, and if any is imperfectly calcined, it is picked out. From the crusher a belt-elevator with cups takes it to the level of the roof of the mill, the upper story of which is a receiving-room. A screw-conveyer passes it from the elevator into this room.

The middle floor is occupied with five run of stones for grinding. The mills are self-feeding by spouts from above. Instead of horizontal stones, they are set on horizontal spindles. The stones are of the best French burr, each stone a single piece, 30 inches in diameter ; and the runner has a speed of 500 revolutions per minute. Each mill, if kept in good trim, will grind 15 barrels per hour of the standard fineness, which is finer than the general practice. The wear of the stones is so rapid that they must be sharpened or dressed for each 1000 barrels ground per mill; and it is better to sharpen for each 500 barrels.

From the mills the cement is spouted to the first or packing-floor. Two shakers pack it either in sacks or barrels. Cement has to be packed by gravity, with a vertical shaking motion. It does not pack like flour.

Railroad-tracks at the door have cars standing to load for immediate shipment. If a surplus is being made, the large warehouse at the same level receives it, from which it can go direct into cars. The arrangement is such that six or seven cars can be loaded at the same time. At the beginning of winter, when demand falls off, this warehouse is filled to its capacity with cement in bulk, and by Christmas the works are able to shut down for a few weeks for the annual overhauling. The necessities of the work will not permit of stoppages long enough for repairs in the busy season ; hence everything is done to insure uninterrupted work during that period.

The one-story wing of the mill contains an engine of 210 horse-power, with two tubular boilers. This furnishes the power for grinding in the mill, crushing in the yard, elevating into the mill, elevating the calcined rock into the receiving-house by the incline, and elevating the raw rock to the top of the kilns by another incline. To avoid the necessity of two additional engines outside the mill, wire-rope connections are made for the transmission of power across the yard ; and, by bevel-gearing, this arrangement is turned at right angles, and connected with friction-gear machinery under the floor at the head of the incline for supplying the kilns. A lever throws it into gear with friction-pulleys; and when the car is delivered at the proper point at the head of the plane, the friction-pulleys are thrown out of gear automatically. It would not be safe to trust a man's promptness to do this.

The rope that does the hauling on the incline winds on a drum under the floor at the head of the plane, the other end being attached to the " traveller"—a little car with weight enough to carry the rope down. This traveller runs on a narrow track inside of the main track and sinks into a pit at the foot of the plane. Over this pit the loaded cars are run; and as the traveller comes out of the pit it pushes the loaded car ahead of it.

Empty cars are let down by pushing them against the traveller; and a man regulates the speed with a lever operating a friction-band on the rope-drum. The crushing and elevating machinery of the receiving-house and mill is run in a somewhat similar manner by another rope across the yard.

The wire ropes for the transmission of the power run constantly at a speed of about 2,400 feet per minute. The strain on them is intermittent and severe. The ropes are f inch in diameter, iron wire, hemp centre and travelling over pulleys 5 feet in diameter fitted with rubber filling. I tried steel wire ropes for comparison, and found that under the conditions it was not as economical as iron. Under the severe intermittent strain, the wires, whether steel or iron, harden and become brittle; and then single wires begin to crack. When the surface-wires show much fracture, it is time to remove the rope ; and when a steel wire rope begins to fracture, it is less reliable, because it is more brittle, than an iron wire under such conditions of intermittent strain.

To complete the plant, a village had to be built on the bluff, as the localit was isolated; and the problem of a water supply (there could be no wells), which could have been met by pumping from a spring stream half a mile distant, was solved in a better way by boring an artesian well, 6 inches in diameter, about 160 feet, which penetrated an open water-bearing sandstone. It is the lower sandstone in the Chicago artesiau wells. A 4-inch iron tube put in caused the water to rise 30 feet above the surface, with some flow. It was allowed to rise 13 feet and run into a tank. From this, with 75 feet of drive-pipe to each of two hydraulic rams of the largest size, the water was driven by the one 125 feet high for the use of the village, and by the other, 90 feet high into a reservoir. This second supply furnished the quantity and head of water necessary to meet the requirements of the drills. The drill-helper, with a -inch iron pipe connected by rubber hose to the leading-pipe could with the greatest ease keep the drill holes free, no matter how rapidly they were sunk. The end of the iron nozzle was closed, and a small hole less than 1-16 inch was drilled for the stream.

It was known at the start that fierce competition was to be encountered in the cement market, and every appliance for success must be used in the production. Hence every arrangement was planned with reference to large and economical production, and at the same time in shape for enlargement without any destruction or disarrangement of plant, and to dispense as far as practicable with manual labor. The work has been a success and profitable from the time of its completion.

The quality of the cement ranks with the highest grade of the natural cements. It is slow-setting, and is largely used in the public works of Chicago.

The standard of quality was placed high in the beginning and has constantly been maintained. The cost of production was then reduced as early as practicable, and by the methods indicated in this paper.

The only analyses I know of are the following, and are given in the form in which they were furnished.

1. Analysis of the rock as determined by the late Professor Blaney of Chicago in 1870, being an average of three analyses:

Carb. lime,	42.25
Carb. magnesia,	31.98
Clay and insoluble silica,	21.06
Iron and alumina,	1.12
Silica,	0.06
Water,	1.07
Total,	97.54

2. Analysis of the cement as determined by G. Bode:

Silicic acid,	35.43
Alumina,	9.92
Lime,	33.67
Magnesia,	20.98
Total,	100.00

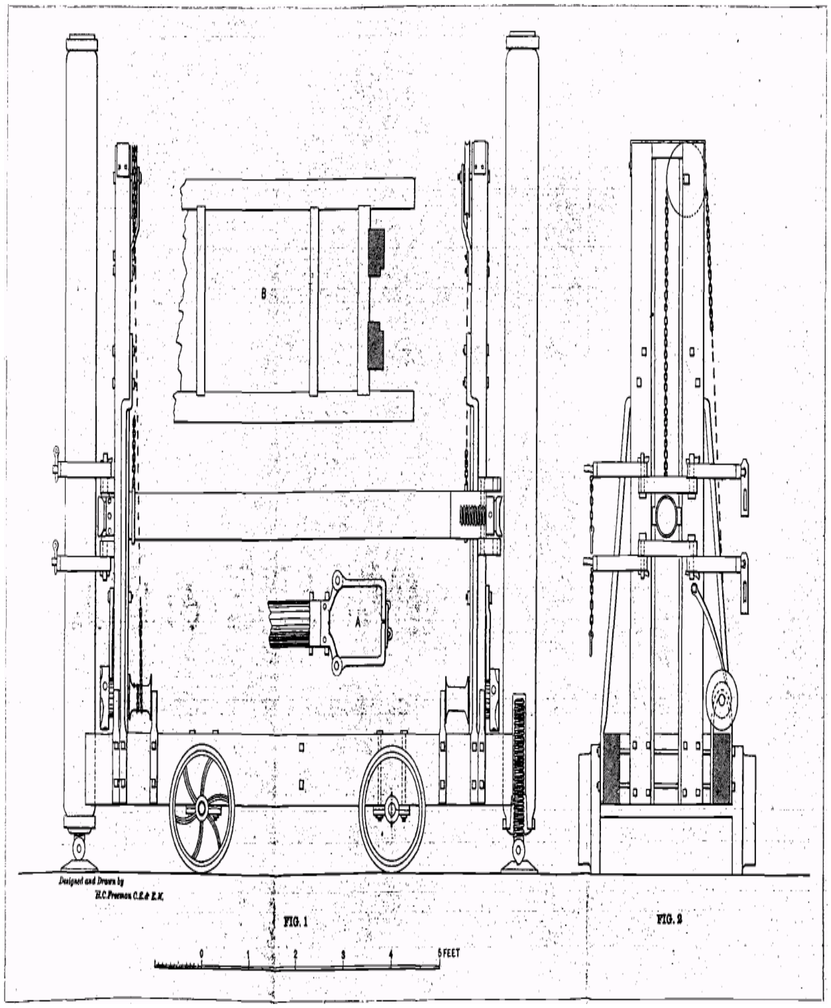


FIG. 1

FIG. 2

This cement-rock is a member of the lower magnesian series, Potsdam period. It is the oldest rock exposed in Illinois, and occurs at this place only in the State. The same beds may be seen about fifty miles southwest of St. Louis, in Missouri, and they probably outcrop along the Mississippi River in the vicinity of the Wisconsin River.

POSTSCRIPT.

I have learned since this paper was written that a slight change has been made in the name of the company. It is now known as "The Utica Cement Manufacturing Company." I learn also that within the last year some changes have been made. They have succeeded in using dualin satisfactorily, and by a new method of crushing with heavy roller in a pan, screening the product, the duty of the mills is lessened to about one-half. The Babcock & Wilcox boiler has also in the past year given way to a common flue-boiler, the change, as I understand, being due to a great reduction in the price of fuel, and the common boiler being served with cheaper labor.

THE MINERS' FUND OF NEW ALMA DEN.

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AT the last meeting of the Institute, several contributions were made to the subject of miners' aid funds. Such matters will always form- important factors in the administration of large industrial enterprises. From the frequently remote and isolated position of mining properties, it is a subject that often forces itself upon the attention of the mining engineer. Local conditions are usually so variable that no single method can be found equally well adapted to all localities. At the same time, a study of different types is often suggestive and valuable, and it is with this in view that these notes are presented.

The Miners' Fund of New Almaden is a remarkably successful ex-ample of what may be done for miners by a wise and at the same time firm management, by simply directing their own efforts and without incurring any great expense to the stockholders,—a practical consideration not without importance in most cases.

The quicksilver mines of New Almaden are situated at a distance-of fifteen miles by wagon-road from San Jose, the nearest town from which medical and surgical aid can be summoned. The great delay in case of accident and the expense in cases of long illness naturally gave rise to much difficulty in the early history of the mine. Physicians would charge a fee of twenty-five dollars for each visit; so that as a matter of mere economy, it was cheaper to die than to fall ill.

In order better to understand the conditions of the problem, a word as to the number and nature of the population will be necessary. The total number of men on the Company's pay-roll at the mine and hacienda (reduction works) varies from 400 to 700. The total population is estimated to vary from 1400 to 1600. The last school-census showed:

316 children between 5 and 17 years at the mine.

105 children between 5 and 17 years at the hacienda.

The total number of minors was estimated at 600. By far the larger part of this population resides at the mine in the so-called " English Camp" and "Spanish Town," the rest live at the hacienda, all on the Company's property. This population is largely Spanish-American. Nearly seventy-five per cent, are of this origin. Most of these are Mexicans; a few are South and Central Americans. About twenty per cent, are Cornish miners and their families; the other five per cent, are Germans, Swedes, and other foreigners, with a few Americans.

Two unsuccessful attempts were made to furnish efficient medical and surgical aid to the mine. The first attempt was made by the management as early as the Fall of 1864, to secure the services of a competent physician. Each male adult at the mine was required to pay one dollar per month, in consideration of which he and his family were furnished with medical attendance and medicine. The whole sum collected was paid over to the physician, who gave his whole time and furnished the medical supplies. Of course this innovation led to much opposition, complaints being made against the compulsory nature of the contributions; so that the scheme was abandoned after a trial of three months.

From that time till the Spring of 1870, the people were left to the tender mercies of local quacks, or were compelled to send to San Jose as before. At the period named the need of a change was so strongly felt by the miners themselves, that a system of voluntary subscriptions was started among them. The plan this time was to pay .over the whole sum to two competent physicians of San Jose, who agreed to visit the mine every other day, alternating with each other; they also agreed to furnish all necessary medicines and to come on odd days without extra charge in cases of emergency. This plan worked well at first; but dissatisfaction arose from the fact that many of the miners who were non-contributors still received nearly as much benefit as those who paid. By degrees, therefore, the number of contributors decreased until the fund became insufficient to pay the physicians; and so the second plan, that of voluntary subscriptions, failed.

The result of this experiment did much to convince the miners that compulsory contributions were necessary to make such a scheme a success; so that in the latter part of 1870, soon after the direction of the mine was assumed by the present manager, Mr. J. B. Randol, the miners were ready to petition that he assume control of the Fund, and that contributions be made compulsory. After convincing himself that this was the wish of a large majority of the employees and residents, Mr. Randol established what is now known as the Miners' Fund, and assumed entire control as Trustee. He has occupied this position for over thirteen years, without salary ; and to his skillful management is due the high state of practical usefulness which the Fund has reached, in spite of previous failures.

At the time he began, the apparent future of the mine did not justify any additional expense on the part of the Company; while on the other haud, it was equally evident that the Fund should be in such a position that it could offer sufficient permanent inducement to a competent physician for him to abandon his regular practice and become a resident at the mine.

With these things in mind, the organization was effected, the rules and regulations of which have since been modified from time to time, as experience under the peculiar conditions suggested.

The rules and regulations now in force may be gathered from the following notice posted at the mine:

MINERS' FUND.

This Fund, instituted for the benefit of the residents of New Almaden, is established upon the following basis:

Employees of The Quicksilver Mining Company, heads of families and all other adults residing at New Almaden, each pay monthly into said Fund, One Dollar. The money so contributed is held by J. B. Randol, Trustee, to be paid out for the following purposes:

1. The salaries of a resident Physician, and of a Druggist, and for the purchase of medical supplies.

2. For relief of contributors whom circumstances may entitle to the same, and for other contingent expenses.

II.

Contributors are entitled, without further payment, to the attendance of the resident Physician for themselves and their immediate families (except that cases of confinement will be charged five dollars), and will be furnished with medicines prescribed by him on payment of cost.

III.

When the Fund is subject to any expense for relief of persons indigent, or otherwise—say for medicines, nurses or supplies—it will be regarded in the nature of a gift, or as an advance to be repaid, as the Trustee may decide to be just, considering the circumstances of each case.

IV.

It is expressly agreed that when the resident Physician is called to attend any person not a contributor to the Fund there shall be a charge of not less than Five Dollars for each visit, to be paid into the Fund, and to be charged against and collected from the head of the house where such non-contributor may be living.

V.

The Trustee serves without pay, and in consideration thereof it is understood that the foregoing rules and regulations will be observed by all persons interested therein; and it is expressly agreed that all sums due, or to become due, to the Fund by the contributors, or any of them, shall be a lien upon any property of the contributors at New Almaden, and upon any money due, or to become due, them for wages from The Quicksilver Mining Company, which money said Company is authorized to pay over to said Fund without further notice.

J. B. RASDOL,
NEW ALMADEN, February, 1883. Trustee.

The peculiarities of the large Mexican element in the population necessitated many of the changes which were made in the rules of the Fund as it was first established. ' For instance, at first, no charge was made for medicines furnished. But it was soon found that the Mexicans would often draw medicine to double the value of their contributions whether they needed it or not. A friend of mine, recently physician on a Mexican railroad, where the government requires that medical aid shall be furnished by the Company, says that the same difficulty is met with there and has occasioned him much perplexity, as it was frequently impossible to determine whether the men were really ailing or not. At New Almaden the difficulty was met by charging the medicines at cost price, as stated in Rule II.

Another difficulty arose from the fact that, in addition to the numerous blood-relatives of a Mexican, he has numerous other connections, such as *compadres, commadres,* etc. All of these godfathers, god-mothers and god-children he regards as members of his own family. As a result, when these non-residents fell sick, they were often imported for treatment at the hands of the resident physician as members of the family of a contributor to the Fund. This soon gave the physician more than he could do; and the place was turned into a health-resort with free medicine and attendance for the vicinity. This was the cause of Rule IV., which, prescribing the fee of five dollars for each visit to a non-resident, at once put a stop to this abuse.

On account of national prejudices, it was found necessary to maintain two separate hospitals, one at " Spanish Town," the other at the "English Camp." Nurses are paid from the Fund as required.

Whenever an employee is injured while at his work for the Company, no charge is made for any medical or surgical supplies furnished him; and if the needs of the case require it, he is furnished with nurses and boarded at the expense of the Fund. When solely dependent on his support, his family is provided for during his illness in the same manner. The same is done for ordinary illness in deserving cases of destitution; and the advance is regarded as a gift or a loan, as the Trustee may decide to be just.

In cases of fatal accident or the death of indigent persons, the burial-expense is sustained by the Fund. It maintains a burial-plot at the San Jose cemetery and also one at the hacienda, and another on a sandstone hill near the mine, which latter is not very popular among the miners for obvious reasons, although no ore as yet has been discovered there.

The physician is paid a regular salary of three hundred and fifty dollars a month, and is required to make a monthly report to the Trustee of:

The number of visits made each month.

The number of office prescriptions.

The number of vaccinations.

The number of obstetric cases.

The number of cases of salivation.

A professional druggist is employed at the mine to attend to prescriptions; but, as he also acts as clerk for the mine, only the time he is actually engaged as druggist is charged to the Fund, at the rate of twenty-five dollars per month.

The collections are made and the accounts kept by the regular bookkeeper of the mine, who receives a salary of twenty dollars per month from the Fund.

A complete record of the fatal accidents during the last thirteen years has not been kept. During the last four and a half years there have been just nine, or an average of two per year. During this time there have been on an average 440 men employed ; this would make an average of less than half of one per cent, of fatal accidents per annum. It is a remarkable fact that in none of these fatal cases did the patients live long enough for treatment. In seven cases death occurred instantaneously, and in the other two, within half an hour. Three of these accidents happened at the surface and six under ground.

During the last four and a half years the highest annual mortality from all causes was 15 per 1000 inhabitants; the lowest, 11 per 1000; the average about 13 per 1000.

Cases of salivation never occur at the furnaces at present, except through extreme carelessness. The chief trouble of this sort at the hacienda is from cleaning the condensers and working the soot. During 1883 there was no salivation at all at the hacienda. In previous years, there has been more or less from the cause stated.

Formerly there was very little salivation in the mines, the einnabar-ores never giving any trouble of that kind. But at present, in working the rich *labores,* or stopes, of the 1600 and 1700-foot levels of the Randol shaft, which contain a great deal of native quicksilver, there-has been some trouble from this cause. This ground is in-places thoroughly impregnated with native quicksilver, a fragment of ore showing drops all the way from the size of a pea to microscopic globules disseminated through it.

Of course the air in such *labores* is pretty thoroughly saturated with quicksilver-vapor, in spite of all attempts at thorough ventilation. The chief source of absorption seems, however, to have been the skin. As the *labores* are rather warm, the men work by preference stripped to the waist. As a consequence, the dust and probably the vapor also, is attacked by the saline matter in the perspiration, and introduced into the system through the skin. At least this is the theory of Dr. S. E. Winn, the resident physician ; and that this is one important cause is substantiated by the fact that since he has insisted that the men be compelled to wear their shirts in the *labores* while at work, the number of cases has diminished. Of course, every attention is paid to bathing; and the use of tobacco in any form is forbidden in these *labores.* No deaths have been known to occur from salivation. The treatment follows the iodide of potassium method. Men disabled by salivation get half-pay.

A remarkable fact is the facility with which the Mexicans recover from wounds resulting from accidents or quarrels, while at the same time they succumb very readily to the attacks of disease. Their chief difficulty is with lung-troubles, pneumonia, consumption and the like. This seems partly due to constitutional predisposition, but largely to their careless, reckless life. They will frequently come out of the hot *labores* after a day's work, and without change of clothes expose themselves to the weather or a night of dissipation. The Mexican miners, although occasionally very well developed, do not as a rule last as long as the Cornishmen. The latter, being more particular about wearing dry clothes at the surface, and not exposing themselves recklessly, suffer much less from lung troubles.

The average age of the miners employed is 35 to 40 years, although some of them are 60 to 70 years old. A few boys and no women are employed in the mine.

The following summary of the monthly reports of physicians will give an idea of the amount of work done.

Summary of Monthly Reports 1874 *to* 1883 *inclusive—ten years.*

Number of patients visited at their homes,	42,156
Number of patients visiting office,	41,238
Number of vaccinations,	729
Number of salivation cases treated,	26
Number of confinements,	209
Total cases,	84,358

The following is a list of receipts and disbursements for the whole period during which the Fund has been in existence:

New Almaden Miners' Fund. Receipts and disbursements for the 13 *years ending December* 31, 1883.

RECEIPTS.

From collections,	$80,447 30	
" sales of medicine,	2,484 00	
" obstetric cases,	1,280 00	
" outside practice,	98 00	
" donations,	24 75	
" sale of horse,	126 50	
" loans repaid,	345 00	
" interest on deposit in bank,	2,551 50	$87,357 05

DISBURSEMENTS.

Salary of physicians,	$47,711 00
Medical stores,	13,283 11
Contributions to sick and disabled,	4,019 24
Commissions for Collector and Secretary,	3,842 34

Hospital nurses,	$2,748 82
Consultations (fees),	1,648 00
Livery,	1,425 78
Funeral expenses,	865 90
Board for patients,	736 65
Furniture,	532 84
Surgical instruments,	501 42
Office boy,	418 75
Incidental expenses,	486 97
Loans	345 00
Subscriptions to medical journals and works,	312 40
Disinfectants,	252 92
Small-pox hospital,	55 25
Collections refunded,	27 50
Taxes,	18 00
Fuel,	15 22
Apothecary's salary,	275 00
Total disbursements,	$79,522 11
Deposits in banks,	7,544 32
Cash at mine,	290 62
	$87,357 05 $87,357 05

The Company furnishes to the Fund at the present time stabling for a horse, and all the necessary buildings for offices, hospitals and dispensary and dwelling for physician, free of expense.

If we assume the same rate for the whole thirteen years as for the last ten, as shown by the monthly reports during that period, it would make the total number of visits made or received by the physicians, 109,665. The salary of physicians during this period was $47,711. This would make the actual cost to the members of the Fund less than 44 cents per visit. This, compared with twenty-five dollars a visit, the original cost, or even with the price that the inhabitants of large cities pay for similar service, is a very satisfactory showing. Now if we divide the total disbursements $79,522.11 by the total number of visits during the thirteen years, we have an average cost of 72½ cents per visit, including all expenses incurred by the Fund, such as medicine, nurses, loans, hospital-expenses, physicians' salary and administration. All this has been secured practically without cost to the Company.

To the naturally improvident Mexican, the establishment of the Fund has been of great value. The present arrangement saves both the miner and his family from considerable suffering in case of sickness or inability to work. The Cornish miners are usually more frugal; but they mostly have large families and get the full value of their contributions in the way of attendance during the year.

The Fund as now arranged seems well adapted to meet the peculiar conditions under which it operates with apparent general satisfaction. Dr. Winn, to whose kindness I am indebted for most of this information, tells me that during the four and a half years of his services at the mine, he has heard of only two complaints. These were from two laborers who worked a couple of months on the roads, and did not happen to be sick while they were engaged. Considering the large and varied population, this absence of dissatisfaction is high praise for the manner in which the Fund has been administered.

THE CERRO DE MERCADO (IRON MOUNTAIN) AT DURANGO, MEXICO.

BY JOHN BIRKINBINE, PHILADELPHIA, PA.

AMONG the notable deposits of iron-ore, the Iron Mountain at Durango, Mexico, is prominent. But, although it has been noticed in records of travel and official reports for three centuries, the statements made concerning it have been so largely alloyed with improbabilities that general credence has not been given to data relating to the *Cerro de Mercado,* that being the name by which this remarkable mountain of ore is known.

LOCATION.

Geographically, the mountain is centrally located, being situated immediately at the City of Durango, which is distant in direct lines (as the crow flies) as follows:

From the Rio Grande River at El Paso, Texas, in the north, 510 miles; from the same stream at Laredo, Texas, in the northeast, 410 miles; from Tampico in the east, 475 miles; from the City of Mexico in the southeast, 520 miles; from Mazatlan in the west, 110 miles.

At El Paso, the standard gauge Mexican Central Railroad, and at Laredo, the narrow-gauge Mexican National Railroad, enter Mexico. Tampico is a prominent Mexican port on the Gulf of Mexico, and Mazatlan occupies a similar position on the Gulf of California. To reach Durango from Laredo or Tampico, spurs of the Sierra Madre Mountains must be crossed, and between Mazatlan

Cerro de Mercado. Durango. Mexico.

and Durango the main range stands as a barrier, so that long detours must be made and steep gradients overcome; therefore for practical transportation Durango may be considered as approximately equidistant from all the points named.

Durango is a city of over 30,000 inhabitants, situated in latitude 24° 4' north, and longitude 105° 9' west of Greenwich, at an elevation of 6893 feet above the sea, on the great plateau of Central Mexico. The prominent features of the topography in the immediate vicinity of the city are two hills which appear like mountain-tops projecting from the sandy plain; the lesser bounds the city on the west, and is known as the *Cerro de Remedios;* the greater adjoins the corporate limits on the north and is recognized as the *Cerro de Mercado,* or as the Iron Mountain,

THE IRON MOUNTAIN.

In approaching Durango from the east or north, the *Cerro de Mere ado* is a landmark for long distances--its dimensions are approximately one mile long, one-third of a mile wide, and its turrets of specular ore rise from 400 to 650 feet above the surrounding plain.

Plate I gives a correct view of the *Cerro de Mercado,* looking northeast from the road leading out of Durango, the city being behind the observer. The cut is copied from a large photograph brought from Durango. The turret B surmounted by a cross, to the right in the plate, is the most elevated portion of the mountain, and is, as far as can be determined, an immense mass of solid ore. The same may be said of the neighboring pinnacle H, and of all the abrupt faces which project from the general slopes of the mountain. These slopes are quite steep, and are apparently a talus formed by the detrital ore falling from the projecting ore-masses. Scattered over these slopes there is a sparse growth of prickly pear and other cacti. What the depth of this talus is, could not be determined from the various excavations which have been made from time to time, chiefly with expectations of discovering more precious metals. Some of these openings have caused large expenditures. On the north side of the mountain, we examined one shaft (now partly filled with debris) made through solid ore for probably 70 feet, and were informed that drifts extended from its bottom,*

* The finding of numerous specimens, which for the greater part are of extraordinary colors and metallic luster, has produced upon ignorant people the illusion that the *Cerro de Mercado* must conceal in its bowels treasures of gold and silver, and, with a view of unearthing them, they have made numerous futile excavations;

The wall in the foreground of the plate bounds the roadway on the east, and opposite its end, at A, is the only portion of the mountain from which ore has been taken,--as far as could be learned, to supply the *Piedras Azules* iron works, of which mention will be made hereafter. But no blasting or quarrying has been done at this point, there being ample detrital ore available. In fact, close observation is necessary to indicate that any ore has been removed.

HISTORY.

The unusual magnitude of the deposit, the specular character of the ore of the Iron Mountain, and the ignorance of those who saw it, led to many exaggerations ; and as most of the information concerning it passed verbally from one to another, it was amplified and embellished. It is therefore not remarkable that, in 1551, the statement should have been published that the *Cerro de Mercado* was a mountain exposing on its surface immense masses of gold and silver in the native state, and that Mercado, from whom it is named, died in efforts to obtain possession of it and own its great treasures.

Even the renowned Humboldt is credited with the belief that this deposit was an immense aerolite, basing his assumption upon the similarity in appearance and composition between alleged specimens from the *Cerro de Mercado* and aerolites. The number of large meteorites found in Mexico may, however, permit of great license as to possibilities of finding others of magnitude. The writer saw a meteorite at Conception, Chihuahua, about five feet high, two feet wide and two feet thick, and he has a photograph of one found near Parral, Chihuahua, on which four men are standing comfortably.

In a report upon the *Cerro de Mercado,* made by Frederico Weidner to the Mexican Minister of the Interior in 1858, the author says:

"Baron Humboldt, in his Political Essays on the Kingdom of New Spain (book 3, chapter 3, paragraph 2, Spanish edition of 1827), speaks of some enormous massesof malleable iron and nickel that are said to be found in the neighborhood of Durango, the composition of which, according to the analysis of Vanquelin and Klaproth, is

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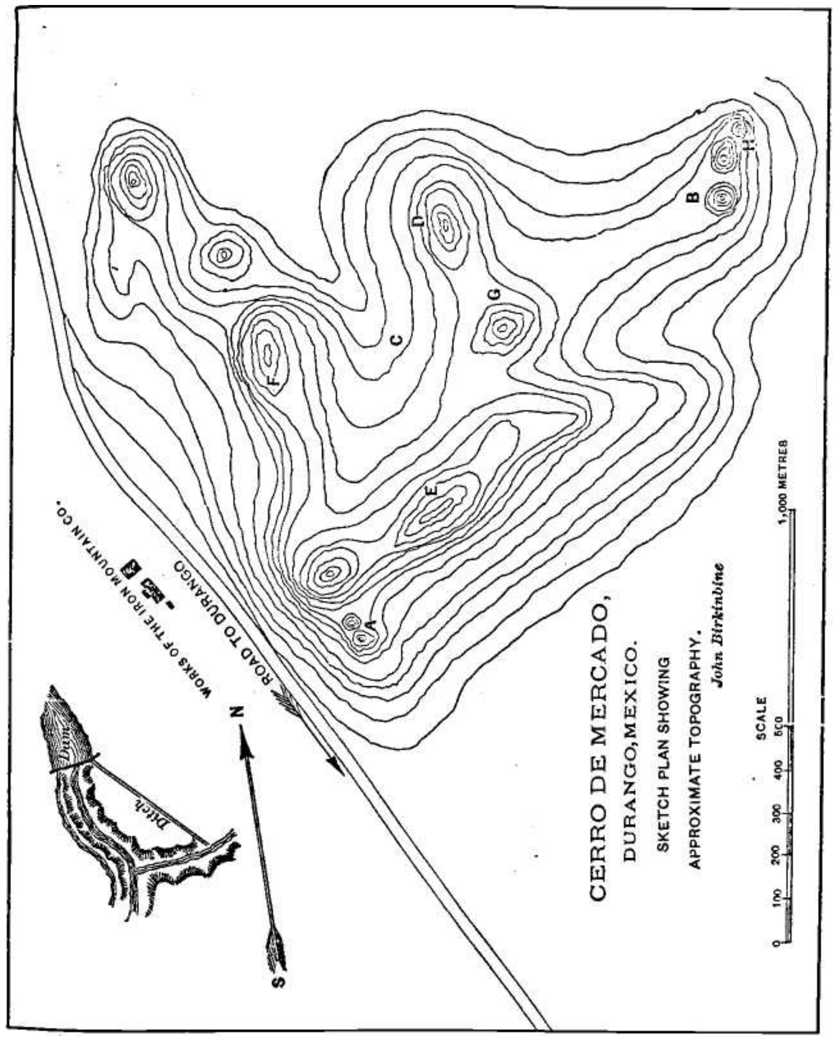
but in no instance have they succeeded in finding any other dominant power than that of *iron.* I can at least assert positively, in reference to the foregoing, that from the date of the finding this mountain I believe that every attempt made with the expectation of finding gold and silver has proved abortive, and that only the ingratitude and covetousness inherent in the human species could induce men to search for gold and silver in a spot where Divine Providence, with a lavish hand, has liberally accorded us a treasury of iron, that properly worked will ensure prosperity and aggrandizement to Durango far greater than all the silver mines of the States together. Translation from F. Weidner's *Report on Cerro de Mercado,* 1858.

identical with that of the aerolites that fell in Hraschina, near Agran, in Hungary, in 1751, and the weight of which is four hundred times greater than that of the aerolite that Sir Rubin de Celis describes in Otumba in Tucuman.



"This remark, emanating from so respectable an author as Baron Humboldt, has caused the erroneous supposition that the *Cerro de Mercado* was also an aerolite, which in some remote period had fallen from the planetary sphere to our earth; but a treatise on the *Cerro de Mercado* and the Iron Works of Durango, published in 1843, very rationally combats this error, by asserting that those stones which bore conviction to the illustrious Baron in all probability had not even come from Durango, but instead were found in Zacatecas, in which city an aerolite has lodged from time immemorial, and was discovered in 1792; and that Baron Humboldt, never having visited Durango, was not in a position to form a correct idea of the *Cerro de Mercado.*

"I am of the same opinion ; because, to suppose that scientific men could confound the meteoric iron of Zacatecas with the metallic stones of Mercado borders on the absurd and impossible, and only goes to prove that the nuggets or masses of malleable iron exhibited to Sr. Humboldt could possibly have been sent from Durango, but that, most likely, they had been dug up at a farm in Guadalupe, an estate contiguous to that city, or from one of the farms to be found on the River Florido y Conception, on the road between that place and Chihuahua; because, in these last two places, I have actually seen plainly by the side of the road, two knolls of malleable iron that looked like aerolites; while I cannot hesitate to attribute the *Cerro de Mercado* to terrestrial origin, or telurico, for the reasons explained.

"The bulk of the aerolites known up to the present time is very small (insignificant), and though one which fell in Otumba, Peru, weighed as an exceptional thing 300 quintals (30,000 lbs.), the greater portion of them do not exceed from two to six pounds, and it is not hazarding much in saying that all the aerolites on our globe united would not compose the thousandth part of the mass of the *Cerro de Mercado.*

"The chemical composition of the aerolites is principally cobalt and nickel and iron, that are found in a natural or malleable state, but in the mass of iron in the *Cerro de Mercado,* nickel and cobalt are not found at all, and the iron is not in a malleable but in an oxide state. I have not had a moment's doubt in considering the *Cerro de Mercado* a volcanic eruption, denying thus the meteoric origin that has been so freely attributed to it." [Translation.]

Ward's *History of Mexico,* 1829, refers repeatedly to the *Cerro de Mercado ;* and it is claimed that the expedition which set out in 1558 to examine the mountain was the initial cause of the settlement of Northern Mexico.

During the three subsequent centuries of Spanish viceroyship the *Cerro de Mercado* was searched to find *toros de oro* (possibly pigs or bars of gold), *bancos de plata* (literally, benches of silver), buried treasures, and in short, for every sort of extravagance, except the iron that abounds in it, and makes it important, until in 1828 the Governor of the State of Durango contracted with an English mining company to establish iron-works on the right bank of the Tunal River. Concerning these works, Weidner in his report, the first edition of which bears date 1858, remarks:

"In 1828 an English mining company, under the patronage of the Governor, constructed on the bank of the Rio Tunal, on a site known as *Piedras Azules,* the iron works, which though renovated and modified at different periods, are the same and the only ones that are now in existence—under the name of the Iron Works of San Francisco. Prior to this, some planters, owners of farms, succeeded in fabrieating with the mineral of the *Cerro de Mercado.* in Catalonian furnaces, the simple iron which they needed to cultivate their lands in the vicinity of the said mountain; and others built furnaces of the same class without obtaining any satisfactory results from them." [Translation.]

In 1855 Julio Guillemin, M.E., mentions eight other iron-works in Mexico in addition to the above, of which he says: " A Catalonian furnace, established in the neighborhood of the Cerro *de Mercado,* has produced an excellent iron from the stones taken in their crude state from the mountain. This forge has running water and abundant fuel."

EXTENT OF THE DEPOSIT.

The general topography of the *Cerro de Mercado* is shown in Plate II., in which the letters indicate the following:

A. The point in the foreground of Plate I. from which the ore-supply for the *Piedras Azules* iron-works has been obtained.

B. The large pinnacle or turret of ore shown on the right of Plate I, surmounted by a cross.

C. A portion of the talus, abounding in apatite crystals.

D. Location of the deep shaft above referred to.

A, B, D, E, F, G and H, represent turrets and masses of ore corresponding with points indicated by similar letters on the margin of Plate I.

Concerning the dimensions of the mountain and its quantity, Sr. Weidner makes the following statement:

" The natural appearance of the *Cerro de Mercado* is exactly similar to other volcanic hills, its body forming a series of single cones with its summit crowned with elevations and peaks and that must be considered as so many centers of eruption closely connected and inclosed at the base by the rocks which surround it.

"To estimate in the first place the immense mass of iron that this hill contains, situated as it is about half a league from the city of Durango on the north, let us now take its longitude from east to west, which is about 1750 varas,* its width 400 varas, and its elevation above the level of San Antonio† 234 varas. We have as the result that the bulk of the hill is 60,000,000 of cubic varas. Also, as the specific weight of the mountain is five times greater than that of water, I found, as a second result, that the quantity of metal amounts to 5000 millions of quintals (250,000,000 net tons), which melted will produce at the rate of 50 per cent the quantity of 2500 millions of quintals (125,000,000 net tons) of metallic iron ; and by selling this at the rate of $10 a quintal ($200 per net ton), it represents a total value of 25,000 millions of dollars.

* A vara = 33.3 inches, or 2;784 feet.

† San Antonio is the plaza in the center of the city of Durango, nearly two miles distant.

"This refers only to the metal visible to the eye upon the surface; but we must believe that the quantity concealed beneath must be much greater than that which we find above, because this is always the case in metallic deposits of this class; and it is also proved by a little hill of a similar nature, that is about a quarter of a league to the east, rising some ten yards above the plain which extends to the rancho of San Ignacio. This little hill has probably a subterranean connection with the principal mountain, and the channels of each must penetrate into the bowels and depths of the earth in a manner similar to the roots of a tree, meeting there a great deposit of metal, of which the two hills contribute only a small portion, which, yielding at some remote period to the expulsion of subterranean gases, has burst forth in a state of fusion to the surface of the earth, cutting through the earthy crust and flowing out over it." [Translation.]

Sr. Weidner's method of estimating the quantity and value of the deposit is interesting, although not entirely novel to those who have read some reports made in this country upon deposits of the more precious metals.

It is hardly necessary to discuss the estimate, as defects are so prominent in it. Admitting (for it does not seem improbable) that there are 250,000,000 net tons of ore in the *Cerro de Mercado,* it could not be immediately mined, for on the basis he gives, the metal produced would amount to 125,000,000 net tons of iron, equal to six years' product of the world. And to pay interest at 5 per cent, on the fabulous valuation he gives would require the mountain to earn §1,250,000,000 annually, for which, even at the extravagant selling price he names, of $200 per ton (estimating one-half of this as profit), 12,500,000 tons of iron must be made each year, a quantity nearly equal to the combined output of pig-iron in Great Britain and the United States in 1883. At more modest profits, the quantity annually won must be correspondingly augmented.

Although the writer cannot indorse the above enthusiastic estimates, there is no question as to the immensity and value of this deposit of iron-ore, and his opinion of it can best be expressed by the following extract from a report he made in March, 1882, upon the *Cerro de Mercado.**

"I am free to say, that, after visiting most of the larger iron-ore mines of the United States, I have as yet found nothing to compare as to quantity in sight' with the *Cerro de Mercado* at Durango. I am fully aware what such a statement means, appreciating from personal inspection the immense quantity and great purity of the magnetic ores of the Adirondack and Lake Champlain regions of New York State, the incalculable wealth of magnetic ore stored in the Cornwall deposit in Pennsylvania, the extent of the hematites of Virginia, Alabama, Tennessee and Kentucky,

* Report made to Hon. W. L. Helfenstein, President of the Iron Mountain Company of Durango, Mexico, by John Birkinbine.

the large output and superior quality of the specular ores from Missouri, and the enormous shipments of rich iron-ores annually made from the upper peninsula of Michigan. Unless the physical and geological indications fail, I have no hesitation in pronouncing the *Cerro de Mercado* the most extensive known single deposit of iron-ore on the American continent, or, possibly, in the world.

" As the visible ore exists above ground-level, the facilities for mining will admit of obtaining it at remarkably low cost, and large quantities of it will require nothing more than shovelling into receptacles for conveyance to an iron-works.

"Just beyond the limits of the city, and less than two miles from its center, the *Cerro de Mercado* rises from the great plateau, a hill nearly one mile long, a third of a mile wide, and from four hundred to six hundred feet in height. The surface of the mountain exposing ore, so as to be classified as good mining lands, aggregates over. 10,000,000 square feet; but there are indications that the deposit is not all above ground, but extends beneath the plain from which its top projects.

"Considerable time was spent in examining the mountain, clambering over its steep escarpments and collecting samples from its surface. I am not prepared to verify some authorities by pronouncing the deposit a solid mass of iron-ore, although almost the entire surface exposes ore to view. I incline to the belief that the *Cerro de Mercado* is formed of one or more immense veins or lenses of specular iron-ore, standing nearly vertical, the fragments of which have, by the action of the elements for ages, been thrown down to form the slopes of the mountain as a talus; but the extent of this detrital ore is too great to permit of locating any foot or hanging walls. While the study of the formation is of great interest, it is unimportant for your present consideration; for the amount of ore ' in sight' is practically inexhaustible, and the question whether the mountain is a mass of solid ore, or whether the projecting turrets and precipitous battlements which arise from its slopes are parts of great veins or lenses, will not affect its value as a source of supply for generations to come. I have therefore not attempted to form an estimate whether the calculations made by others as to the number of hundreds of millions of tons of ore in the deposit could be verified or not.

"Not only was the surface examined, but old shafts and drifts, ant-hills in the talus, and every possible method of determining the contents of the mountain, were investigated, all showing the deposit to be one of great immensity."

An interval of two years has not lessened the favorable opinion formed of this remarkable mountain, which presents to the eye only masses of solid iron-ore or slopes of detrital ore relieved by no vegetation save occasional *cacti,* which exist everywhere.

CHEMICAL COMPOSITION.

A large number of samples were taken from various parts of the mountain to indicate the peculiarities of the formation. These were several hundred in number, and owing to their weight, the expense and difficulties of transportation, it became necessary to reduce the number and size of the pieces; but an effort was made to have representatives of all the peculiarities of the deposit and also of the various topographical sections. Twenty-seven typical specimens were forwarded to Mr. A. S. McCreath, Chemist of the Second Geological Survey of Pennsylvania, with a request to make an analysis to represent the average.

In the anxiety to obtain samples which could not be considered as *show specimens,* an average was selected which indicates what will certainly be below the practical mining yield in metallic iron.

On Plate II. apatite crystals are mentioned as abounding at C; and in the samples analyzed there were some of these crystals imbedded with ore-crystals.

Mr. McCreath's analysis of an average of all the samples collected from about 10,000,000 square feet of the surface is:

Magnetic oxide of iron,	2.071
Ferric oxide,	77.571
Manganic oxide,	.113
Titanic acid,	.71
Lime,	5.050
Magnesia,	.364
Sulphuric acid	.212
Phosphoric acid	3.041
Loss of ignition—water, etc	1 984
Silica,	7.760
Alumina, etc., undetermined,	1.124
	100.000
Metallic iron	55.800
Manganese,	.079
Sulphur,	.085
Phosphorus,	1.328
Phosphorus in 100 parts iron,	2.379

A second analysis of the average of samples from about 7,000,000 square feet of surface showed the following:

Metallic iron,	62.775	per cent.
Phosphorus,	.288	"
Silicious matter, including a little titanic acid,	5.240	"
Phosphorus in 100 parts of iron,	.458	"

In collecting specimens, the mountain was divided arbitrarily, and each sample lettered to indicate the topographical section from which it was procured ; the second analysis was made from ores from all the sections except three, in which the apatite crystals were abundant and prominent.

In addition to the samples of ore collected, a piece of pig-iron from the furnace, and a piece of bar-iron from the mill of the *Piedras Azules* iron-works, were also brought by the writer from Durango.

These were submitted to Mr. McCreath, and his report was as follows:

" The samples of pig- and bar-iron yield respectively the following results:

	Pig Iron.	Bar Iron.
Silicium	.771	.105
Phosphorus,	.428	.193

"The pig-iron contains less phosphorus than the average of our mill- or forge-irons. Although the percentage of phosphorus in the bar-iron is considerable, yet it is by no means excessive. Analyses by me of standard English and American wrought-irons show the following :

	No. 1	No. 2
Phosphorus	.248	.197

"No. 1.—Sir William G.Armstrong's Ridsdale iron, coil-bar, for gun-tube; best iron, four times worked. No. 2.—Ulster-iron, coil-bar, for gun-tube; extra best iron, four times worked.

" The small percentage of titanic acid shown by the analyses, will not be sufficient to materially affect the working of the ore in the blast-furnace.

"The phosphorus in the pig-iron seems to be about the average of what the pieces of ore would produce—ore containing .288 per cent, phosphorus, or .458 in 100 parts iron. Assuming that the pig-iron would contain 95 per cent, metallic iron, said pig-iron would contain .435 per cent, phosphorus, an amount agreeing closely with the percentage actually found in the sample analyzed, namely, .428 per cent."

The deposit is such that there would be no difficulty in selecting large areas where ore of a quality much superior to that shown in the second analysis could be mined. Mr. C. Gilbert Wheeler, of Chicago, examined some selected specimens of the ore, and reports their composition as follows:

Silicic acid,	2.133	
Titanic acid	475	
Alumina	890	
Lime,	1.325	
Magnesia	650	
Sulphuric acid	062	
Sulphur	122	
Phosphoric acid,	008	
Ferric oxide,	94.335	
Total	100.000	
Sulphur,	.147	per cent.
Phosphorus,	.003	"
Metallic iron	6.035	"

It is not to be expected that a deposit of such magnitude would present a uniform composition, nor does it seem improbable that large quantities of ore suitable for Bessemer purposes could be won. It should be remembered that Mr. McCreath's analyses are averages of samples of ore collected from 7,000,000 and 10,000,000 square feet respectively, while Mr. Wheeler's determination represents ore from a single locality.

As noted in the description of the *Piedras Azules* Iron Works, the ore as won yields 60 per cent, of metallic iron in the blast-furnace.

In connection with these later investigations, the composition of the ore as reported by Mr. Weidner will be of interest, and his statement is given below.

It will be noted that the analyst evidently sought for but five components, and made their proportions aggregate 100 in each case.

. "Five specimens of ore from the *Cerro de Mercado,* that the new director of the iron-works carried to the United States of the North, were analyzed by M. H. Boye, in Philadelphia, on the 25th of May of last year (1857), and they give in accordance with that attempt the following results:

	In a hundred parts of Metal are—				
Oxide of iron,	96.3	93.8	93.2	71.0	67.1
Silica	2.6	3.4	0.6	28.1	25.5
Alumina	0.1	1.2	0.5	0.2	0.5
Carbonate of lime,	0.3	0.0	0.0	0.0	0.5
Water,	0.7	1.6	0.7	0.7	6.4
Total,	100.0	100.0	100.0	100.0	100.0
Produce of pure iron,	66.77	65.3	68.8	49.23	50.55

"The ferruginous ores that are very common in other places, and almost entirely lacking in the *Cerro de Mercado,* are hydrate or yellow ochre of iron, and the carbonate or spar of iron. Equally and fortunately, we meet there very little of the sulphurous iron, that is commonly called *bronce blanco,* nor of the phosphate of iron, because the sulphur and phosphorus are not totally destroyed in melting, and always partially mingle with the iron, the sulphur producing red-shortness and the phosphorus cold-shortness.

"The *Cerro de Mercado* has also other advantages very essential to the working of iron, in having all the iron in an oxide state, as that is the class of ores most easy to reduce to metallic iron ; in having its ore almost entirely pure, and not mingled with rocks, stones, or other metals, that in other countries make a previous preparation unavoidable before they can be melted; and in containing a great variety of ferruginous ores, the mixture of which facilitates the smelting ; also v. g., the pure oxide of iron that needs earthy substances to form grease, is found here to cooperate with the other ores that abound in it. Aluminous ores, melted alone, attack the silica of the stones of the furnace, by forming silicate of alumina; on the other hand, metals overcharged with silica injure and destroy the iron, and the silicate so formed is lost in the dross, while, by mixing both ores, such annoyances are avoided; the silica of one ore becomes saturated with the alumina of the other, the grease melts, and the entire mass runs out clear and light, without any lumps, and with a good rendition of iron." [Translated.]

There is considerable interest in the above description, and the blast-furnace managers may look well to the liberal formation of "grease," so as to obtain good results. The word "grasa" in the original may be defined as grease or fat, but in this case should be rendered " slag." It is proper to remember that the first report of Sr, Weidner was made in 1858, that the chemical knowledge of ores and of furnace-operation was then limited, that the author was living in a country away from any actual metallurgical operations, and that the translation may be incorrect in details.

In actual developments most of the apatite crystals above mentioned could, if necessary, be mechanically separated, but there is little probability that the demands on the deposit will be such as to require any such attention for several generations, as these crystals appear in quantity on but a limited area of the mountain.

The appearance of the ore varies considerably, but the great masses are of compact specular character. Numerous specimens are covered with octahedral crystals, which would indicate a magnetite; but the ore gives the typical red streak of the specular ores. Professor B. Silliman, of New Haven, examined specimens of the ore, and wrote a monograph entitled, *Martite of the Cerro de Mercado or Iron Mountain, Durango, Mexico, and certain other ores of Sinaloa.**

From this article the following is extracted :

"At first sight the octahedral crystals of very various sizes suggested only magnetite, but the magnet failed to attract the ore, while the streak immediately indicated hematite, and left no reasonable doubt that the whole mass was martite. In the collection I find the crystals of martite of all sizes, from those measuring more than one inch on the side to druses of two to three millimeters. They are all simple crystals, the larger ones dull, sometimes iridescent, the smaller lustrous and quite black. There are no isolated crystals, like those found in the original locality described by Spix and Martins, and mentioned, with other Brazilian localities, by Mr. Derby, in his paper published in May of this year. All are firmly attached to the massive ore, some masses of which, in my hands, weigh ten to twenty pounds. There is nothing in the mode of occurrence of this ore, or in the chemical constitution, which lends any support to the opinion of Gorceix that martite is derived from

* American Journal of Science, vol. xxiv., p. 375, November, 1SS2, art. xiii.

the transformation of pyrite. In support of this statement I am permitted to cite the analysis of an average sample made up from twenty-seven pieces of the Durango ore collected by Mr. Birkinbine.*

" The powder of this ore is attracted by the magnet, but fragments of the size of grains of wheat are not affected by a magnet of moderate power.

" This enormous mass of valuable iron-ore, thanks to the near approach of the railway system of Mexico, is now likely to become of commercial importance."

A large specimen which has been in the writer's possession for over two years has been examined by many experts, some of whom pronounce it a superior specimen of martite. Mr. Theodore D. Rand, in examining it, called attention to what had been considered a fracture, and pointed out that it was evidently a decomposition-crack. Subsequent examination showed this to be the case, and the opinion that the slopes of the *Cerro de Mercado* are detrital ore, is strengthened.

OTHER MEXICAN IRON-ORES.

The existence of iron-ore in Mexico is not confined to the *Cerro de Mercado,* although that is undoubtedly the largest deposit of which we have any knowledge in the country.

In describing the *Tula* iron-works, a plant first erected in 1850, in the State of Jalisco, Mexico, and, in 1876, consisting of two blast-furnaces, four bloomary-fires, a rolling-mill, foundry, etc., Mr. J. P. Carson† gives analyses of a number of ores from the State of Jalisco. These are principally specular and brown hematite ores, and analyses of ten of them show the following:

Iron,	46.68	44.36	67.18	67.18	66.44	66.36	62.73	60.67	65.09	65.72
Phosphorus,	0.092	0.20	0.17	0.026	0.092	0.06	------	0.20	0.092	0.16

Dr. Persifor Frazer‡ has lately presented analyses of ores from the State of Coahuila, near Monclova, showing : Metallic iron from 54 to 63 per cent.; sulphur, 1.5 to 4.5 per cent., and no phosphorus.

The writer examined also a deposit of magnetic ore known as *Piedra Yman* or the *Carissal* Mountain, in the State of Coahuila, which presented the following composition as determined by Mr. C. P. Williams, of Pottsville, Pa.:

* See McCreath's report, above quoted.

† *Vide* Transactions, vol. vi., pages 398-415.

‡ *V*ide Transactions, vol. xii., p. 537.

Metallic iron,	57.75
Sulphur,	0.027
Phosphorus,	0.0349
Silica,	10.5C0

A determination made for the writer by Mr. A. S. MoCreath from a large number of specimens of the *Piedra Yman* ore shows the following composition :

Metallic iron,	64.025
Sulphur,	.004
Phosphorus,	.042
Lime,	.4.320
Silica,	4.240
Phosphorus in 100 parts of iron,	0.065

Specimens were also obtained from deposits near Rio Florido, in the State of Chihuahua, and from near Culiacan, in the State of Sinaloa. These last were analyzed by direction of Mr. E. P. North, C.E., of the Sinaloa and Durango Railroad, by Mr. J. Blodget Britton, of Philadelphia, and were found to have the following composition :

Locality.	Tepuche.	[illegible]	[illegible]
Metallic iron,	65.09	66.75	67.25
Oxygen with the iron,	26.93	27.35	28.01
Water,	1.20	1.87	1.06
Silica,	5.08	2.68	2.46
Phosphoric acid,	0.146	0.076	0.225
Sulphur,	none	none	none
Titanic acid,	none	none	none
Manganese,	0.08	trace	trace
Undetermined,	1.374	0.775	0.995
	100.000	100.000	100.000
Phosphorus in 100 parts of iron,	0.099	0.047	0.123

Other iron-ores than those above-mentioned exist in Mexico; but it is only in the southern portion of the republic that any attempt to work them is made, and there crude methods only are employed.

FUEL.

There is ample evidence, therefore, of an abundance of mineral, and it would be contrary to natural laws not to find accessible some fuel for smelting it. Coal is reported to have been found in various parts of Mexico, but the deposits have not been sufficiently opened to prove their quantity, or tested to determine their quality. Late advices say that coal has been found 40 miles from Durango, but no definite information as to quality or quantity is obtainable at present writing. But an industry of moderate size can find at Durango ample vegetable fuel convenient; for the Sierra Madre Mountains, which form the backbone of the republic, have numerous foot-hills and spurs which are generally well timbered with woods similar to those which are indigenous to our country. On table-lands and plateaus moderately watered the *mesquite* and *huysachic* woods abound. These are both hard woods, making a dense heavy charcoal, equal to that produced from hickory. The trees are low and spreading, the trunks and limbs being gnarled and twisted. A growth of either *mesquite* or *huysachic* resembles, in appearance and in the spaces between the trees, a mature apple orchard.

Wood is sold by weight or by the stick, and the universal custom is to buy or sell charcoal by weight, the prices ranging from six to twenty cents per arrova (25 pounds). Either of these fuels is ordinarily carried on the backs of burros (donkeys), 175 to 275 pounds at a load, although they sometimes are conveyed in two-wheeled vehicles. There are few instances where the charcoal is made in large quantities; the great bulk of it being the work of peons and Indians, who pursue this as a means of gaining a living. Consequently the yield is very low, and will not exceed 22 bushels per cord on the average, because small pits of 12 to 15 cords only are made. Again, there is a great waste of wood, it being cut a *vara* (33 inches) long. As the cord or bushel is not in use, no absolute data concerning the yield could be obtained. Charcoal can be obtained sufficient for any industry which can be maintained in operation until the railroad (now 150 miles distant) is completed to Durango, and this method of cheaper transportation can be emploved ; or, if mineral fuel is required, an iron-works at Durango will have to bring well-tested metallurgical fuels no further than some blast furnaces and iron-works in the United States now transport coke and coal. There seems to be, therefore, ample inducement to encourage the development of the *Cerro de Mercado.*

In the absence of mineral fuel, the gas-producer would permit the utilization of saw-dust, chips and waste wood, as in Sweden, or might possibly prove an economical method of using the grasses which abound in the neighborhood.

DEVELOPMENT.

It is difficult to realize that the citizens of Durango, living under the shadow of this great deposit of iron-ore, pay 25 cents per pound for nails, or 10 to 15 cents per pound for ordinary bar-iron and castings, or that rails, spikes, bolts, etc., for the street-railway now being constructed for the city of Durango, are purchased abroad, and brought at heavy transportation charges almost to the foot of this mountain of rich iron-ore. Yet such is the case, and no local efforts have been made to work the ore except, as above stated, on a small scale, at the *Piedras Azules* iron-works, the following interesting history of which is taken from Sr. Weidner's report (1858):

" The English company possessed the requisite capital, and constructed a dam on the river Tunal (which has secured them a motive power much stronger and more equally distributed than that of forty horses), and a blast furnace.

"By the time they commenced making metal their outlay had amounted to $250,000, and when they unfortunately failed in their first melting (because the stack of the blast-furnace had not been secured by bands of iron), they could not afford to make any new trials, and were compelled to abandon the undertaking, throwing no little discredit on a branch of industry that the people of Durango had built such sanguine hopes on in the future.

" In 1834 a new company successfully reformed all the metallurgical operations, adding to the blast-furnace Catalonian forges, constructing a machine for blowing moved by a great water-wheel, and other necessary apparatus, which increased the expense about $50,000. The result was, that they produced weekly from 50 to 80 quintals (5000 to 8000 pounds) of iron, with a consumption of from 1500 to 2000 arrobas (37,500 to 50,000 pounds) of charcoal, at a total cost of from 5500 to $800. The Catalonian furnaces were replaced in 1847 by Castilian furnaces, the owner pursuing the method of the previous years with some, though little profit, working in the same manner that his ancestors had worked, which in reality is that pursued in Vizcaya and the other side of the Pyrenees.

" During all this last period of ten years they have produced about 25,000 quintals (1250 net tons) of hammered and forged iron, which they sold in part as plates at the rate of $12 a quintal (12 cents per pound), and part as horseshoes and articles of agriculture and mining, at the rate of §20 per quintal (20 cents per pound). In 1857 the owner brought from England some intelligent metallurgists, and established at a cost of $50,000 more the method of working iron that is in vogue in civilized Europe.

"To the blast furnace then he has returned its reputation: the want of mineral coal he supplied with pine coal mixed with wood of green oak ; the blowing machinery that used to be so ponderous and slow he has replaced with a double-action cylinder. Formerly they worked the modest Catalonian furnace in the heart of a field full of brambles and briars of prickly Indian pear and cochineal fig-trees; at present, in the midst of smiling tracts of arable land the new edifices and offices of the iron works of San Francisco rise like castles, and the whirlwind of flame and smoke escaping from the high chimneys and furnaces of the establishment, proclaim that below them skill and industry dispute the palm. The problem of the successful attempt of working the iron of the Cerro de Mercado is solved.

"At the date of this article (1S58), having completed the first compaign in the blast furnace, which, for a period of seventy-five consecutive days, has produced in each twenty-four hours from 50 to 120 quintals (2} to 6 net tons) of iron, they have now a considerable store of pig-iron that in a little time, by means of the cupola, and by refining-furnaces now building, can be fabricated and converted into malleable iron. It is well known that the pig or cast-iron produced by the blast-furnace, on account of containing three to four per cent, of carbon is brittle, and consequently has a very limited use, but by destroying this mixture of carbon wholly or in part by a process of refining they obtain the steel, and all classes of iron of the quality that the intended use of each requires. Among the various large pieces of machinery that they have cast in this blast, I must mention a pair of cylinders (rolls), that after being turned and polished in a lathe of great size and elegant construction, brought from the United States of the North, are used in the said establishment for stretching and rolling the iron.

"The cast-iron that is obtained even from this first experiment is in part of the best quality, and of that gray color that according to the analysis of Bromeis indicates that it is mixed with 0.930 per cent, and mingled with 2.340 per cent, of carbon in a manner that makes the forged iron of this establishment fully equal to the best class of it in England and Sweden.

" By this particular system of melting they have dispensed with much of the work done by hand, and have reduced the consumption of coal from 40 arrohas to 20 per quintal of iron (from 1000 to 500 pounds of fuel per 100 pounds of iron)."

Twenty years later (1878) he writes that:

"During the twenty years which have elapsed since the first and second edition of this work, the ways of communication connecting Durango with the oilier States of the republic have not greatly improved, nor did the production of iron in those iron-works called San Francisco have any very notable increase. The actual owner would be willing to supply the State with the iron it consumes yearly, at the price of $15 per quintal (10 to 15 cents per pound), all ready fabricated; that is to say, at a price so low that competition of the imported iron in any other part of the country, or in any districts of the said State, would be impossible.

"In the iron-works at Mazatlan they receive from $6 to $10 per quintal (6 to 10 cents per pound) for castings, and sometimes $12 or $16 when they are refined and worked ; but, on an average, ordinarily only $8 a quintal ($180 per gross ton). In Durango, the lowest price is $15 per quintal ($336 per gross ton), which, with the cost of freight to Mazatlan, raises the cost to near $20 per quintal ($448 per grosston)."

Concerning these iron-works the writer made the following observations, in March, 1882, shortly after visiting them :*

" Five miles south of Durango, on the bank of the Rio Tunal, is the plant of the *Piedras Azules* (Blue Stones) iron-works, consisting of a blast furnace, 35' x 8'; a heating furnace, a puddling furnace, one train of rolls, two sinking-fires, one wooden helve-hammer, and three smith-fires.

"Power is obtained from a masonry dam across the Rio Tunal,giving a head and

* Journal of the United States Association of Charcoal Iron Workers, vol. iii., p. 8.

fall of seventeen feet. There are four water-wheels—two over-shot, one under-shot and one turbine; but the water-power cannot be depended upon all the year; and the practice at the *Piedras Azules* iron-works is to run the blast-furnace until a stock of pig iron accumulates, and then use the water-power to operate the mill, forge, etc., so as to work up the crude material.

"The blast-furnace is built of stone. The bottom of the crucible is 24 inches square; the top, which is 5 feet 6 inches higher, is 32 inches square. The bosh then slopes at an angle of 55° from the vertical, to 96 inches diameter. The crucible and bosh are built of sandstone, brought by wagons 200 miles. The shaft of the furnace is constructed of a silica firebrick, made from clay and crushed quartz. It runs nearly straight for the first 10 feet above the bosh, and is then drawn in by curved lines to the open top, 32 inches in diameter.

"Blast is delivered cold from two 2½-nch open tuyeres, the air being supplied by two iron blast cylinders, 60 inches diameter and 5 feet stroke, placed horizontally, and operated by an over-shot wheel. The charge is raised by hand-winch, on an inclined plane, to the tunnel-head, and consists of one buggy of oak charcoal, 7 to 10 *bateas* of ore, 2 *bale's* of a rotten limestone, and ½ *batea* of clay. These *bateas* are wooden dishes, and each contain two arrovas (50 pounds of ore).

"The charge may, therefore, be considered at from 350 to 500 pounds ore, 50 pounds limestone, and 15 pounds clay to 20 bushels of charcoal.

" The average daily product of the furnace is 60 quintals (6000 pounds) pig iron, the ore yielding 60 per cent, in the furnace, and requiring 1¾ quintals of charcoal to 1 of iron, equal to 175 bushels of 20 pounds to 1 ton (2000 pounds) of pig iron.

"Connected with the furnace-plant there is a puddling-furnace and a heating furnace, in both of which pine wood is used for fuel. There are also two sinking-fires, in which pig iron and scrap can be converted into blooms.

"A short wooden-helve trip-hammer, raised by four cams on a wheel revolving at right angles to the hammer-helve, is used for shingling the loupes and puddle- balls. The cams strike the helve back of the hammer-head, and a spring-piece assists in intensifying the force of the blow.

"The smith-fires use pine charcoal for fuel."

This plant makes less than 1000 tons of pig-iron per annum ; and its forge, rolling-mill, and foundry are the only local means of converting this pig-iron into merchantable products. The power is insufficient for continuous operation of all branches of the works, and the blast-furnace and mill work practically alternately.

It is not surprising that, in view of the advantages the deposit possesses, and the opportunity for disposing of manufactured iron at liberal figures, this mountain has become the property of a company of American and Mexican capitalists, who are taking active measures to develop it. A temporary blast-furnace is now in course of erection, and the equipment for a foundry and machine-shop has been sent to Durango, so that the company can convert its ore as far as possible into castings, etc., for a more complete blast-furnace plant, which is then to take the place of the temporary structure, thus saving a large outlay in transporting material. The immediate purpose is to complete a stone blast-furnace stack, which has been partially constructed, line it with refractory material, making a monolithic hearth, and place blowing-machinery in the machine-shop convenient to the boilers. The gases will be conveyed by iron flues to the boilers, and wrought-iron blast-pipe will connect the blowing-engine with the bustle-pipe of the blast-furnace.

The furnace will be operated with cold-blast until sufficient pig-iron is produced to supply the foundry and machine-shop for company purposes and general trade. A rolling-mill and nail-works, and other industries, are also contemplated by the Iron Mountain Company, to use the metal made from the ore of the *Cerro de Mercado.*

These works are located on the plain at the western end of the mountain, between it and a stream from which water for the plant will be taken, as shown on Plate II. A large tract of land has been purchased, from which a supply of wood is to be obtained to tatisfy for the immediate future the requirements of the plant in the matter of charcoal.

In Mexico iron has heretofore been a *precious* metal. To-day carts are there in daily use, into the construction of which no iron whatever has entered; and Mexican farmers employ a sharpened tree-knee in lieu of a plow. The construction of 3000 miles of railroad in Mexico within the last three years has awakened the people to a better knowledge of iron and its uses. Any effort, therefore, which places iron manufactures accessible to all classes of the people will be welcomed; and, when once its value is appreciated, iron will become indispensable. The small quantities which have heretofore been produced, and sold at extravagant prices, have made iron or steel in almost any form a luxury ; and when it can be obtained by the poorer people it will soon be recognized as a necessity.

The immediate uses for manufactured iron are as castings for household or other purposes; round and flat bar-iron for gratings to protect the unglazed windows of houses and prevent thieving ; for wheel-tires and running-gear of vehicles; for mining-bars and general smithing, nails, horseshoes, screws, wire, light mine-rail, skip-buckets and cars. The prospective requirements will embrace all classes of iron and steel manufactures for which the development of the country will produce a market.

Senor Romero, Minister Plenipotentiary of Mexico to the United States, estimates that the present population of Mexico is 12,000,000. Of this number about one-eighth live north of the Tropic of Cancer, which crosses the republic about 40 miles south of the city of Durango. Mr. Joseph Nimmo, Jr., says that the area of Mexico is 741,791 square miles,* and that the value of iron and steel manufactures imported from the United States into Mexico, in the year ending June 30th, 1883, was $3,395,528—this did not include rails, but it did include 1,503,990 pounds of nails and spikes. Many. of the rails and much of the iron and steel used in Mexico are imported from European countries, so that the aggregate consumption of iron in Mexico is sufficient to encourage the belief that any judicious development of the native wealth of iron-ore in the *Cerro de Mercado* will prove profitable. It is not to be expected that the immediate demands for manufactured iron will be equal to what they would be for the same number of people in the United States; but the rapid increase of mining, the extension of railroads, the investment of foreign capital and the influx of Americans will soon change the character of the people and make all kinds of iron or steel manufacture necessary.

The large importations demonstrate that already there is an extended market; and as the country is developed this will be yearly increased.

Much of this paper is devoted to extracts and quotations. Some of the former are from previous publications by the writer, and it was considered advisable to present them in this shape, rather than to republish them with slight variations of phraseology as new matter. Most of the quotations are from a report which contained so much of what was believed interesting and worthy of preservation that liberal use was made of it. The writer is not responsible for the translations; but they have been compared with the original Spanish report, and prominent inaccuracies which were discovered have been corrected. Sr. Frederico Weidner embodies in his report a lengthy geological treatise, accompanied by a map indicating the supposed formations; but it has not been considered advisable to incorporate it in this paper, because of its length ; the writer being unwilling to assume the responsibility of abridging it. The various extracts given from Sr. Weidner's report do not occur in the order in which they appear in the original; and hence asterisks have not been employed to indicate omissions.

* Commerce between the United States and Mexico, 3884, pp. 8 and 26.

THE BLAKE SYSTEM OF FINE CRUSHING.

BY THEODORE A. BLAKE, M. E., NEW HAVEN, CONN.

MORE than a quarter of a century has passed since the introduction of the machine known as the Blake crusher, the invention of Eli W. Blake, of New Haven, Conn.

Although originally designed for breaking stone for road-metal, its importance for crushing ores of the precious metals, and those of iron, copper, and zinc, as well as emery, phosphates, plaster, etc., was soon recognized, and for many years its use has been world-wide, and its construction so well known that no special description of it is deemed necessary.

Following its introduction, many different machines for the same purpose, containing the same essential features of upright convergent jaws, one of which is movable with respect to the other, but having some slight modification of such movement (generally a rubbing motion) or of the non-essential method of imparting motion to one or both of the jaws, have been offered to the public for sale and use, but have, as a rule, in time disappeared from the market.

If we seek for the reason of the success of the Blake crusher, aside from its simplicity of construction, we shall find it in the adherence to the principle of crushing by *simple pressure* and careful avoidance of attrition. In this lies the economy of power and of wearing-surfaces.

To reduce any hard and brittle material to a fine powder by many different methods—by attrition, impact, or percussion—is a comparatively easy matter; but to accomplish this by the employment of either of the above-mentioned principles involves such a consumption of wearing-surfaces (generally iron) or of power, that the numerous devices that have hitherto been presented to the public as solutions of the problem of fine crushing have proved utter and complete failures when tested with reference to the power employed and the wear of iron in doing their work.

Aside from the use of crushers with the harder ores, the only two methods of fine crushing in general use, and, in the writer's opinion, worthy of consideration, are by means of stamps and rolls; the former doing their work by percussion, the latter by pressure, provided they are properly run and fed, but generally by pressure and attrition combined.

It is not proposed, within the limits of the present paper, to enter on a detailed analysis of the comparative economy of stamps and rolls. Of the greater economy of crushing with rolls, as compared with stamps, the writer has no doubt, provided the material to be crushed by the rolls is already broken to a small and tolerably uniform size before being fed to them, and the feed is uniformly distributed in such a manner as to avoid any accumulation of material between them. If fed with such materials their tendency will be to wear evenly, and if accumulations of material between them are avoided they will not be thrust apart, their product vitiated, and unnecessary power consumed.

In crushing, either by stamps or rolls, efficiency largely depends upon the preliminary work with the crusher. To reduce any material fine enough to be fed to rolls, to secure the best economical results, it is necessary that it should be crushed to about corn-grain size, or say a quarter of an inch in diameter. When ore is reduced to this size by a crusher it is safe to say that from twenty to thirty per cent, of it will pass a fifty or sixty-mesh screen ; that is, a screen with from 2500 to 3600 holes to the square inch. If, then, so large a percentage of the material can, in a preliminary operation with crushers, be brought to such a fineness, why cannot the whole be reduced to the same degree of fineness?

The great difficulties, however, in crushing fine with an ordinary Blake crusher have been the liability of the material to pack in the jaws, and the greatly diminished product of the machine when the jaws are set so as to yield a fine product.

The solution of the problem of fine crushing will be found in making the discharging capacity of a Blake crusher, when set to crush fine, sufficiently great to permit the rapid discharge of the material as it is crushed. This requirement is fully satisfied by the writer's invention of *the* Blake fine or multiple-jaw crusher—a machine the value of which, when fine crushing is required, will, in the writer's opinion, prove to be as much greater than that of the ordinary Blake crusher as fine crushing is more difficult than coarse crushing.

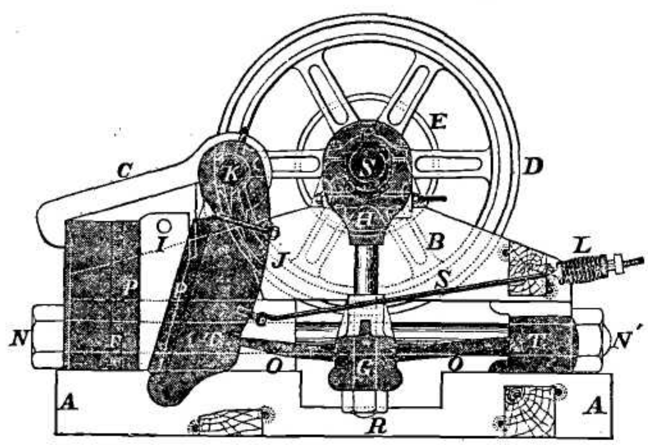
In the Blake fine or multiple-jaw crusher, while the principle of crushing is the same—that is, simple pressure between upright convergent jaws—the discharging capacity may be increased to almost any reasonable limit, even if the crusher is set to crush to a great degree of fineness.

The Blake system of fine crushing, then, consists in nothing more than the use of a series of crushers, beginning with one sufficiently large to receive the largest fragments and to give the required hourly or daily product, and ending with a fine or multiple-jaw crusher, from the product of which that which is sufficiently fine is withdrawn by screening or other methods of separation, and the coarse returned to the same machine to be still further crushed.

The following illustrations will serve to show the machines employed and the system:

Fig. 1 shows the latest and best form of Improved Blake Challenge Breaker—a construction that has proved of great and sub-

FIG. 1.



A A, lower timber-frame; B, upper timber frame; C, clamps; D, fly-wheel; E, pulley; HE, pitman; 1, cheeks; ,J, swing-jaw; K, swing-jaw shaft; N N, main tension-rods; O O, toggles.; P P, jaw-plates; R, pitman-rod nuts for adjustment of stroke of swing-jaw; S, eccentric shaft.

stantial value, not only on account of its sectional character, but also by its power of resisting the enormous and sudden strains to which it is often subjected.

Fig. 2 represents a Blake fine or multiple-jaw crusher, with seven jaw-openings, each twenty-four inches by half an inch, equivalent to a single crusher with jaw-opening or receiving capacity of one hundred and sixty-eight inches by half an inch.

FIG. 2

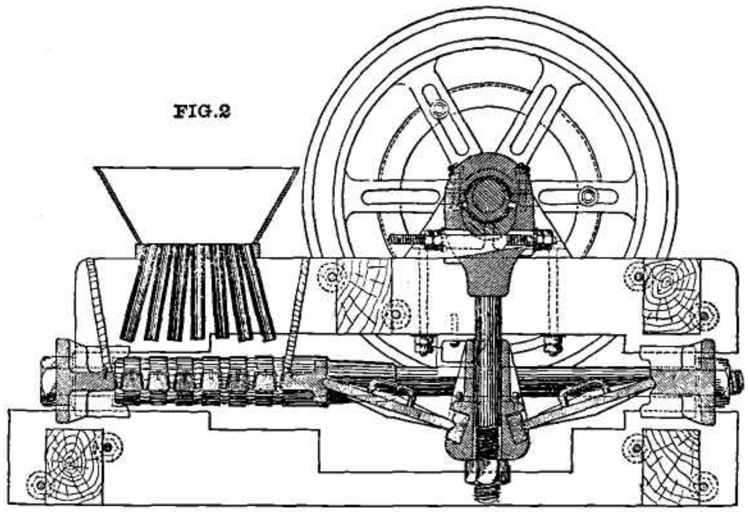
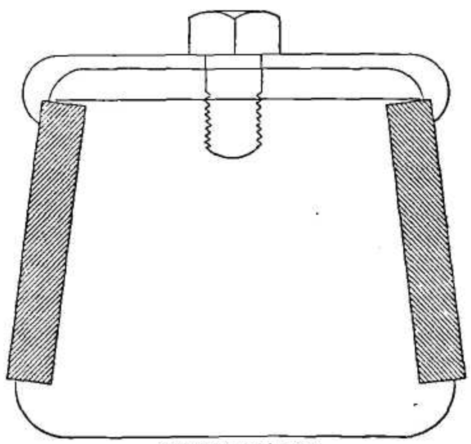


Fig. 3 shows a full-size cross-section of one of the series of sliding-jaws in a 24-inch fine crusher, with plates of 1½ by ¼ inch tool-steel for wearing-surfaces.



SECTION FULL SIZE
FIG. 3

Fig. 4 is a longitudinal elevation of one of the series of sliding-jaws in the same machine--one-eighth full size.

It will be seen that the crushing is done between a scries, in this instance, of sliding-jaws supported by and sliding upon the main

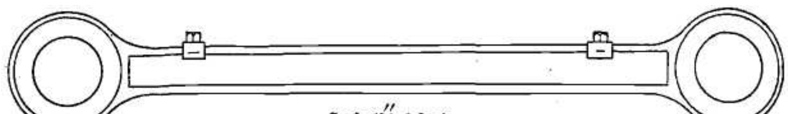


FIG.4

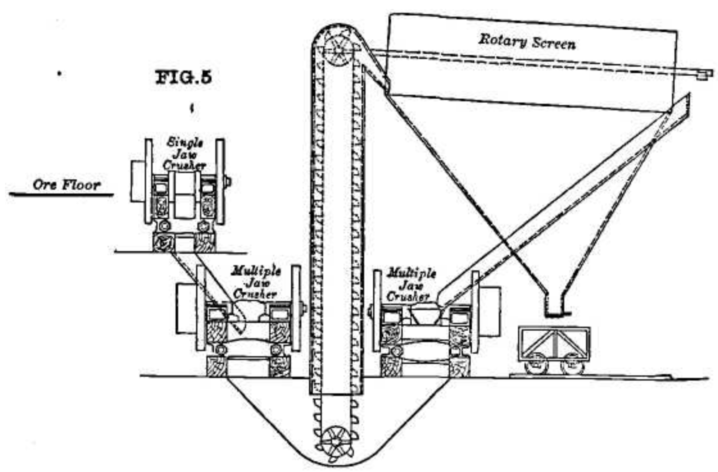
tension-rods. These jaws are separated and held by rubber rings placed between them on the tension-rods.

The method of imparting motion adopted is the same as in the regular Blake crusher, by means of the toggle-joint, pitman, and eccentric shaft.

The revolution of the shaft, bringing the toggles more nearly into line, throws the main sliding-jaw forward, thus compressing the whole series of sliding-jaws, the crushing pressure being transmitted through the material to be crushed, with which the jaws are supposed to be filled.

It is evident, that, if a piece of iron or steel should by accident get into one or more of the jaws, the only result would be to render that

FIG.5



jaw for the time inoperative, the motion that it would have with respect to the next succeeding one being taken up and distributed through the other jaw-openings.

Fig. 5 is a sketch illustrating the Blake system of fine crushing. In this series the first or single jaw-crusher is a 10 by 7 improved

Challenge. The second machine, to which the product of the 10 by 7 goes by gravity, is a multiple jaw-crusher with three openings, each twenty by two inches. The product of the second crusher, reduced to corn-grain size and dust, is elevated to a screen with holes of required fineness, and then screened, the coarse going by gravity to a (24 by ½) 7 fine crusher. The product of the fine crusher goes by gravity to the same pit, and is elevated and screened, the coarse returning to the fine crusher to be again crushed. In this way the entire mass of material may be reduced to almost any degree of fineness, the services of but one man to feed the first machine being necessary. The crushing may be either wet or dry.

It will be seen that, in the above-described plant, as the fineness of the ore increases we increase the discharging capacity. Beginning in the series with a discharge width of ten inches, we jump, in the second machine, to sixty inches, and in the third to one hundred and sixty-eight inches.

The number of single-jaw crushers to be employed in a series may, in some cases, of course be increased with advantage. The product of a 20 by 15 may pass to a 30 by 5, and so on, the discharge capacity rapidly increasing; and any number of Fife and multiple-jaw crushers may be employed.

We have in the Blake system, then, a system of crushing with crushers alone, and in the new multiple-jaw or fine crusher the old Blake crusher over again, so far as the principle of crushing is concerned, with an entirely new and completely effectual provision against breakage, due to the multiplicity of its jaws.

The results already attained have been so remarkable that the writer thinks it perfectly safe to assert that the problem of fine crushing has been, by this invention, completely solved; that the days of the old stamp-mill for ores of the metals, and the burr-stone for phosphates and cements, are practically numbered, and that they will shortly be replaced by a machine quite as simple and even more durable than the original Blake crusher, which was intended and is invaluable for spalling or reducing ores to a size suitable for further reduction by other means.

The first example of the Blake system is to be found at the works of the Chateaugay Ore and Iron Company, near Plattsburg, New York, of which Mr. A. L. Inman is the general manager, where the writer designed and placed a crushing-plant of the capacity of two hundred tons a day, from 10 inches to a size to pass a ¼-inch round hole. The works were run continuously, day and night, for six months, giving even an excess of the daily product required, but are now idle on account of the dullness of the iron market. The ore is magnetic iron in grains disseminated through a tough feldspathic gangue. Works for the same company, of a capacity of 1500 tons a day, are in contemplation.

The second example is at the works of Messrs. George H. Nichols & Co., or Laurel Hill Chemical Works, of which Mr. J. B. F. Herreshof is the manager, where a small plant, consisting of one 10 by 4 improved Challenge and one (24 by ½) 7 multiple-jaw crusher, was put in to crush copper matte. The requirements were one ton an hour to twenty fine. The machines replaced an 8 by 12 Dodge crusher and a pair of 24 by 12 Cornish rolls, of which the product was but about 500 pounds an hour to twenty fine, while the product of the Blake system, with machinery about one-third the weight, was 3000 pounds an hour, with an expenditure of less than one-third of the power required by the crusher and rolls.

The third example is at the works of the Orford Copper and Sulphur Company, Bergen Point, New Jersey, where a duplicate plant to that of No. 2 has just been installed. Other plants for gold-ores, phosphates, etc., are now on the way to destination for installation.

The results attained have already assumed such importance that I have deemed it desirable to announce to the members of the Institute the introduction of this new machine. I hope before long to give them the results in a more complete form, with comparisons of other methods of crushing based on actual and accurate statistics.

A NEW METHOD OF SHAFT-SINKING THROUGH WATER-BEARING LOOSE MATERIALS.

BY JAMES E. MILLS, B.S., QUINCY, CALIFORNIA.

IN the work of exploring certain gold-bearing gravels in the American Valley, Plumas Co., California, entrusted to my charge by Prof. A. Agassiz, of Cambridge, and Q. A. Shaw, Esq., of Boston, it became necessary to sink a shaft through loose materials containing in some layers large quantities of water, and I have been compelled to devise a new method which has proved successful and may be of service elsewhere.

The American Valley is a comparatively level tract of about 4500 acres, surrounded with steep mountain-slopes, which rise on the east, south and west to peaks of an elevation about 3600 feet greater than that of the valley. The floor of the valley is of loose materials, --gravels, sands, clays, etc. and these rest in a rocky basin. The lip of the basin at the lowest point of its rim, where the waters leave the valley, is 165 feet higher than the bottom of it where the shaft struck the bed-rock, and the surface of the loose materials at the shaft is 45 feet higher than the lip. There is, therefore, at the shaft a thickness of 210 feet of gravels, sands and clays, resting in a bowl which receives water from a large area of mountain-slopes. The shaft was sunk by the method to be described 20.7 feet further into the underlying bed-rock, making its whole depth 230.7 feet.

On geological grounds it was probable that the lower portions of the basin were filled with a mixture containing so much clay, that water would pass through it slowly; and I tried to reach this comparatively compact material by the ordinary process of excavating and pumping out the water;* but at 14 feet below the surface the inflow of water became 67 cubic feet per minute, and was fast increasing, and the material was fine and was running in under the shoe and caving down outside of the shaft. It was evidently impracticable to sink to any considerable depth through such material, under the pressure existing when the water was pumped out of the shaft, even if the water should not exceed the practicable limits of pumping.

Exploration with drill was then made and showed that for 60 feet the materials to be passed through were sands and gravels of a kind to run badly in places, and that below that depth, although the material as a whole was more clayey, there were at intervals strata of loose open sands and gravels as far as the drill went, which was to 170 feet.†

The depth was too great to permit the use of compressed air to balance the pressure of the water, and there was no way left but to sink the shaft without taking out the water. The Kind-Chaudron process was not available, for the material would not stand unsupported for more than a few feet, in places not more than a few inches,

* The shaft started for this purpose is shown at A Fig. 1 of the accompanying drawings. It was rectangular, and had an iron shoe, Aa Fig. 1, which was pressed down with jack-screws as the excavation proceeded, and plank " cribbing " was built in as the shoe descended.

† There were geological data for concluding that the depth to bed-rock was not more than 250 feet.

much less for the whole depth. A caisson must be carried down with the excavation, and be kept pressed against the bottom.

The caisson adopted (B, Fig. 1 of the accompanying drawings) is a cylinder of 55 inches outside diameter, of wrought-iron one-half inch thick, leaving inside diameter 4½ feet. It is made of rings four feet long, and the rings come together edge to edge, with edges accurately planned, and are joined together by butt-straps placed on the inside five inches wide and one-half inch thick, to which the two adjoining rings are rivetted. Each ring is of one sheet, the ends of which are accurately planed and brought together edge to edge, and connected at the vertical joint thus formed by a vertical butt-strap of the same width and thickness as the horizontal one, and, like it, placed on the inside. The caisson is therefore a smooth cylinder on the outside, but on the inside the butt-straps project inward one-half inch. The lower edges of the horizontal straps are chamfered, the upper edges left horizontal. The vertical straps are thinned at the ends to pass under the horizontal ones, so as to add to the projection of the latter not more than three-eighths inch. The rivets are three-quarters inch in diameter, countersunk at both ends, and 2½ inches apart from centre to centre in the rows, and the two rows at each joint are the same distance apart. The caulking was all done at the edges of the butt-straps. The lower part of the cylinder which was to withstand the greatest pressure was tested under a pressure, applied to the outside, of 150 pounds to the square inch.

The rings were put together in pairs where they were manufactured, making sections 8 feet long, so that there remained one horizontal row of rivets to be driven and one horizontal seam to be caulked, to each eight feet in length of caisson, at the shaft.

At the lower end of the caisson is a shoe (Ba, Fig. 1) of rolled steel one inch thick, welded at the ends of the sheet so as to make a continuous ring without vertical seam. Its lower edge is not quite horizontal, but bevelled so that the outer surface of the ring is one-quarter inch longer than the inner surface, making a cutting edge. It is scarfed to the ring next above; one half of its thickness being cut away all around for a length of three and a quarter inches, and the ring above lapping by for the same length, so as to rest on the shoulder of the scarf, and have its outside surface flush with that of the ring.

At the upper edge of the caisson there was always a butt-strap, projecting half its width. It would not do to bring to bear on this butt-strap the pressure necessary to force down the caisson; and a wrought-iron band (Bb, Fig. 1), an inch thick and four incheswide, was put there, resting on the edge of the main sheet, and surrounding the butt-strap, and projecting 1½ inches above the upper edge of the latter. The band was in halves, joined by bolts with nuts, as shown in the figure.

When the ground had been excavated, and the caisson pressed down until its upper edge was 8 feet below the working-floor, the band was taken off, another section rivetted on, and the band put on top of the latter.

As the excavation proceeded, the caisson was forced down by hand with screws, reinforced toward the last by a falling weight.

The screws acted directly upon timbers 14 inches square on the end, resting on the band above mentioned. The bottom of the timbers, which rested directly on the band, was shod with 9 inches wide of wrought-iron 1 inch thick. As the thread extended for only about 5 feet in length of the screws, blocking was put in between them and the lower timbers as the caisson went down, and removed when a new section was put on.

The screws, with their nuts and steps, are shown at C, Ca, Cb, Fig. 1, and need no further description, except that they were of strong cast-iron, called "gun-metal" in Boston where they were made, and there were anti-friction buttons of hard steel in the steps. They were six in number, arranged, as shown in Fig. 1, in two sets of three each ; but for the greatest part of the time only four were used, in two sets of two each. The nuts of each set were fixed into a timber 14 inches square on the end (D, Fig. 1), and this was held down against the thrust of the screws by four rods (E, Fig. 1) of round-iron, 1½ inches in diameter, which passed through it and a similar timber (F, Fig. 1) placed under the main shaft-head timbers; the rods having nuts at both ends, and cast-iron washers, a foot square, between the nuts and the surface of the timbers. The shaft-head timbers bore the weight of the hoisting-frame, and of a part of the building, and a load of gravel and clay, which was increased from time to time as became necessary.

One or more hydraulic presses, driven by the engine, would do the work much better, and at much less expense, than these screws. The pressure could then be kept even and constant while the excavation was going on.

The excavating was almost wholly done by a modification of the sand-pump used in sinking artesian wells, which I will call the drill-pump. It is shown at *G,* Fig. 1, and in Figs. 2, 3, 4. It is es-

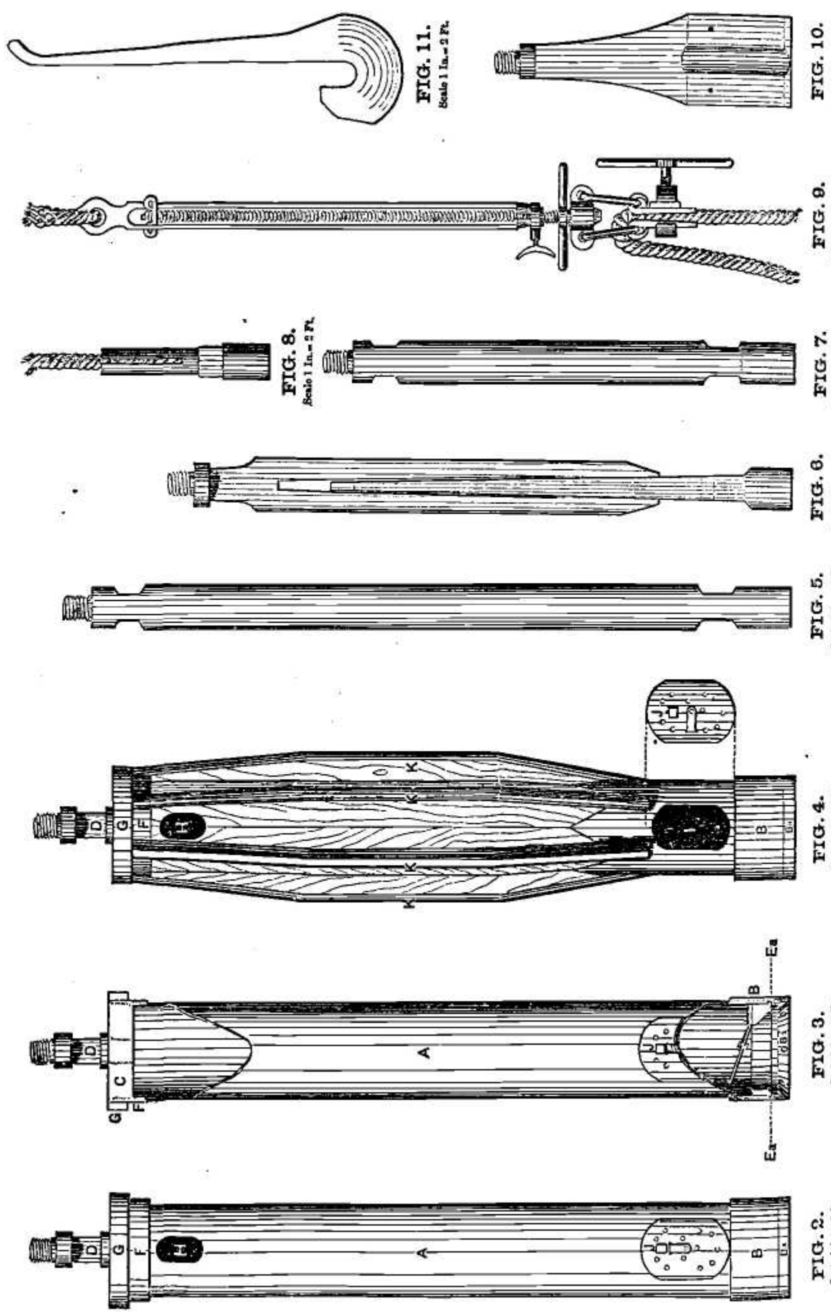


FIG. 11. FIG. 10. FIG. 9. FIG. 8. FIG. 7. FIG. 6. FIG. 5. FIG. 4. FIG. 3. FIG. 2.

sentially a cylinder or barrel, with an annular drill at its lower edge, and a valve seated just above. It will be more fully described below. The flat-drill, shown in Fig. 10, was made to be used in ground too hard for the drill-pump, and to break up large boulders, and was tried for these purposes a few times, but to little or no perceptible advantage. The drill-pump itself loosened the ground, broke up the boulders when too large to pass through the valve, and raised the material efficiently,

The auger-stem (H, Fig. 1 and Fig. 5), jars (I, Fig. 1 and Fig. 6), sinker-bar (J, Fig. 1 and Fig. 7), rope-socket (K, Fig. 1 and Fig. 8), temper-screw and clamp (L, Fig. 1 and Fig. 9) and wrenches (Fig. 11) were the same as are used in the oil-regions of Pennsylvania, where the tools were made, except that the auger-stem and sinker-bar were made shorter, and the necessary weight was secured by increased diameter, because the distance between the floor and the sheave (M, Fig. 1) was too short for tools of ordinary length.

The drill-pump could not have a diameter near that of the shaft, like the sand-pump of artesian wells, nor could it extend (like the drills used in artesian well-boring, and in the Kind-Chaudron process) across the shaft, so as to be brought to bear on the whole area of the bottom by being turned around. It was, therefore, hung from a movable point, so that its position could be shifted, and it could be placed over and dropped on to any part of the bottom of the shaft. This could hardly be accomplished with the walking-beam ordinarily in use in artesian well-boring; and the drill-rope, therefore, instead of being suspended from such a beam, was connected through the clamp and temper-screw with another rope (N, Fig. 1), which was attached by a loose wooden eye (O, Fig. 1) to the wrist-pin of the gear-wheel through which the drilling motion was imparted to the tools.*

This latter rope, on its way to the gear-wheel, passed over a rolling horizontal drum (P, Fig. 1, and A, Figs. 12, 13, 14), and between two vertical rollers (B, Figs. 12 and 13). The drum could be moved forward by a winch (Q, Fig. 1), and run back by a weight (R, Fig. 1), and the vertical rollers could be moved to right or left by a screw (C, Figs. 12, 13, and 14), and so the point of suspension of the tools could be placed over any part of the floor of the shaft, where the drill-pump was to work.

The hoisting-frame and machinery were the same that were put

* Such a connecting-rope is in common use in sinking small artesian wells by horse-power, but it passes over a sheave fixed in position.

in and are now used for ordinary hoisting and pumping, except that for pumping, a larger gear-wheel has been put in the place of the one which imparted drill-motion to the tools. The winding-reel (S, Fig. 1) was operated by friction-gear in raising the tools and load, and controlled by brake in lowering them.

The tools were let down, and the connecting rope attached by the

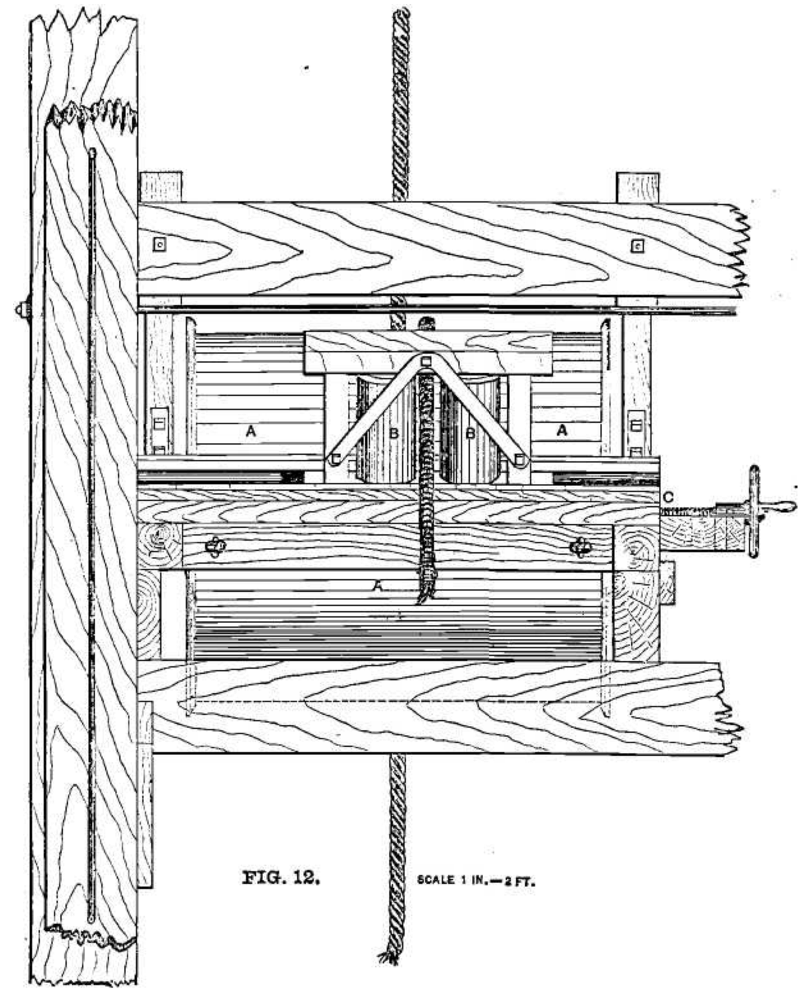
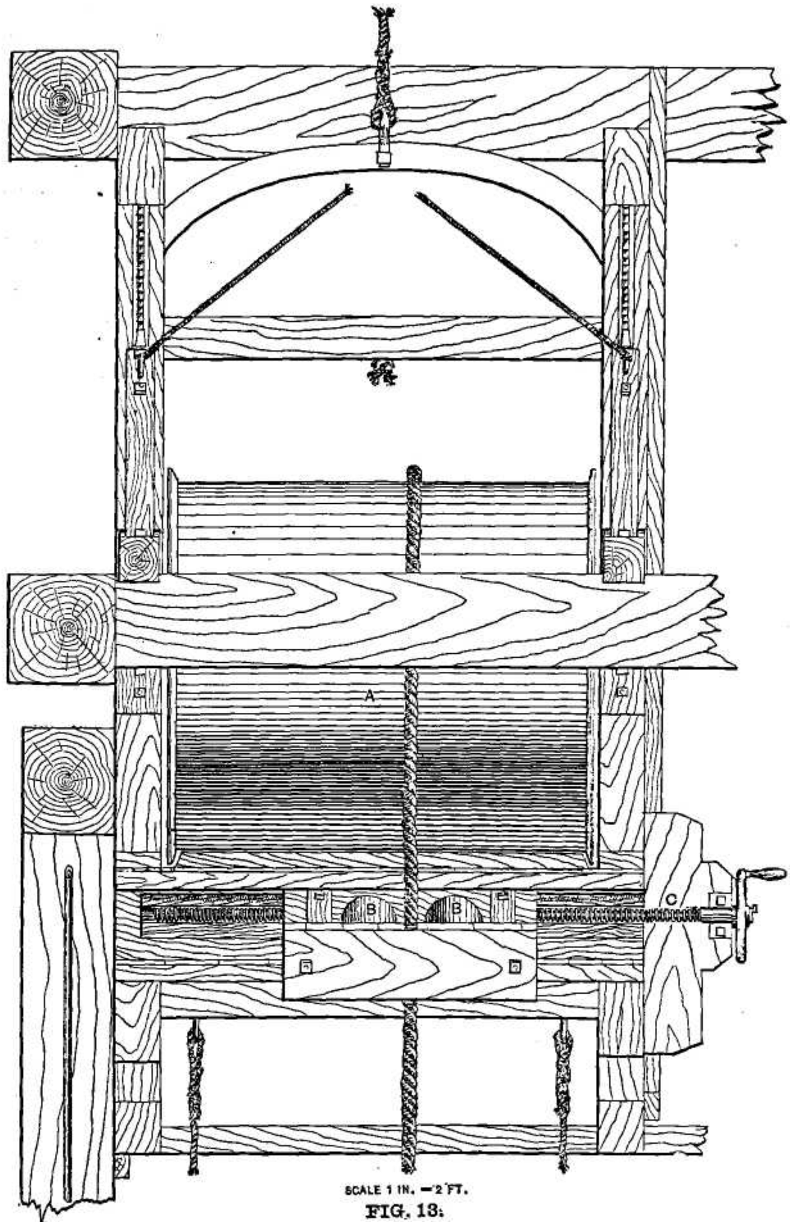


FIG. 12. SCALE 1 IN.—2 FT.

clamp La, Fig. 1, and put into place by moving the drum and rollers ; the main rope slackened above the clamp, and the machinery started, giving the lift-and-drop motion to the tools. When the drill-pump was loaded, the connecting rope was unclamped from the main rope and disconnected with its driving-wheel by slipping the



SCALE 1 IN. = 2 FT.

FIG. 13.

wooden eye from the wrist-pin, the drum moved back, the tools raised and the drill-pump emptied.

The drill-pump and its parts are shown at G, Fig. 1, and in Figs. 2, 3, 4. The whole length of the pump is 7 feet and 7 inches besides the connecting pin (D, Figs. 2, 3, 4), which extends 10½ inches above the head. The main barrel (A, Figs. 2, 3) is of wrought-iron, ¼ inch thick, with welded vertical seam; is 7 feet 1 inch long, and its inside diameter is 1 foot. The shoe (B, Figs. 2, 3, 4) screws on to the barrel at its lower end. Its cutting edge is formed by a bevelled steel ring (Ba, Figs. 2, 3, 4) which is fastened with set-screws to the iron of the shoe. The valve-seat (E) is held in place by a projection (Ea, Fig. 3) at its lower edge, placed between the shoe and the lower edge of the main barrel. The head (C, Fig. 3) consists of a wrought-iron plate, 3 inches thick, held to the barrel by a band (F, Fig. 3) screwed on to it and on to the outside of the barrel. The joint was made more firm by shrinking an iron ring (G, Figs. 2, 3, 4) on to the band over the edge of the plate of wronght-iron ; and to make the joint more secure, a similar wrought-iron plate should be put into the upper end of the barrel, and a ring shrunk on to the band over its edge. The pin (D), Figs. 2, 3, 4) by which the drill-pump is attached to the auger-stem, is screwed into the iron plate of the head as shown in Fig. 3. An opening (H, Figs. 2, 4) below the head let out the air as the drill-pump descended into the shaft, and the water above the load during the drilling. The load was taken out of the barrel through the opening (I, Fig. 4) just over the shoe, with a small hoe made for the purpose. The opening was closed by the gate (J, Figs. 2, 3, 4). To prevent hitting the butt-straps of the caisson with the sharp edge of the shoe and the upper edge of the pump, the guard of wood and iron (K, Fig. 4) was put on.

The weight of the tools as suspended was :

Pump,..	872½ lbs.
Auger-stem,..	692 "
Jars,..	385$ "
Sinker-bar...	436 "
Bole-socket, ...	54 "
Total, ...	2440 lbs.

To this is to be added the weight of the rope, which increased with the depth. But the weight of the rope, rope-socket, sinker-bar and upper link of the jars added nothing directly to the force of the downward blow, and aided it only by overcoming the friction of the rope in passing through the water. In fact the sinker-bar was omitted for the greater part of the distance, but toward the last seemed to be of some service, especially when the water was thick with mud. The wood of the pump-guard weighed about 72½ pounds when water-soaked, not far from the weight of the water it displaced, and neither increased nor lessened the force of the blow materially. There remained of the pump 800 pounds of iron, which with the 692 pounds of the auger-stem and the 193 pounds of the lower link of the jars made a weight of iron 1690 pounds. This, falling through water, is equal to 1472 pounds falling through air, with some deduction to be made for the difference between the frictional resistance of air and water, and some further deduction for the greater weight and frictional resistance of the water when heavily charged with mud in suspension. The weight and consequent force of the blow increased as the pump became loaded, and at times the weight reached nearly the equivalent of a ton falling through air.

The lift and drop of the tools when drilling which was found best fitted for safe and efficient working of the machinery, was 2 feet, and the number of drops 32 per minute.

When the drilling was going on, a man stood with his hand at the temper-screw to let down the tools by turning the screw as the drill-pump excavated, fast enough to render the blow effective, but not enough to permit the tools to topple over against the caisson. He could judge of the blow by the jar at his hand.

The length of time required to load the drill-pump varied with the character and compactness of the material; but it was generally kept in motion at the bottom 20 minutes. The raising and lowering, connecting and disconnecting at the clamp and wrist-pin, taking out the gate and the load, and replacing the gate took about 10 minutes more, making 30 minutes to each charge, or two charges to the hour.

The area of the cross-section of the caisson, including its wall, is 16.5 square feet, and the area of cross-section of the drill-pump 0.785 of a foot, or about 1/21st of that of the caisson. The material in the drill-pump was less compact than in place at the bottom of the shaft. A load of 1 foot in depth in the drill-pump would lower the bottom of the shaft about ½ inch, and a load—quite often attained—of 4 feet in depth of the drill-pump would lower the bottom of the shaft 2 inches, and 20 such loads in a day of 10 hours would lower it 40 inches. The latter rate of sinking was sometimes attained, but the average rate was much lower.

The caisson was put into the rectangular shaft A, Fig. 1, which had already been sunk 14 feet, and the space outside of the caisson and within the rectangular shaft filled with clay. The only settling about the shaft observable at the surface was within the rectangular shaft. It was but little, and as it took place, clay was added at the top.

Before the work was fairly started, some days had been spent in becoming accustomed to the work and making needed alterations in the tools; and during this time the caisson had been sunk 5 feet, or to 19 feet from the surface. The shaft and caisson were sunk the next 59.6 feet, or to 78.6 feet below the surface, in 41 working-days often hours each, or at the rate of 1.45 feet per day. This included the time spent in putting on new sections to the caisson, which was 13.6 days.

At this depth (78.6 feet below surface), the water was taken out of the shaft. The material passed through had become more compact from about 60 feet downward, and I had expected to sink from here by ordinary methods; but the inflow of water at the bottom, which was at first 3.2 cubic feet a minute, increased in about four hours to 5.3 cubic feet per minute, and it was plainly best to continue on with the method that had succeeded so well thus far. The caisson was in good condition, whole and water-tight; but slightly curved from end to end, so that the centre at the bottom was about 45/8 inches from a plumb-line dropped from the centre at the top.

After a delay of some months in getting more sections of caisson, work was resumed, and the shaft was excavated and the caisson sunk 102.4 feet further, or to 181 feet below natural surface, in 91 days of ten hours each, actually spent upon the work. This included 221/3 days spent in putting on new sections of caisson.

To this point the working force consisted of one skilled man to tend the engine, and two skilled drillers, and one or two laborers a portion of the time to aid at the screws, besides the engineer in charge. The working time was limited to ten hours a day, because the work was novel and it seemed hardly safe to have it go on in my absence, and also because I wished to observe carefully the character of the deposits passed through. The principal danger was that the excavations might be carried too far ahead of the caisson, and so cause caving and loosening of the material about the caisson. This would be obviated if hydraulic presses were substituted for screws as above suggested.

At the depth now reached (181 feet), the effect of the curve in the shaft began to be seriously felt; for the drill-pump hanging vertically from the top could not be made to drop on to all parts of the floor, and left untouched a crescent-shaped area under the over-hanging portion of the cylinders. The material thus left had to be partly caved in and partly crowded in by increased pressure on the caisson. The force at the screws was increased and consisted at times of six men ; and a few weeks later the pressure of the screws was reinforced by blows of a ram consisting of a stick of timber 21 inches square and 22½ feet long, weighing, with eye-bolt, nut and washer by which it was suspended, 2280 pounds. This was dropped two feet, thirty times a minute, on to a timber placed between the timbers on which the screws acted directly and the upper edge of the caisson.

Including the time consumed in putting on the ram, and putting on new sections, it took 23.5 days to sink the caisson the next 15.5 feet, to the depth of 196.5 feet below the surface. The excavation was 5.7 feet deeper.

The water was then again bailed out of the shaft. The curve of the shaft now left nearly half of the floor outside of the direct blow of the drill-pump, and in the area thus out of reach were bowlders of hard material and flattened shape, one of which was 0.44 cubic foot in bulk. These materials on the higher part of the floor were cut down by hand and thrown to the other side where the drill-pump could reach them, and then taken out by the drill-pump. In all, about four hours of time was spent in excavating by hand, and this was all the excavating done by hand in sinking the shaft.

At the lower edge, the shoe showed a slight bulge extending over about nine square inches of area, and projecting inwards about one-half inch at the middle of the bulge. Otherwise the caisson was unimpaired.

The inflow of water was varying, but at first averaged about 1.21 cubic feet per minute, and increased to about 2.34 cubic feet.

The next 13.5 feet brought the caisson to the surface of the bed-rock, at 210 feet below the natural surface. It took 23 days, including the time (4 days) spent in putting on two sections of caisson.

The bed-rook was a friable and rather soft clay slate, and was easily excavated with the drill-pump. The caisson was sunk 20.7 feet in the bed-rock, to the depth of 230.7 feet below natural surface. To sink this 20.7 feet in bed-rock took 46 working days, including all the time of excavating, pressing caisson and putting on the sections of caisson.

After a month's delay, the water was bailed out of the shaft. The caisson was in good condition, but somewhat deformed at its lower edge, not enough, however, to materially impair its usefulness. I think this deformation was caused by the bed-rock swelling and pressing against it unevenly.

The inflow of water varied, but averaged about 3.6 cubic feet per

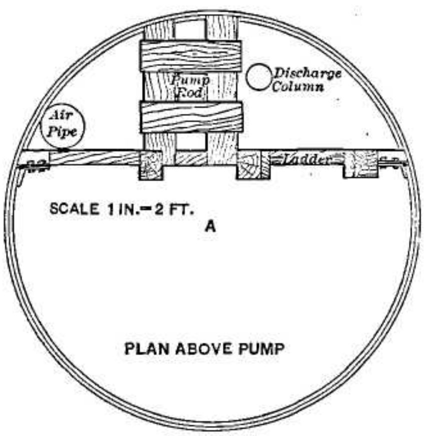


FIG. 15 *a*.

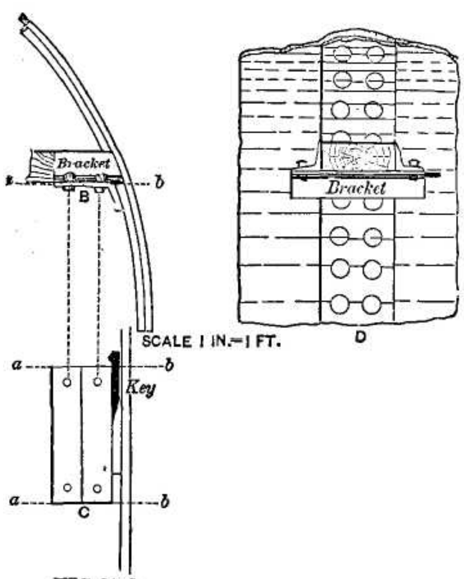


FIG. 15 *b*.

minute, or less than 5½ per cent, of the inflow at 14 feet from the surface. It came through the bed-rock clear, and was therefore not enlarging its channels.

The shaft had not only been sunk successfully through 210 feet of loose materials, and 20.7 feet of rock, but the caisson had shut out the water of the upper loose gravels and sands and of the lower layers of similar materials, had prevented the running in of sand, and left, to be contended with at the bottom, only a small inflow of clear water coming through rock.

A partition with ladder attached was put in as shown in Fig. 15, dividing the shaft into hoisting and pumping compartments, and a common "jackhead" pump, of 5 inches diameter and 4 feet stroke, was carried down at the same time with the partition.

A portion of the bed-rock was found loose and running; and where it was so, rods of round iron one inch in diameter, and three feet long, pointed at the outer end, were driven out into the bed-rock through holes drilled through the shoe, 2 inches above its lower edge, and 2 inches apart from centre to centre, and into the bed-rock as far as the rods were to go.

The shaft was then sunk by hand four feet below the lower edge of the shoe, for a sump, and secured by slaves driven around iron hoops. The staves were started about a temporary hoop of outside diameter 3 inches less than the inside diameter of the shoe, but the other hoops have the same inside diameter as the caisson, and when the staves were all in they were pushed outward and upward by the outer surface of the shoe so as to rest against it at their upper ends.

A row of iron rods like those before mentioned, were driven over the space where the opening for the drift or gallery was to be made, and just above the second butt-strap counting from the bottom. The opening was cut out through the caisson between the lower edge of this butt-strap and the upper edge of the shoe. The plan of the opening and the timbers at the beginning of the drift are given in Fig. 16.

As long as the work is one of exploration, kibbles will answer for hoisting; but when necessary, a cage can be used to occupy the whole cross-section of the hoisting apartment, and when still more hoisting room is needed, another shaft can be sunk near by, and one of the two given up wholly to hoisting, and the other left for pump, ladder way and ventilating pipes; and indeed the capacity can be increased to any required extent by sinking a group of such shafts near one another, but with space enough between them to prevent breaking down or disturbing the ground between them while sinking. Shafts much larger than the one here described, indeed, of any ordinary size, could be sunk by the same method.

All the serious difficulty which this method of sinking encountered was caused by the curve of the caisson; and this is an avoidable difficulty. The use of hydraulic presses, as above suggested, would obviate the danger of excavating too far below the foot of the caisson, and would reduce the working force to three skilled hands.

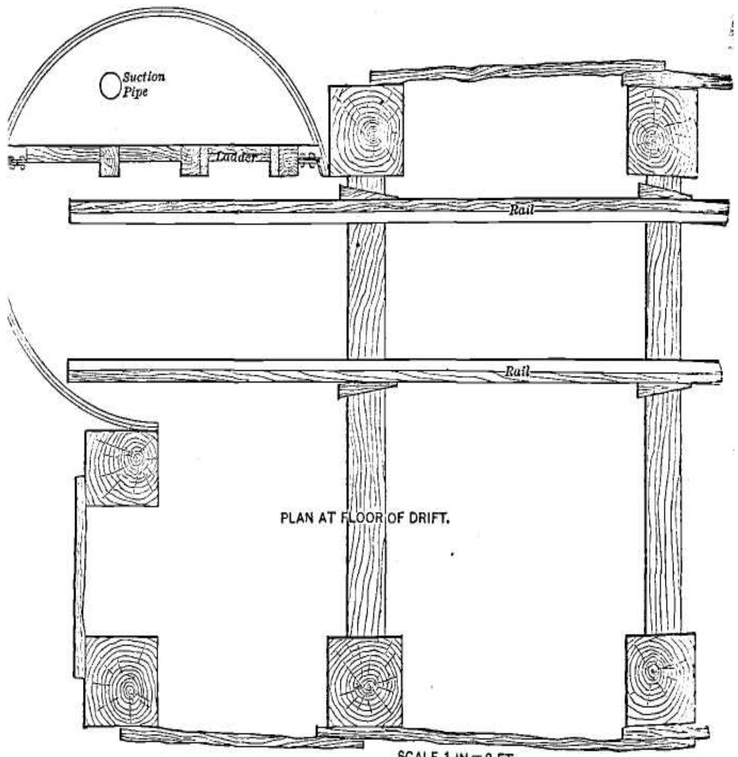
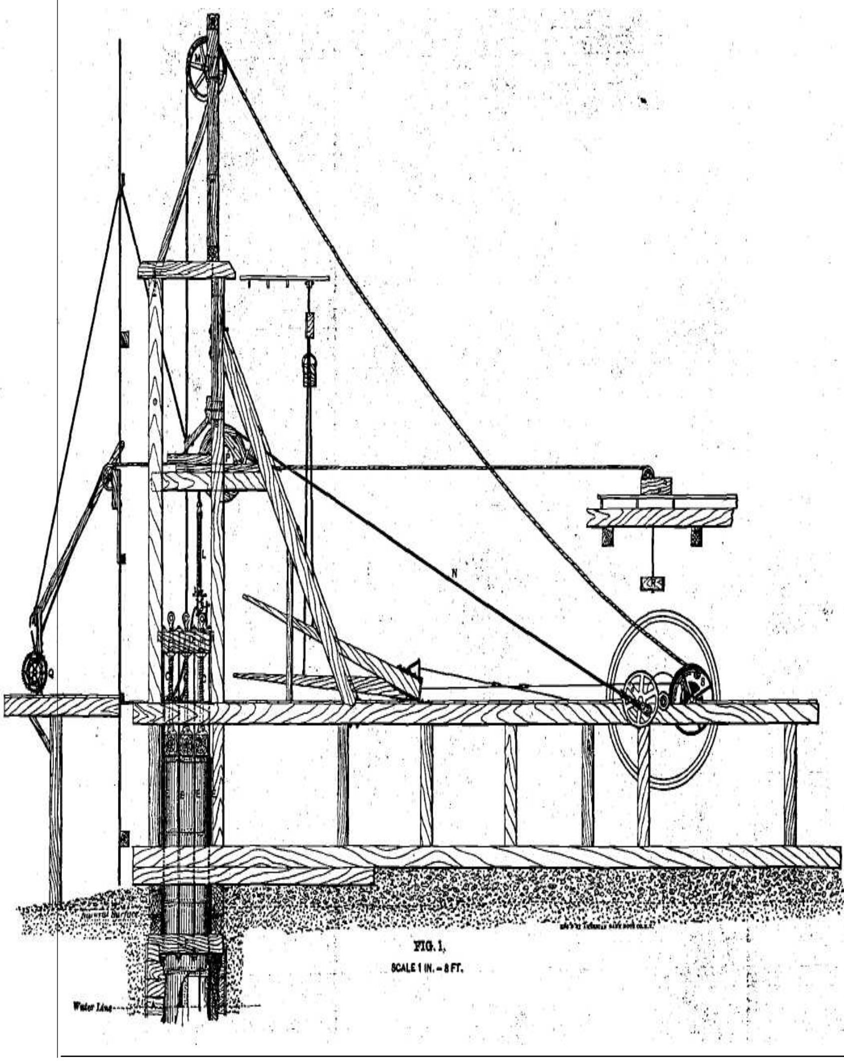


FIG. 16.

The method is not only an efficient one where ordinary methods would fail, but it is also an economical, rapid and safe method of sinking through water-bearing loose materials, and could be applied to sinking caissons for bridge piers and other foundations, as well as to mining shafts and large artesian wells.

I have given above the time actually spent in sinking. The work was not, however, done continuously, but in intervals of time spent partly in waiting for new sections of caisson to be made and transported to the ground, but principally caused by delay in ordering them. The drilling began August 21, 1882, and ended November 29, 1883. The tools were contracted for in March, 1882, and at



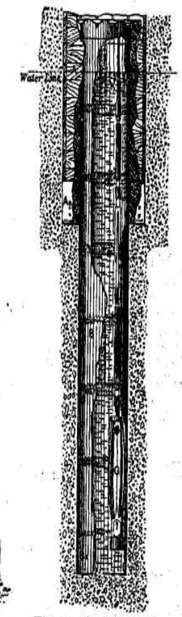


Fig. 1.—Lower Part.

the same time 80 feet in length of the caisson, with shoe, screws, etc. The remaining sections of caisson were ordered in several lots. The reason for not obtaining enough to go to the bottom after the experience of a few feet had proved the efficiency of the excavating tools, was the lack of data for judging of the friction to be encountered. If the caisson had been perfectly vertical, I could now present definite data for determining the friction to be overcome under similar conditions ; but on account of the curve in the shaft the necessary friction on the outer surface of the caisson cannot be separated from the added resistance of the materials at the bottom which were not reached directly by the drill-pump; and I can therefore add little on the subject to what is above shown, namely, that to the depth of 230 feet the friction on the outer surface of such a caisson carried through such materials is overcome with a pressure easily applied and safely within the endurance of a wroughtiron cylinder, having the thickness of iron proportioned to area of its cross-section as in the one above described, and having a shoe of rolled steel, proportioned as the one described.

NOTE.--In Fig. 1, the engraver has not reduced the ropes to scale. Their diameters should be as follows: Ropes N and M--S, 2 inches; P--Q, and P--R, 1 inch; and the rope passing up from Q,, over a small sheave, and down to pawl of ratchet of P, ½ inch.

NOTE ON TANTALITE AND OTHER MINERALS, ACCOMPANYING THE TIN-ORE IN THE BLACK HILLS.

BY PROFESSOR CHARLES A. SCHAEFFER, CORNELL UNIVERSITY, ITHACA, N. Y.

SEVERAL months ago, some specimens of the minerals occurring at the Etta tin mine, Dakota, were received at the laboratory of the Cornell University. On examining the heavy brownish-black portion, which I presumed was the tin-stone, I was surprised to find only a faint indication of tin. Further investigation showed the mineral to be tantalite. On searching carefully all the fragments received, a considerable quantity of that mineral was found, and only a single streak of cassiterite, which was attached to a mass of spodumene.

Another lot of specimens, from the same locality, consisted of samples of the greisen, some garnets, and a quantity of "stream-tin." The latter sample weighed about 500 grammes, of which about one-fourth consisted of small, pinkish garnets, averaging about the size of a grain of mustard-seed. The remainder comprised a lot of rounded brown pebbles, averaging in diameter ¼ inch. These were carefully examined with the blowpipe, and of thirty pieces six proved to be tin-stone; one, the largest of the lot, was hematite; and the rest were tantalite. Bo wolfram was found in any of the specimens, and I think it is a fair inference that the heavy black mineral to which Professor Blake alluded in his paper* as "apparently wolfram," is tantalite.

An analysis of the tantalite gave the following results:

Tantalic oxide,	79.01	per cent.
Stannic oxide,	0.39	"
Ferrous oxide,	8.33	"
Manganous oxide,	12.13	"
	99.86	

Specific gravity, 7.72.

So far, I have been unable to find the least trace of columbic or tungstic acids, or of any of the rarer metals. The Dakota tantalite is thus much simpler in composition than the mineral from Alabama, which, according to the late J. Lawrence Smith,† contains tungstic acid, as also oxides of zinc and copper in small amounts.

Pressure of other work has prevented me from analyzing additional specimens of the mineral; but I think it highly probable, from the fact that the color of the powder differs more or less in the different specimens, that they would give results varying somewhat from the above figures.

A third lot of minerals, from the same locality, received from a friend who obtained them at the office of the Harney Peak Mining Company, in New York city, presented precisely the same appearance as the specimens that I had received directly from the Etta mine, except that in the massive specimens the tin-stone was present to a very encouraging degree, though the tantalite was by no means absent.

In a report made to the above-named company, by Professor Gilbert E. Bailey, the following passage occurs: "No titanic acid,

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* *Eng. and Min. Journ.,* N. Y., vol. xxxvi., No. 11, p. 164, Sept. 15th, 1883.

† See Professor Smith's analysis, *Transactions,* vol. xii., p. 161.

wolfram, sulphur, arsenic, or other injurious substances were found in the ore."

So far as my knowledge goes, there may be no wolfram present, but there must be, instead, a very considerable amount of tantalite accompanying the tin-ore. As to arsenic, the first lot contained two large lumps of scorodite,--remarkably good specimens, with here and there kernels of leucopyrite. Further, one of the massive specimens of tantalite contained two little cavities which were filled with olivenite. From this it seems that arsenic does occur in at least three of the minerals which accompany the tin-ore. By proper concentration, however, it will be a very simple matter to remove the most of these arsenical minerals from the ore. But how to separate the apparently large amount of tantalite from the tin-stone is a matter which will, I believe, prove puzzling to the wisest metallurgist.

HADFIELD'S PATENT MANGANESE STEEL.

BY JOSEPH D. WEEKS, PITTSBURGH, PA.

MANGANESE has, until recently, been most highly esteemed as a good thing to keep out of steel. Its value in the process of manufacture has been fully recognized, but after it has played its part in the crucible or the converter, then the less of it the better. It is true that the mission of this metal and its influence upon the character of steel has been a source of much controversy. Our own Holley, in one of his special reports on ferromanganese, states that " it has been suspected by some, and believed by a few, while it is still denied by many, that manganese as an ingredient in steel has not only a body-giving and toughening influence, but a positive neutralizing influence upon any excess of hardening or cold-shortening substances, as phosphorus." In another paper on the same subject he states that " it should appear from such facts as we have that manganese toughens" the structural steels, " increases their soundness and prevents red-shortness." Notwithstanding these rather guarded assertions as to its value, the general belief, it will be found, is with Dr. Siemens, that manganese is " merely a cloak to hide impurities," and its presence in steel has been endured, not welcomed.

But whatever may have been the difference in opinion as to the effect upon steel of a small percentage of manganese, not to exceed, say, 1½ per cent., there has been a general agreement among metallurgists that any amount in excess of this would produce metal rotten and utterly worthless. In the Terre Noire experiments, referred to in Mr. Holley's report before quoted, 1 per cent, is the highest given as found in the steels reported upon. In a paper read by M. Gautier, of Terre Noire, before the British Iron and Steel Institute, on the " Uses of Ferromanganese," this same percentage is given as the proper amount to be used in the manufacture of what this distinguished metallurgist terms "manganese steels," while in all three of the papers the analyses of the steel show the usual percentage of manganese to be much below this. Indeed, from 1 per cent, to 1½ per cent, has been regarded universally as " high manganese," and the published testimony is that more than this renders steel worthless.

In opposition to these views, Mr. Robert Hadfield, of the Hadfield Steel Foundry Company, Sheffield, England, has demonstrated that a steel containing from 7 to 30 per cent, of manganese is not only not a rotten and worthless product, but that in the ingot as cast, it is harder, stronger, denser and tougher than most steel now manufactured, even when forged and rolled, and in addition it possesses curious and remarkable properties, which, it is believed, will make this steel exceedingly valuable for many purposes for which the ordinary steels are not now used.

In the samples of steel which, through the kindness of Mr. Hadfield, I am permitted to exhibit to the Institute, the manganese is from 9 per cent, in ingot No. 10 to 19 per cent, in the ax. No samples of the higher percentage have reached me. The bent flat piece contains 9½ per cent.; ingot 180 and the pit car-wheel which has been so badly hammered with so little effect, 11½ per cent.; the adze, 13¾ per cent.; and ingots Nos. 20 and 21,14½ per cent. The ax and adze are castings just as they come from the sand, neither forged nor hardened, and have been ground since I received them. These are rough specimens, the Hadfield Foundry not being adapted to this class of work, but with proper care in moulding and manufacture, such articles can be made as smooth and clean as cast-iron. Indeed, some of the most valuable characteristics of this steel are shown in casting. It possesses great thinness and fluidity, casts without misrunning, does not settle as much as ordinary castings, and does not draw, particularly at the junction of the thick and thin parts. It is also free from honeycomb and other similar defects.

It is evident that a metal that casts in this manner, and that needs no hardening nor tempering, must be especially adapted not only to the manufacture of most articles that are now cast, but for a wide range of articles that are now forged, rolled or hammered, such as the larger edged tools, hammers, picks, etc., guns; armor-plate, shell and other projectiles, car-wheels in place of chilled wheels, implements and parts of machinery, especially bearing parts, safes, steel toys, plow-steel, etc. A razor has been cast from this steel and used without hardening. It was not equal to the best steel razor, but it was a fair implement.

But perhaps the most remarkable and valuable of the properties of Hadfield's steel is its great toughness, combined with its extreme hardness—two properties that are generally regarded as incompatible. The toughness will be evident upon an inspection of the fracture of the ingots. The little steel needles scattered all over the face of the fracture, forming an acute angle with the face, show the character of the rupture to be entirely different from that of ordinary steel. These needles are very tough, and, small as they are, do not break off when struck, but bend almost like native copper. It also requires a blow of considerable force to bend them. It was exceedingly difficult to break these ingots, a number of blows of a steam-hammer being required, sledges having no effect. Ingot No. 10, with 9 per cent, of manganese, was broken from a piece 2 feet 6 inches long, supported at both ends. It bent 1 $^{1}/_{2}$ inches before breaking, though it had not been forged. Hammered samples from this ingot gave 42 tons (94,080 pounds) tensile strength, and 20.85 per cent, elongation in 8 inches. The flat piece—No. 180 (9 $^{1}/_{2}$ per cent.)—which has been hammered, was bent cold, and does not show the least crack. This piece has been drilled. The bulging of the steel under the drill-point is quite noticeable. This piece of wire was also bent cold after drawing. The small colliery-wheel (11 1/2 per cent.) was struck 50 blows with a heavy sledge, and bent as will be seen.

Notwithstanding this toughness, the steel is extremely hard. The lower percentages—say 9 per cent, to 10 per cent.—which are the toughest, can be drilled and machined, but not as readily as the ordinary steels; those somewhat higher with difficulty, while it is practically impossible to drill, turn or otherwise machine the higher percentages. The colliery-wheel, which bent so under the sledge blows, shows on the head and hub the results of attempts made in this country, at my request, to drill and turn them. The edges were taken off the tools instantly, hardly scratching the wheel. The ax (19 per cent.) and the daze (13| per cent.), as has been already stated, were sent me rough as they came from the sand, and were ground by Messrs. Hubbard, Bakewell & Co., Pittsburgh. Regarding the steel, Mr. Charles W. Hubbard writes me:

" The steel ax and adze we ground for you were extremely hard. There seems to be a peculiar close, hard, greasy nature about the material that resists the action of the grindstone and emery-wheel, as they have less effect on them than anything we have ever seen in the line of steel or iron. I would say the material has the very essence of anti-friction. A journal made of such material would run to an extreme number of revolutions in a sand-box without friction or heat."

I have not tested this ax, but one made in a similar way cut through 3/8 iron. I have already intimated that this steel can be rolled and forged. The lower percentages are more easily worked, but steel with as much as 18 per cent, has been hammered. The higher percentages require great care, however. One of the most remarkable properties of this steel exhibits itself in connection with hammering or drawing it. When thus manipulated, it becomes exceedingly hard and loses some of its toughness. If now the steel is heated to a hot heat, yellow or nearly welding, and allowed to cool in the air, or is cooled in water or oil, it becomes exceedingly tough. The flat piece, No. 140, was so heated and cooled before being bent. The wire was similarly treated after drawing, which made it extremely hard. This is virtually annealing, but it will be noticed that it has an effect upon Hadfield's opposite to that upon carbon steel. It should be noted that this steel is non-magnetic in bulk and a poor conductor, though fine drillings and scrapings are attracted by the magnet.

The process of manufacturing this steel is exceedingly simple. Melted ferromanganese high in manganese (Mr. Hadfield suggests 80 per cent.) and as low as possible in carbon, silicon and other foreign bodies, is added to iron that has been nearly or quite decarburized, or to molten steel. The manganese is thoroughly incorporated by stirring, and the steel poured into ingots or other suitable molds. The percentage of ferro to be used, and consequently the amount of manganese in the steel, must be raised according to the use to which it is to be put. No absolutely exact proportions can be given. To produce a steel suitable for armor-plates, sufficient ferro to give, say, 10 per cent, manganese in the steel should be added ; for car-wheels, axles or railway-plant, say 11 per cent.; edge tools and steel toys, 12 per cent.

THE POCAHONTAS MINE-EXPLOSION.

BY J. H. BRADIWELL, ROANOKE, VA.; STUART M. BUCK, COALBURG, W. VA.; AND EDWARD H. WILLIAMS, JR., BETHLEHEM, PA.

(A Committee Appointed by the President of the Institute.)

THE Southwest Virginia Improvement Company began operations in the Bluestone Flat-Top coal-field, situated in Tazewell County, Virginia, in the fall of 1881. In May, 1883, the company had built 200 coke-ovens, and by March, 1884, had 9000 feet of entries, exclusive of air-ways, in the Nelson or Big coal-bed of this district (which here averages eleven feet in thickness), and had extracted 200,000 tons of coal, representing an area of about twenty acres. About this opening has grown the recently incorporated city of Pocahontas, and the completion of the New River branch of the Norfolk and Western Railroad to this point enabled the company to make large contracts for supplying coal and coke, so that it was deemed necessary, on account of the limited area developed, to work the mine day and night to fill orders.

At 1.30 Thursday morning, March 13th, the inhabitants of Pocahontas were awakened by a violent shock, and within a few minutes all knew that the East mine had been the scene of an explosion of so general a nature that, of the 114 men at work, not one had escaped. The daily papers gave more or less distorted accounts of the number of victims, the scenes in and about the mine, and the probable cause of the disaster.

At the request of the company, the President of the American Institute of Mining Engineers appointed the undersigned a committee of three to investigate the matter, and the committee thus constituted presents the following report, accompanied by a copy of the testimony taken during the investigation, for preservation in the archives of the Institute.

Pocahontas was reached on Thursday, April 24th, and left on Friday, May 2d. During this interval the committee made repeated visits to the mine, especially to the points of most importance, examining it carefully in every part, and summoned a number of witnesses, twenty-six of whom appeared and testified.

The mine had been left in the same state as when the bodies were removed, in order that tests for gas might be made as well as that the traces of the explosion might not be destroyed.

On the part of the miners, and especially of the mine-boss, lately discharged, there was a determination to withhold all information, as they thought the investigation to be a company affair, and did not wish to neutralize whatever effect their testimony might have should legal proceedings be begun by the relatives of those lost in the explosion. Much valuable time was consumed in removing this impression. In addition to this, a great number of the men who worked in the East mine on the day-shift had gone to other districts, and much valuable testimony was lost. In fine, had a thorough investigation been undertaken at once, when all interested were on the spot, and before there could have been any collusion on the part of those interested in withholding and distorting the facts of the case, a much greater value would attach to the direct testimony in regard to points now at issue. The best method now remaining, of solving the questions involved, will be tests made at the mines for the presence of gas after the mine is again in full operation.

After viewing the effects of the explosion as exhibited at the entrance to the mine, it is almost incredible that so little damage has been done to the mine itself. In undertaking this investigation the committee had regarded themselves in the light of possible martyrs to science, and take pleasure in reporting that, while in some places the timbers are raked out and the wooden track torn up, with here and there a local resultant fall of fire-clay, on the whole the mine is little the worse for the explosion, and two or three weeks' work will remove all traces.

The accompanying map will facilitate the comprehension of the committee's observations and conclusions. In explanation of it, we may remark that the course of the main entry from the mouth at the lower right-hand corner of the plate to the face near H is nearly north. The letters "1 E," "1 N," etc., indicate the various entries and cross-entries hereafter referred to. The positions of doors are shown by D, D. The heavy arrows indicate the normal course of the ventilating currents, and the light arrows the course of the explosion-currents, while the places where bodies were found are marked with crosses. The robbing of pillars in progress in the area F, is shown by shading the portions removed.

The explosion probably originated in the north branch of the third east entry (near D), and spread in all directions. One portion of the current went westward and northward to the headings of Nos.

1 and 2 north off No. 3 east, to those of the main entry and air-way (near H), and of 4 and No. 5 west (near K); another part went south through the region C, where the dust was deep and dry, and here its power was increased by this agent, while throughout this area its greatest effect is exhibited. At the second east entry, part went west to the main entry, turned northward to the third west, went along this and traversed the area G, while the remainder continued south through the area B, and received further increase of force. On reaching No. 1 east, a part turned eastward, extending to the headings of this entry and its air-way and traversing the area A, while the rest turned west, tearing up the track, raking out the props, and blowing track, props and cars out of the main and intake openings.

The rebound from the area G crossed the third west in part and traversed the area F, while the remainder went west and out of the fan-opening, wrecking the fan. Part of the westward current along No. 1 east was deflected northward in the main entry, and went partly through No, 1 west and the area E, while the rest went out No. 2 west with the part that came south from G.

The current carried a burning body of gas and dust, the latter in all states of coking; and all the bodies, with a few exceptions, were found badly burned. Owing to the length of time between the death of the men and the removal of their bodies, the latter were in such a state as to make an examination as to the amount of asphyxiation an unpleasant if not absolutely impossible task. In some cases the evidences of burning had been destroyed by the submergence of the bodies in water. The evidences, therefore, of the relative amounts of fire in the areas mentioned have been gathered from the mine itself; but it may be well to state that conclusive evidence has been adduced that within five minutes after the first explosion there was not a man alive of those in the mine; so sudden and so general had been the catastrophe. The attempts to enter the mine immediately after the explosion have been described in the daily papers and will not be narrated here, as all were fruitless from the fact that there were practically no experienced men on the spot. It was not as if the disaster had occurred in a thickly-settled mining region, with numerous collieries to contribute their quota of men experienced in similar cases. In this little town, cut off from the world, with so large a percentage of its population killed at an instant, the leadership among the miners fell upon a boss who knew nothing of gas and its workings, and who, after making one or two aimless attempts to enter the mine, retired to bed and remained there for a fortnight, while a feeling of horror pervaded all and disposed everyone to magnify whatever was seen. When, therefore, the parties returned with practically the same story, it was accepted as proven that the mine was a mass of fire; and it was decided to close the openings until experts from abroad could give needful advice. These experts counselled sealing the mine and smothering the fire. Under the circumstances perhaps this course was wise, as, had the ventilation been restored while any of the coal-dust was still glowing and fire lingering among fragments of smouldering timber, a serious conflagration might have been started and the mine ruined.

The mine was closed by building double dams with clay stoppings, and an attempt was made to flood the workings. As they were toward the rise, this was impossible from the compression of the air in the upper workings, which brought such a pressure upon the clams as to cause large crevices and a corresponding leakage. To remove the air and relieve the pressure, a bore-hole was sunk to strike the extremity of No. 3 north off No. 1 east, and so accurately had the mine-surveys been kept up that the entry-center was struck within a few inches. This allowed the water to flood about one-eighth of the mine, while the air, as it escaped through the hole, showed that the fire was extinct. After draining the workings and removing the clams the bodies were removed, and only such changes made as were absolutely necessary, the position of the bodies being noted and marked on the mine-map.

SYSTEM OF VENTILATION.

Previous to the explosion the Pocahontas Mine was divided, for purposes of ventilation, into two distinct districts. The first embraced the areas E, F, G, with the intake at the crop-openings of Nos. 1 and 2 west. The air then crossed the fan-entry No. 3 west by a bridge, passed up No. 2 north and returned by No. 1 north to the fan-entry, where it joined the main return-current and was drawn out by the fan.

The second and larger district consisted of that portion of the mine east of the main entry, together with the main headings and those of Nos. 4 and 5 west. The intake was by the air-course at the side of the main entrance. The air passed to the head of No. 1 east, and, returning, was led up No. 4 north and back on No. 3 north, then to Nos. 1 and 2 north, the division between them depending on the drag. The current was deflected by canvas doors up the first room on each side, and passed through the areas B and C in succession ; then, as there was no door to force it up to the headings of No. 3 east, it passed to the main air-course, and thence to the head of the main entry, by which it returned to No. 3 west, and, being joined by the current from the west district, passed direct to the fan. The doors were all single.

There was no provision for measuring the division of the air between the two districts or the total amount passing through the mine, but from the speed and capacity of the fan the average amount of air was estimated at 70,000 cubic feet per minute.

A coal-hurning locomotive was run to the head of the main entry and for short distances inside of the doors leading to the cross-entries ; but no provision was made for keeping the smoke on No. 1 east cross-entry from mingling with the general ventilating current.

All the impurities of the mine were thus led around the workings and concentrated in their course, while, to increase the difficulty, the work was pushed day and night with a force of inexperienced men, using at least twice the quantity of powder properly required.

The door-service on the night-shift was imperfectly performed; and the committee has been able to show, by concurrent testimony, not only that doors were frequently left open, but that on the night of the explosion and for a part of the time during the fortnight previous, the two most important doors--at the junction of the main entry and No. 1 east--were left open, untended and hooked back.

SYSTEM OF MINING.

This is clearly shown on the accompanying map, and may be described as pillar-and-stall worked out in panels or blocks.

The mine has been opened by a main-level gangway, No. 1 E., with parallel air-way along the strike of the seam, off of which a system of double cross-headings are driven at right angles up the "rise," intersected at intervals by double cross-entries parallel to the main-level gangway, thus dividing the coal into blocks or panels of 500 feet X 1500 feet (bisected in length by extra cross-heading, *e. g.,* No. 2 E.), with rooms turned off to the right and left of the double cross-entries.

The main gangway and cross-headings are driven 10 feet wide and 8 feet high; pillars are left standing, 100 feet in thickness, on either side of the main gangway ; and pillars of 30 feet are left between entries and air-courses. These pillars are broken through every 100 feet for ventilation.

The rooms are started 9 feet wide, and at about 7 yards are widened out to 18 feet. Pillars between rooms are 15 feet thick; from 2 to 3 feet of coal is left in the top to keep up the friable shale overlying the coal; two parallel rows of single props are set in the rooms, the lines of the rows being 6 feet apart, and the props in the rows stand 10 feet center to center; wooden tracks are used in the rooms, and laid next to the upper pillar, and ballasted with coal-slack. The top coal is drawn when the pillars are robbed. This takes place in each panel or block as soon as the rooms are worked out to their boundary and simultaneously with the general advance work "in the mine. By this system the extent of workings to be kept up is greatly reduced and concentrated and the coal won from the pillars still firm and in good condition. The coal won in the advance, exclusive of robbing pillars, is estimated to be 30 per cent, of the entire bed. The final work will leave 20 per cent, in the mine.

The coal is collected in cars of two tons capacity and brought by mules to sidings on the east and west headings, near their junction with the main gangway. From these sidings the coal is taken by a mine-locotBotive to the tipple, and the empties are returned.

GENERAL CONDITION OF THE MINE, APRIL 24TH, 1884.

On the 9th of April, nearly one month after the explosion, the mine was relieved of the water-dams, and on that day it was entered by Mr. William Moody, the mine-superintendent now in charge, with a party of experienced miners from the Wilkesbarre District of Pennsylvania, to recover the bodies of the dead miners. His narrative of exploration and recovery in the accompanying testimony is a clear and graphic recital of the appearance, condition and attitude in which all the bodies recovered were found.

His opinion as to the probable position and action of the miners in the different sections of the mine at the moment of the explosion is well drawn, and has been valuable in assisting to form some conclusions relating to the possible condition of the mine and miners at the moment of the explosion. On the afternoon of the 24th of April the committee, accompanied by Mr. Moody, made their first entrance into the mine. The first general impression, on passing through, was caused by the apparently small amount of serious damage done to the workings. Notwithstanding extensive areas had been completely swept of their timbers and props, very few falls were encountered.

Strikingly noticeable, in the second place, was the large accumulation of coal-dust and soot, similar in appearance to lamp-black, distributed throughout the different sections of the mine. The bodies had already been removed, but otherwise the mine was apparently in the same condition as it had been left immediately after the explosion, except in the small flooded area.

The superintendent had given instructions that nothing should be disturbed, except where it was necessary to remove obstructions in the gangways in order to carry out the bodies. This greatly facilitated the work of the committee, and its correctness in minor details, relating to the spread and direction of currents, intensity and direction of the explosive force, and the possibility of determining the locality of the origin of the explosion. Near the point D on the map, or more precisely at the north and south branches of No. 3 east, the committee found the most destructive and violent action in the whole mine unmistakably to have taken place. Here the explosion originated, and extended southward and westward through all sections of the mine.

The complete destruction of the mine-cars and the badly-burned and mutilated condition of the men's bodies found in the headings of the north and south branches of No. 3 east present conclusive evidence of the tremendous force which had its origin at this point.

Only small pieces of the miners' boxes and powder-kegs were to be found. Fragments of flesh were scen adhering to the breast of the headings. The appearance of the wrecked cars and position of the bodies would indicate a force tending towards the face of the headings, but by far the greater and more violent action was in a westward direction until it reached the main entry of No. 2 north • here the current split, one part being deflected southwards through the district C, sweeping with an irresistible force through the face of the rooms, destroying everything in its course.

In all of the seven or eight rooms in the northeast corner of the district marked C the powder kept in the miners' boxes seems to have exploded ; but, excepting here and in a number of the rooms north of the fan-entry, no powder was exploded, although the cartridge-paper at the side of the powder-kegs was in many instances charred,, and in Nos. 3 and 4 north off No. 1 east, the kegs themselves were charred. That no warning was given is evident in the position of the bodies, as all were found lying close to their work, mangled and badly burned. Timbers and track were swept out of place, and cars wrecked.

Evidence of an intense flame, in strong incrustations of coke on the roof and ribs of the room, was everywhere observed throughout the northeast area of C. The, general appearance of the other portions of this district is hardly less marked. On the left side of C the men appear to have had some slight warning, as a few were found in their rooms, stricken down while running to the entry. The mangled body of the night-foreman, Hampton, was found dismembered in the gangway in the lower part of No. 1 north, a short distance off of No. 2 east; the fragments of another body were found in close proximity to that of Hampton. These had evidently been struck by the cars, which were blown with great force down No. 1 north, as we found the cars jammed and wrecked in No. 2 east, and upon the axle of the first, on the under part of the frame, were pieces of clothing, as if the cars had passed over the bodies.

The main body of the explosion undoubtedly had its center of action in the lower half of the district B, throughout which large accumulations of coal-dust and soot were everywhere visible.

In B, east of No. 2 north, portions of track are swept out from the face of the rooms toward the entry, whilst in B, west of No. 1 north, this action appears to have confined itself more within the line of the second " break through," back from the face of the rooms. From B the explosive force tends south ward towards No. 1 east, and thence up No. 3 and No. 4 north. This section of the mine, A, had the purest air, and the action of a strongly-heated current of gas surcharged with the finest particles of coal-dust, coming with great velocity into an atmosphere of fresher air, naturally created intense combustion and generated the highest temperature in the mine. Charred timbers and a strong coating of coked dust adhering to the face, sides, and roof of almost every room and through the entry, with occasional sections of coal coked on the solid pillar, furnish conclusive evidence to substantiate this, apart from the fact that the bodies found here were more badly burned than in any other portion of the mine, and in almost every instance had their hands held before their faces as if to shield them from a flame which they must have seen coming towards them. Throughout this area A, the men in all of the rooms which were being worked had some warning, the bodies being found on their faces with their arms extended and hands opened, as if they had fallen whilst running; none, however, had run more than fifty feet. In the upper rooms of A the men were caught in the working-faces.

Some had been sitting down talking, and had only time to jump up before they were killed. Others had seen the flame coming, and, putting up their hands to shield their faces, had fallen in this position and were found on their faces.

The man found at the face of No. 4 north heading had probably been sitting on a pile of coal smoking, and, seeing the flame coming up the entry, had jumped down, and was found lying at the foot of the pile, on his back, with his arms above his head, with clenched fists.

Of those instantly killed without warning, some were at work making their undercuts, and were found, pick in hand, in the act of striking. One, sitting on the floor with his dinner-can between his legs, was evidently killed while eating. All the bodies in A were badly burned and charred. The action of any violent explosion in this district was not noticed, as all the timbers were standing, and the tracks in the rooms were intact, and none of the bodies were mangled.

When the current from the explosion in the lower half of B entered the entry No. 1 east, it broke through the stopping of the air-way immediately opposite, and divided, the greater portion going westward to daylight, and the remaining portion turning east. A part of this easterly current passed up into Nos. 3 and 4 north, but the strongest force was directed towards the face of the air-courses and the headings of No. 1 east.

The man found in the air-course had been decapitated and his body cut in two parts, possibly by flying timbers. The man found in No. 1 east heading had been thrown violently against the face, where small portions of the flesh and clothing were still adhering to the coal.

Returning westward on No. 1 east towards the main entry, and passing the district B, we encountered evidences of a great force in wrecked care and the dislodgment of heavy sets of timber, caused in part by the cars being thrown against them. The air-course parallel to No. 1 east, which was the main intake, was swept clear and scored with deep furrows by the cross-ties and timbers which were hurled out to daylight. Returning to No. 3 east at the spot D, we noticed in the close headings of Nos. 1 and 2 north, the loaded cars forced off the track towards the face. The bodies of the men at work had been thrown forward and badly burned and lacerated.

The main currents, rushing from the face of the north and south branch headings of No. 3 east, met at the air-way and the main gangway, part going north and part going south. The four men at work in the main headings showed only slight signs of being burned, but were badly contused from the severity of the concussion. The same fact was noticeable on the bodies of the men at work in the close headings of Nos. 4 and 5 west; the cars were also wrecked by the direct action of the current. The reaction forced some loaded cars down the main entry, and these, jumping the track, knocked out a few props, occasioning a small fall of roof. Proceeding southwards, down the main entry and air-way, the currents were not very strong, as they were neutralized by the opposing currents from No. 2 east, as shown by the fact that the trip of loaded cars standing in this part of the main entry had been stopped by the front car leaving the track; the others, ten or twelve in number, *were* wholly uninjured, not even the coal on the surface being disturbed. Taking up now the course of the current issuing west out of No. 2 east, we find that it divided, a part going north as described, and the stronger and greater force rushing through the main entry into No. 3 west, projecting the empty-cars standing on the track at that point to the junction of the same with No. 1 west piling them up in an inextricable mass and sweeping out timbers the entire length of No. 3 west entry, allowing the roof to fall for a distance of about 200 feet. This, as far as we could judge, was the greatest material damage done to the mine proper.

In G, where the current was next deflected, about thirty colored hands were working. These men had congregated in an entry, talking and playing whilst waiting for cars, as was testified by one of their number who had come out of the mine, not feeling well about half an hour previous to the explosion. At such a distance from the origin of the explosion it is quite natural to presume that they must have had some little warning, and this was evident from the manner in which their bodies were distributed along the entry. They must have made a rush to escape, but none had proceeded more than 50 feet before being struck down by the force of the explosion and killed. There are evidences of a quick, intense flame sweeping through this area, from the charring on the timber and finely-coked dust covering the sides and roof of the rooms, in some instances extending close up to the face. The bodies were all more or less burned and almost stripped of their clothing. An explosion must have occurred in the lower half of G, as we found props down and track twisted out of place in some of the rooms.

All the powder kept in the rooms was uninjured with the exception of two or three kegs in the lower half of G, where evidences of explosion were strongest. Passing southward into F, a body of gas coming from *G* entered the better-ventilated portion of F and exploded. The force shows itself again in a southeasterly direction, coating roof and sides, and filling it with coked dust and wrecking a few cars in entry No. 2 west. There were only a few men engaged at work in F, and some of these met an instantaneous death in the heavy slate-fall, which crushed them while in the act of robbing, this being *the* only portion of the mine where pillars were being drawn.

CONCLUSION.

The conditions leading to the explosion were the following:

1. The unusual dryness of the mine.
2. The very large quantity of dust in an extremely fine state of division.
3. The constant working of the mine day and night, allowing no time for clearing the air.
4. The use of excessive quantities of powder, largely increasing the amount of dust.
5. The probable existence of small quantities of fire-damp slowly given off from the coal.
6. The employment of incompetent and inexperienced men.
7. The almost complete stagnation of the air on the east side of the main entry, owing to the fact that the main doors were untended and fastened open, allowing the air to pass up the main entry direct to the fan.
8. The failure to recognize and appreciate the previous warnings of danger given by occasional flashings of unusual extent when shots were fired, indicating the need of special precautions.

The existence of fire-damp in the Pocahontas Mine is the disputed point. This committee is not satisfied on the subject, and meanwhile submits the following evidences bearing on the case:

The superintendent and the mine-boss unite in declaring that they had seen no evidence of gas, and that no complaint of gas had been made to them previous to the explosion. The same is true of the timber-man and of the man employed to keep the rooms on their true course. In this connection may be stated the explanation given by the superintendent regarding the mention of gas and blowers in the mine-regulations. The rules were copied from a set used in eastern Pennsylvania, and the intention was to omit all references to gas, but one paragraph was inadvertently retained.

On opening the mine after the explosion and flooding, no trace of fire-damp was discovered.

On visiting and thoroughly inspecting the mine, the committee found no traces of fire-damp, though ventilation had been only partially restored, especially in the workings to the rise.

On the other hand, there is testimony, although from men generally inexperienced with gas, leading to the belief that when the mine was strongly worked there was a slight but general escape of firedamp, too slight to admit of detection except in rare cases, and probably in all cases too slight to occasion danger if unmixed with coal-dust and if diluted by proper ventilation.

We would mention :

1st. The burning of the Ray brothers by a powder-explosion, their powder-keg being fired, as was supposed, by a blown-out shot from a distance of 120 feet, and not in direct line, being at the time protected by the angle of a break-through.

2d. The burning of George Britten, described by himself as having been done by a flash following a shot fired in the face of his room, he being about 35 feet distant and protected by an angle of the coal.

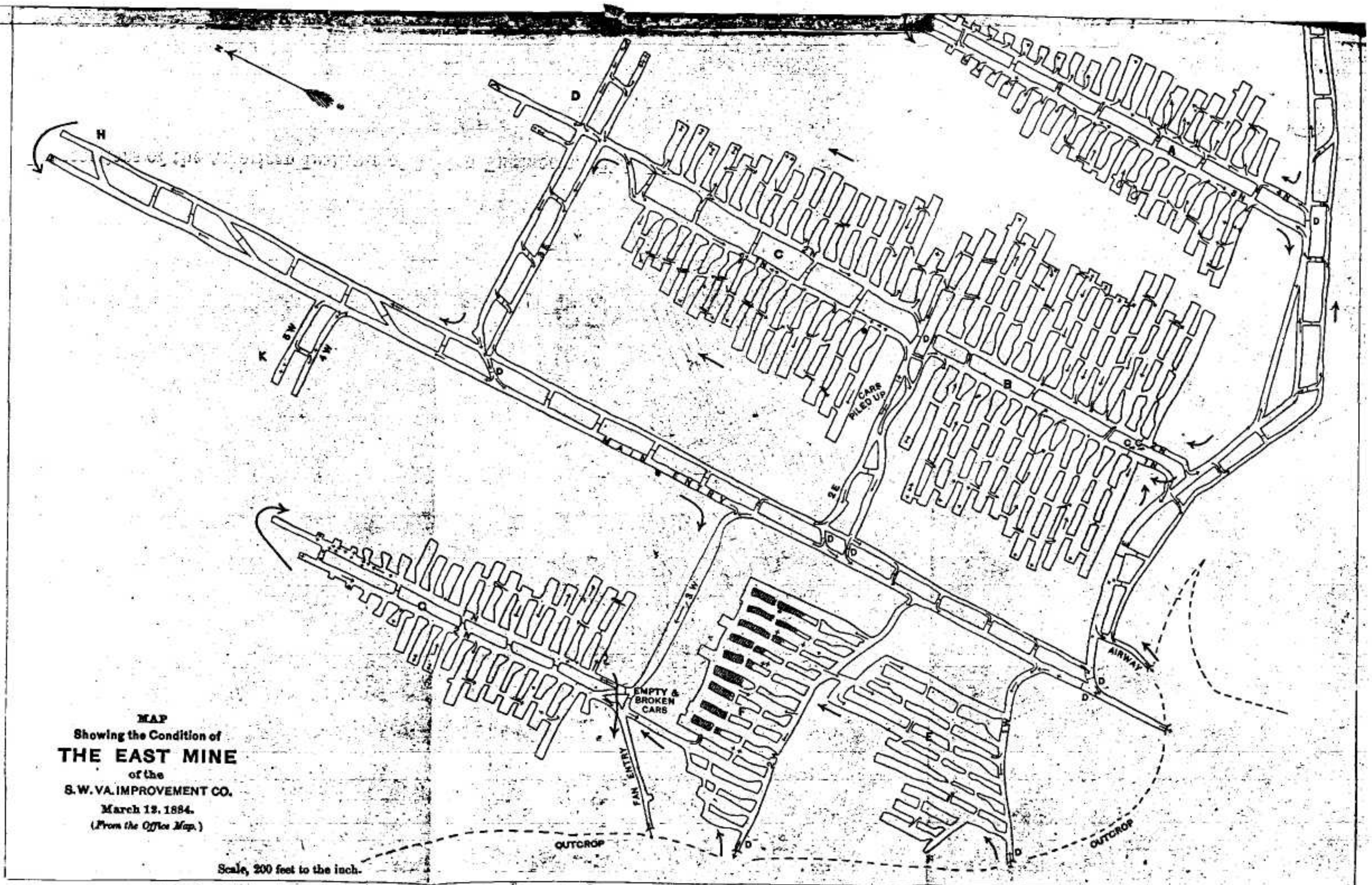
3d. One insfance related of a flickering blue flame seen in the undercut near a miner's lamp, and attributed by him to fire-damp issuing from the shaly slate left in the floor and overlying the lower bench of coal remaining unworked.

4th. The general practice of flashing the powder-smoke after a standing shot by holding the lamp at the face of the coal in the hot smoke, and occasional instances when a similar effect has been produced by the shot itself.

The flashing of the smoke seems to have been almost wholly unknown to the management, and, while not unusual in other mines, the practice seems to have been so general here and the flame so persistent as to lead to the supposition that the products of imperfect combustion of the powder may have been reinforced and quickened by a small amount of fire-damp.

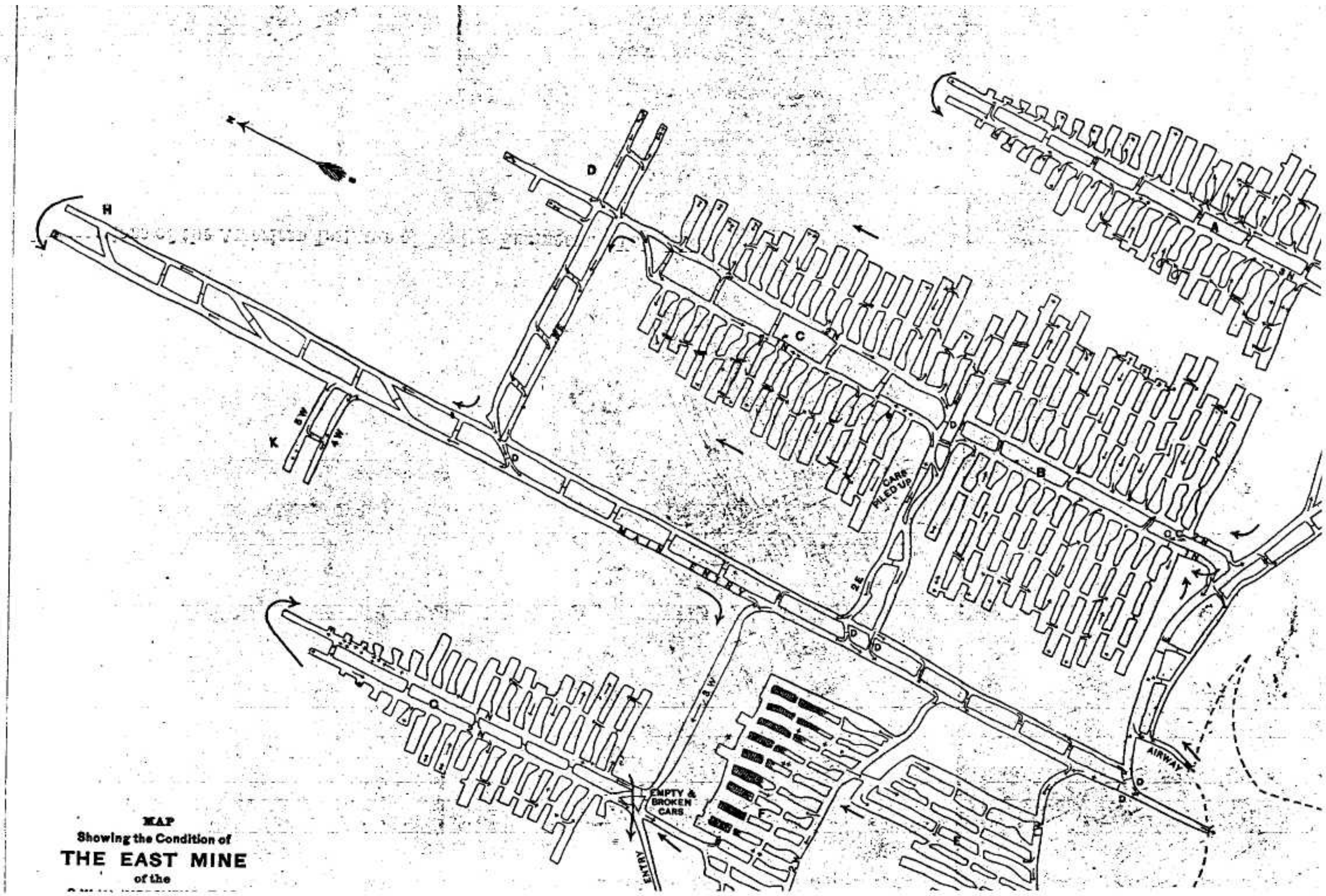
5th. Two instances in which a body of flame has been described as flashing back 60 to 100 feet from the head of an entry, following the firing of a shot, without injury to the men.

In conclusion: *We* believe that the explosion was due mainly to dust, and that it originated either in the east headings at D, or very possibly in one of the rooms south of D, the evidence of a short northward current being obliterated in the latter case by the stronger



MAP
Showing the Condition of
THE EAST MINE
of the
S. W. VA. IMPROVEMENT CO.
March 12, 1884.
(*From the Office Map.*)

Scale, 200 feet to the inch.


MAP
Showing the Condition of
THE EAST MINE
of the
H
K
5 W
4 W
D
C
B
A
E
2 E
3 W
CARS PILED UP
EMPTY & BROKEN CARS
ENTRY
AIRWAY

reaction from the close headings. *We* cannot determine the initial cause, whether a blast or the accidental ignition of a small accumulation of fire-damp, but we have obtained no direct proof of any past occurrence of fire-damp sufficient of itself to account for even a slight explosion, and are forced to believe that the explosion was due either to dust alone or to dust quickened by an admixture of firedamp too slight for detection by ordinary means.

At the time of our examination the mine was in no condition for determining these points, and we were not prepared to conduct such experiments; but as soon as the mine is again in full working-order a course of experiments should be undertaken, both in the interest of science and for the better preservation of life and property. Repeated tests should be made on the spot, of air from different parts of the mine, and trials made with suitable apparatus to explode the dust alone, especially where the finely-divided mineral charcoal or mother-coal abounds.

POSTSCRIPT.

The necessity for full tests and systematic experiments, as above mentioned, is emphasized by the occurrence of a slight and harmless explosion which has taken place since the resumption of work, notwithstanding the employment of experienced men, the cleaning and wetting down of the mine, and the improved condition of ventilation.

A NEW BOCK-DRILL WITHOUT CUSHION.

BY A. C. BAND, NEW YORK CITY.

THE invention to be described in this paper is the work of Frederic A. Halsey, Engineer for the Rand Drill Company, of New York, and its use will abridge the notable wastefulness of power of the striking rock-drill, and, at the same time, increase its capacity for work.

That the older type of rock-drill is wasteful in power, is generally admitted, the cause being the use of steam* without expansion, and the "cushion " of the blow, by the incoming steam upon the lower† end of the piston before the cutting tool strikes the rock.

* Compressed air may be substituted for steam.

† Throughout this paper, the machine will be spoken of as if in a position to drill a vertical hole downwards.

In the old type of machines in general use, there is full pressure of steam upon the lower side of the piston at the time the blow is given, and the power utilized is *only that due to the difference* between the driving-steam behind the piston and the cushion-steam in front of it. Iu the new type, there *is no pressure* upon the lower side of the piston when the blow is given, and the full power of the steam is utilized.

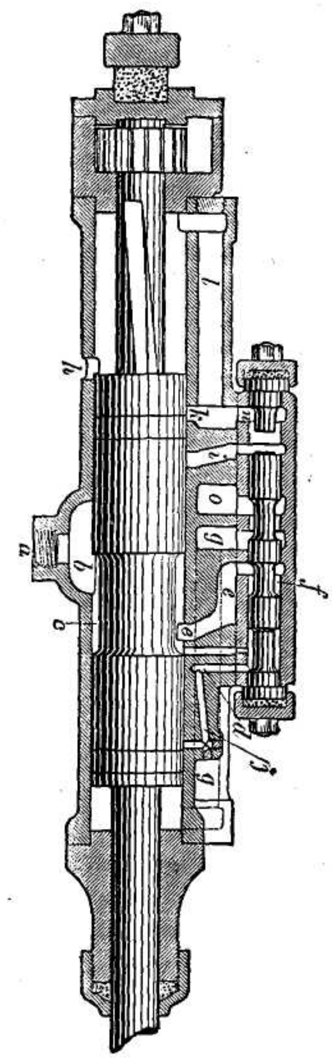
The necessity for a variation of stroke, to permit the passage of the cutting tool through seams, and to prevent the cutting tool from glancing in starting a hole, is the cause of the design, which causes the wastefulness of the old type. The new design permits any variation of stroke, without its loss of power due to the cushion, and without decrease in the number of blows given per minute.

Another important feature of the invention is the use of steam expansively. The cut-off may be arranged, when the machine is designed, to operate at any given point in its stroke, so that in localities where labor is cheap and fuel expensive, *a* considerable degree of expansion can be practiced to advantage. Still another new feature is to be noticed in the use of the exhaust-steam cushion to stop the piston at a predetermined point on the upward stroke of the piston, instead of the live-steam cushion ordinarily used. This change of practice, it is estimated, will make good the ordinary port-loss.

The machine is illustrated in section in the figure.

Steam enters the machine at the nozzle *a,* and, flowing through the passage *b,* fills the annular groove c in the piston. This annular groove answers the purpose of a steam-chest, and from it the steam flows through the passages *e,f, g,* and *i, n, k, I,* to one or other end of the cylinder as needed.

The piston is shown in the position where it has just reached the point marking the end of the shortest possible striking stroke,—it having just uncovered the hole *d,* leading from the steam-chest to the lower end of the valve-chest, and thereby established the condition which will reverse the valve. If we suppose the piston still moving downward in order to complete a stroke of normal length, it will be seen that an arrangement is desired which, in spite of the hole *d* being open, shall yet delay the movement of the valve until the instant of striking the blow. This is accomplished by simply constricting a portion of the hole *d,* making it of such small size that the steam necessary to move the valve shall not be able to get through the hole until the piston has had *time* to pass on and complete *its c* stroke. If the piston be stopped in its course, at the point shown in the drawing, by the cutting tool coming in contact with the rock, the reversal of the valve is insured in the same manner and in the same time as if a long stroke were made.



The cut-off is effected by using the piston itself as a cut-off valve. The steam, in order to reach the ends of the cylinder, must pass through the ports *e*, *i*, and these are so located as to be closed at the proper-time by the piston passing over them. Their position, lengthwise the cylinder, can be varied at will in the design, and thus an early or late cut-off be obtained as desired. In practice, it has been found in some machines made, that a cut-off at half stroke gave—with the uncushioned blow—a drilling capacity about equal to the old type *of full stroke c*ushioned-blow machine, and with a later cut-off, an average increase of drilling capacity which may be safely stated to be not less than twenty per cent, has been obtained.

The exhaust-steam cushion, for arresting the upward motion of the piston, is obtained by making the piston act as an exhaust-valve for the upper part of the cylinder; A is the only exhaust-opening from the upper end of the cylinder. It is opened near the end of the down-stroke by the piston uncovering it, and is closed again near the commencement of the return-stroke by the piston covering it.

Various changes in point of cut-off can be readily made in designing this machine, according to the relative cost of labor and fuel in different localities. It is more than likely that operators in Chili, South America, where fuel is extravagantly high and labor cheap, and, perhaps, in Nevada, where both fuel and labor are high in price, will choose the early cut-off called the "Economizer;" while, on the other hand, with the price of fuel near the seaboard, the increased duty of twenty per cent, in drilling in the late cut-off called the "'Slugger" drill, may be considered the better economy, inasmuch as the cost for labor is not increased.

It is just possible that in some localities, where the rock is excessively hard to drill, the "Slugger" machine may give so hard a blow as to dull the steel too quickly, in which case, a larger cutting tool may be advantageously used, or one with a shorter stroke, a smaller machine or an "Economizer" machine chosen. For tunnel driving, with a moderate price for fuel, there is but little doubt that the ultimate economy is in the use of the machine doing the greatest amount of work consistent with portable weight over the bench or débris; and just here the "Slugger" inarks a new era in tunnel-driving, where the drilling-machine is to be used on a portable column, carried over the broken rock and set to work immediately after the blast. The limit of convenient weight for thus handling is reached at about 3 $^{1}/_{8}$" diameter cylinder (No. 3), and the "Slugger" does the work of the next larger size of the old type.

As one of the results of the invention, it is to be noted that a still further economy is effected in the cost of compressor used to drive the drills, and in turn the cost for boiler to drive the compressor.

The writer is aware that a drill without a cushion has been proposed before Mr. Halsey's invention, and on the testimony of Drinker's *Tunnelling* it is condemned, and probably with justice, if made with any device which would materially reduce the *number* of blows given; for it is plain that any advantage derived from an increase in weight of blow might readily be overbalanced by a decrease in the *number* of blows given, or by any complication arising from the devices used.

The expansion-principle applied to rock-drills is likewise discussed unfavorably in Drinker's *Tunnelling*. It is creditable to the inventor of this machine, that by bringing new factors to his aid and by making new combinations, he has wrought out so successful a system as the actual trials in mines and tunnels indicate; the fact being that not a single machine yet sent out has failed to perform as claimed, except in one case where the blow was too heavy for the cutting tool used (and the remedy for that has been stated), and in a year's performance not even the first machine has missed a stroke.

MOTES ON COAL-DUST IN COLLIERY EXPLOSIONS.

BY E. S. HUTCHINSON, NEWTOWN, PA.

THE subject of the influence of coal-dust in mine-explosions has received considerable attention both in England and on the continent of Europe, but until the recent disaster at Pocahontas, Va., it seems not to have been of special interest to engineers in this country.

The reason, perhaps, is that most of our bituminous mines are worked by short shafts, slopes and drifts; few have been specially dry; and the explosions that have occurred could readily be traced to fire-damp with no complicated circumstances. The object of the present paper is to bring together, for the convenience of members of the Institute, the principal English opinions upon this important subject.

Messrs. Lyell and Faraday, in their report to the Home Secretary,* in England, on the Haswell Colliery explosion in 1844, seem to have been the first to point out that dust fed the flame originating in a

* *Philosophical Magazine,* 1845.

fire-damp explosion, and that much of the carbon of this dust remains unburnt only for want of air.

The influence of coal dust has been briefly referred to in some of the annual reports of the English mine-inspectors; but general attention was first attracted to the question by the reading before the Royal Society of a paper "On the Influence of Coal-dust in Colliery Explosions," by William Galloway.* In it, he describes an apparatus he had erected at Llwynpia Colliery in the Rhondda Valley, Wales, which had been used for testing safety-lamps, and which he had adapted for his coal-dust experiments. Fresh air was allowed to enter into one end of a box and pass out at the other end into the up-cast shaft. A lighted lamp had also been placed in the box, and coal-dust was introduced from a hopper. The air was charged with coal-dust in various degrees, from a scarcely visible cloud to one which extinguished the flame of the lamp. Dust from steam-coal and also from highly bituminous coal was used—the finest and dryest of each that could be obtained. Mr. Galloway con cluded, after repeating his experiments many times, that while the flame of the lamp seemed to be lengthened by the dust, "a mixture of air and coal-dust is not inflammable at ordinary pressure and temperature."

He then disconnected his apparatus from the up-cast, and introduced, by means of a small fan at one end, fire-damp from a blower, and air, which thus became thoroughly mixed; and found "that a mixture of 1 volume of fire-damp, and 15 volumes of air w*as* inflammable, and that, with 16 volumes of air, it was *not* inflammable at 57° F.;" also, " that a mixture of fire-damp and air, in the proportion by volume of 1 of the former to 112 of the latter, becomes inflammable at ordinary pressure and temperature, when charged with fine dry coal-dust." (This represents 0.892 per cent, of fire-damp.) He therefore considered it reasonable to conclude, "that an explosion, originated in any way whatever, in a mine of this class, may extend itself to remote parts of the workings, when the presence of fire-damp is unsuspected."

In June, 1876, a paper by Messrs, Henry Hall and George Clark, was read before the North of England Institute of Mining Engineers† on the " Mechanical Effects of 'Blown-Out' Shots on Ventilation." Their attention seems to have been called to the matter

* *Proc. Roy. Soc,* March 2d, 1S76, vol. xxiv., p. 239.
† *Trans. N. of Eng. Inst. of Min. and Mech. Eng.,* vol. xxv., p. 239.

by an accident at Wynnstay Colliery, near Raubon, North Wales, April 24th, 1873, by which two men lost their lives from the effects of a blown-out shot at the distance of 47 and 180 yards, respectively, from the initial point. It appeared in evidence at the inquest, that the mine was inspected by the fire-boss and one of the managers daily, and that *no* fire-damp had been discovered before the accident or since.

The authors fired several shots from a strong iron tube with varying charges from the face of a brick-lined adit, 45 yards in length, with a sectional area of 30 feet. Gauze sheets were hung at intervals of 15 feet, and powder was distributed in the adit, but in no case was the gauze or powder burned beyond 5 yards from the face. The flame, travelled no further even when the explosion burst the tube. When the floor was thinly covered with dry coal-dust for 8 or 9 yards from the face, gauze sheets and powder placed as before, and a 2 1/2 pound shot fired, the sheets and powder to 60 feet distance were all burnt, and the blast at mouth of adit—45 yards distant— was very fierce, lifting and driving for 15 yards a metal pipe weighing about 50 pounds, and moving a coal-car on the pit-heap, 75 yards distant.

For the last shot, with 2 1/2 pounds of powder, dust was scattered on planks, the whole length of the adit. In this case, the flame issued strongly at the mouth of the adit and the blast was fatally fierce. The floor and roof were very wet, and the temperature was 50°.

These gentlemen concluded, as the result of their experiments, that if coal-dust be present, even in a comparatively damp mine, the flame from a blown-out shot may travel 50 yards; and that in a dry mine of a high temperature, this distance would be greatly exceeded.

In April, 1878, Messrs. D. P. Morison and A. Freire Marreco read a paper before the Chesterfield and Derbyshire Institute of Mining, Civil, and Mechanical Engineers,* entitled "Results of Some Experiments on the Effect of Coal-dust in Colliery Explosions," in which they gave an account of experiments they had made at Elswick Colliery, in August, 1876. They used a box about 8 feet long and of proportionate width, with a brattice running up the middle, so constructed as to represent a working-place. Two miniature cannon were fitted into the end of the box, from which charges

* *Trans. Chest, and Derb. Inst. Mm,, Civ, and Meek. Eng'rs,* vol. v., p. 267.

of powder of different sizes were fired, to represent blown-out shots. The first experiments were with a clean box, and without coal-dust. No effect was produced beyond the report and smoke.

They nest experimented with coal-dust sprinkled on the floor and blown against the sides, brattice, door and props. Sixteen trials were made with shots varying in weight from 30 to 120 grains. In several of these, props and brattice were blown down, the dust was fired, and flame projected from the windows. (It will be remembered that this was a mixture of air and coal-dust and no firedamp or gas) The writers concluded as the result of their labors, that not only was coal-dust inflammable under such circumstances, but that, with the double shot, one following the other before dust raised by the first had time to subside, the effects of the explosion were much more intense. They inferred, also, that the danger of shot-firing was greatly increased in a dry and dusty mine, in the atmosphere of which was an infinitesimal quantity of fire-damp. So far as their knowledge extended, the heavier disasters had invariably occurred in dry and dusty mines, while in those in which the dust had been laid by dampness, the explosions had been only local.

The authors then describe the explosion in 1866 at the Pelton Colliery, at which Mr. Morison was resident engineer. The seam had been worked a comparatively short time, and was unusually dry. The air, during working-hours, was charged with fine coaldust, presenting almost the appearance of a fog. Though known as a " fiery " seam, it was well ventilated, and gas was seldom observed. Some traces of fire-damp had been observed following a heavy fall of roof, and the miner in that place was warned to withdraw his Davy lamp carefully. Another miner, in a heading not far distant, had also seen indications of gas in his lamp. An explosion occurred by which 24 lives were lost. Some of the bodies were charred, most such cases occurring far away from the central point of the explosion, and in places where gas could not have entered. In nearly every portion of the seat of the disaster, the sides and roof of the galleries and rooms, as well as the props, were coated with fine coke, 1/8 to 3/8 inch thick, The initial cause was undoubtedly an explosion of fire-damp, which appeared to be aggravated and extended by the ubiquitous coal-dust.

In the discussion which followed, Mr. Thomas Evans (Chief Inspector of Mines for the Midland District), said he had always found that gas was the cause of explosions, and he never knew of one caused by a spent shot; and that he had no doubt that coal-dust aggravated the results of explosions.

In *Iron,* in June, 1878,* Mr. William Galloway began the description of an accident at Llan Colliery, near Cardiff, Wales, December 6th, 1877, by which 17 men lost their lives. He entered the workings about 2½ hours after the explosion, and made a careful study during that day and the four succeeding days. Three 5-foot seams were worked with 24 feet of rock and shale between the upper and the middle, and 41 feet of fire-clay and shale between the middle and the lower seam.

No powder was used in the workings, owing to the extreme friability of the coal and intervening strata. All the testimony adduced showed that there was no accumulation of fire-damp in the workings within an hour before the explosion. On the two days next ensuing, Mr. Galloway found fire-damp in two cavities in the roof at points not readily accessible, and at a point in the upper seam approached by a chimney from the middle one. He assumes the initial cause of the disaster to have been a local explosion of fire-damp, caused by a naked light in one of the rooms in the middle seam. The deposits of coked coal-dust were well marked, extending through the middle seam level and along the cross-measure drift into the upper seam, into which they extended about 50 yards. Mr. Galloway finally concludes that the various phenomena are inexplicable except on the supposition that a feebly explosive mixture of air and fire-damp and dust exploded, and the flame feeding on the dust filled the greater part of the workings in which the coked coal-dust was found. The coal of the middle seam contained 30 per cent, of volatile matter.

Mr. Galloway considered also, that the weather being unusually cold, the air, having a low percentage of hygroscopic moisture, would, on attaining the higher temperature of the mine, absorb moisture and thus render the dust abnormally dry and inflammable, This> however, is not an unusual state of things, as it must take place every winter in dry mines.

Mr. Galloway describes also an accident which occurred at Fowler's Steam Coal Colliery, Pontypridd, near Cardiff, October 21st, 1876.† Two colliers and a fireman were burned in the mine simultaneously with the firing of a shot which blew out. He visited the scene of the accident the same day, and on October 23d, 28th and 29th, and

* *Iron,* June 8th, 1878, vol. xi., p. 708.
† Iron July 13th 1878 voll. xii., p. 34.

November 1st, and made a careful inquiry into all the attending circumstances. The coal is very hard and compact and cannot be advantageously worked without the aid of powder. It emits a good deal of fire-damp, so that locked safety-lamps are used, and special men are appointed to fire shots. Two miners were driving a cross-heading up an 18° slope, so as to connect a lower level with a sloping road driven in the solid. They made a side-cut, bored a shot-hole 3 feet, 2 inches deep and sloping upward at a sharp angle, and charged it with 1 1/2 lbs. of powder. The fireman made the usual examination at the face, and all retired. The shot blew out; and two of the men, 50 feet distant, around a corner, were knocked down and severely burned, one being permanently injured. The third, distant 60 yards, was also knocked down, but was only slightly burned. The brattice running up the middle of the heading was not disturbed. About 50 yards of the main heading were covered with coked coal-dust, but in the cross-heading tills was found only at its foot. The flame extended about 7 yards further from the origin than the last trace of coked coal-dust. The floor in front of the shot was covered with a quantity of small coal and dust to the depth of 1 foot to 18 inches ; and the theory is that the incandescent gas from the blown-out shot, impinging against this combustible mass, fired it, with the results described. Mr. Galloway adds that, although there was no accumulation of fire-damp in any part of the workings, there must have been more or less of it constantly given off by the coal. Subsequent experiment showed that not less than 34 cubic feet per minute of fire-damp was entering the place when the shot blew out. This quantity, when the furnace was in full operation, would be at least 0.54 per cent, of the total atmosphere, and might reach to 0.75 per cent.

On November 2d, 1878, Professor A. Freire Marreco and D. P. Morison read before the North of England Institute of Mining and Mechanical Engineers, a paper entitled " An Account of Some Recent Experiments with Coal-Dust."* These were carried on at Harton Colliery; the apparatus consisting of two boxes, one of which, about 12 feet long and 6 inches square inside, was fitted with two miniature cannon at one end and communicated at the other with an air-passage that could be regulated by a slide. The other box was about 10 feet long, communicated with the first at one end, and was open to the air at the other. Each side had 3 windows

* *Trans. N. of Eng. Ind. of Min. and Mech. Eng.,* vol. xxviii., p. 85, November 2d, 1878.

through which the length of flame could be observed. The boxes were so arranged that the current of air passed along the 12-foot box close to the cannon-face and thence through the 10-foot box to the open air. One shot would be *against* the current of air and the other *with* it.

At the outset of their work, the authors were met by the inquiry, What is an *"explosion"?* And this led them to seek for a dust, to use in their apparatus, the result obtained with which should serve as a basis of comparison with other dusts under precisely similar conditions. Knowing the destructive results from the explosion of flour-dust, they adopted this as a standard of comparison. Forty-three experiments were made with 30-grain charges of powder, and two with 15-grain charges. The dust used was from various English, Scotch and Welsh coals, from roadways and screens, and four kinds of flour-dust. In conducting these experiments, they soon found that it was perfectly easy to fire shots in the immediate neighborhood of coal-dust without producing any perceptible effect. They were also led to think that while, strictly speaking, they had not got, on this scale, what could be called absolutely an explosion, they had demonstrated, not only that coal-dust was capable of lengthening indefinitely the flame from a blown-out shot, but also that such a mixture might be made of air and dust as would not require for its explosion the initial flame of the burning gases from such a shot. Professor Marreco observed also that as finely powdered charcoal readily fires at an open flame, the volatile portions of the coal-dust might not be the only means of propagating an explosion.

In the discussion which followed the reading of this paper, Mr. Stephenson stated that in North Staffordshire, where a mine was dry, ventilation good and no gas present, sufficient dust was produced, when the miners were at work, to show a "cap" on the flame of the safety-lamp, which was not the case after work had ceased for an hour or so.

Mr. William Galloway read a second paper before the Royal Society, in March, 1879,* in which he described a series of experiments at Llwynpia Colliery, with the return-air from the mine containing less than 2 per cent, of fire-damp, which, he considered he had demonstrated, was rendered inflammable by coal-dust. His apparatus was placed close to the fan, in such a way that a current of air from the up-cast could be made to pass through it. An oil-lamp

* *Proc. Roy. Soc,* vol. xxviii., p. 410, March 13, 1879.

with a large flame was placed in the box, raising the temperature to about 74.5° F., and coal-dust was introduced through a hopper. The immediate result was the appearance of a large and very hot flame, the length of the visible part of which was 6 to 8 feet, and it was accompanied by large volumes of black smoke and dust.

Other experiments were made with a specially constructed apparatus, to illustrate the effects of an explosion of fire-damp in a dry mine containing coal-dust. This apparatus consisted mainly of a box or gallery 79½ feet long and 14 inches square on the inside, and fitted up with a fan and other necessary appliances for introducing measured amounts of fire-damp and dust. The mixture of firedamp and air was fired by the spark from a powerful magneto-electric machine. The temperature of the air-current within the gallery varied from 74° at the firing end to 60° at the other.

When there was no coal-dust in the gallery the flame of the firedamp explosion did not extend further than 7 to 9 feet; but when it contained coal-dust, scattered along the floor and on a few shelves, the flame of the explosion traversed its whole length and shot out into the air to a distance varying from 4 to 15 feet. Mr. Galloway found as the results of his labors "that a mixture of coal-dust and air will be *inflammable,* if it contain a larger proportion of fire-damp than 0.892 per cent.;" that "if it contain more than 0.892 per cent, of fire-damp, it will be more and more explosive, according as the proportion of fire-damp is greater, until a maximum point is reached, beyond which its explosiveness will again begin to decline." Again, "if it contain less than 0.892 per cent, of fire-damp, or even if it consist only of coal-dust and pure air, it will still be so nearly inflammable that it will probably become so when it undergoes the *compression* and consequent heating which an explosion must produce."*

On the 8th of September, 1880, an explosion 'occurred at the Seaham Colliery in the County of Durham, England, by which 164 miners and others lost their lives. Professor F. A. Abel, Chemist to the War Department, was instructed by the Secretary of State for the Home Department to make examination of the dusts of the colliery with a view to ascertain what effect, if any, they had on the

* The apparatus was described by Professor Abel to be very ingenious, but he questioned whether the means of preventing the escape of minute quantities of firedamp into the channel where the dust was raised, were effective or not. In his subsequent paper, No. IV., Mr. Galloway estimates that this leakage would not amount to over one volume of gas to 7000 of air.

late explosion. Thirteen samples of carefully selected dusts were sent him, which, after having dried at 100° F., he passed through a screen of 50 meshes to the inch, to remove the coarser particles. The experiments were carried on at Garswood Hall Colliery, Brynn, near Wigan, in Lancashire.* The apparatus used was very similar to that employed by Mr. Galloway and Professor Marreco already described, although considerably shorter, being 28 feet from the dust-hopper to the end. The general fittings were of a simple nature, but great pains were taken to secure accuracy and uniformity in the velocity of the air-currents employed, in the proportions of gas used with the air, and in the intimacy of their mixture. The temperature of the air-current was maintained at 75° to 85° F., by first passing it through the tubes of a steam-boiler.

The sources of heat and flame were an uncovered Davy or Mueseler lamp, a wide gas-jet supplied with fire-damp from the colliery, and a small cannon fitted with electric fuse and charged with 80 grains of fine powder. The dusts were collected in different parts of the mine, from roadways, props, stones, screens, etc., and contained from 54 to 96 per cent, of actual coal-dust, after being sifted -and dried at 100° F.

These experiments were, without doubt, conducted with all that conscientious skill for which the distinguished author of this Report is celebrated. Professor Abel summarizes as follows:

That it appears to be demonstrated:

1. " That coal-dust in mines, not only, much promotes and extends explosions in mines, by reason of the rapid inflammability of the finely divided combustible, and of the readiness with which it be comes and remains suspended in air-currents; but

2. "That it may also itself be readily brought into operation as a fiercely-burning agent, which will carry flame rapidly as far as its mixture with air extends, and will operate even as an exploding agent, through the medium of a proportion of fire-damp in the air of the mine, the existence of which, in the absence of the dust, would not be attended by any danger.

3. "That dust from coal-mines, quite apart from any inflamma bility which it may possess, can operate in a distinct manner, as a finely divided solid, in determining the ignition of mixtures of only small proportions of fire-damp and air, and consequently in develop ing explosive effects.

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* *Blue-Book,* March 23d, 1881, Appendix.

4. " That a particular dust in a mine may, therefore, be a source of danger, even though it contain only a small portion of coal or combustible matter. Although the explosion, which may occur through the agency even of a non-combustible powder, in the manner described, may be of very mild or feeble character in the first instance, it may be almost at once increased in magnitude and violence by coal-dust, which the first ignition will raise and bring into action.

5. " The proportion of fire-damp required to bring dust in a mine into operation as a rapidly burning or an exploding agent, even upon a small scale, and with the application of a small source of heat or flame, is below the smallest amount which can be detected in the air of a mine, even by the most experienced observer, with the means at present in use.

6. " With dusts of a highly sensitive or dangerous character, in the presence of a source of considerable heat and flame, such as a blown-out shot or an overcharged hole would constitute, a small proportion of fire-damp, the possible existence of which, in the mine, might not be in the least suspected, may serve as the inciting cause to the development of an explosion of coal-dust.

7. " In air containing 2 to 2.75 per cent, of fire-damp, and travelling with a velocity of 600 feet per minute, different coal-dusts suspended in the air produced explosions. Air containing 2.75 per cent, of fire-damp, and travelling at the same velocity, was ignited through the agency of a perfectly non-combustible powder. The same result was obtained by dust in an air-current of 100 feet per minute, and containing only 1.5 per cent of fire-damp.

8. "In the complete absence of fire-damp, coal-dust exhibits some *tendency* to become inflamed when passing a very large lamp-flame at a high velocity ; if exposed to the action of a large volume of flame, such as produced by the explosion of freely-exposed gunpowder or gun-cotton, it exhibits in addition, a *decided tendency* to *carry* or *propagate* flame. But so far as can be determined by experiments on a moderate scale, this *tendency* is of *limited* nature, and very different indeed, from the *property* of carrying or propagating flame, which even comparatively non-sensitive dusts possess *in the presence of a very small quantity of fire-damp.*

9. " It may be admitted as possible, that with the large volume of flame and the great disturbing effect of a blown-out shot, as the initiatory cause of the ignition of dust, and its suspension in the surrounding air, such inflammation may, in the complete absence of

fire-damp, be propagated to a greater distance than the results of small experiments would warrant one in assuming. But it can scarcely be maintained that the air of a mine in which the coal gives off gas at all, can be at any time, *free* from fire-damp; and as the existence of very small and unsuspected quantities of that gas in the air of a mine, may suffice to bring about the ready propagation of flame by coal-dust, and thus to develop violent explosive effects, it would appear needless to assume that coal-dust may, in the entire absence of fire-damp, give rise to explosions, even of only limited character, in coal-mines, in order to account for casualties which cannot be ascribed to the existence of accumulations or sudden outbursts of fire-damp."

By way of explanation of the peculiar phenomena exhibited by some dusts examined by him, Professor Abel states that while the richness of a dust in coal, influences the rapidity and consequent violence of the explosion of dust and fire-damp, the physical character and mechanical condition evidently contribute more than the richness in coal of the dust-sample, to determine the comparative readiness with which it brings about the inflammation of a gas-mixture, not susceptible of ignition *per se* under otherwise similar conditions. The ignition of a dust-and-gas mixture is most probably ascribable to the influence of a *few* small dust particles which having been instantaneously raised to incandescence by the flame, must have the effect of localizing and consequently intensifying the heat at those points.

" From certain phenomena observed in the experiment with *non-combustible* powders, it appears not improbable, however, that another quite distinct mode of action of the finely-divided and heated solid may operate very importantly, and at any rate, contribute in determining the ignition of gas-mixtures which are not susceptible of inflammation by the application of flame alone."

He concludes, " This subject will receive, at the hands of the Royal Commission on Accidents in Mines, the further investigation which it demands."

At the Seaham Colliery inquest, April 12, 1881, Professor Abel gave testimony * which is, perhaps, more specific than some of the general statements of his report just cited.

Air containing 3 ½ per cent, *of fire-damp* was just explosive in currents ranging from 600 to 1000 feet per minute. Air containing

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* *Blue-Book*—" Seaham Colliery Explosion," p. 146 *et seq.*

4 ½ per cent, of fire-damp just bordered on the explosive when the current had a velocity of 100 feet per minute. He could not obtain any indication of either the enlargement or taking up of the flame from exploded gunpowder or guncotton by coal-dust alone, even in considerable quantities in an air-current with a velocity of 100 feet per minute ; but when the velocity was increased to 1000 feet per minute, a considerable flame was produced.

Coal-dust, in the absence of fire-damp mixed with air, will carry flame to a very limited extent only. He was confident that in all his experiments in which he obtained the carrying along of flame by coal-dust to a considerable distance, the quantity of gas present was considerably below 1 per cent.

If the dust were always exactly of the same character, and the conditions were always the same, he was of the opinion that the conclusion *that if coal-dust alone would have exploded, every colliery would have been wrecked long ago,* would be quite correct; but the dusts vary very greatly with regard to sensitiveness, and to the tendency they have to promote the ignition of these explosive mixtures; so that the result, after all, is comparatively exceptional.

With regard to the manner in which the dusts for these experiments were collected, he thought that perhaps the importance of merely skimming the dust had not been sufficiently realized; that he could only speak of the samples as they arrived; that the results furnished by them were put forward with the greatest reserve, and that he did not consider that the indications of burning afforded anything like a decided evidence as to the extent to which the dust took part or entered into the action of this explosion.

The verdict of the jury neither gave an opinion as to the point of origin of the explosion, nor as to its cause. It should be added that this colliery was exceptionally dry and dusty, and especially so immediately before the explosion. Considerable blowers had been known to occur, and small issues of fire-damp were not uncommon in many places.

In a third paper read by Mr. Galloway before the Royal Society, June 16, 1881, and revised by him February 10, 1882,* he describes a new series of coal-dust experiments, began by him at Llwynpia Colliery in September, 1880, with a larger apparatus than he had formerly used. In this the explosion-chamber was 6 feet long and 2 feet in diameter, and the gallery 126 feet long by 2 feet square

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Proc. Roy. Sac., 1881, vol. xxxiii., p. 490.

inside, divided into seven section?, one side of each of which could be opened like a door. He showed that in the absence of coal-dust, "the flame of the fire-damp explosion travels along the gallery to an average distance of 12 feet."

In the presence of coal-dust, however, it is important to note "that if the whole of the sections are closed, making the gallery *continuous throughout its whole length of* 126 *feet, the flame of the coal-dust arising from the fire-damp explosion, does not reach farther than* 50 *or* 60 *feel from the origin;* but if the sides of the fourth and fifth sections are open, making the closed portion only 54 feet long, and leaving 36 feet with only *three* sides" (allowing plenty of air) "the flame will, as a rule, *be* 70 *feet and sometimes* 80 *and* 90 *feet long.* The flame of the coal-dust appears to be self-supporting in *pure air,* but it cannot get much beyond the point to which the more *energetic* action of *the fire-damp* explosion has extended."

This conclusion, it will be observed, does not appear to be quite in harmony with Mr. Galloway's previous statement that coal-dust is capable of extending indefinitely throughout a mine a local explosion of fire-damp.

He also says that he "does not find that heating the air to a temperature of 70° or 80°, makes any difference," which is in opposition to the conclusion of Professor Abel from his Seaham experiments.

Mr. Galloway refers also to the accident at Penygraig, which took place December 10,1880, three months after the one at Seaham. Having been intrusted with the exploring operations connected with the opening of the mine, he had an excellent opportunity of acquainting himself with the details of that disaster. He noted that " the flame of the explosion *had passed through or penetrated into every part of the workings* except one wet heading at the foot of the down-cast shaft," and that " there were deposits or crusts of coked coal-dust in every *working place where the coal-dust was comparatively free from impurities,* while, on the other hand, the same kind of deposits were very rare in the main road-ways, *where the coal-dust was largely mixed with shale-dust and other impurities;"* and he concludes that as a very large amount of fire-damp was being constantly given off along the face of the solid coal, so that the air as it passed into the up-cast shaft always contained rather more than 2 per cent, of fire-damp, this fire-damp acting in conjunction with the coal-dust, was a most important factor in promoting and intensifying the explosion.

Mr. Galloway's next paper was read before the British Association at York, September 7, 1881; but as it refers to a series of experiments more particularly described in a communication to the Royal Society five months later, it will require no further notice here.

In his paper No. 4, read before the Royal Society December 29, 1881,* he gives the details of 63 experiments made during the warm weather between the 14th and 21st of the preceding July, and with the apparatus mentioned in his paper No. 3. About 10 per cent, of fire-damp was introduced into the explosion-chamber, and the *fresh-air* current passing through the gallery had a velocity of 1000 feet per minute. The coal-dust used had been deposited in a still atmosphere within a building in which coal had been ground for coke-making. He states that he could not obtain the results that he had previously obtained with dust taken from screens, nor from mine road-ways, thus showing a marked difference between his determinations and those of Professor Abel.

In his previous experiments, the longest flame was obtained from coal-dust when the doors of the gallery were open, free access of fresh air being permitted; but his present experience was that the more nearly air-tight the gallery, the greater prolongation of flame. The results of 34 experiments rnay be summarized as follows :

1. The. average length of 14 fire-damp flames was 12 feet, 6 inches.

2. The average length of 15 flames of coal-dust, fire-damp and air was 118 feet, 5 inches.

3. The average length of 5 flames of coal-dust, fire-damp and air, augmented by the explosion of heaps of 2 to 4 ounces of gunpowder, placed on shelves and on floor of gallery, was 145 feet.

In the first series, the 15th experiment gave no tabulated result.

In the second series, 15 were omitted from the computation (though all but 3 gave tabulated results) by reason of the seams in the gallery being open ; and 8 others of the series gave no tabulated results.

Of the third series, 6 only gave tabulated results, one of which, showing the shortest flame, was not taken into account, for the reason that the flame came out of the open section before reaching the end of the gallery.

The experiments with coal-dust, and closed or open boxes showed:

Average length of flame in 5 experiments, closed box, 140 feet, 7 inches.

Average length of flame in 4 experiments, one section open, 132 feet, 9 inches.

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* *Proc. Boy. Soc,* 1881, vol. xxxiii., p. 437.

Average length of flame in 10 experiments, two sections open, 114 feet, 6 inches.

Average length of flame in 1 experiment, three sections open, 122 feet.

'Which seem to warrant Mr. Galloway's statement, given above, that the more nearly air-tight the gallery the longer the flame. It should be noted, however, that in all the four experiments with closed galleries, except one, heaps of gunpowder were placed on shelves and on the floor. The single experiment without powder gave a flame only 108 feet long. In the experiment giving the next to the longest flame, two of the three heaps of powder were not burned.

No table is given in this paper showing the results of either chemical or microscopical examination of the dust used, from which we may infer that Mr. Galloway did not consider this important— which agrees with his testimony given before the Royal Commission.

Mr. Galloway considers that the experiments described in his first paper seemed to show that a mixture of air and coal-dust was not inflammable at ordinary pressure and temperature, without the presence of a small proportion of fire-damp; but those described in the fourth paper showed conclusively, he thought, that fire-damp is altogether unnecessary, when the scale on which the experiments are made is large enough, and when the fineness and dryness of the dust are unquestionable. This is somewhat different from his reply to Professor Abel, one of the Royal Commission, that his experiments in coal-dust, of one and the same description, but of different degrees of dryness, seemed to give very much the same results.

The Royal Commission on Accidents in Mines * was sitting in 1879 and 1880, and much of its work was contemporaneous with that of Messrs. Galloway and Abel, and also of the Committee of the Chesterfield and Derbyshire Institute of Engineers, whose labors will receive attention further on.

The Report of the Commission, presented in 1881, was a preliminary one; the Commissioners stating that as some time must necessarily elapse before the experimental inquiries were in a sufficiently complete condition to allow of the results, and the conclusions to be derived therefrom, being reported, they had deemed it desirable to present the whole of the evidence given before the Commission. In submitting their summary of the evidence, they pointed out that it had been framed only with the object of presenting a concise review

* *Preliminary Report Royal Accidents Commission,* 1881.

of the information elicited, and not with the object of conveying any definite conclusions arrived at by themselves upon any of the numerous subjects included in their inquiry, desiring to reserve the expression of such conclusions until the completion of the experimental and other investigations upon which, as already stated, they were still engaged.

The Report in itself is brief; but the evidence is voluminous, consisting of about 15,000 answers to questions, and several pages in which the testimony of each of the witnesses was collated for easy reference. The final report, though anxiously looked for, is not expected for some time to come.

The Report treats of the subject under sixteen different heads on which information has been elicited. With regard to the influence of coal-dust, they say:

"The proportion of fire-damp required to bring dust in a mine into operation as a rapidly burning or an exploding agent, even on a small scale, and with the application of a small source of heat or flame, is below the smallest amount which can be detected in the air of a mine, by the most experienced observer, with the means at present in use. In air travelling at a velocity of 600 feet per minute, different coal-dusts suspended in the air, containing from 2 to 2.75 per cent, of fire-damp, produce explosions. At a velocity of 100 feet per minute, the same result was obtained with air containing only 1.5 per cent, of gas; and ignitions of dust approaching explosions, and extending to considerable distances, were obtained with dust in air containing much smaller proportions of gas. Mixtures of fire-damp and air bordering on those which will ignite on the approach of flame, were instantaneously inflamed by a lamp when they contained only a few particles of dust in suspension, and it was found that these need not be combustible, but that some perfectly non-combustible dusts possessed the property of bringing about the ignition of mixtures of air and gas by a lamp-flame, which were otherwise not inflammable."

It is interesting in this connection to give the individual views of a few witnesses before the Commission on the effect of coal-dust.

Mr. Joseph Dickiuson (Inspector of Mines) states that hundreds of explosions had come under his observation, but he never knew of an instance where the explosion could be attributed to coal-dust alone.

Mr. Thomas Wynne (Inspector of Mines) says, "there must have been gas before the coal-dust ignited. I have never known a case, nor do I think there has ever one occurred, in which an explosion has been traced to coal-dust alone."

Mr. Frank Wardell (Inspector of Mines), while considering that an explosion is carried further through the mines by coal-dust, thinks it is doubtful whether its force is increased by the dust.

Mr. James Willis (Inspector of Mines) thinks dust may largely increase the damage done by an explosion of gas.

Mr. Thomas E. Wales (Inspector of Mines) considers that only in extensive explosions of gas would coal-dust add very much to the intensity, and he would not look upon coal-dust as being inflammable to any serious extent. He instanced a recent disaster, in which the gas-flame extended over 150 yards, yet in which the coal-dust had not been touched, though it was very dry and 4 or 5 inches deep in the place.

Mr. Thomas Cadman (Inspector of Mines) stated that while instances had come to his knowledge when dust had contributed to the violence of an explosion, he had never had an accident which could be ascribed to dust independently of gas.

Mr. Richard Foster (Manager of Hilton Collieries) had never seen a case in which the dust was fired by a blown-out shot. He believed dust would add to an explosion, but could not cause it.

Mr. William Lishman (Mining Engineer) could conceive that coal-dust might intensify an explosion, but it would not cause one without the presence of gas; and he thought a great deal more had been made of coal-dust than was warranted.

Mr. Alfred Hewlett (Manager Wigan Coal and Iron Company) had no doubt that coal-dust greatly aggravates an explosion of gas or with a blown-out shot. But there is not much fear from dust if gas has not been ignited.

Mr. William Pickard (Wigan) did not think it possible for a blown-out shot, without the presence of gas, to explode or ignite the coal-dust itself.

Mr..Bryam (Manager of Rosebridge Colliery, Wigan) considered, from his experience, that dust simply extends the flame and does not add much to its force.

Mr. Richard Bedlington (Past-President of the South Wales Institute of Engineers) was of the opinion that the effects of an ex-plosiou might be extended to great distances by fine dust, more or less incandescent, but could not believe that a continuous flame had been carried so far.

Mr.-Thomas Joseph (Merthyr Collieries, South Wales) thought that coal-dust would never produce an explosion; but as there is a good deal of gas lodged in dust, it would add. to the .explosion.

Mr. John Nixon (Navigation Collieries) believed that dust adds to the inflammability of the atmosphere, when present with gas.

All those whose testimony has been cited appear to be in accord that while dust is not in itself explosive, it is abundantly able to intensify an explosion initiated by gas.

The most complete series of experiments, the results of which have yet been published in England, are those made by a Committee of the Chesterfield and Derbyshire Institute of Engineers, appointed in April, 1879 ; their very extensive report appearing in vol. x. of their *Transactions* for 1882.

The Committee numbered eighteen, all of whom were distinguished for their knowledge of and interest in the subject, and two—Professor Freire Marreco and Mr. D. P. Morison—had previously made and reported on extensive experiments of their own, already noticed in this paper.

The apparatus, similar to that used by Galloway, was a wooden tube 82 feet long, in sections generally of 12 feet in length, and 18 inches by 14 inches on the inside. Connections and fittings were provided for a blowing-fan, a heating-coil and a gas-jet. A hopper for introducing: coal-dust, rests for pistols and other explosive agents, force- and recoil-indicators, hygrometer, thermometer, a fan underneath the hopper to effect a thorough mixture of coal-dust, gas and air, as well as other appliances necessary for the convenience and safety of the observers, were parts of the apparatus.

As the gas used was from the town mains of Chesterfield, it was necessary to determine the equivalent explosive proportions of coal-and pit-gas in air; and as a preliminary step, Mr. Jones, General Manager of the Chesterfield Gas Light Company, ascertained, by experiment, the most explosive proportion of coal-gas in air to be 1 in 7, or 14.28 per cent.

Atkinson gives the most explosive mixture of pit-gas in air as 1 in 10.4, or 9.61 per cent. Hence, coal-gas is, in this sense, $\frac{9.61}{14.28} =$ .67 as explosive as fire-damp.

The terms "explosion " and " inflammation," having hitherto been often used somewhat indiscriminately, were defined as follows:

An "explosion," to be anything which caused a *sudden* increase of pressure in the surrounding air or gases from the sudden and violent expansion of any substance in their neighborhood ; and an " inflammation," to be the quiet production of flame, unaccompanied by any sudden or violent changes of pressure in the surrounding gases.

Dusts were taken from various districts, mines and seams in England and Wales. Most of them were the finest particles that could be obtained with a feather-brush, from roads, screens, props, etc. Others were sifted through fine muslin, after reduction in a mortar. Microscopical examinations, but not chemical analyses, were specially made for the purposes of the experiments.

There were made in all, 211 experiments, of which 31 were excluded for reasons given, leaving 134 made with dust only, and 46 with gas and dust, for analysis and comparison. Generally the air-current was 300 feet per minute. The table below gives number and percentage of ignitions under different conditions both with and without gas.

	Dust.—No Gas.						Dust and Gas.		
	One pistol-shot.	Two pistol-shots.	Loose and compressed powder.	Explosive mixture H_2+O.	With shots and powder.	Total dust without gas.	Pistol-shots.	Loose and compressed powder.	Total dust with gas.
Ignitions, ...	8	13	11	4	32	36	17	4	21
Non-ignitions, . . .	46	44	4	4	94	98	24	1	25
Totals, ...	54	57	15	8	126	134	41	5	46
Percentage of ignitions,	14.81	22.46	73.33	50.00	25.40	26.86	41.46	80.00	45.65

No one of the 36 ignitions *without* gas was caused by a single pistol-shot with 60 grains of powder.

The following table gives, in a condensed form, the proportions of dust and gas in the different ignitions.

Dust.—No Gas.			Dust and Gas.			
Ignitions.		Ounces of dust per cubic foot of air.	Ignitions.		Ounces of dust per cubic foot of air.	Per cent. of gas.
Causes of.	No.		Causes of.	No.		
Pistol-shots and loose and compressed powder, .	32	0.09–3.84	Pistol-shots, . . .	17	2.14	0.35–8.06
Expl. mix. H_2+O,	4	2.28–2.93	Loose and compressed powder,	4	2.52	0.75–2.97

With 8.06 per cent, of gas, the flame was forced through the joints of the tube, a result which was to be expected.

The next table shows the length of longest, shortest, and average flames, with percentages of dust, gas, etc.

	Dust.—No Gas.					Dust and Gas.					
	Length of flame.	No. of pistol-shots.	Relative humidity.		Oz. of dust per cubic ft. of air.	Length of flame.	No. of pistol-shots.	Relative humidity.		Oz. of dust per cubic ft. of air.	Per cent. of gas in air.
			Out-side.	In-side.				Out-side.	In-side.		
Longest flame,	31′ 0″	2	34.2	50.3	0.09*	30′ 0″	1	67.7	58.5	2.14	5.76
Shortest flame,	10′ 3″	1	72.7	58.2	2.4	10′ 6″	1	55.0	43.3	2.52	1.09
Average flame,	18′ 0″	..	68.3	60.8	..	20′ 1″	..	69.7	61.2	...	2.32

The force- and recoil-indications it was not deemed necessary to present in tabular form, but the committee generally were of the opinion that they bore out and confirmed the observation that the ignited dust travelled along the tube at a rate certainly-not much, if at all, exceeding the velocity of the air-current.

They state that some of the experiments, in which the coal-dust ignited, were made under circumstances not especially favorable to such a result as regards the hygrometric condition and temperature of the air-current, and cite experiment 106 as giving an ignition when "the dry and wet bulb stood respectively outside 60° and 61° and inside 69° and 65°." This is presumably a misprint, as in all the accompanying tables the outside observation is given dry bulb 61°, wet 60°. The difference is material; in one case the relative humidity is 94.1, while in the other it would indicate that water was suspended in the air as a clearly observable mist, an especially unfavorable condition for ignition.

By referring to the tabular statements, I think it will appear, however, that not only was ignition No. 106 anomalous and probably attributable to other causes, but that generally the length of flame seemed to vary inversely as the amount of hygroscopic moisture in the air of the box.

We have as follows:

* The extreme lowness of this figure suggests that it may be a clerical or typographical error.

	No. of experiment.	Relative humidity. Outside.	Relative humidity. Inside.	Length of flame.	Oz. of dust to cubic ft. of air.	Description of dust.
1. *Dust-Ignitions.—No Gas. One Shot.*						
Mean of 8 ignitions,	..	72.7	58.6	15′ 9″	...	Busty Bank seam, Durham district. Sieved.
Longest flame, . . .	156	72.7	52.4	29′ 0″	1.45	
For comparison, . .	106	94.1	79.6	14′ 0″	2.7	
2. *Dust-Ignitions.—No Gas. Two Shots.*						
Mean of 13 ignitions,	..	64.0	60.05	19′ 0″	...	Black shale seam, Chesterfield, from above screens. Pounded and sieved.
Longest flame, . . .	83	34.2	50.3	31′ 0″	0.09*	
For comparison, . .	106	94.1	79.6	14′ 0″	2.7	
3. *Dust-Ignitions.—Loose and Compressed Powder. No Gas.*						
Mean of 11 ignitions,	..	70.0	63.3	16′ 6″	...	Top hard seam, Nottingham. Bank dust, pounded and sieved.
Longest flame, . . .	128	72.7	54.5	25′ 0″	2.40	
For comparison, . .	106	94.1	79.6	14′ 0″	2.7	
4. *Dust- and Gas-Ignitions.*						
Mean of 21 ignitions,	..	69.7	61.2	20′ 2″	...	Black shale seam, Chesterfield, from above screens.
Longest flame, . . .	210	67.7	58.5	30′ 0″	2.14	
For comparison, . .	106	94.1	79.6	14′ 0″	2.7	

From the above it will appear that, without gas, the longest flame resulted when the relative humidity inside was below the mean from 6.2 to 9.75 per cent; and when gas was used the humidity was still below the average of the series 2.7 per cent. If we group the experiments more closely together we shall have:

Ignitions.	No. of experiment.	Relative Humidity. Outside.	Relative Humidity. Inside.	Length of flame.
Mean of 53, ...	.....	68.46	60.95	18′ 5″
Mean of longest flame,	.....	61.8	53.9	28′ 9″
For comparison, . .	106	94.1	79.6	14′ 0″

* The extreme lowness of this figure suggests that it may be a clerical or typographical error.

In order that we may get a clearer view of the peculiar atmospheric conditions that seemed to environ No. 106, we can tabulate with them the barometric and hygrometric observations made during the five preceding experiments, in which there were no ignitions, all being made on the same day, June 19th, 1880.

No. of experiments.	Barometer.	Outside.		Inside.		Length of flame.	No. of pistol-shots.
		Hygrometer.	Relative humidity.	Hygrometer.	Relative humidity.		
101	29.52	61 / 60	94.1	72 / 64	62.4	0	1
102	"	"	"	"	"	0	1
103	"	"	"	"	"	0	1
104	"	"	"	"	"	0	1
105	"	"	"	69 / 65	79.6	0	2
106	"	"	"	"	"	14 ft.	2

We see from the above that in the first five of the series, there being no ignition, the outside air was 94.1, and the inside 62.4 per cent, saturated ; and in No. 105, when the percentage of hygroscopic moisture in the box-air had increased to 79.6, there was no ignition, and yet, under precisely similar conditions to the latter, the flame in 106 was 14 feet long. In experiments Nos. 107 and 108, made on the same day, and excluded from the computation, as the dust was fired by the explosive mixture $H_2 + O$, the relative humidity inside the tube was in the former 75.1, and in the latter 67.2 per cent.

From this unlooked-for result the question might naturally arise whether or not experiment No. 106 should be taken into account when considering what relation, if any, exists between the hygroscopic condition of the air-current within the apparatus and the extent of the ignition. It is possible, also, that there may have been attendant and unobserved circumstances that would have explained the great length of flame in this particular instance.

The conclusions of the committee were summarized as follows:

They were unanimous that no explosion, only ignition of dust, occurred *without* gas. Special circumstances must combine to insure ignition of dust *without* gas.

It appears that almost any coal-dust can be inflamed under specially arranged conditions, such as may never occur in a mine.

The same dust is more readily inflammable under some conditions than others.

Dust from floors and roadways of dusty mines did not inflame, but the finest and dryest particles, swept off props and bars, and Such as had floated upward through the atmosphere, and settled above screens, were found to be not less inflammable, if not more so, than pure coal-dust pounded and sifted.

In a very dry and dusty mine only is the dust-flame capable of extending the effect of a small explosion of gas (by which, more likely than by any other means, it may have been itself originated, and which might be confined to one spot if there were no dust) to other gas-laden spots.

The finest, freshest and most inflammable coal-dust floating in the air-current of a mine in its ordinary working condition, and free from fire-damp, could not, they believe, be ignited by the direct action of any blown-out shot; the great quantity of dust required for such an ignition being sufficient to make the current an intensely black cloud surcharged with dust.

The dust-flame that might result from the projecting of a blown-out shot flame into a deposit of dust, even though augmented by passing dust, would not continue far from its origin.

There appears to be little, if any danger of the ignition of dust from the ordinary lights of miners.

The indications are that in a dry and dusty mine, the air-current of which is charged with such a low percentage of fire-damp—½ to 3 per cent.—that the most careful observer would fail to detect it by the ordinary safety-lamp, a heavily charged blown-out shot, or violent concussion, might raise a cloud of dust, and at once convert the air-current into an inflammable mixture.

Generally, the experiments may be taken to show that the purer the atmosphere of a mine the greater proportion of dust required to render it inflammable; and conversely, the higher percentage of dust the less fire-damp required to bring about the same dangerous condition.

In a lecture on "Some of the Dangerous Properties of Dusts," delivered before the Royal Institution of Great Britain, April 28th, 1882,* Professor Abel deals with the whole subject of the influence of cotton, flour, rice, coal and other dusts on explosions. He reviews at considerable length the observations of English and Continental

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* *Proc Roy. Inst. of Great Britain, vol. x.,* Part I., 1882.

investigators, as well as his own work in connection with the Seaham disaster and the Royal Accidents Commission. With regard to his experiments with non-combustible dusts, he favors the view that "a dust possessing particular physical characteristics exerts a contact or catalytic action upon gas-mixtures, similar to that known to be possessed by platinum and some other substances under particular conditions."

In many of the experiments with calcined magnesia, he distinctly noticed that a dark space intervened between the gas-flame, used as a source of heat, and the flame produced by the ignition of the gas-mixture through the influence of the dust-cloud suspended in it; which would seem to indicate that the dust-particles, immediately upon passing through the flame, established some amount of oxidation of the fire-damp, which proceeded with increased rapidity as the dust became more highly heated through the chemical action developed, so that within a short distance from the point where the heating commenced, the dust became incandescent, and the ignition of the gas-mixture followed. Further experiments which he contemplates may elucidate the precise nature of this action of non-combwstible dust.

Professor Abel made particular reference to special experiments made at his suggestion in masonry galleries in some old fortifications at Chatham, for the purpose of determining the influence of dust in extending the flame from a blown-out charge of powder. The result was that in one instance the flame, from a 1 1/2 lb. charge, was projected with sufficient force to burn gun-cotton at a distance of 20 feet, and in another case 32 feet, in the absence of dust and gas. With clouds of fine dust blown into the gallery and suspended in the air, tufts of gun-cotton were fired about 39 feet from the initial point.

He concludes, finally, that while admitting that the results of certain experiments seem to favor the conclusion of Mr. Galloway that the presence of fire damp is altogether unnecessary to bring about a coal-mine explosion, its realization necessitates the fulfilment of conditions which cannot but be very exceptional.

In a paper entitled, "The Explosive Properties of Coal-dust, Coal-gas, and Atmospheric Air, with Special Reference to Mines," read before the Manchester District Institution of Gas Engineers, February 15th, 1883,* Mr. Charles E. Jones, General Manager of

* *Lond. Journ. of Gas Lighting,* February 27th, 18S3, vol. xli, p. 358.

the Chesterfield Water Works and Gas Light Company, describes his experiments with mixtures of different proportions of coal-gas and air. He had been the member of the Chesterfield and Derbyshire committee to whom had been intrusted the experimental determination of the most explosive mixture of coal-gas and atmospheric air ; a work already alluded to.

Among other results, Mr. Jones demonstrated that the time required to insure perfect diffusion, without artificial agitation, of coal-gas and air, was one hour to each cubic foot of mixture. He also points out that, if there should be a trace of bisulphide of carbon in the air of a mine containing a low percentage of fire-damp, the mixture would readily explode, the inflaming point of that compound being about 300° F.

Mr. Jones considers that coal-dust may act as a finely-divided solid, and would also be subjected to destructive distillation, and thus, in two ways, contribute to the force of an explosion. He concludes that coal-dust would not, of itself, explode, except it be in a cloud so dense that the particles would be able to communicate, almost by contact, ignition to each other ; that the temperature must be higher than that usual in a mine; and that, assuming all the above conditions to be fulfilled, and the dust ignited, coal-gas would be generated so rapidly that the supply of oxygen would soon become exhausted, and the inflammation or explosion terminate.

In his paper, No. V., read before the Royal Society, May 15th, 1884,* Mr. William Galloway remarks, that since his previous comunications he has had unusual opportunities for studying the causes of several remarkable explosions, with the result that he is more than ever confirmed in his hitherto-expressed views regarding the influence of dust. He claims, also, that no earlier author than himself had credited coal-dust with being the principal factor in mine-explosions, relegating fire-damp to a secondary place.

Mr. Galloway says that his reasons for feeling it incumbent upon him to prove that a mixture of air and coal-dust is inflammable, are that in some great explosions it was found that the flame had passed through very long galleries containing, *presumably,* pure air and coal-dust, but no fire-damp ; and that certain other explosions could not be accounted for except on the supposition that they had been originated by the firing of a shot, the galleries containing only pure air and coal-dust, but no fire-damp, as before.

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* *Proc. Roy. Soc,* vol. xxxvii,, p. 42.

Mr. Galloway is manager of the Dinas and Adare Collieries, in South Wales, and has had exceptional opportunities to examine the phenomena due to the explosion which occurred at the former mine, January 13th, 1879. He had frequently inspected the workings previous to that time, and had done the same at intervals of less than a month since then, so that he has been entirely familiar for several years with all the conditions of the mine. No sudden outbursts of fire-damp had ever been known; the temperature had ranged from 75° to 82° F.; the floor was covered with dry coal-dust, and shot-firing had been carried on at night. The damage done to the workings by the explosion was so extensive as to lead to their temporary abandonment; and it was only near the close of 1883, and early in the present year, that certain remote workings could be examined. He saw no traces of burning, nor deposits of coked coal-dust in any one of the main roadways, but did find well-marked deposits of coked coal-dust in all the working-places in the two districts particularly indicated. These districts were independently ventilated, so that he thought it impossible that any outburst of fire-damp in one district should affect the quality of air in the other. He considers, therefore, that he is compelled to fall back on the coal-dust hypothesis as furnishing the only satisfactory explanation of this and similar disasters.

Neither assent nor dissent with regard to the views that have been quoted is intended to be expressed in this paper. But the facts, nevertheless, remain, that there are dusts and *dusts,* and that the ratio of the number of serious mine explosions to the total number of blown-out or overcharged shots and local explosions of fire-damp, in dry and dusty mines, is a small one; whereas, if the coal-dust theory be true to the extent insisted upon by its most strenuous advocates, every such local occurrence, in a mine of this description, should be followed by the more or less complete wreck of the colliery.

In France, the dust question has been written upon by Du Souich, Verpilleux, Burat, Vital, Chansselle and Desbief, Dornbre, Jamin, Goupillière, Mallard and Le Chatelier, Pernolet and Aguillon and others.

The general conclusion of the French Commission is quite different from that of the English.

They consider it established that the inflammability of coal-dust is in proportion to the amount of volatile matter it contains; that the quantity of dust to be mingled with the air, to cause ignition and transmit it, is such that it can only be placed in suspension by very active mechanical means, and that it can only be kept in sus-pension for a very short time after this mechanical action has ceased; that the dust in suspension can only be ignited by very large flames such as can result only from a blown-out shot or an explosion of fire-damp; and that the rapidity of transmission of the ignition is practically nil. From which they finally conclude that coal-dust with air can give rise to local explosions, only, of very limited extent.

A COMBINED VACUUM-PUMP AND TABLE-BLOWPIPE.

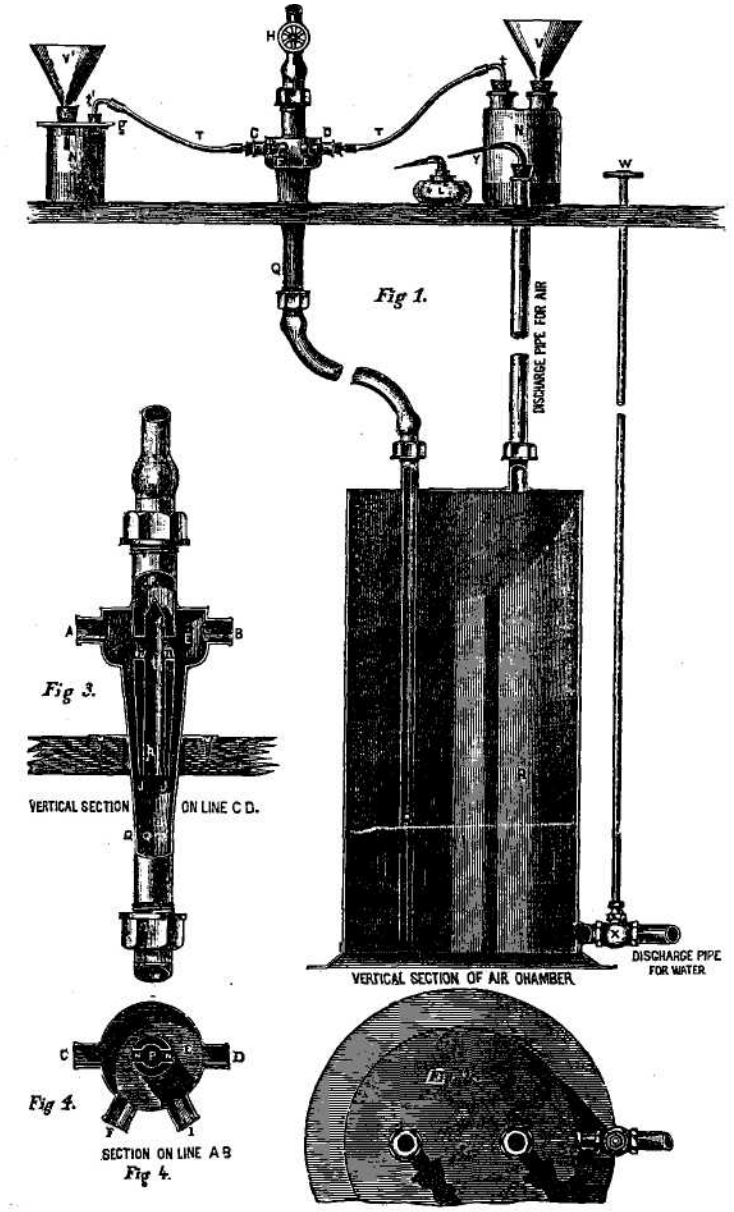
BY W. F. DURFEE, BRIDGEPORT, CONN.

THE apparatus described in this paper was designed by the writer, in the year 1869, for use in the laboratory of the " American Silver Steel Works," at Bridgeport, Conn., where only the vacuum-pump was erected ; but on two subsequent occasions I have had the combined vacuum-pump and table-blowpipe constructed as represented in the drawings, in which Fig. 1 is a general elevation of the apparatus, the air-chamber being sectioned vertically; Fig. 2, a plan of the air-chamber; Fig. 3, a vertical sectional elevation of the vacuum-pump, the section being on line C D, of Fig. 4, which is a horizontal section on line A B, of Fig. 3.

The vacuum-pump is constructed of copper, and consists of a vacuum-chamber, E, supported upon the upper expanded end of a vertical pipe, Q. The vacuum-chamber is provided with four nozzles, C, F, I, D (Fig. 4), two of which are shown in section at A, B (Fig. 3).

Passing vertically through the centre of the vacuum-chamber E, is seen the water-supply pipe P, whose lower extremity incloses an internal pipe *p,* which is supported, and placed in communication with the vacuum-chamber E, by means of the two elliptical nozzles n, n. The upper part of the pipe *p* is closed by a conical cap, and its lower end is in the same plane with the extremity of the water-supply pipe P, within which it is placed.

The relative sizes of the pipes P and *p* are such that an annular adjutage, one-sixteenth of an inch in thickness, is formed between their lower extremities, through which the water from the supply-pipe P passes into the pipe Q, drawing any air that may be in the vacuum-chamber E, and the upper .conical part of the pipe Q, along



PLAN OF AIR CHAMBER
SCALE: for Figs. 1 and 2, $\frac{1}{10}$; for Figs. 3 and 4, $\frac{1}{2}$.

with it, the air in the vacuum-chamber E having free access to the interior of the hollow cylindrical jet through the nozzles *n, n,* and the internal pipe *p*.

When the apparatus is used to facilitate the operation of filtering, either or all of the nozzles C, F, I, D are connected by rubber tubes to the vessel which is to receive the filtrate. In Fig. 1, two kinds of receiving-vessels are shown. That on the right consists of a common two-necked bottle N, to whose right-hand • neck is fitted a cork, through which is passed the stem of a glass funnel V, containing the filter-paper, and the solution to be filtered ; the left-hand neck is provided with a cork through which is passed the lower end of a bent glass tube, *t,* to whose outer extremity is attached the right-hand end of the rubber tube T, the other end being connected by a short glass tube to a perforated cork adapted to the nozzle D of the vacuum-pump. The form of receiving apparatus shown on the left of Fig. 1, consists of a beaker, N, of common form, having its lip ground to an air-tight contact with a glass cover-plate, *g,* provided with two holes to which are fitted corks for the reception of the filter-funnel V and the bent glass tube *t',* which last is connected to the nozzle C of the vacuum-pump by the rubber tube T' . Whenever the apparatus is employed as a vacuum-pump, such of the nozzles C, F, I, D(Fig. 1) as are not connected with filtrate-receivers must be closed with cork stoppers, as are the nozzles F, I; the cork stopper in the upper end of the discharge-pipe for air must be removed, and the valve X, in the discharge-pipe for water, must be kept wide open. This adjustment of the apparatus allows the mixture of air and water, which is discharged from the vacuum-pump through the pipe Q into the air-chamber R, to separate and pass away without resistance through the respective discharge-pipes for air and water. The rapidity and power of the action of the vacuum-pump may be readily adjusted at will by means of the valve H (Fig. 1), which controls the amount of water admitted to it in a unit of time.

Having thus described the action of the apparatus when used to hasten the process of filtering, I will now ask your attention to its use as a means of furnishing blast to a table-blowpipe.

In Fig. 1, the apparatus is represented (for the purpose of compactness of illustration) as acting, at the same time, as an exhauster and compresser of air, though in practice it is never used in this way. When it is desired to use it for the latter purpose, it is adjusted as follows:

The cork stoppers are removed from each of the nozzles C, F, I, D, thus allowing the air free access to the vacuum-chamber E (Figs. 3 and 4); the valve X, in the discharge-pipe for water, is partly closed, and a cork having a bent, tapered glass tube Y (Fig. 1), to serve as a blowpipe-tuyere, adapted to it, is inserted in the upper end of the discharge-pipe for air. This tuyere-pipe Y can be adjusted vertically, by moving it up or down in the cork through which it tightly passes, so as to adapt it to the height of the blowpipe-lamp L. In case it is necessary to use the blast at a distance from the upper end of the discharge-pipe for air, one end of a rubber tube of any convenient length may be attached to this pipe, its other end being provided with a tuyere, which may be held in any suitable support, and thus the blast may be carried to any form of lamp or other heat-generator.

The apparatus being adjusted as described, all that is required to put the blast in action is to turn on the water to the vacuum-pump by means of the hand-wheel H (Fig. 1). The water, as it passes

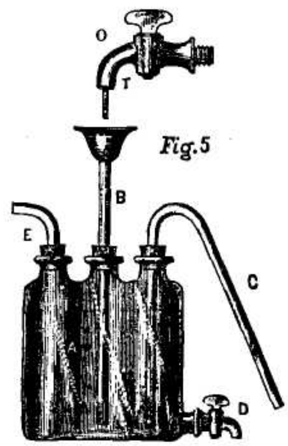


Fig. 5

through the hollow cylindrical adjutage *j j* (Fig. 3), draws the air through the four open nuzzles C, F, I, D, and carries it through the pipe Q, (Fig. 1) into the air-chamber R, in which the air and water separate, the former finding an escape through the discharge-pipe for air and its attached tuyere, and the latter passing off through the discharge-pipe for water. It is desirable that the air-chamber R should be located ten or twelve feet below the point of discharge of the blast, whose intensity is influenced to a great degree by the distance from the vacuum-chamber to the bottom of the air-chamber, as also by the pressure of the water supply through the valve H. The volume of blast may be regulated within its maximum limit by means of the valve H, and its pressure within the same limit by properly adjusting the valve X by means of the hand-wheel W.

Another form of blowpipe-apparatus, dependent for its action on similar principles to that already described, is illustrated by Fig. 5. It was first constructed by me in the year 1863, for use in the laboratory of the Steel Works at Wyandotte, Mich. It has the advantage that it can be readily arranged with the means usually at hand in any well-regulated laboratory. It consists of an ordinary Woolf bottle, A (Fig. 5), to whose central neck is tightly fitted (by means of a cork through which it passes) a funnel-tube, B, extending nearly to the bottom of the bottle. To the right-hand neck is fitted, in a similar way, a siphon, C, whose inner end nearly touches the bottom of the bottle. (In case a two-necked bottle having a tabulation on one side is available, a small cock, as shown at D, may be substituted for this siphon.) The left-hand neck of the bottle A has adapted to its cork a curved pipe E, to which may be attached a rubber tube for conveying the air delivered by it in any desired direction, for use in a blowpipe or other apparatus.

When it is desired to put the apparatus described in action, it is placed under a hydrant-cock, O, which is provided with a glass tube, T, slightly smaller in diameter than the funnel-tube B, and through the tube T a regulated stream of water is discharged into the funnel-tube. This stream will draw down with it into the bottle A a large volume of air, which, separating from the water, is discharged through the pipe E, while the water finds its escape either through the siphon C, or the cock D, as the one or the other is used in the construction of the apparatus.

In the course of my practice I have had occasion to construct several of the vacuum-pumps described, and they have given entire satisfaction in use. At the time when the first one was made (the summer of 1869) I had never heard of anything of the kind, though I have since been informed that what is known as the " Bunsen filter-pump" was then in use in a few laboratories; but as that did not furnish a blast, and could only be employed with one filter, I am disposed to believe that the idea of the combined apparatus I have described, as well as its realization in practice, was original.

PROCEEDINGS

OF THE

XLth (PHILADELPHIA, PA.) MEETING.

SEPTEMBER, 1884.

COMMITTEES.

*Executive Committee.**

John Birkinbine, *Chairman;* Charles A. Ashburner, *Secretary;* Theodore B. Rand, *Treasurer;* Eckley B. Coxe, W. E. C. Coxe, Henry S. Drinker, William Lorenz, Percival Roberts, Jr., S. B. Whiting. *Headquarters:* The rooms of the Engineers' Club of Philadelphia, 1523 Chestnut Street.

Excursion Committee.

Percival Roberts, Jr., *Chairman;* Charles E. Billin, F. von A. Cabeen, W. E. C. Coxe, Henry S. Drinker, Nicholas Lennig, William Lorenz, David Townsend,

Joint Committee A. I M. E. and A. A. A. S., Anthracite Excursion.

Charles A. Ashburner, *Chairman;* John C. Sims, Jr., Trans. Com. A. A. A. S., John Birkinbine, Executive Committee A. I. M. E., John E. Wooten, General Manager Philadelphia and Beading Railroad Company, S. B. Whiting, General Manager Philadelphia and Reading Coal and Iron Company, Joseph S. Harris, President Lehigh Coal and Navigation Company, P. W. Sheafer, Citizens' Reception Committee, H. S. Goodwin, General Superintendent Lehigh Valley Railroad Company, Joseph M. Wilson, Executive Committee A. A. A. S., Hon. Eckley B. Coxe.

Citizens' Reception Committee.

P. W. Sheafer, *Chairman;* Colonel D. P. Brown, Joseph S. Harris, General William Lilly, Lewis A. Riley, Heber S. Thompson, S. B. Whiting.

All the sessions of the meeting were held in Association Hall (Philadelphia Young Men's Christian Association), Fifteenth and Chestnut Street.

On Tuesday, September 2d, at noon, the Institute attended, as invited guests, the opening ceremonies of the International Electrical Exposition, comprising an address of welcome by Hon. William B. Smith, Mayor of Philadelphia (introduced by Hon. George H. Boker, Chairman of the Committee on Ceremonies); procession

* Elected by the Local Committee, which comprised all members and associates residing in Philadelphia and vicinity.

from the lecture-room of the Exposition to the grand galleries of the main building; prayer by Rev. J. S. Macintosh, D.D., of Philadelphia; address by William P. Tatham, Esq., President of the Franklin Institute of Philadelphia; address and declaration of opening, by His Excellency, Hon. Robert E. Pattison, Governor of Pennsylvania.

At the opening session on Tuesday evening, Mr. John Birkinbine, Chairman of the Executive Committee, after a few words of greeting in behalf of the members residing in and near Philadelphia, introduced Hon. William B. Smith, Mayor of Philadelphia, who delivered a cordial address of welcome to the Institute in the name of the city.

President J. C. Bayles responded briefly for the Institute to the sentiments expressed by the mayor, and continued as follows :

Gentlemen of the American Institute of Mining Engineers, Ladies and Gentlemen: Neither the example of those who have preceded me in the honors and responsibilities of the Presidency of the Institute, nor the expectation of the membership, imposes upon me the duty of delivering a technical address from the chair at this meeting. Moreover, it is probable that the attention of the membership has of late been fixed, as mine has been, more upon economic than upon technical questions. The extreme industrial depression through which the country is passing, and of which we have not yet seen the end, invites consideration as one of the phenomena of civilization, resulting, curiously enough, from conditions eagerly sought, enthusiastically promoted by the engineering profession, and, when attained, regarded as in the highest degree promotive of the general welfare. The higher and more complex our social organization, the more certain, I think, will be the periodical recurrence of these seasons of depression, which a wise foresight keeps ever in view. Whether they would occur as frequently, if at all, under that absolute freedom of trade among nations of which the political economists dream, I do not know and it is idle to speculate. The tendency of nations is steadily in the opposite direction, and the efforts which are now made in the principal countries of the world to dispense with such of the products of other nations as can be produced at home, even at the sacrifice which is assumed to attend the diversion of labor from pursuits yielding the largest return for the least effort, are attended with such congestions of the markets of the world that the impulse of progress is, as we know, intermittent, 'and capital becomes sensitive to even slight encouragements and discouragements. We cannot, however, be sure that even the Utopia of the economists would be exempt from alternations of prosperity and depression. We are taught, as fundamental truths of economic science, that the end and aim of all human endeavor is abundance; also, that all commercial relations necessarily rest upon the basis of mutually advantageous exchanges. Taking these two elementary truths together, we find that the producing nations of the world are, at the moment, possessed of a greater supply of products than can be exchanged for other products with advantage. We know as a matter of fact, that the condition of abundance has not been reached, and yet we are suffering from a partial paralysis of our national energies because of what is popularly known as "over-production." If a manufacturer in any line is asked what is the cause of the present depression in business, he will promptly reply, "over-production." The thoughtful student of social science will answer that it cannot be, for the reason that there are millions of people whose wants are only partially supplied, and who need more of everything than they are able to procure. The manufacturer will in turn reply that, while this is undoubtedly true, as an abstract proposition, it is none the less a fact that the people whose wants are unsupplied have nothing to give in exchange for what they need except labor, and that if this labor were employed in extending production, the supply would be still further increased, so that a greater distribution on this basis of exchange would still further aggravate the evil. This seeming paradox can, of course, be explained, but for all practical purposes we may assume that over-production is an economic fact, though perhaps called by the wrong name; and that as a fact it must be recognized. At the present time the demand (by which we mean the desire and ability to purchase) is much less than the actual or possible supply; and while this condition of affairs continues, the manufacturer who can produce at least cost is master of the situation, and the fittest to survive.

It is only natural that these convulsions in trade should occur Wore frequently as civilization advances. In a state of barbarism they would be impossible; in countries possessing a low grade of civilization they could occur only in modified form and wholly as the result of external influences. They were practically unknown— save in such phenomenal forms as resulted from the Tulip Mania and the South Sea Bubble—at the time when every household wove its own textile fabrics and made its own clothing; when carpets were made on hand-looms and were only seen in the houses of the wealthy; when iron was scarce and articles made from it were cherished as family heirlooms; when travelers journeyed from place to place at an average speed of four or five miles an hour; when money was seldom handled in large amounts and trade was carried on by means of merchandise exchanges; when banks were few and their deposits unimportant. The progress of a century has changed all this. The steam-motor; the improvements in machinery and the concentration of production in the great industrial centers, where the large factories are crowding out the small ones; the introduction of railways and steam-vessels, and the rapid and cheap conveyance of food and manufactured goods through their instrumentality ; the multiplication of banks and financial institutions, and the tremendous power of the large accumulations of money thus secured—all these, as well as other powerful agencies not so obvious, have had their influence in shaping our present splendid, but evidently unbalanced, industrial development. Railroads, banks and workshops depend so closely on one another, that whatever affects one interest is felt by the others. They work hand in hand in extending civilization, in providing what we now believe to be the necessaries of life, and in sustaining the great exchanges which perform, nationally, functions similar to those performed by the circulation of the blood in the human system. But as the net result of all this progress we find the sensitive organism of the body politic subject to influences previously unknown or unfelt, and which produce the successive phenomena of health, languor, debility, fever, delirium, sleep and convalescence.

The depression through which our iron and steel trades are now passing, was not unexpected, nor did it come abruptly. Prices have declined steadily since they touched the highest point, but it has taken two and a half years to come down to present figures. There has, therefore, been ample warning of impending trouble, and the absence of widespread failure among iron and steel-manufacturers shows that the warning has been heeded. Probably no industry in the United States is to-day on so solid a basis of financial strength as the manufacture of iron and steel. An occasional failure does not contradict this statement; for there are always some establishments improperly equipped or managed which are doomed to fail even in prosperous times. In this condition of affairs there is no use in mourning over the departure of high prices and praying that they will soon again return. Rather is it the part of wisdom to do all iu our power to prevent their return. Continuous business at reasonable prices with moderate profits is far better than the spasmodic activity and sharp reactions to which the American iron-trade has so long been subject. It would be better to sell foundry pig-iron at $20 a ton, bar-iron at 2 cents a pound and steel rails at $30 a ton, and have a regular demand, year in and year out, which could be depended upon, than to get $40 for pig-iron, 4 cents a pound for bar-iron and $70 a ton for steel rails for six months, to be followed by years of declining prices and shrinking demand.

From the earliest dates in the world's statistical history, the tendency, with temporary exceptions, has been steadily in the direction of lower prices for the products which are in general demand. On the settlement of a new country, while there is a scarcity of labor, wages will be very high and prices of all sorts of products will consequently be high; but with the increase of population comes a competition for employment and for business which results in lower wages and lower prices. From time to time there are disturbances of the industrial equilibrium which cause prices to advance immoderately; but as lead expands when heated and stretches when cooled, growing longer or sagging lower in either case, so a decline in prices, when once established, is never fully recovered. The average of the next ten years will undoubtedly be lower than that of the past ten years. Probably, $35 will be above the average for steel rails, §20 for foundry pig-iron and 2 cents for refined bar-iron. There are other causes at work to bring about this result than are usually counted among those contributing to the average decline in prices. Among these, the most important is the increasing use of steel in competition with iron. Probably the severity of this competition is not generally appreciated. Mr. Isaac Lowthian Bell, in his address at the opening of the August meeting of the British Institution of Mechanical Engineers, shows by figures, which cannot be disputed, that the time consumed in the conversion of a ton of pig-iron into pneumatic steel ready for rolling, is one-sixth of that required for puddling the same quantity of iron and rolling into muck-bar; and that the steel in the ingot costs in British works $4 per ton less than the muck-bar. We need no better reason than this, and we need it on no better authority, to explain why steel rails are now selling for less than the commonest iron rails were ever sold for in this market. We all know very well that the high average price of steel rails in this country has not been due to the fact that their cost was high in proportion, but to special advantages enjoyed by the earliest established works during the life of the basis patents.

The increase of competition since the expiration of those patents, has materially changed the conditions of profit in the business. We also know that the causes which have made iron-manufacture relatively more expensive in this than in other countries, have been materially modified, and that the competition among domestic manufacturers has had a more marked influence upon prices than foreign competition has ever had or would have now, even under a revenue tariff. Considering the present development of iron and steel-manufacture in this country, particularly the latter, I am impressed with the fact that we must face the inevitable conditions of low prices and small profits to manufacturers, and that, in our seasons of speculation and excitement, the high-water mark of prices will, in each instance, be lower than that last recorded; and that the low prices of one decade will be the high prices of the next. For those of us who cannot adapt our manufacturing costs to the average price of the market in which we have to sell, there is very little chance.

The trouble with the iron trades to-day, is not so much over-production as the capacity for over-production. It is not because too many furnaces are in blast, but because there are a great many proprietors of furnaces, that have outlived their usefulness, who are standing, match in hand, ready to light their fires the moment prices advance to a point at which they can afford to make iron. If we could insure the maintenance of prices at or near the present level, the race would, indeed, be to the swift, and the battle to the strong, as in the end it must be. It is this inexorable law of nature which renders futile all attempts to artificially advance prices or induce a scarcity of products. It is this which makes so. hopelessly impracticable, the efforts now in progress to secure a six weeks' suspension of pig-iron production by the banking of furnaces, between now and the end of December. Such expedients are concessions from the strong to the weak. The weak are not permanently benefited, while the strong are deprived of the advantages which their strength should secure to them. When we seek to protect from nature's penalties, those who disregard or violate nature's laws, we enter the domain of benevolence, which lies wholly outside the domain of business. Benevolence is often misdirected and usually mistaken, always when it shapes a business policy and seeks to adjust the conditions of competition on such a basis that those who cannot stand alone, are held up by those who have strength and to spare. If the natural laws of trade are left to work out their own legitimate and proper results, we shall fare better in the end than if we try to enforce laws of our own making. If it is possible to keep the price of iron fairly steady, at or about the figure at which it is fairly remunerative to those who can produce it to the best advantage, we shall not be troubled by an over-supply of metal. At no time since 1873, have the number of blast-furnaces in operation in the United States, equalled 64 per cent. of those on the active list. It will, doubtless, be a matter of surprise to many, that, at no time, within eleven years, have we seen two-thirds of our furnaces in blast, and at present, about three-fifths of our furnaces, or to be accurate, 61 per cent, are idle. The average activity of our blast-furnaces is scarcely 50 per cent. of the capacity, and has never reached 66| per cent. since accurate statistics were compiled.

But it is scarcely worth while to further consider the economic aspects of the industrial situation, as the most important of the many practical questions growing out of it invites attention. It is a deplorable fact that the steady decline of prices during the past two and a half years, has encouraged a disposition to cheapen the cost of production by the use of inferior materials. This is, perhaps, an inevitable result of low prices, but it is none the less mortifying, and however regarded, it is well calculated to excite grave apprehensions. If the membership of this Institute standing in controlling or advisory relations to our great metallurgical industries could be instrumental in checking this tendency, the existence of which cannot be denied or doubted, we should do more to promote the best interests of the country than by any other service we could render. Americans have, in the past, had good reason to be proud of the high reputation of their manufactures.

But with low range of prices for iron and steel, dangerous practices have crept into many branches of the trade. The meanest stuff ever run through a furnace is furnished as pig-iron, and commands a market where good iron is refused. The most inferior grades of wrought scrap are made to do duty in mills which once proclaimed with pride the quality of their best refined bars. Much of this stuff has sunk so low in the scale of quality that manufacturers are ashamed to put their brands upon it, and so-called private brands, frequently changed to mislead the purchaser, are substituted by dealers. The standards of steel have also suffered deterioration, and steel plates, which should be thoroughly honest considering the uses to which they are put, are in many cases made from materials of which those using them have good reason to be ashamed. In the cheap railroad-axles and car-wheels now going into service the travelling public have grounds for grave uneasiness • and there is reason to suspect that if the railroads were a little less particular than they are in the matter of rail inspection, twenty-eight dollar steel rails would be worth very little more than they cost.

When we seek to fix the responsibility for this tendency we find it shifted from shoulder to shoulder. Naturally, the manufacturer blames the consumer, and assures us that, as the demand is for cheapness and quality is made a secondary consideration, he must produce cheaply, even if quality suffers. This is, at best, an unworthy plea. There are scores of manufacturers who refuse to stoop to disreputable methods of earning a profit on their goods, and, in spite of a competition without honor or principle, they maintain their standards of quality, demanding and receiving higher prices than those expect who have debased their goods. I do not know that the tendency to lower quality-standards as prices decline can be checked save by an appeal to self-interest. It is a business mistake, and will do more injury to our manufacturing interests than can be corrected in years of effort in the opposite direction. Let us hope that, before the evil shall have gone too far, conditions favoring reform will have succeeded those which have induced so many to adopt the short-sighted policy of encouraging the downward tendency of prices by debasing their products.

Gentlemen of the Institute, in opening this session for the business which is to engage your attention, I congratulate you upon the promise of a delightful and instructive meeting. I congratulate you on the opportunity of again assembling in Philadelphia, and especially at a time when so many gentlemen eminent in different departments of science in this and other countries are attracted-here by the meeting of the American Association. I congratulate you on a record of thirteen years of honest, earnest work, which warrants us in feeling that the American Institute of Mining Engineers, with nearly fifteen hundred members, including those most eminent in many fields of abstract and applied science, may meet even in this good company without apologizing for its presence. I congratulate you upon eleven volumes of *Transactions,* which compare favorably with those of any technical society of the world. I especially congratulate you on the fortunate chance which permits us to meet so many gentlemen eminent in various departments of learning, representing the most important scientific societies of the world. To members of foreign societies who may honor us by participating in our work or our recreations, we extend a cordial welcome.

Mr. C. Henry Roney, of Philadelphia, Pa., then gave a verbal account of a method of laying subterranean electrical conductors, which the members would find illustrated at the Electrical Exposition ; and R. W. Raymond, of New York City, made some " Further Comments on the Law of the Apex " (an appendix to a previous paper, prepared for publication together with that paper, in volume xii. of the *Transactions).*

The papers read at the second session, on Wednesday morning, were:

The Desilverization of Lead by Electrolysis, by N. S. Keith, of New York City.

An Experiment in Coal-Washing, by Dr. T. M. Drown, of Easton, Pa.

A New Charging-Bell, by Frank Firmstone, of Easton, Pa.

At the afternoon session on Wednesday, A. E. Lehmann, of Philadelphia, Pa., exhibited and explained an improved protractor, after which the following papers were read :

Coal-Mining in the Connellsville Coke Region, by John Fulton, of Johnstown, Pa.

Fire-Clays and Fire-Bricks in Sweden, by N. Lilienberg, of New York City.

Quicksilver-Reduction at New Almaden, by S. B. Christy, University of California, Berkeley, Cal. (Read by the Secretary in the absence of the author.)

On Thursday morning the members and associates of the Institute attended the opening general session of the American Association for the Advancement of Science.

At the fourth session of the Institute, held on Thursday afternoon, the following papers were read :

The Spence Automatic Desulphurizing Furnace, by W. H. Adams, of New York City.

Notes on the Patio Process, by Charles A. Stetefeldt, of New York City.

The Siemens Patents for Improvements in Glass-Furnaces, with Suggestions for their Use with Natural Gas, by Professor B. Silli-»>an, of New Haven, Conn.

A New Pressure-Filter, by R. P. Rothwell, of New York City, (Read by the Secretary in the absence of the author.)

The Deep River Coal-field of North Carolina, by H. Martyn Chance, of Greensboro, N. C.

On Thursday evening the Institute attended, by invitation, a lecture on The Geological Evolution of the North American Continent, given at the Academy of Music before the American Association for the Advancement of Science, by Professor J. S. Newberry, of Columbia College, New York City.

The fifth and final session was held on Friday morning, when the following gentlemen were elected members and associates of the Institute:

MEMBERS.

William H. Ainey,	Allentown, Pa.
P. E. Alden,	Monroetown, Pa.
John H. Allen,	Pueblo, Colo.
S. C. Baker,	Altoona, Pa.
Robert Beveridge,	Walkerville, Montana.
George D. Blair,	Spruce Creek, Pa.
A. P. Blakslee,	Delano, Pa.
Max Boehmer,	Leadville, Colo.
Samuel D. Bridges,	Pueblo, Colo.
George A. Brooke,	Pottsville, Pa.
Arthur C. Carson,	Butte City, Montana.
Frank D. Chase,	Pueblo, Colo.
George S. Clemens,	Ashland, Pa.
William Coutie,	Troy, N. Y.
Charles W. Dabney,	Raleigh, N. C.
James G. Dagron,	Pittsburgh, Pa.
Horace W. Disston,	Philadelphia, Pa.
William Disston,	Philadelphia, Pa.
Douglas Dixon,	New York City.
M. M. Duncan,	Rockwood, Tenn.
John W. Eckman,	Port Kennedy, Pa.
A. L. Fowler,	Tombstone, Arizona.
Erich Gaertner,	Chicago, Ill.
F. E. Gladwin,	Tombstone, Arizona.
David Halberstadt,	Pottsville, Pa.
James L. Houghteling,	Chicago, Ill.
W. G. Johnson,	Pine Grove, Pa.
James E. Jopling,	Ishpeming, Mich.
John N. Judson,	St. Louis, Mo.
Edward Kearcher,	Shamokin, Pa.
Albert B. Knight,	Virginia City, Montana.
Henry M. Luther,	Ashland, Pa.
R. C. Luther,	Pottsville, Pa.
Charles McMillan,	Princeton, N. J.
William W. Marsh,	Schooley's Mountain, N. J.

Henry G. Morris, ...	Philadelphia, Pa.
J. H. Olhausen, ...	Pottsville, Pa.
W. W. Pierce, ...	Franklin Furnace, N. J.
John H. Pollard, ...	Ashland, Pa.
John T. Richards, ...	Scorries, Cornwall, Eng.
Reuben Rickard, ...	Berkeley, Cal.
Frederick F. Thomas, ...	Jerome, Arizona.
William Van Slooten, ...	New York City.
T. Frank Walter, ...	Mauch Chunk, Pa.
Barge C. Weidman, ...	South Bethlehem, Pa.
Frank P. Weiser, ...	Ashland, Pa.
Thomas D. Whitaker, ...	Cedar Grove, Phila.
J. Chester Wilson, ...	Philadelphia, Pa.
H. C. Zacharias, ...	Shamokin, Pa.

ASSOCIATES.

Clarence R. Claghorn, ...	Philadelphia, Pa.
Richard Gatewood, ...	Phœnixville, Pa.
Joseph P. Gozzan, ...	St. Louis, Mo.
Walter M. James, ...	Philadelphia, Pa.
Edmund B. Kirby, ...	St. Louis, Mo.
William H. McCallum, ...	Wayne Junction, Pa.
E. A. Peter, ...	St. Louis, Mo.
Leonard Waldo, ...	Mauch Chunk, Pa.
Edmund L. Zukoski, ...	St. Louis, Mo.

The status of associate W. S. Humbert was changed to membership.

The following papers were then read :

Experiments with a Straight or No-Bosh Blast Furnace, by William J. Taylor, of Chester, N. J. (Read in the absence of the author by John M. Hartman, of Philadelphia.)

The Vallecillo Mines, Mexico, by Richard E. Chism, of Monterey, Mexico. (Read by the Secretary in the absence of the author.)

Prospects of the Ammonia Process for the Manufacture of Soda, by O. J. Heinrich, of Drifton, Pa.

The following papers were read by title :

The Separation of Strata in Folding, by Frederick G. Bulkley, of Leadville, Col.

The Electrical Activity of Ore-Bodies, by Carl Barus, of New Haven, Conn.

Geology and Mineral Resources of the Rio Grande Region in Texas and Mexico, by E. J. Schmitz, of New York city.

The Iron-Ores of Putnam County, N. Y., by Arthur F. Wendt, of New York city.

the Determination of Phosphorus, by Josef Westesson, of Thur-low, Pa.

American Mining Machinery in Mexico and Central America, by F. H. McDowell, of New York city.

Note on a Fire-Bulkhead, by Charles M. Rolker, of New York city.

Notes on Rhode Island and Massachusetts Coals (a communication to the Secretary from Dr. Arthur B. Emmons, of Newport, R. I.).

The President read a letter received by the Secretary from Mrs. Mary H. Holley, acknowledging the receipt of a presentation-copy of the volume issued by the Institute in memory of her late husband, Mr. Alexander L. Holley.

On motion of W. F. Durfee, duly seconded, the following resolution was unanimously adopted :

Resolved, That the Secretary be and is hereby directed to express to the corporations, societies, firms, and individual citizens of Philadelphia and vicinity, to whom such acknowledgment is due, the thanks of the Institute for the courtesies so cordially extended to visiting members; and that the thanks of the Institute are hereby tendered to the Local Committee, and its efficient Executive Committee, for the careful and judicious arrangements which have contributed so much to the pleasure and profit of this meeting.

The President then declared the meeting adjourned, and announced that the next meeting of the Institute, in February, 1885, would be held in New York city.

EXCURSIONS.

On Wednesday afternoon at 5 o'clock, the members and associates of the Institute, with ladies and friends, as the guests of the Local Committee, left the wharf at the foot of Arch street on the steamer Edwin Forrest, for a river-excursion. Through the courtesy of the U. S. Coast Survey, beautiful and minutely accurate maps of the Delaware river from Philadelphia to Wilmington had been prepared by the Local Committee, and were distributed throughout the party. The cruise extended first to Port Richmond, then back, past the city water-front and indefinitely towards Wilmington, Del.—the time of return being so chosen as to bring the steamer back to the wharf at about 10 P.M. Supper was served on board, and an excellent military band enlivened the occasion. The refreshing air of the balmy evening, the radiance of the harvest-moon, and the opportunity offered by this excursion for the social intercourse of new and of old friends, conspired to render it a delightful episode.

. On Friday afternoon, numerous minor excursions were organized in response to cordial invitations from John McArthur Jr., architect in charge of the new City Hall; Messrs. Burnham, Parry, Williams & Co., proprietors of the Baldwin Locomotive Works; Henry Disston & Sons, of the Keystone Saw, Tool, Steel, and File Works at Tacony; the Trustees of the Girard College, and others. The rooms of the Engineers' Club of Philadelphia, generously placed by the Club at the disposal of the Institute, were the headquarters and starting-point for the various parties. Among the objects of interest at the rooms was a fine *suite* of rock-specimens, illustrating the geology of Philadelphia and vicinity, exhibited for the information of members by Mr. Theodore D. Rand.

A considerable number of members availed themselves of the opportunity to revisit and study more closely, under the guidance of Mr. N. S. Keith, the International Electrical Exhibition. Others attended the sessions of the various sections of the American Association for the Advancement of Science.

On Saturday occurred the great joint excursion given to the Institute and the American Association, through the anthracite regions, by the Philadelphia & Reading R.R. Co. To the liberal cooperation also of the Philadelphia and Reading Coal and Iron Co., the Lehigh Valley R.R. Co., the Lehigh Coal and Navigation Co., Mr. H. J. Mumford, lessee of the Switchback R.R., and the citizens of the region, represented by the Citizens' Reception Committee, as well as to the great zeal and ability displayed by the special joint committee having the excursion in charge, must be ascribed the remarkable success with which all its details were carried out.

The party, numbering between four hundred and five hundred, left the Thirteenth Street depot of the Reading R.R. in a special train at 8 A.M. and proceeded up the Schuylkill valley, via Pottstown, Phœnixville, Reading and Mt. Carbon (where it was joined by additional guests from Pottsville) to Trackville on Broad Monntain, at the head of the Mahony Plane. Here lunch was provided by the

Citizens' Committee. The cars were subsequently let down the plane, and the train was formed again at the foot, and proceeded to the Indian Ridge Colliery of the Philadelphia and Reading Coal and Iron Co. Here the entire company, in parties of nine, was rapidly, comfortably, and safely lowered in cages to the bottom of the main shaft, and conducted through a gangway to a large breast, illuminated for the occasion with electric lights, so as to display some 25 or 30 feet of the Mammoth bed (the total thickness of which at this place is 50 feet). After viewing also the underground pumping-machinery, returning to the surface and inspecting the coal-breaker, the party proceeded via Mahony City, Tamaqua and Lausford, to Summit Hill, where it was transferred to the cars of the Switch-back R.R., and descended swiftly and delightfully along that famous and romantic way to Mauch Chunk. At this place supper had been provided by the Philadelphia Local Committees of the two societies; and after supper the members of the excursion party divided—the larger part returning to Philadelphia by the special train, while many remained at Mauch Chunk, to see more of its picturesque neighborhood, and others accepted the courtesy tendered by the Lehigh Valley R.R. Co., which conveyed them to such points on their homeward route as suited their convenience.

The interest and instructiveness of this excursion was enhanced by excellent maps of the region posted in the cars, and an illustrated description freely distributed in pamphlet form among the guests. For these timely and valuable helps to a comprehension of the geographical relations and geological structure of the anthracite region, the party was indebted to Mr. Charles A. Ashburner, geologist in charge of the Pennsylvania Anthracite Survey.

MEMBERS AND ASSOCIATES PRESENT.

The following members and associates registered their names at the headquarters of the Local Executive Committee :

William H. Adams.
W. F. Aldrich.
H. W. Armstrong.
Charles A. Ashburner.
W. S. Ayres.
F. E. Bachman.
Edward Bailey, Jr.
Charles H. Baker.
Richard D. Baker.
George T. Barns.
James C. Bayles.
Charles D. Bell.
Charles E. Billin.
John Birkinbine.
F. C. Blake.
E. Borda.
J. H. Bowden.
Jerome L. Boyer.
Alfred F. Brainerd.
George W. Bramwell.
J. H. Bramwell.
George Brooke.
P. H. Bronn.
Stuart M. Buck.
William Burnham.
F. von A. Cabeen.
James P. Carson.
H. M. Chance.
B. W. Cheever.
Harvey B. Chess.
George H. Clapp.
Ellis Clark, Jr.
F. W. Clark.
Thomas C. Clarke.
Frank G. Clemens.
Edward T. Clymer.
Edgar S. Cook.
George H. Cook.
Robert A. Cook.
Martin Coryell.
Torbert Coryell.
W. E. C. Coxe.
Albert de Deken.
E. V. d'Invilliers.
H. C. Disston.
William Disston.
Douglas Dixon.
Wallace H. Dodge.
John C. Dods.
William J. Donaldson.
W. F. Downs.
H. S. Drinker.
T. M. Drown.
Charles B. Dudley.
W. F. Durfee.
Alfred Earnshaw.
Edward H. Earnshaw.
A. H. Emery.
J. D. Estabrook.
John D. Evans.
B. F. Fackenthal, Jr.
Frederick J. Falding.
Isaac Fegely.
Robert P. Field.
C. B. Findley.
Frank Firmstone.
Colonel H. H. Fisher.
John J. Fisher.
H. S. Fleming.
William Forsyth.
Persifor Frazer.
John Fulton.
Howard V. Furman.
James Gayley.
F. A. Genth, Jr.
William Glenn.
J. K. Griffith.
Reuben Haines.
E. B. Harden.
J. H. Harden.
O. B. Harden.
Joseph S. Harris.
Edward Hart.
William R. Hart.
John M. Hartman.
Robert E. Hastings.
Oswald J. Heinrich.
C. Hanford Henderson.
J. A. Herrick.
C. John Hexamer.
James M. Hibbs.
Frank A. Hill.
Levi Holbrook.
Herman Hollerith.
C. B. Houston.
George S. Humphrey.
Frederick F. Hunt.
S. Warren Ingersoll.
William A. Ingham.
E. P. Jennings.
G. Jones.
Captain W. R. Jones.

Edgar B. Kay.
N. S. Keith.
William Kent.
Max Kinkead.
Charles Kirchhoff, Jr.
Henry C. Kriete.
William B. Lamberton.
J. S. Lane.
Edward K. Landis.
W. A. Leavitt.
A. E. Lehman.
Nicholas Lennig.
J. P. Lesley.
James F. Lewis.
N. Lilienberg.
William Lilly.
John P. Logan.
E. F. Loiseau.
N. W. Lord.
William Lorenz.
Benjamin S. Lyman.
Andrew S. McCreath.
J. King McLanahan.
Charles McMillan.
Thomas S. McNair.
Charles MacDonald.
James B. Mackintosh.
W. R. Maffet.
William M. Marple.
R. L. Martin.
Jean A. Mathieu.
George W. Maynard.
Captain O. E. Michaelis.
Philip W. Moen.
William P. Moore.
Charles H. Morgan.
Henry G. Morris.
S. F. Morris.
William H. Morris.
Alfred J. Moses.
James Neilson.
William G. Neilson.
William J. Nicolls.
J. M. Ordway.
George Ormrod.
Edward Orton.
Maurice B. Patch.
Leonard Peckitt.
R. Peters, Jr.
Samuel Peters.
William H. Pettee.
Willard Ide Pierce.
Joseph C. Platt, Jr.
George A. Porter.
John N. Pott.
William B. Potter.
J. Thorpe Potts.
J. Wesley Pullman.
Theodore D. Rand.
R. W. Raymond.
Jacob M. Rich.
Edgar Richards.
Lewis A. Riley.
S. M. Riley.
Percival Roberts.
P. Williamson Roberts.
Charles E. Ronaldson.
C. Henry Roney.
Pedro G. Salom.
Charles A. Schaeffer.
Meyer Schamberg.
C. H. Scharar.
T. Z. Schellenberg.
W. H. Scranton.
S. P. Sharples.
A. W. Sheafer.
P. W. Sheafer.
William P. Shinn.
J. M. Silliman.
H. N. Sims.
Oberlin Smith.
John C. Smock.
Albert Spies.
E. G. Spilsbury.
William F. Staunton, Jr.
C. A. Stetefeldt.
John Stevenson, Jr.
Lewis Stockett.
Charles P. Stone.
John H. Strauch.
P. A. Taylor.
A. Thies.
Samuel W. Thomé.
C. O. Thompson.
Heber S. Thompson.
J. N. Tilemann.
Herbert G. Torrey.
Dolphus Torrey.
David Townsend.
George R. Waite.
Bard Wells.
Arthur F. Wendt.

Charles R. Westbrook.
H. A. Wheeler.
Joseph Westesson.
Thomas D. Whitaker.
S. B. Whiting.
William H. Wiley.
Edward H. Williams, Jr.
Samuel T. Williams.
Eugene B. Wilson.
Jones Wister.
J. P. Witherow.
Albert H. Wolfe.
Harrison Wright.

PAPERS

OF THE

XL th (PHILADELPHIA, PA.) MEETING.

SEPTEMBER, I884.

A NEW PRESSURE-FILTER.

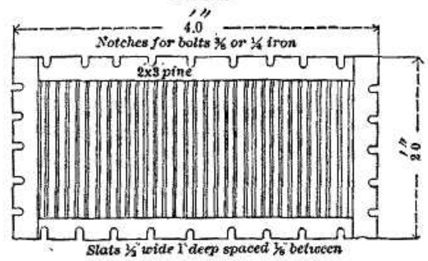
BY R. P. ROTHWELL, NEW YORK.

A YEAR ago I commenced experiments in precipitating and saving gold from chloride solution, in the course of which I found H_2S (made from paraffine and sulphur) the most convenient and inexpensive precipitant. The gold is thrown down as gold sulphide; and a considerable time is required for this precipitate to settle. Even after it appears to have settled, we find by experience that there is a notable loss of gold, if the clear liquor be decanted off in the usual way.

To remedy this evil, I made a small and very cheap pressure-filter, which has now been used for nearly nine months, and has given the utmost satisfaction. This filter is constructed as follows:

Three frames, about 4 feet by 2 feet, are made of 2-inch by 3-inch pine. Two of" these frames are filled in with ½-inch slats leaving about 1/8-inch spaces between the slats, as shown in Fig. 1.

FIG. 1



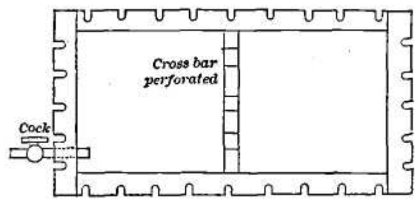
Plan of outer frames

These slats are covered with cloth or drugget, and Swedish filter-paper is laid on the top of the cloth. The notches shown in the figure receive bolts of § or ¼-inch iron, to hold the frames together.

The third frame, shown in Fig. 2, is of the same size and thickness as the others, but has, instead of slats, only one or more cross-bars. When the filter is put together, the third frame is placed between the other two, and the cross-bars serve to press on the joints of the filter-paper and keep the sheets together. The cross-bars are perforated, to permit the passage of the liquid, which enters through a pipe at the end provided with a faucet, and fills the whole filter.

Fig. 3 shows in perspective the filter complete. It will be seen that the middle frame, keeping the other two apart, furnishes a space

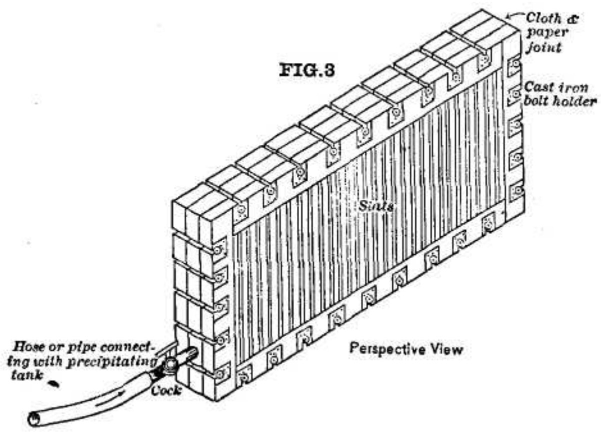
FIG. 2



Plan of inner frame

between them to be filled with liquor. This is brought through a rubber or iron pipe from the precipitating-tank. Since the filter is

FIG. 3

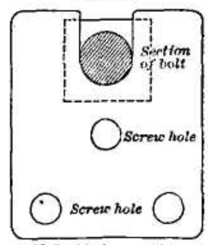


set on a lower level, any desired head or pressure can be obtained. About five or six feet is generally enough. The liquor passes out through the filter-paper, which collects the gold ; through the cloth, which is merely a support for the filter-paper, and then between the slats forming the sides of the filter.

Fig. 4 is an enlarged view of one of the malleable iron castings screwed on the outside frames, to receive the bolts. These, when loosened a little, may easily be lifted out of the notches, and thus the filter is very quickly opened. Before opening, it is laid on a sheet-iron tray. After the filter has been opened, the gold precipitate is rolled up in the filter-paper, fresh sheets are put in, the frames are again bolted together, and the apparatus is ready for further use.

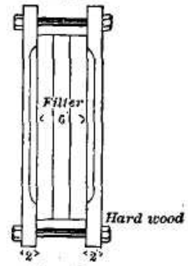
We strengthen the filter still further by a couple of cross-bars of hard wood, as shown in Fig. 5. This is required by the swelling of

FIG. 4



Malleable iron casting screwed on frames to hold bolts which clamp sides together

FIG. 5



Clamp for strengthening filter

the frames, held around their edges by bolts, which tends to loosen the joints of the frames.

The total cost of the filter will not exceed five dollars. It requires no attendance; the cloth lasts indefinitely (since the liquor is necessarily neutral before the gold will precipitate); and we have still the original cloth of one of our filters. Such a filter, 4 feet by 2 feet in size (giving an area of two sheets of filter-paper and hence containing, on the two sides, four sheets), will filter from fifty to one hundred and fifty gallons per hour, according to the amount of precipitate on the paper. The liquor passes very rapidly through it at first, and more slowly as the precipitate accumulates; but the filtrate is always perfectly clear. When the filtering becomes slow, the faucet is closed, the hose is disconnected, and the chemist and his assistant carry the whole apparatus into the assay-office, where it is laid in a sheet-iron tray, and opened as already described.

No one but the chemist has anything to do with it; and, standing in a closed box, it attracts no attention.

DISCUSSION.

C. A. STETEFELDT, New York City : In European works, where solutions with precipitates have to be filtered, the filter-press is now in general use, and there are quite a number of good constructions. I have myself seen those of Dehne and of Johnson. Johnson's are of English construction and can be bought in New York. No doubt Mr. Rothwell's press is quite an ingenions one and has been got up for this special purpose at slight expense; but perhaps it would be preferable, where large quantities of solutions have to be filtered to buy a filter-press of more perfect construction. They are exceedingly convenient and filter almost anything, leaving the precipitate in the form of a dry cake. In Oker, Germany, they are used, for instance, in Claudet's process. The filter-press has largely taken the place of the centrifugal machine.

THE BESILVERIZATION OF LEAD BY ELECTROLYSIS.

BY N. S. KEITH, NEW YORK CITY.

IT seems proper, before describing the plant which has been erected in Rome, N. Y., for the purpose of demonstrating the practicability of my process of refining and desilverizing lead by electrolysis, to state in a few words the principles that govern the process. They are well known to those who have studied electrical science, and to the practical electro-platers of the country, and are briefly these:

If we take a plate, or other form, of metal (impure lead in this case), and immerse it in a bath consisting of a solution of the main metal (that which contains the impurities), and also immerse another plate, which shall be a conductor of electricity, in the bath, but separated from the first by the solution, and connect the former plate with the positive pole of the source of electricity, and the other plate with the negative pole, an action will go on in this bath which is called electrolysis. There is first a decomposition of the solution constituting the bath; then a solution of the metal at the positive pole (called the *anode),* and a deposition upon the other plate connected with the negative pole, which plate is technically called the *cathode.* If the bath is properly constituted, and the current of electricity which is passed through the bath is of the proper strength and electro-motive force, the dissolution of the anode and the deposition of the metal upon the cathode will be exactly equivalent. The analysis and synthesis are opposite and equal. If, on the other hand, this solution (called an *electrolyte)* be not properly constituted, decomposition will go on, but there will be these effects: a super-oxidation at the anode and a liberation of free hydrogen at the cathode, which free hydrogen escapes finally in bubbles through the liquid to the surface, and into the atmosphere. In the electrolytic treatment of metals simply for their purification and recovery, it is important that the electrolyte should be so constituted that nothing will be dissolved from the anode but that which is to be deposited upon the cathode; and the action should take place in exactly equivalent quantities. In this case, for a given weight of lead dissolved from the anode, a given weight of lead should be deposited upon the cathode. If not so, there will be a waste of electrical energy in the liberation of the hydrogen which escapes to the atmosphere. There is a decomposition of the electrolyte; oxygen is freed at the anode, and sub-oxides and sub-salts are then formed, which finally act to cut down the current of electricity, or, in other words, act contrary to the electrical energy. This action is, therefore, not only uneconomical, in the way of the production of the metal, but uneconomical also by reason of the decomposition of the electrolyte, which should remain permanent in its constitution to avoid expense, to say the least.

With these principles in view, I commenced, several years ago, a series of experiments, as is probably familiar to the most of our members, through articles published from time to time in various journals, and papers in the *Transactions* of the Institute. These experiments were undertaken for the purpose of demonstrating the practicability of treating a material which is produced in abundance in this country--work-lead, or " base bullion."

In the pursuit of this investigation I tested many solutions as electrolytes, and finally settled upon a solution of acetate of soda, in which is dissolved sulphate of lead. The chemical reasons I need not enter into here. Suffice it to say, in the use of this bath, the dissolution of the lead from the anode and its deposition upon the cathode are exactly equivalent. This condition was secured after trying many solutions which, after a time, were found to suffer decomposition. The acetate solution above mentioned has shown itself, in many months, amounting to years, of trial, to maintain perfectly its integrity of constitution.

A few months ago, the erection of an experimental plant was commenced at Rome, N. Y., on a considerably larger scale than anything I had undertaken before, for the demonstration to capitalists of the feasibility of this process. When I commenced the experiment years ago, electrical science and appliances for the economical production of electricity had not reached the present advanced stage. Now we seem to have approached very nearly to perfection, since we are able to convert mechanical energy into that form which we call electrical energy with very slight loss. Dynamo-electric machines are used which return in electrical energy 84 to 96 per cent, of the actual mechanical energy applied to them by the belt of the steam-engine.

I will now describe the steps of the process to which the base bullion is submitted at this establishment in Rome, giving merely a short account of the main apparatus, and leaving to some future paper the electrical and chemical considerations involved in the process.

The metal is brought in pigs to the works, and is taken to a reverberatory furnace having a bowl-shaped hearth. At the bottom of the hearth is an iron pipe leading through the outer wall of the furnace. At the end of this iron pipe, within the bowl, there is a valve which opens inward by means of a rod passing through the pipe. The metal melted in this hearth is submitted to the action of a reducing flame produced with wood. About one-third of a cord of hard wood is burned in ten hours, and ten tons of bullion are melted in that time. Alongside the furnace is a frame which carries twelve moulds. These moulds are made to cast plates of bullion of the size 24 x 6 x inches. The frame is annular, and revolves upon rollers along the side of the furnace so as to bring the moulds (which are placed vertically on the ring) successively under the pipe from the furnace. As each mould is brought to the place, an attendant moves the valve to draw enough of the metal to fill it, and so on in succession.

As the frame is rotated, other workmen open the moulds, by turning clown one side of each, and remove the plates; but before closing the moulds they put in each some pieces of perforated copper ribbon, which, being subsequently surrounded by the metal of the next cast, serve for the suspension of the plate. The moulds are then closed, and pass on to be again filled in due succession.

After some practice, the workmen cast five of these plates per minute. The average weight is 7.6 pounds, so that we get 38 pounds of metal cast per minute, or a little over a ton per hour.

The plates are then taken by other workmen and hung temporarily by the copper strips on hooks, while a muslin bag is drawn over each plate from the bottom upward. In the following operation, as the lead is dissolved from the plate, there remains a residue, consisting of the impurities of the lead, viz., antimony, arsenic, copper, iron, silver, gold, and other metals. This residue would naturally drop to the bottom of the vat and become mixed with the lead. The office of the bag is simply to retain the residue.

After the bag has been drawn.upon the plate it is hung upon what is called the anode-frame.

This frame consists of six radial wooden arms fastened to a central cast-iron plate. Upon the outer ends of these arms there are roller's. The whole frame is a little over six feet in diameter. On the under-side of these wooden arms are copper conductors placed radially, so that their inner ends are in close contiguity. To these conductors on the under-side of the anode-frame are fastened twelve concentric rings, two inches apart; and upon these rings are metal hooks for the purpose of receiving the plates of bullion hung by the copper strips. The anode-frame holds two hundred and seventy-six of the plates, which hang on the twelve concentric rings from the frame above. The anode-frame is lifted from its place of rest by a travelling crane, carried and lowered into a vat containing the electrolyte which I have described. These vats, of which there are thirty in this plant, holding each a little over a ton of the metal, are 6 feet 1 inch in internal diameter, and are constructed of an asphaltic cement upon an asphaltic floor, so as to make them water-tight.

There is a system of pipes or conduits for the electrolyte, so that it may be conducted to each vat as desired. Thence it continually overflows the edge of the vat into gutters between the vats, and returns to an underground cistern, whence it is pumped to an overhead cistern which supplies a head to force the solution to enter the vats. In that way we obtain a continual circulation of the solution, which is necessary both electrically and chemically.

Within each vat there is also placed what is called a cathode-frame. This is built up of thirteen sheet-brass cylinders, placed concentrically, two inches apart. When the anodes are lowered into the vat they pass between the separate cathode plates, so that a cathode is upon either side of each anode-plate, at the distance of about 1 inch. The vats are so connected with the source of electricity that the current passes from a dynamo into vat No. 1 and up through the center of a core, 2 feet in diameter, built within the vat. This is built within the vat for two purposes: first, to sustain the copper conductor which passes up in its center; and second, for the purpose of occupying (instead of the solution) the central part of the vat, since it would not be practicable to bring the plates in annular arrangement around the center any closer than 2 feet.

Each one of these vats holds six hundred gallons of the electrolyte. The conductors leading to the vats are of 11/8 inch diameter round copper. From the inner periphery of each vat a copper conductor passes through the side and down underneath to the center of the succeeding vat, and so on over the whole series of thirty. The dynamo used is one made by Mr. Edison for the purpose. It furnishes an electric current having a difference *of* potential, or an electro-motive force at its binding-posts capable of rising to 6 or 7 volts; but in practice we use the current up to 2½ or 3 volts. The current which it supplies can be varied to suit the requirements of the case, but has been made as great as 1400 amperes, and from that to a thousand, and below; but the production of lead is in exact proportion to the ampéres of current. One thousand amperes of current passed through these vats enable us to dissolve this lead and deposit it upon the cathodes at the rate of 8.5 pounds per hour in each vat; so that we succeed in treating 1 ton of base bullion in each vat in ten days of twenty-four hours. The bullion requires no attention after being immersed in the vat, except that it is occasionally turned. This turning is to prevent " short-circuits," and can be done by means of the anode-frame having rollers upon the outer ends of the arms as described, which rollers rest upon the edges of the vat.

The lead is deposited upon the cathode in feather-like crystals, which build out from the cathode towards the anode, and in a short time, if not disturbed, would build across, so that the current of electricity, in preference to taking a path through the electrolyte, would pass directly by the metal, and we would cease to gain any dissolution, or deposition. Hence the operation of turning, which is now done by means of a lever; but it is in contemplation to have the movement take place continuously by mechanical power. After the lead is nearly all dissolved (some 5 per cent, is left) the anode-frame is lifted out, the bags are removed, and the residues are washed out into a vat.

After these residues settle to the bottom the water is drawn off by means of a siphon, and they are mixed with nitrate of soda in proper proportions and fused. As a result the gold and silver are found at the bottom of the crucible and the other metals are retained in the slag. The economical separation of these other metals, such as antimony and arsenic, will be pursued. The residues when dried appear as a black, impalpable powder, but at the same time of sufficient coarseness not to pass through the muslin bag. They can be readily filtered from the solution through coarse twilled muslin.

This plant, as laid down, has demonstrated the feasibility of the plan. It has been found somewhat imperfect, but has determined all the questions which have risen relating to the economic treatment. Other vats will be built to avoid the mechanical difficulties which we have encountered. The main difficulty is one of leakage. Unfortunately the vats were placed upon imperfect foundations, and from' the weight of the solution, the metal, etc., they have settled somewhat unequally, and cracked, so that we unavoidably lose considerable solution through the ground below. It is contemplated hereafter to place the vats upon a substructure of timber that will enable us to get at the bottom and remedy any leakage if such arise. Perhaps no leakage would have occurred in this case if the foundation had been properly constructed.

DISCUSSION.

C. HENRY HONEY, Philadelphia, Pa.: I would like to propound to Mr. Keith at least one or two inquiries. These are: whether he finds there is any perceptible leakage of the residue through the cotton or muslin bags into the bottom of the vat; whether any of that residue is carried over mechanically in pumping up his liquid to the over-head system in order to keep up a constant circulation, for the object I suppose he means to secure, of obtaining solution of the same density throughout; and, further, whether, in the leakage of the vat, of which he speaks, any loss of electrical energy is transmitted to the earth.

MR. KEITH : The question of the mixing of the residues by passing through the bag has been thoroughly worked out, and we find that practically there is none. If those plates with their bags over them had to be handled in any manner there would be some of the residue forced through the bags, but they are not handled ; they are simply moved around through the solution, and we find no wash of any kind. What is rather remarkable is that the residues remain upon the plate until it is completely dissolved. By carefully removing the bag (cutting it so as not to drag it off) when the plate has been reduced nearly to the thinness of fine writing-paper, it still apparently retains its original thickness and almost its original external appearance; but when touched, the finger (or whatever it is that applies the touch) sinks into it. This black, pasty-like material can be easily drawn off, so that the lead will remain underneath without any other coating. The motion of these anodes is through the solution, and they have no handling. The movement of the solution does not carry anything over the top of the bag, because the bag is drawn somewhat higher than its surface. It conies just above the edge of the solution.

There is one additional point which I have omitted to state, hav-ing reference to the collection of the lead. There are scrapers which hang from the frames down between the cathodes; and, when the anodes are moved around in the vat, these scrapers scrape off the lead-crystal deposit, and this deposit drops into the bottom of the vat. When cleaning-up time conies, we withdraw the solution by means of a siphon over the top, and at the same time lift out the anodes. The cathodes are then lifted out, and, after that, we get into the bottom and shovel out the deposit of lead. This lot of crystalline lead remains, while under the solution, in a perfectly metallic form, utterly unaffected by oxidation or any other apparent action for an indefinite length of time. Some of it now in my possession has been kept in a bottle, under the solution, for a period of over six years, and is as bright to-day as it was at the beginning. This demonstrates that there is no chemical action going on in the solution which would affect the lead.

With reference to the other question, as to a leakage of current, I would say that we found on an electrical test, at the commencement, before the vats were filled with liquid, that there was practically no leakage of current with the electro-motive force which was used. Since that time there has been a slight leakage, but none of any account.

The amount of horse-power which is consumed in the separation of this material is, we may say, merely nominal. The difference of potential at the binding-posts or electrodes of the vats is scarcely one-quarter of a volt. The current passing through is one thousand ampéres. This one-fourth of a volt and these one thousand ampéres are produced at less than one-half of one horse-power. The main consumption of energy is in overcoming the resistance of the conductors between the source of electricity and the vats themselves, and the conductors between the vats. For instance, the longest single piece of conductor is twenty-eight feet of one and one-eighth inches round copper between the dynamo and the first vat; and my measurements show that one-sixth of the energy which is passed into this circuit is consumed in that particular copper conductor. So small is the electrical resistance of this conductor that in the ordinary electrical measurements such as prevailed two or three years ago it would have been set down as nothing; but it should be recollected that while in those clays we were accustomed to deal with one million ohms of resistance, we may now be obliged, in some electrical measurements, to treat of the millionth part of an ohm of resistance, and of all amounts of resistance within these extremes.

R *W.* RAYMOND, New York city : The merits of this process, as concerns the purity of the lead produced, are, of course, unquestioned and unquestionable. The drawbacks of the process, economically, appear to fall under two heads, namely : first, the slowness with which it proceeds; thus causing an accumulation at one time of a large quantity of valuable material in the works, which in turn requires the constant use of a very large floating capital, where this material is high-grade bullion; the number of tons in the works at, any one time representing a sum averaging probably $200 per ton, in gold and silver values alone, to say nothing of the lead, or of all that the extensive plant requires. On the other hand, the declaration of Mr. Keith that the product of lead is in precise proportion to the number of amperes, or proportional to the quantity, of current, raises the question at once whether, with a given plant, the rapidity of production may not be increased simply by increasing the quantity of current. If Mr. Keith's works, using a thousand ampéres, produce for each vat a ton in ten days, then would it be possible for him, by doubling that quantity of electrical current, to produce double that amount of lead, *i.e.,* treat double that amount of bullion in the same time?

The second objection to this process is also, more or less, an economical one. It is this, that the process furnishes us with pure lead, but it also furnishes us, in the residues, with the worst sort of material for further treatment. I wish to inquire what has been Mr. Keith's experience so far, in the matter of the extraction of gold and silver from the residue. The fact that he gets all the lead, and that he makes it pure or nearly pure, is excellent so far as it goes. Possibly it may be done with such great cheapness and regularity, and so little skilled labor, as to make it compare favorably with the ordinary processes of calcination and desilverization. But on the other hand, there is the question whether there is loss on the gold or the silver, whether the slag which comes from the crucible in which the nitrate of soda has been used is itself worth anything, and whether we are obliged to follow remnants of gold and silver down through that waste material for further treatment; all of which questions will have to be further considered before we can sum up the advantages or disadvantages which this process, like every other, must possess, and decide upon which side the balance of advantage inclines. I fancy, though I have not had any personal experience of the advantages of the process, that it will turn out, like most other processes of acknowledged merit, to be economical under some conditions and in some localities, whereas in other localities and under other conditions it could not, perhaps, compare economically with the present processes.

ME. KEITH: The impression which I desire to convey is this, that this plant is an experimental one, but an experiment upon a large scale. Every point which we have met has been favorably decided. The question of the separation of the residues to their ultimate constituents has not been fully determined, but the slags which are produced are very fluid ones, and the separation of the gold and silver, as far as our tests have gone, seems to be complete. The chemical separation of antimony has been thoroughly considered, but not yet carried into practical effect. There seems, so far, to be very little, if anything, against it upon theoretical consideration.

As to the economy of plant, considering the amount of material which must be placed under treatment, I will say this, that the process has been carried on at the rate of dissolving these plates in two and a half days or sixty hours, and the action was still as effectual as at the slower rate. It may be considered as settled that, with the proper means for the increase of our "quantity," the time could be at least reduced from seven days or one hundred and sixty-eight hours to sixty hours. That decreases the necessary size of the plant for a given output very materially.

It was not thought necessary, in this plant, to go to that extent, but the experiments which have been carried on, and to which no practical objection has been urged by those who are experienced in such matters, settle that point. At the time of the first publication of this process, it was considered by myself impracticable to dissolve these plates with a greater rapidity than in about eight days, for this reason: If the solution is not properly circulated, it does not enter the bag and filter through it, so that the sulphate of lead which is formed within the bag by the electrolytic action can be dissolved by the acetate solution and carried from the bag into contact with the cathode. There would thus be, in the case of an imperfect circulation, a formation of a crust of sulphate of lead, which would not be dissolved, and would interrupt the process. But I am now satisfied that the time can be reduced, as I have said, to sixty hours, without impairing the efficiency of the operation in that way.

Now, as to the cost of production of these plates, the putting of the bags upon them, and hanging them upon the anodes, it is somewhere between 90 cents and $1 per ton under the arrangements which I have described. The power applied is about 12 horse-power, and, as I have said, fully three-fourths of this is absorbed by the conductors themselves, which it was thought were made large enough. They are large enough if we consent to expend energy day by day in overcoming their resistance. If we conclude it is better to increase their size, and therefore decrease the daily consumption of energy and its attendant expense, we will also decrease the expense of the production of the current.

M. B. PATCH, Houghton, Mich.: I would like to ask Mr. Keith whether there is any difference in the amount of lead deposited resulting from any difference in the speed with which the solution is allowed to flow in and out of the vat. For instance, it makes a great difference in blast-furnaces what force of air goes in to make your combustion perfect.

MR. KEITH : The amount of lead deposited is exactly the same in all the vats. If there is any obstruction in the circulation of any vat, it cuts down the production of lead in all the vats. We have overcome all such obstructious due to defective circulation. This solution is replaced at the rate of 600 gallons each hour and a half. It can be done a little more rapidly. We find by electrical tests that if it is done more slowly there is a greater tendency to the production of counter electromotive force or resistance to the passage of the current and the consequent cutting down of the product.

Somewhat as we bring oxygen in immediate contact with fuel as fast as the carbon may absorb it, so we want to bring the lead which is in the solution in contact with the cathode so that it may be deposited. If no lead is there present, no lead will be deposited, and the current is resisted at that point. The tendency is to take the material which is present rather than the one which should be present. It takes more energy to deposit certain constituents of the solution than it does the lead constituent. If lead be not present, it requires more energy to deposit hydrogen, that being the only other material. If zinc happened to be in the solution, it would require more energy to deposit that zinc. If there be a proper amount of the lead, no zinc will be deposited; and, conversely at the anode, as long as lead is present, no other metal is dissolved, with the exception of zinc, if it be present.

FIRE-CLAYS AND FIRE-BRICKS IN SWEDEN.

BY N. LILIENBERG, NEW YORK CITY.

REFRACTORY materials play much the same part in the produc-ion of metals as houses and shelter for men, and it therefore seems useful to discuss sometimes the ways of manufacturing them. In fact, it appears to me that too little has been said on this important matter, probably because the manufacturers of fire-brick do not care to publish details for the benefit of competitors, but perhaps, also, by reason of the indulgent indifference of consumers. Judging from the revolutions in the manufacture of iron and steel caused by using calcareous materials for the furnace-bottoms, it does not seem improbable that in the future basic bricks may be produced sufficiently strong for building also side-walls and arches, and perhaps, also, for use in blast-furnaces. But the existence of the present difficulties of great shrinkage in burning and small strength against compression, which limit the possibility of using basic bricks to Bessemer converters and such open-hearth furnaces as permit the bottom to be separated from the superstructure, seems to indicate still a long and extensive use of silica fire-bricks.

I am not prepared to say anything about American fire-brick making, but knowing that industries abroad are watched with increasing interest by American manufacturers, I have imagined that this association would like to hear some facts about the way firebricks are made in my country—Sweden. Well-known as it is that Sweden produces a high quality of iron, it is perhaps not so universally known that the same country produces a very high grade of silica fire-brick, whereby most of its own wants are supplied.

In giving the following sketch I can, of course, not claim that all the facts are entirely new, but shall consider my object attained if American manufacturers can derive some benefit from the comparison of the following methods with their own, and if some discussion on this important subject can be aroused which will contribute to further progress.

In order to show the extensive use of domestic fire-bricks in Sweden, where English bricks are easily obtainable, I mention the fact that about twelve millions of all kinds of fire-bricks (reduced to nine-inch size) are yearly produced iu that country of about four million inhabitants, waking yearly about 750,000 tons of all kinds of iron, and that about 1500 tons of Swedish fire-clay are yearly consumed by the four porcelain and earthenware works in Scandi-navie, being mostly used for saggers, in which the products are burnt.

The only fire-clay district in Sweden is located in the northwest corner of the southern peninsula, where the material is associated with the only existing Swedish mineral coals. The distance of about three hundred miles from the centers of iron-making within the country is a great obstacle to the development of this coal and clay deposit. The first discovery of this deposit dates as far back as about two centuries, when the coals were first used for household purposes, being especially adapted for this on account of being easily burnt. The clay was at that time mixed together with the coal and laid aside unused in heaps around the mines. It was only after about one generation that the excellent qualities of these clays began to be appreciated, and the further extension of their use has been so slow that only within the last ten years the Swedish metallurgical works have come to a general employment of domestic fire-bricks. The Swedish coal and clay deposit belongs to a younger geological period than the English coal-beds, and, judging from the abundant fossil vegetation, geologists have identified the formation as the Rhætian.* A noticeable feature is the very small amount of pyrites in the coals, while these, as well as the clays, are sometimes intersected by mica, gypsum, and carbonate of lime. The clay-beds vary considerably in thickness, from a few inches to several *feet,* while they follow the coal-strata in their much-varying and broken course. Most of the days belong to the shales, being sometimes charged with so much sand as to form real hard sandstone, while pipe-clays are only seldom to be found, and then in isolated beds. The clays are divided into three principal classes, each requiring special treatment and serving a different purpose, viz.:

Clays free from sand and coal.

Clays containing sand and no coal.

Clays saturated with coal and containing very little sand.

Where the amount of coal is more than fifty per cent, the mixture is termed and used as coal.

* The Swedish official catalogue at the Vienna Exposition (1873) says the age of this formation is not perfectly determined, but it is generally accepted as belonging to the Trias and Jura.

As the clay-strata lie at depths of from fifty to four hundred feet the mining must be carried on entirely by shafts. These have a circular section ten to fifteen feet in diameter. The raising of solid materials is effected by double elevators, and that of water, which is very troublesome in these mines, by pumps nine to twelve inches in diameter, while the water from the lower parts is forced by pulso-meters to the bottoms of the pump-shafts.

A peculiar difficulty is the very loose structure of the rock, especially its upper part, which makes it necessary to line the shafts with wood all the way up. The old method of taking out and raising the entire thickness of coal and clay and separating them above ground, only leaving so much in the mine as was necessary for supporting the roof, was of course long ago replaced by the more economical way of making the separation underground and filling the empty spaces up to the roof with waste rock, thus creating a support. The blasting-materials mostly used are Sebastine and dynamite, which, besides the advantage of more rapid and economical work, cause, in the small drifts (only three feet high), less inconvenience from smoke than gunpowder.

The three classes of clay above mentioned are in practice subdivided so that there are, in all, ten classes, of which five are of superior quality. The best of these clays have, in the calcined state, about the following composition :

	Per cent.
Silica	52 to 59
Alumina	42 to 37
Flux,	6 to 4
	100 100

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About one-half of the flux is iron and the remainder lime, magnesia, and alkalies. It will be seen from these analyses that the bricks may be termed alumina-bricks as well as silica-bricks. The colors of the crude clays vary from white to entirely black, depending on the amount of coal they contain. When burnt, they are all light or dark yellow.

The density in the natural state is so great that the shrinkage in burning only amounts to abont eight per cent, of longitudinal mea sure. The power of absorbing water in the burnt clays is so vari able that some absorb five times as much as others. The strength of the nine-inch bricks against compression is 1600 to 2600 pounds per square inch.

The clays containing more than twenty-five per cent, of coal are laid up at some distance from the shaft-building in order to prevent danger daring their spontaneous combustion. These clays are intended for the so-called *chamotte.* All clays containing less than twenty-five per cent, of coal, but still too much coal for directly forming the main substance of the bricks, are transported direct from the shafts to the ehamotte-kilns in buggies containing each about six cubic feet. The yellow, white, and light gray clays, intended for the main substance of the bricks, are heaped radially around the shaft-openings and left exposed to the open air during a whole year, thus facilitating the subsequent grinding and oxidizing several impurities, which are thus made soluble in the rain. Pyrite and car-bonateof lime are thereby changed to sulphates of iron and of lime, which are dissolved by the water. The crude clays, having originally the hardness of granite, are, by the cold of one winter, the rain of one spring, and the heat of one summer, reduced from large blocks into fine-grained powder, ready for further treatment. The transportation to the brick-works is then effected in railroad cars holding about one hundred cubic feet each, and moved by locomotives or horses.

By the grinding process, the fibrous structure of the clay is destroyed, a perfect homogeneity obtained, and facility given for introducing additions of sand or *chamotte,* As it is necessary that the clay should be dry before grinding, in order to obtain a perfectly homogeneous and floury product, it can, during the summer time, only be taken direct from the shaft-heaps to the mills. In winter it needs to be dried before use. This is effected in large sheds heated by steam, or by underground flues through which the waste heat from boilers and kilns is passing.

The grinding is done by the three following machines:

1. *The perforated-bottom day-pan,* having the same shape as the well-known English mortar-mills, although much larger and more solid, the diameter being about 9 feet. The exterior part of the bottom is composed of sectional cast-iron slabs, perforated with inch holes about ¾| inch apart. On the average, the bottom makes 24 revolutions per minute. The rollers working on this bottom are provided with chilled cast-iron rings about 3 inches thick and fixed . to the cast center with wedges of Norway pine. One iron scraper before each roller shoves the clay under them, after which the centrifugal force throws the powder to the perforated part of the bottom, where the dusfc slips through, and the coarse grains are

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The density in the natural state is so great that the shrinkage in burning only amounts to abont eight per cent, of longitudinal mea sure. The power of absorbing water in the burnt clays is so vari able that some absorb five times as much as others. The strength of the nine-inch bricks against compression is 1600 to 2600 pounds per square inch.

clays are piled up in extended heaps and set on fire as soon as dry enough. The heaps burn for weeks, months or even a whole year, according to their *size*. . The burnt clay is gradually carried away to the mills while the remainder is still burning.

The black clays containing less than 25 per cent, of coal are burnt in kilns, much in the same way as limestone. The best shape of these kilns is that of a half-egg, point downward, the height being double the diameter, which is generally 12 feet. A chimney-stack of about 36 feet stands on the edges of the kiln. Coal and clay are charged alternately into the kiln in proportion of 1 to 6, the working being continuous. Such a kiln holds about 1000 cubic feet and gives about 200 cubic feet *chamotte* in 24 hours.

As the *chamotie-c\&y* has not been broken by exposure to the air, like the light-colored clays, it must pass through a special crusher, which is of the generally-known Blake construction.

The *chamotte* is ground also in the above-named granite mill and in a special so-called *rolling-mill.* The latter has two pairs of horizontal rollers, placed above each other. The upper pair is made of granite, leaving about § inch space; the lower of cast-steel, with about $_T{}^3{}_B$ inch opening. As the granite mill produces pure dust and the rolling mill coarser grains of flat and sharp-edged form, these two products have to be mixed. The dust alone would make the clay too dense, and the grain alone would make it too "short," and liable to cracks.

The proportions between clay and *chamotte* are about 4 to 1 for ordinary fire-bricks, and 1 to 1 for special bricks, such as converter-bottoms, tuyeres, gas-retorts, etc., the amount of *chamotte* being increased with the size.

The first mixing of clay and *chamotte* is made partly on the above-named perforated pan, partly in heaps on a wooden floor, the heaps containing, about 100 cubic feet each and shovelled by hand. When duly mixed, the mass, or so-called pulp, is laid up in rectangular shape, sprinkled with water and left in this state for some hours. The pulp is then charged into the *pug-milk,* which are constructed in a way similar to the ordinary clay-mills, that is with a vertical iron or wooden drum about 6 feet high and 2 feet in diameter, in which revolves an axle provided with steel blades, placed spirally. When pressed out through the opening below, the pulp intended for common-sized firebricks goes direct to the moulding,- but for gas-and iron-works special bricks, it passes the pug-mills twice, and is then clubbed together into troughs to the height of about 1 foot and left during one night.

There are several methods used in Sweden for moulding the fire-bricks. During the summer-time the most simple moulding is done by hand, two bricks being formed at the same time, much in the same way as red bricks, the moulded bricks being left to dry in long rows on a brick-floor, until they have the hardness of leather, when they are put into hand-presses worked by eccentrics on a shaft. In the season when exterior heat does not serve for evaporation, the pulp is made stiff in the pug-mills, cut into squares about filling the moulds and then forced down into the moulds by oak clubs, or sometimes, by lifting the mould with its contents some inches and allowing them to drop on the table; this being repeated 2 or 3 times. Whenever steam-presses replace hand-moulding, the passing through the pug-mills is omitted, and the pulp or the sandy clays are mixed in the perforated pan with so little water as to form a semi-dry mass. The bricks made from this mass direct by the steam-press are so dry that they can be immediately carried to the kilns. One "semi-dry" brick-machine turns out from 8000 to 10,000 nine-inch bricks per day.

The drying of the pressed, ordinary fire-bricks is effected during the summer in large open sheds, provided with a roof, so much projecting as to keep out the rain. Ordinary fire-bricks, in the rainy and the cold seasons, as well as extra shapes in any season, are dried on long floors heated by underground flues, through which the waste heat from the kilns passes.

When sufficiently dried, the bricks are carried to the kilns for burning. These kilns are fired with solid fuel or with gas. Of the first class there are three kinds; one for continuous use, burning all ordinary sizes, and two working periodically, in which extra sizes and shapes are burnt. The continuous or so-called Hoffman kiln has a chamber 7 feet high and 9 feet wide provided with vertical projections on the insides, whereby a division into from 10 to 24 compartments can be effected. This chamber forms a tunnel, extending into an elliptical shape. The compartments are separated by iron plates or (of late years) by specially prepared paper. In filling the compartments with bricks, openings are left under the charging-hoppers in the roofs, through which the fuel is dropped. Iron doors on the outside serve for entering the chambers at the time of filling and emptying. The firing is done in one compartment after the other, and the air for combustion is admitted through the last-burnt chambers, thereby contributing to a more rapid cooling of these, while itself entering upon the fire in a pre-heated state.

The periodical kilns have either a rectangular or a circular shape. The former are about 24 feet long, 14 feet wide, and 12 feet high. On the long side are built fireplaces with grates, from which the flame rises through the bricks to the roof, and escapes through flues in the floor. In order to protect the nearest bricks against the strongest heat near the fire, there are walls about 4 feet high surrounding three sides of the fireplaces. The bricks are charged and emptied through one door located on the end of the kiln.

The circular or so called cupola-kilns are 12 to 16 feet high, and 16 feet in inside diameter, with fireplaces 18 to 24 inches wide, located in the circumference, the circulation of the flame being the same as in the rectangular kilns.

When only one kiln is used, the escaping gases are led through a flue of clay pipe in the centre, and by flues connecting with holes in the bottom, from which they run to a chimney about 25 feet high, built either on the side-wall or on the top of the kiln. In using several kilns, a single separate chimney-stack is built, serving them all.

The periodical kilns hold from 15 to 20,000 nine-inch bricks. The fuel for direct firing is mineral coals, mostly Swedish, but also, in order to obtain the last white heat, English so-called "pottery-coal."

Of the gas-kilns, use is made in Sweden of the so-called Mendheim chamber-kiln only; aud this is employed, notwithstanding its great cost of erection, because it gives invariably a good product, which is not always the case with the circulating gas-kilns working in a way similar to that of the Hoffman kiln already named. The Mendheim kiln has a rectangular shape, and contains from 16 to 18 compartments in two parallel rooms. The separating-walls are built of fire-bricks, each wall containing 5 vertical flues leading the gases from one compartment to another, the inlets being near the floor, and the outlets near the roof. Air for combustion is admitted through about 60 small holes in the floor, having passed an already burnt chamber, thus accumulating some heat. The gases, before escaping to the chimney-flue, circulate through all the filled compartments, thus effecting a gradual pre-heating. Gas-producers are placed before one end of the kiln, while the chimney-stack is erected at some distance from the opposite end, leaving a space so as not to bar possible enlargements.

The period for burning bricks varies of course, according to the dryness and size, depending also on the construction of the kiln, but is generally from 60 to 80 hours. All bricks ought to be exposed in the kilns to such a heat as is to be actually applied afterwards in their practical use. The consumption of mineral coal per 1000 nine-inch bricks varies from 20 to 40 cubic feet.

In giving this outline sketch of Swedish fire-brick making, I have obtained valuable information from Mr. C. Matton, a Swedish engineer of considerable experience in this line, who will willingly answer further questions from any one who likes to pursue the matter into further details.

The extraction of the Swedish clay costs at one prominent fire-brick works, about 2¼ cents per cubic foot, and the average cost for 1000 nine-inch bricks about $11.50.

The need of something more refractory than ordinary fire-bricks in the construction of certain parts of steel-melting furnaces, has called into existence in Sweden a successful fabrication of bricks made from coarse-grained pure quartz and fire-clay, which of course, stands very little mechanical strain, but resists excessive heat as well as the renowned English Dinas bricks. I am not prepared at present to give details of this process, but will probably be able to do so at some future time.

The Swedish fire-bricks compare favorably with the best English ones, according to numerous testimonies from the most prominent iron-works.

In comparing different kinds of fire-bricks, due consideration should be given to the chemical action of matters brought into contact with them. In a blast-furnace, the lime, manganese, alumina and oxides of iron attack the silica-bricks at a heat much below what these wonld stand if simply exposed to an elevated temperature. In an open-hearth steel-furnace, the addition of iron-ore, as practiced in some places, does much to shorten the duration of the lining (which, therefore, by the by, should be made of basic materials.)

In judging the quality of fire-bricks, it would also be fair to consider the great damage to a lining by frequent cooling-down of the furnace. Finally, I beg to point out that fire-brick makers have often received the blame for bad results actually due to great carelessness in brick-laying. As brick-moulds are so easily made, it ought not to be too much trouble to obtain furnace-bricks of such shapes as to avoid nearly all cutting. This operation is not only a very expensive one, but the surfaces can never, in that way, be made.

so smooth as to give sufficiently thin joints. The use of briek-fragnients and mortar to fill up cavities between defective bricks, should of conrse never be allowed. In building arches of re-heating and steel-melting furnaces, it seems that due consideration should be given to the fact that the flame eats the joints more rapidly lengthwise, and that the arch-bricks should, therefore, be shaped and laid so as to break joints in the longitudinal direction. The arch-bricks should never be used to turn the flame down on the metal, but the direction of the gas and air ought to be broken before they meet. I say this, knowing that a number of open-hearth furnaces have been built without observing this precaution.

In connection with this subject, I can hardly omit to mention that the bottoms in the Swedish Bessemer converters are built of whole bricks, so large as to contain one tuyere each, the spaces being filled with exactly-fitting blocks; and that these bottoms have been found to show great resistance as well as to be easily changed.

In regard to blast-furnaces, I beg to say, that the bricks in the part below the bosh are in most cases laid horizontally. The edges in the conical surface thus project, forming regular scaffolds, thereby increasing the resistance for the descending materials. In many cases these are allowed to wear off, causing the surface to take a more or less irregular shape; but in other blast-furnaces these edges are cut before filling, which cutting amounts to at least 400 square feet in an ordinary coke-furnace. I beg leave to ask, why all this is not avoided by cutting the upper surface of the first layer of brick at a right angle with the conical surface, and then laying the following bricks sloping in the same direction.

In the Swedish blast-furnaces the lower cone is made of a stamped mass of quartz and fire-clay in the proportion of about 10 to 1 in the lower part and about 8 to 1 in the upper part, thus forming a lining without joints, perfectly smooth and of great resistance.

Allow me, in conclusion, to mention the unnecessarily liberal use of fire-brick, shown in many furnace constructions, where they appear in flues hardly exposed to a dull red heat.

DISCUSSION.

W. F. DURFEE, Bridgeport, Conn.: In connection with this subject, I will describe the construction of the roof of a reverberatory furnace, which I erected some ten years since. The roof was made of crushed fire-brick combined with a very little fire-clay. These two substances were intimately mixed dry, and then the whole was wetted with a saturated solution of common salt. This mass was then rammed one foot in thickness upon a rudely formed wooden center in the furnace. It was then allowed to stand a day or two to dry in the air. Then the gas was turned on in the furnace, and a low heat kept for a number of days until the moisture was expelled from the roof. Of course, the center was burned out immediately. Then a more intense heat was applied, and finally the whole interior surface of the roof was baked into one entire fire-brick mass, so to speak. That furnace was used under my supervision for over a year, in some cases with a temperature as high as that of the welding heat of iron, and the roof was a great success in every way. I have no doubt that, when it is possible to give time enough for a furnace-roof to dry before it is burned, the plan I have described will be found much more satisfactory than the ordinary construction composed of small pieces or masses of fire-brick.

ANDREW S. MCCREATH, Harrisburg, Pa.: I would ask Mr. Lilienberg, whether this Swedish fire-clay has ever been tested for titanic acid, and whether the effect of that ingredient has been noted?

MR. LILIENBERG : It contains very little titanic acid. I think that has no practical effect.

COAL-MINING IN TEE CONNELLSVILLE COKE REGION OF PENNSYLVANIA.

BY JOHN FULTON, E.M., JOHNSTOWN, PA.

THE Connellsville coal-field is a separate strip of the upper coal measures, flanking the Chestnut Ridge along its western side. It extends from a point a few miles sonth of Uuiontown, in Fayette County, following a northeasterly course parallel to the trend of Chestnut Ridge, through Fayette and Westmoreland counties, with its terminal prongs resting on the southern portion of Indiana County, north of the town of Blairsville.

This belt of coking coal will average about three miles in width and over sixty miles in length, affording nearly, if not quite, two hundred square miles of this large coal-bed.

The accompanying cross-section of the Connellsville field (see plate) will show its geological structure. It is a shallow synclinal, with slopes of 7° to 3°, moderating downwards towards the middle of the basin. Sufficient levelling has not been done to ascertain the position of the axis-line of this large basin. The indications are, from what is known," that its structure will harmonize with the general law of the Appalachian region, *i. e.,* will show a rise along its axis-line northeastward. But this law is never uniform over long distances, as the bottoms of all basins are interrupted by "swamps" and "summits," resulting mainly from the variableness of dips along their course, or rather from the forces that formed these dips.

The mine-workings of this region are confined to the one principal seam, the Connellsville or Pittsburgh coal-bed, which is found here in its best development as regards size, while its quality of coal is peculiarly adapted to the great industry of the region—coke-making.

This large coal-bed preserves a remarkable uniformity of thickness over the whole field, generally affording from eight to nine feet of coal, and seldom falling below seven feet in thickness. The typical sections, *a, b, c, d,* and *e,* on the accompanying plate, exhibit the condition of this bed in several widely separated localities of the field.

The coal-bed is underlaid with fire-clay, and has a roof of carbonaceous slates and shales. This roof, for a height of 8 to 16 feet above the coal, is sliced into blocks by cleavage-planes, rendering it quite brittle and easy to let drop in short sections. This condition of the roof governs the width of adits, headings, and rooms. A portion of the upper bench of the coal-bed, from 6 to 12 inches, is usually left attached to the roof, for the purpose of stiffening it, and also to prevent its ravelling down in the mine-ways and room-workings.

The coal is quite soft and easily hewn down, as the bed is slashed with planes into thin plates nearly at right angles to the bedding-plane. No "bearing-in" or undercutting is required—merely a cutting down or excavating process. The coal is bright, and mines into small pieces or "fine coal."

The following analyses, from very careful sampling, will show its general character:

I.

Analyses of Connellsville Coal.

T. T. Morrell, chemist.

	C. I. Co. Morrell Mine.	Morewood Mine.	Herold Mine.	Kintz Mine.	Soxman Mine.
Moisture, ...	. . . .	1.02	1.26	0.79	1.02
Fixed carbon, . .	60.30	58.88	60.79	56.46	58.25
Phosphorus, . . .	.01	.011	.013	.02	.03
Sulphur, ...	1.09	.805	.67	1.32	1 42
Volatile matter, . .	31.38	32.27	28.83	31 91	32.07
Ash, ...	7.24	7.01	8.44	9.52	7.24

In comparing the composition of coals across the Appalachian field, in the western section of Pennsylvania, it will be noted that the Connellsville variety occupies a peculiar position between the rather dry semi-bituminous coals eastward of it and the fat bituminous coals flanking it on the west.

II.

Analyses from Hie Upper Coal Measures, in a Westward Order.

A. S. McCreath, chemist

Localities.	Moisture.	F. Carbon.	Sulphur.	Vol. mat.	Ash.
Anthracite, . . .	1.35	89.06	0.30	3.45	5.81
Cumberland, Md., .	0.89	74.28	0.71	15.52	9.29
Salisbury, Pa., . .	1.66	68.77	1.24	22.35	5.96
Connellsville, . .	. . . .	60.30	1.09	31.38	7.24
Greensburg, . . .	1.02	61.34	0.86	33.50	3.28
Irwin's, ...	1.41	54.44	0.64	37.66	5.86

III.

Analyses from the Lower Coal Measures, in a Westward Order.

Messrs. Morrell and McCreath, chemists.

Localities.	Moisture.	F. Carbon.	Sulphur.	Vol. mat.	Ash.
Anthracite, . . .	1.35	89.06	0.30	3.45	5.81
Broad Top, . . .	0.77	73.34	1.02	18.18	6.69
Bennington, . . .	1.40	61.84	2.60	27.23	6.93
Johnstown, . . .	1.18	74.46	1.86	16.54	5.96
Blairsville, . . .	0.92	62.22	4.92	24.36	7.59
Armstrong Co., . .	0.96	52.03	3.66	38.20	5.14

This special position and condition of the Connellsville coal-bed for coking has made this region famous. It is, in fact, the Durham of America.

Beneath this Connellsville or Pittsburgh coal-bed, occurs an interval of from 400 to 600 feet of "barren measures," separating it from the lower productive coal-measures of Western Pennsylvania.

Tables II. and III. show the great similarity in composition in the coals of these upper and lower coal-measures in the same geographical belt or basin. This should afford the Connellsville coke producers a large additional supply of coal from the beds in the lower coal-measures.

From the geological cross-section given in the plate it will be seen that along the flanks of the basin, the Connellsville bed comes to the light in places along the hillsides, forming steep escarpments. These massive outcrops early invited attention to the presence of this coal. A large number of "country-bank" coal mines are still found along such outcrop-edges of the basin. These have been, and are now, worked in a very primitive way, with appliances of great antiquity. But for the discovery that this coal was admirably adapted for coke-making, the region might have remained in its normal obscurity. In 1841 Provence McCormick and James Campbell, two carpenters, learned that coke-making might lead to profitable, results. By their enthusiasm they interested John Taylor, a worthy stone-mason, who owned a tract of coal-land, and who was engaged in coal-mining at the time. These three formed an industrial " pool;" Taylor, the stone-mason, was to build the coke-ovens, and the carpenters, McCormick and Campbell, were to build two "arks" to convey the coke by water to Cincinnati.

In the spring of 1842 the fleet of two arks, carrying 1000 bushels of coke each, or 40 tons in. all, reached Cincinnati safely. But the proprietors found to their amazement that this new fuel was almost unknown to the iron-founders of that city, who, when canvassed for its purchase, regarded it with suspicion, indignantly denominating it "cinders." A portion of this cargo was traded for groceries at unprofitable rates, and the remainder was shipped in canal-boats to Dayton, Ohio, where Judge Gebhart, the owner of a foundry, used the coke, and discovered its superior value in iron-smelting.

After the completion of the Pittsburgh and Connellsville Railroad, Connellsville coke was shipped to Pittsburgh and tested in the blast-furnace of Graff, Bennet & Co., where its superior value was first firmly established in 1859. An attempt at this furnace to substitute coke made- from Pittsburgh coal near the furnace proved unsatisfactory, and the Connellsville coke was again used. This test gave the first impetus to mining for coke-making in the Connellsville region, so much so that thirty new ovens were built in 1860.

The following statement exhibits the progress of coal-mining and coke-making:

In 1841 the number of coke-ovens was,				2
In 1850	"	"	"	4
In 1860	"	"	"	70
In 1870	"	"	"	550
In 1879	"	"	"	4,200
In 1884	"	"	"	10,364

The amount of coal mined and used for coke-making in 1879 was 3,222,306 net tons, from which 2,013,941 net tons of coke was made. This was 73.17 per cent, of all the coke made that year in the United States.

If all the ovens of this region could be kept in use during the present year, 1884, the consumption of coal would be 8,102,880 net tons, yielding 5,064,300 net tons of coke.

In addition to the coal used for coke-making, from 100,000 to 150,000 tons are now annually shipped for other purposes, making the total coal required from the mines, when all the ovens are in operation, 8,500,000 tons, nearly.

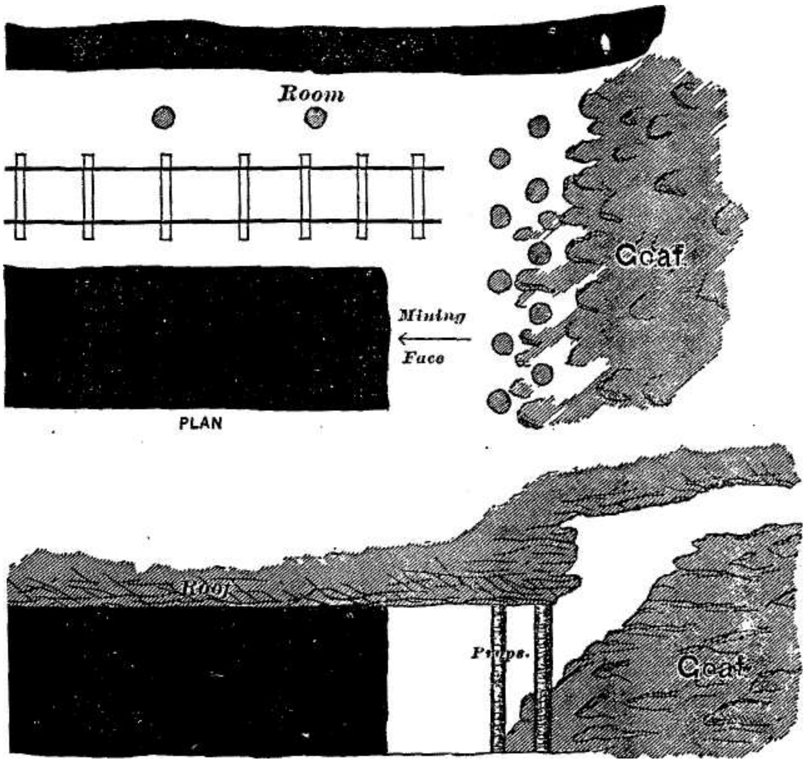
Taking the product of an acre of coal at 13,500 tons net, the present annual requirement of full work would exhaust the coal from a square mile of this territory each year.

The early methods of coal-mining for coking consisted mainly in slopes, following the coal-bed down its dip towards the bottom of the basin. The main headings were usually driven at right angles to the slope. "Butt"-headings were driven from the adits at angles to insure moderate gradients across the floor of the coal-bed; from these the rooms were laid off mainly parallel to the main headings. The rooms were made of a width to suit the tenacity of the roof, usually 10 to 14 feet, the "ribs" or pillars being 8 to 12 feet thick (see Fig. 3).

From the beginning of mining operations until the year 1882, little attention was given to exhaustive mining. The coal-pillars or "ribs" were left as narrow as possible in the direct working of rooms. When these rooms had been driven to their full length, then in coming back the ribs were further reduced by cutting along their flanks or by cross-cuts through these pillars, the remainder gradually splintering down, with the entire loss of from 20 to 40 per cent, of the coal. A very large area of this fine coal-bed has been lost in this way. In the sections of the coal-field where the covering is light, the presence of these lost coal-pillars can be plainly seen on the surface in ridges, between the greater depressions caused by the full sinking of the room-workings.

During the year 1882, a revision of the previous wasteful methods of mining was carefully considered, and some of the companies

Flg.1.



Floor
Section **scale 10 feet to1 inch**

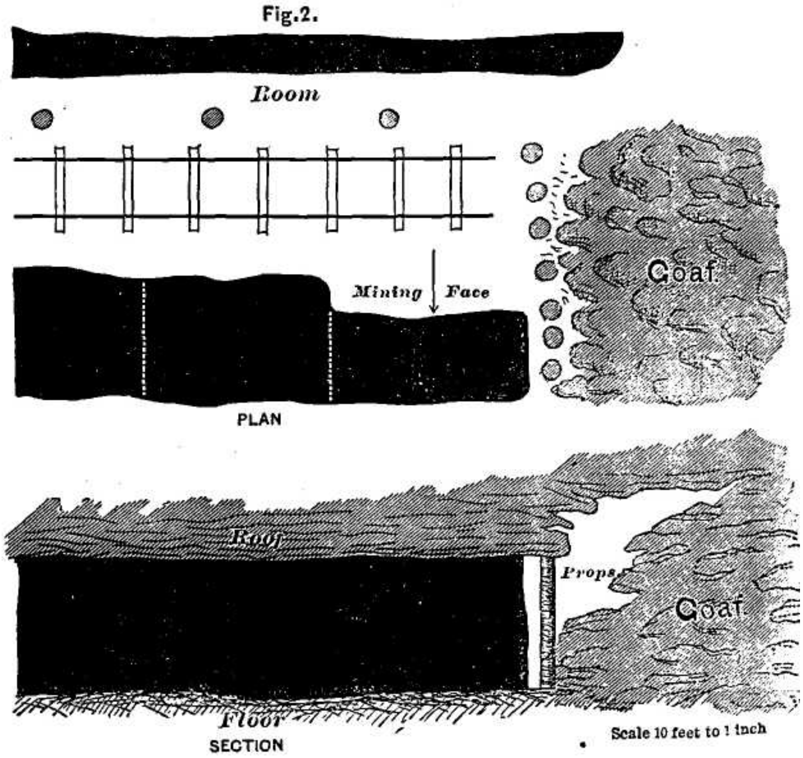
adopted the plan of exhaustive mining, by withdrawing the coal-pillars between rooms, when the latter reached their full length of 300 feet, more or less (see Fig. 3).

Taking the available coal in this bed at 7½ feet thick, an acre will yield, in round numbers, 13,500 net tons. By the old system of mining, under its most favorable conditions, about 33 per cent, of the coal was lost in ribs or pillars. This loss would be 4,455 net tons per acre. Estimating the coal at a royalty of 9 cents per net tou, this is a loss of $400.95 per acre.

On the other hand, the owners of coal rights generally do not own the surface of the land. The land is quite valuable for agricultural purposes, selling for $100 per acre. Any mining operations displacing this surface or injuring it for farming purposes would incur damages.

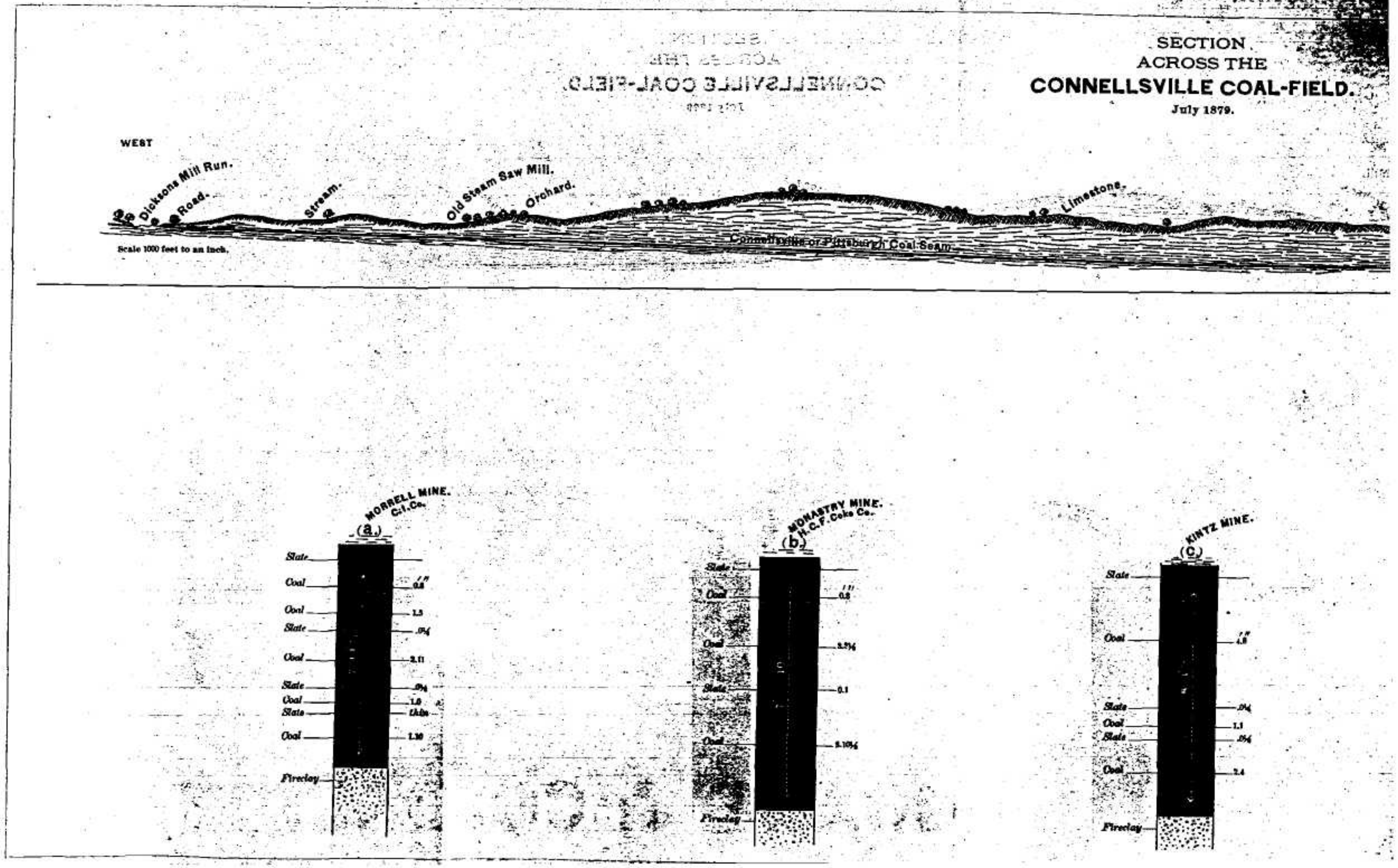
Where 100 feet or upwards of covering is found over the coal-bed, very little, if any, disturbance of the surface follows, since the enlarged space occupied by the breaking up of the roof-slates and sandstones compensates for the coal-space made vacant. But antici-

Fig. 2.

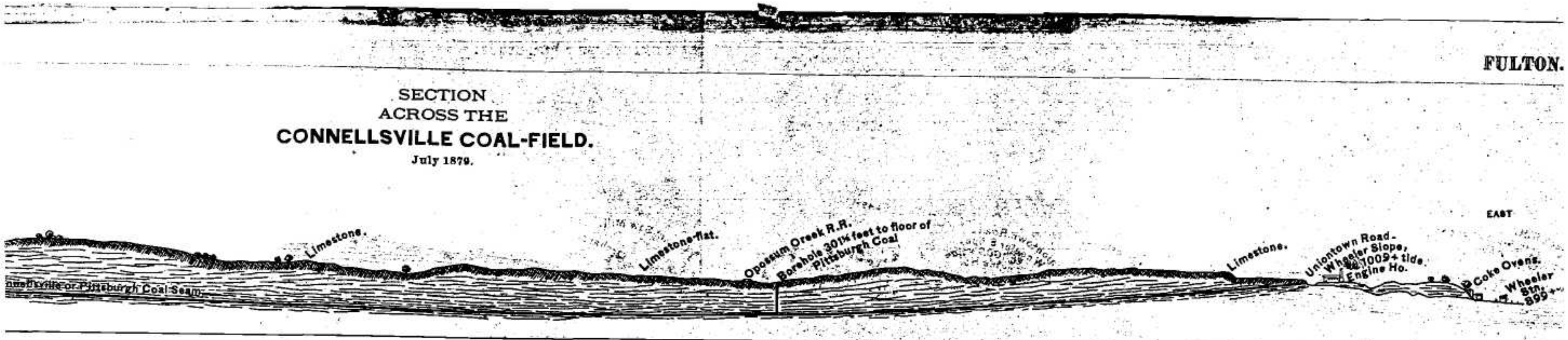


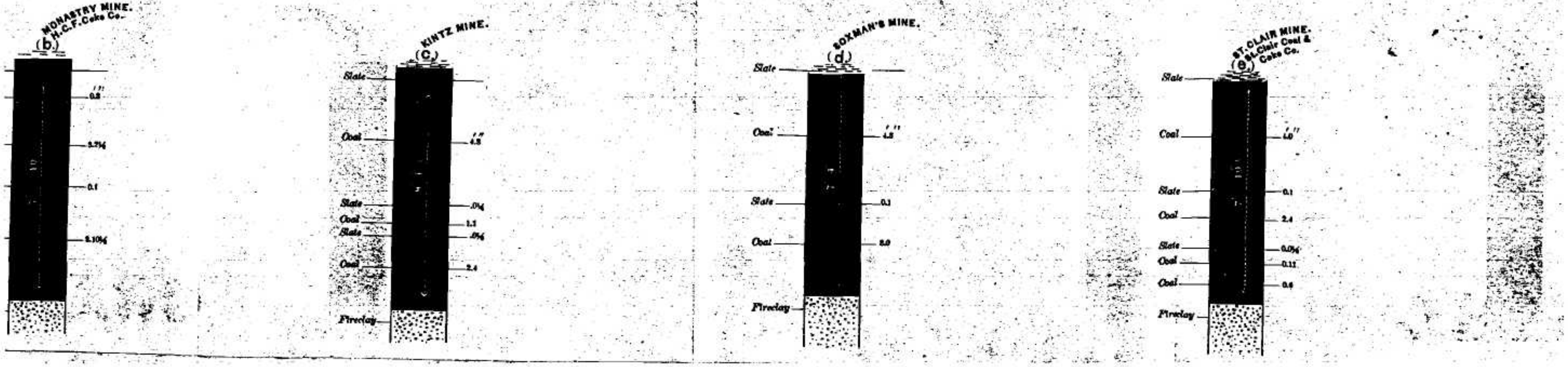
pating the worst condition of shallow covering and breaking np of the land surface at $30 per acre, a balance of $370 per acre would remain to reward exhaustive mining.

When other sources of economy are considered, such as the hauling out of the pillar-coal over the room-tracks previously laid down,


SECTION ACROSS THE
CONNELLSVILLE COAL-FIELD.
July 1879.
WEST
Dicksons Mill Run.
Road.
Stream.
Old Steam Saw Mill.
Orchard.
Limestone.
Connellsville or Pittsburgh Coal Seam.
Scale 1000 feet to an inch.
MORRELL MINE. C.I.Co.
(a.)
Slate
Coal
Coal
Slate
Coal
Slate
Coal
Slate
Coal
Fireclay
MONASTRY MINE. H.C.F. Coke Co.
(b.)
Slate
Coal
Coal
Slate
Coal
Fireclay
KINTZ MINE.
(c.)
Slate
Coal
Slate
Coal
Slate
Coal
Fireclay

SECTION
ACROSS THE
CONNELLSVILLE COAL-FIELD.
July 1879.





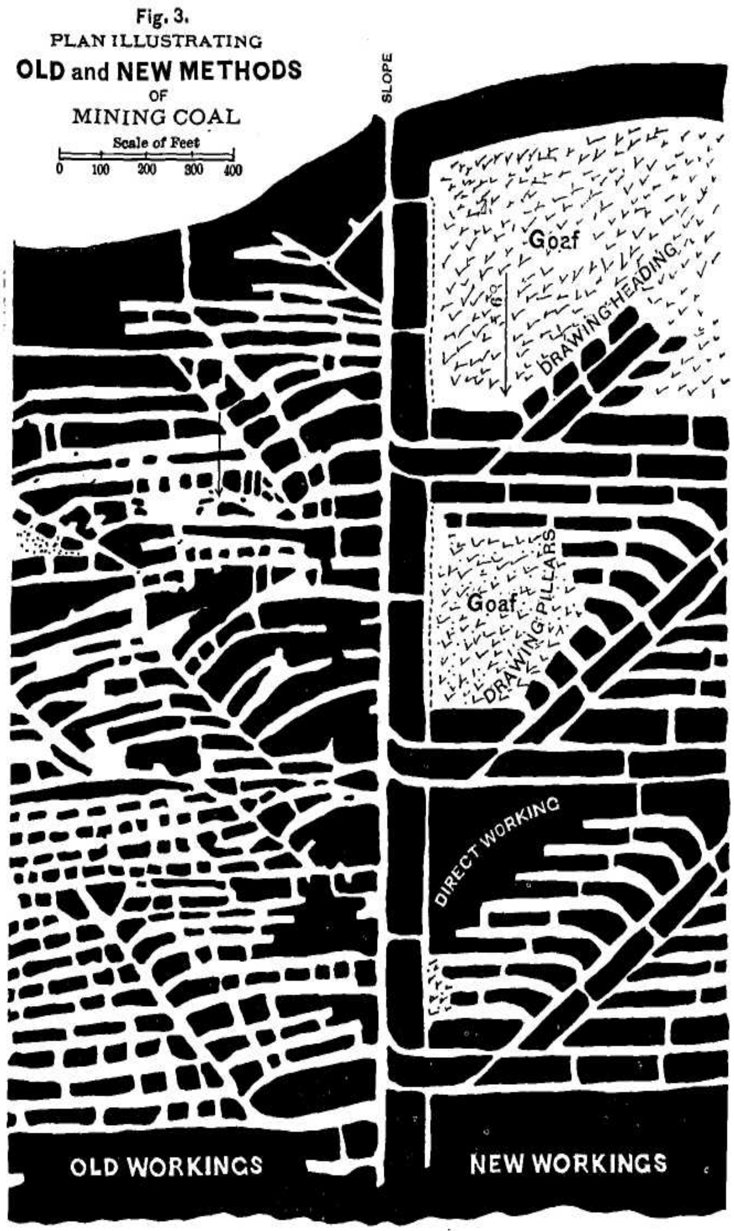
the saving of props, and the improved condition of air by confining it to the actual workings, it is safe to say that at least §100 per acre should be saved by exhaustive mining.

Two general methods are now in use in the work of drawing coal-pillars. The first consists in hewing the coal on the face of the pillar (see Fig. 1), the miners being protected by a double row of props, which arrest the falling of the roof, and also prevent the talus, of falls of roof from encumbering the mining-face. As the mining advances, the line of props next to the roof is moved to the front rank, and this work of alternating the two lines of props is continued until the pillar has been withdrawn. The props of each line are placed from 2 to 3 feet apart, and the two hues are about 3 feet apart. This double set of protecting props is extended a sufficient distance across the room-working to prevent the roof from coming down so far in advance of the line of mining-face of the pillar-working as to encumber the loading of coal in cars near the end of the track.

The second method consists in protecting the miners by a single row of props placed 6 inches to 1 foot apart, near the working-face of the coal-pillar (see Fig. 2). This not only arrests the breaking down of the roof in its usual plates and blocks, but holds back the talus of these from interrupting any of the mining operations. Under this system the miners attack the coal-pillar on the flank instead of the end, removing it in sections of from 5 to 8 feet in length. When each section has been removed, and the track has been lifted, these fender-props are moved to a new line close to the coal-face or end of pillar. The superior safety of this plan is apparent. The props hold the roof steadily at one fixed line until the section of pillar in advance of it has been removed.

In both these operations, involving the breaking down of the roof, it has been found expedient to require the miners to use safety-lamps to guard against explosions from sudden outgushes of fire-damp from the breaking roof. The character of the roof-slates in the Connellsville field is such as to assure the easy execution of this method, and involve no additional danger to the miners. No accident has yet occurred in drawing pillars in the large mines of the Cambria Iron Company.

The same system of removing coal-pillars between the rooms in a mine can readily be applied, at the proper time, to the withdrawing the coal-pillars alongside the levels or main headings, the butt-headings, or other ways of the mine.



AMERICAN BANK NOTE CO.N.Y.

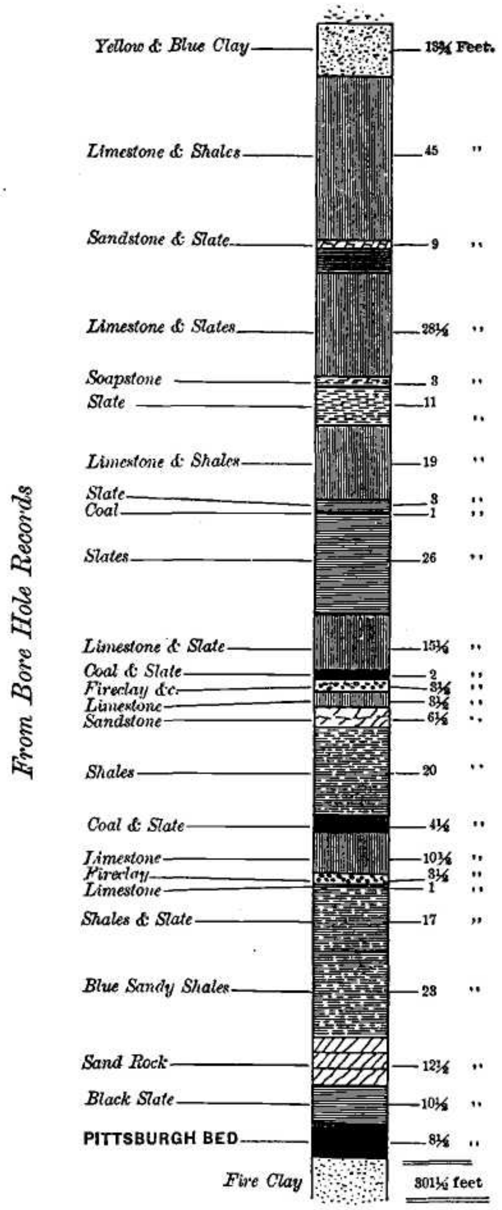


Fig. 4. SECTION OF BORE HOLE
Scale 50 feet to 1 inch.

As the safety and economy of this system of exhaustive raining have been fully established during the past two years, it is to be hoped that all mining in this valuable bed of coking coal will in the future participate in the benefits arising from this system of drawing of coal-pillars, and its related economies.

Fig. 3, already referred to, needs no further explanation for mining engineers. It illustrates the old and new systems, in a plan, assuming that the same bed, with a dip of 6 degrees toward the bottom of the plan, has been worked on the left of the slope by the old system, and on the right by the new.

Fig 4 shows a section of the bore-hole indicated in the geological cross-section of the plate.

DISCUSSION.

R. W. RAYMOND, New York city : Why is it, considering the comparatively low pitch of the vein, as shown on the diagram before us, that the simple system of long-wall has not been adopted? It seems as if some trouble and expense in opening chambers might be saved by putting the whole thing in long-wall. An objection to the long-wall advancing system might be that it would leave an area of goaf between the men and the slope, in which there might be danger of the accumulation of fire-damp; but the retreating system would be free from this objection, and would, apparently, effect some saving, though I do not think that the saving would be large in comparison with the main economy that Mr. Fulton has already effected.

MR. FULTON : The same thought has occurred to us over there, but it has not been acted on, as we are only just getting out of the old rut. But the roof is so friable, so feeble, that we have to leave a foot of coal overhead to keep it up in the ways. I think we had better extend our main ways in and then pull it back. It would be worth while for those who are mining in this peculiar field to try the long-wall system. As to fire-damp, it is a strange thing that in this mine, which has been open for several years, we never found any gas until last year. We have also a mine at Johnstown, in which no gas was found until last year. It seems as if a wave, beginning in Colorado, swept across the continent eastward, and when it reached us here, we had serious trouble with fire-damp. Strange to say, since that time we have had no men burned and have found no gas.

H. M. CHANCE, Greensboro, N. C.: What is the size of your props?

MR. FULTON: From 6 to 8 inches, seldom over 8 inches. When we have the single row the props are put about half a foot apart. This keeps the slate back from the miner. We use no caps, but leave a little piece of the coal to make a shield against the soft slates. The roof comes down in blocks of about eighteen inches, or two feet square. The miners find no trouble or danger in that. In fact, we are often obliged to caution our men to be a little careful, as they seem to be utterly regardless of the rolling down of the roof. They regard it as they would the rolling down of a sand-hill.

As to the matter of economy, we studied that carefully before we proposed to go into this method. Our superintendent has figured up a saving of five cents per ton, but I think that that is too much. A saving of about two or three cents a ton, I think, would be the economy in the matter. Perhaps if it were long-work, the saving would be greater.

AN EXPERIMENT IN COAL-WASHING.

BY THOMAS M. DROWN, EASTON, PA.

THE following description of an attempt to separate bituminous coal from its slaty and mineral admixtures without the aid of jigging, was suggested by the successful use of dense solutions (such as the double iodide of mercury and potassium and cadmium borotungstate) in the separation of the mineral components of igneous rocks.*

In the case of coal it is essential that we have a solution of a specific gravity greater than the coal, and less than the mineral or slate associated with it. Further, in order that such a solution should be practically admissible, it must be cheap and readily obtainable. Calcium chloride fulfils all these conditions, although it is not intended to be affirmed, in the absence of actual trial, that its use on a large scale would be economically successful.

The records of experiments on several samples of bituminous coal

* The idea is not in itself new. Rittinger gives calculations of the rate of the fall of spheres of varying specific gravity in a solution of zinc vitriol of 1.5 specific gravity, but I do not know that dense solutions have been actually tried in ore-dressing or coal-washing.

go to show, that, on a small scale in the laboratory, the separation is easily effected and is thoroughly satisfactory.

A sample of coal was crushed so that it all passed through a twenty-mesh sieve, and it was then treated with a calcium-chloride solution of a specific gravity of 1.40. After stirring, the greater part of the fragments rose to the surface of the liquid, and a portion settled to the bottom.

The results were:

	Ash.	Sulphur.
Lighter portion (91.54 p. c.), . . .	8.02 p. c.	0.863 p. c.
Heavier portion (8.46 p. c.), . . .	50.65 p. c.	1.540 p. c.

It was found that the presence of fine dust interfered with the process and prevented a prompt separation of the lighter and heavier particles. Another sample was then put on a sixty-mesh sieve, after having passed the twenty-mesh sieve. This coal, freed from dust, gave a prompt separation when treated with the calcium chloride solution of a specific gravity of 1.30.

The results were:

	Ash.	Sulphur.
Lighter portion (79.05 p. c), . . .	6.02 p. c.	0.795 p. c.
Heavier portion (20.95 p. c.), . . .	29.84 p. c.	2.19 p. c.

The use in this case of a solution of less specific gravity than in the first instance, gives a larger proportion of the heavier particles and a consequent greater purity of the lighter coal. The strength of the solution in practice would have to be regulated according to the composition of the coal.

The next table gives results still more in detail:

I. Fine coal through 20-sieve, ... 22.10 per cent.
II. Retained by 20-sieve, lighter than 1.35 sp. gr., . 42.38 "
III. " " heavier " " . 35.52 "
IV. Original coal (calculated):

	I.	II.	III.	IV.
Moisture, . . .	0.88	0.980	0.96	0.951
Volatile matter, .	19.28	19.667	16.10	18.314
Fixed carbon, .	69.27	72.216	49.70	63.567
Sulphur, . .	1.01	0.807	1.93	1.251
Ash, ...	9.56	6.330	31.31	15.917
	100.00	100.000	100.00	100.000
Coke, . . .	79.34	78.75	81.98	80.112

It will be noted from the above that the fine dust is much purer than the original coal, and could in practice be directly added to the purified coal before coking. Another series of analyses gave:

I. Fine coal through 40-sieve, ... 9.50 per cent.
II. Retained by 40-sieve, lighter than 1.35 sp. gr., . 44.60 "
III. " " heavier " " 45.90 "
IV. Original coal (calculated):

	I.	II.	III.	IV.
Moisture, . .	0.57	0.63	0.66	0.638
Volatile matter, .	19.97	20.31	16.57	18.550
Fixed carbon, .	68.82	72.63	51.68	62.587
Sulphur, . .	1.03	0.80	1.34	1.071
Ash, . . .	9.61	5.63	29.75	17.154
	100.00	100.00	100.00	100.000
Coke, . . .	78.95	78.65	82.10	80.272

The process tried on a sample of coal of great purity gave:

I. Fine coal through 20-sieve, ... 21.63 per cent.
II. Retained by 20-sieve, lighter than 1.35 sp. gr., . 76.37 "
III. " " heavier " 2.00 "
IV. Original coal (calculated):

	I.	II.	III.	IV.
Moisture, . .	0.63	0.79	1.02	0.760
Volatile matter, .	20.11	19.84	11.56	19.730
Fixed carbon, .	75.11	75.16	69.58	75.040
Sulphur, . .	0.77	0.67	4.40	0.766
Ash, . . .	3.38	3.54	13.44	3.704
	100.00	100.00	100.00	100.000
Coke, . . .	78.88	79.04	85.22	79.127

The influence of very slight differences in the specific gravity of the calcium chloride solution is shown in the treatment of another sample of coal-of the following composition:

Moisture, ...	0.64
Volatile matter, ...	18.97
Fixed carbon, ...	69.70
Sulphur, ...	0.81
Ash, ...	9.88
	100.00
Coke, ...	80.00

This broken coal was separated on a 20-mesh sieve, and treated with a solution of 1.35 specific gravity. The products were:

I. Through 20-sieve,	28.70	per cent.
II. Lighter than 1.35 specific gravity,	43.53	" "
III. Heavier " " " "	27.77	" "

	I.	II.	III.
Moisture,	0.62	0.66	0.67
Volatile matter,	19.51	20.04	18.12
Fixed carbon,	72.10	74.44	57.32
Sulphur,	0.82	0.71	1.04
Ash,	6.95	4.15	22.85
	100 00	100.00	100.00
Coke,	79.46	78.95	80.68

Similar treatment of the same coal with a solution of 1.38 specific gravity gave :

I. Through 20-sieve,	25.80	per cent.
II. Lighter than 1.38 specific gravity,	53.24	" "
III. Heavier " " " "	20.96	" "

	I.	II.	III.
Moisture,	0.91	1.31	0.67
Volatile matter,	20.03	19.71	16.86
Fixed carbon,	71.47	72.65	53.14
Sulphur,	0.88	0.77	1.06
Ash,	6.71	5.56	28.27
	100.00	100.00	100.00
Coke,	78.62	78.60	81.94

In practice the advantages of this method of purifying coal would be its promptness, and the cheapness and simplicity of the plant required for the separation. As an offset to these advantages niust be put the loss of calcium chloride in the liquid adhering to the coal and slate.

To determine how thoroughly this could be removed by washing, the following experiments were tried :

611 grammes of purified coal were allowed to drain 15 minutes, and were then washed six times wilh 350 c.c. of water, 5 minutes in each case being allowed for draining.

From the 1st washing 21.90 grammes were recovered.

"	"	3d	"	0.76	"	"	"
"	"	4th	"	0.17	"	"	"
"	"	5th	"	0.15	"	"	"
"	"	6th	"	0.10	"	"	"

This last amount, remaining in the coal after the 5th washing, is equivalent to about 5½ ounces of calcium chloride to the ton of coal. The washing would, therefore, be a somewhat tedious process, and would require a series of large tanks. The dilute wash-waters could be nsed for subsequent lixiviation, until they became sufficiently saturated to be still further concentrated by heat to the original density. The heat need not be here considered as an item of expense, for there is always plenty going to waste about coke-works.

The effect on the quality of the coke of the small amount of calcium chloride, which would always remain in the coal, would be inappreciable. The ash would be slightly increased, and, perhaps, there might be some sulphur volatilized; but this is not worth consideration.

All the above determinations were made by Mr. P. W. Shimer.

THE SPENOE AUTOMATIC DESULPHURIZING FURNACE

BY W. H. ADAMS, NEW YORK CITY.

AMONG the persistent experimenters of the present century no one man is more widely and favorably known in the metallurgical world than the late Peter Spence of Manchester, England, to whom we are indebted for many of the successful processes in the manufacture of acids and alkalies, and for much of that perfection in mechanical detail which goes so far towards insuring success.

For the past twenty-five years—a period covering the greatest changes in soda-processes and a revolution in acid-manufactures effected by the substitution ofpyrit.es for brimstone—Mr. Spence was constantly engaged in perfecting the plant for the economical treatment of pyritous ores; and no text-book has been complete without reference to his many inventions, patented or otherwise.

The results of his labors for the past six years were not given to the public, by reason of the active competition existing among manufacturers on the continent of Europe and in Great Britain ; but it was well known and conceded that the crowning triumph of his life had been achieved in the successful working of his automatic desulphurizing furnace, which mechanically calcined "smalls" or finely crushed pyrites—the bugbear of all chemical

That he was met by many delays and disappointments, and that

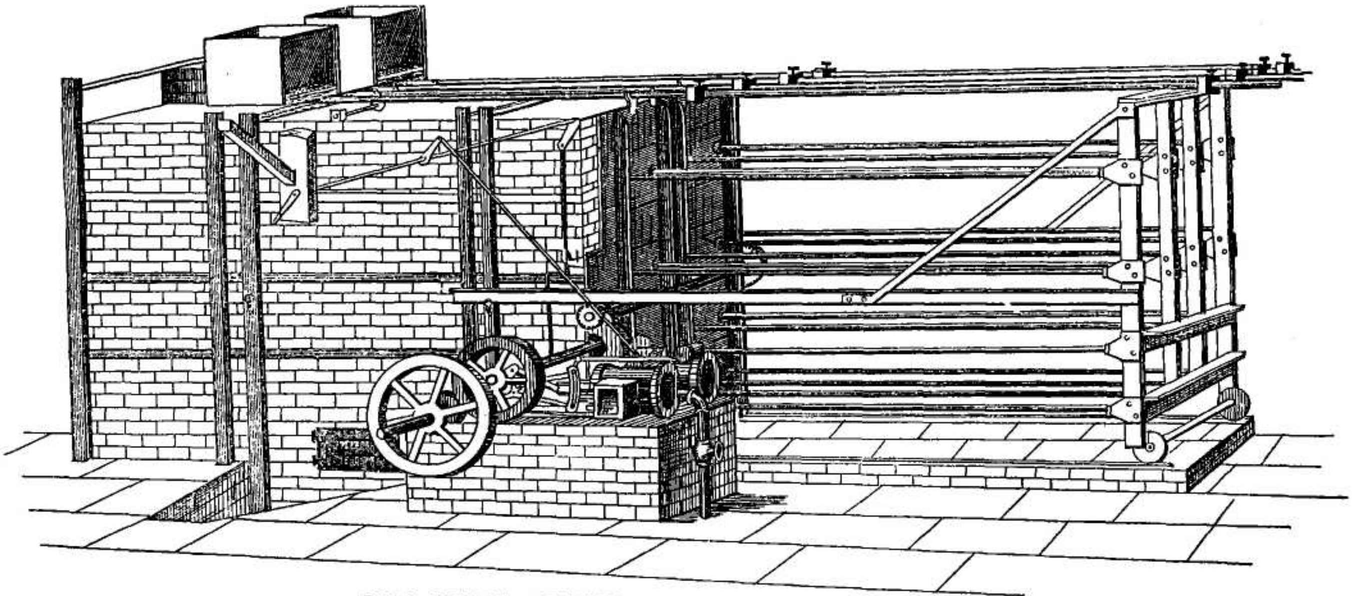


FIG. 1. SPENCE AUTOMATIC DESULPHURIZING FURNACE.
ELEVATION IN PERSPECTIVE SHOWING ENGINES, RAKES, FEED-HOPPERS & EXTRA FIRE-BOX.

many difficulties were overcome by him personally, goes without saying, when we remember the wrecks of so many attempts in this direction; but the systematic workings of these furnaces, at the several factories under his control, attest the correctness of his plans and the careful attention he paid to details, giving him as a reward unquestioned advantage over all competitors, an advantage held for several years already, against all opposition or new devices.

Although negotiations have been in progress for two years past, it was not until after the death of Mr. Spence that patents for this furnace could be secured outside of England, or that the study of its mechanism could be made; but now that Americans have the control of the invention in this country, and since, without doubt, this perfected mechanical furnace will play an important part in the future treatment of all classes of ores containing sulphur, I deem it worthy of early mention before the Institute.

Fig. 1 shows the double furnace in perspective; the space occupied by it being 34 feet x 18 feet. When two double furnaces are coupled together and run by one engine (as preferred in all cases), the space required is 34 feet x 32 feet. A building 40 feet x 40 feet is therefore necessary to accommodate this plant, with a shed-roof, if connection is made to towers and chambers, or an ordinary flat-roof building with supporting posts placed between the furnaces, when connected direct with the chimney, as in the process of desulphurizing gold ores.

Figs. 2 and 3 are longitudinal sections which explain themselves.

A striking feature to the observer, however skilled he may be in mechanics or furnace-working, is the simplicity of the parts, the certainty of the action, and the absence of all the complications attendant upon such operations generally. All the parts might be thrown together in a heap, yet so obvious are their forms and uses, that any man of intelligence could put them together from drawings here given. The same may be remarked as to the furnace, which is simply a multiple-shelf type of the hearth-furnace, used from time immemorial in every prominent mining center of the world.

Mr. Spence exemplified his well-known good judgment and practical mechanical sense in working from tried and satisfactory models: and whether he ever was led into experiments with any of the types connected with so much sorrowful experience to most metallurgists, cannot be seen in any one part of this, his finished production, which is built from common forms of brick and tile, operated in a positive manner with little gearing, and adapted in all respects to every-day service.

There are several practical points of excellence about the furnace (which has been in operation near New York for past three months),

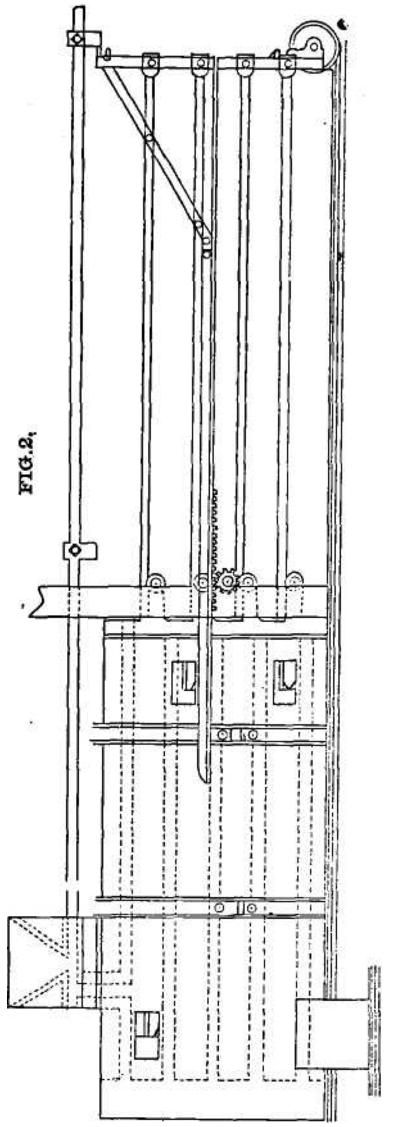


FIG. 2.

which entitle it to careful examination by engineers. I do not think it necessary to enter into details connected with its working, further than to state generally the method of handling ores and the results obtained, leaving to those most interested the study of separate parts or special features.

The action of the furnace will be understood to be automatic, the ores being elevated from the furnace-floor, brought in from the floor aboye, or by other means supplied in quantities as required to keep the hoppers full. This matter of detail will readily be understood by those practiced in handling of ores from different levels, and the drying of the ores (if wet) will also be understood to be a simple matter when small quantities are regularly fed.

The hoppers being filled, a small auxiliary engine is started, and by means of a changeable gear, properly connected, opens the valves to start the pair of engines shown in the foreground of Fig. 1.

These engines, having 7 in. x 12 in.-cylinders, and running at 40 revolutions per minute (giving a minimum of wear and tear for the service performed), quietly and positively operate by means of geared wheels the rods to which, in the furnace, are attached toothed rakes (Fig. 2).

The rods are very firmly held in place and position by the rack, which, supported at its rear end by wheels, travels along a railway.

The movement of the rack (with rakes inside the furnace) opens the ports for the admission of fresh ore from the hoppers to the first shelf, and the discharge of finished or calcined ore from the lower shelf into cars. When the rakes have finished the forward stroke, the engines reverse automatically, and the rack returns to and stops in position.

The auxiliary engine continues running, and at stated times (determined by the manager) again starts the large engines, another operation of stirring and raking with feed and discharge of ores taking place.

This automatic and regular method of feed and treatment of the ore on the bed of the furnace is the result of years of study and practice, directed to the object of replacing by a uniform mechanical procedure the discretionary operation of hand-labor.

By study of the plant now in operation, the following conclusions are reached:

1. The constituent elements of the ores being first determined, the feed and discharge is regulated to exact amounts in pounds, and the number of charges fed into the furnace is duly registered.

2. The auxiliary engine being set to start the motive power, say, every five minutes, and the time required for the forward and back stroke being, say, one and one-half minutes, it follows that the

interior parts of the rakes are exposed to action of heat and acid fumes but one-third of the time, thus approximating manual labor in wear and tear of plant.

3. The draft of air being regulated and controlled by the chemist at will, insuring the proper oxidation of the ores, and no more, less chamber-space must be required than by any other process of burning pyrites, and, moreover, no special care need be given to location of plant, since strong winds or variable currents can have no effect in causing " blow-outs " of gas at the doors.

4. The movement of the ores from the hoppers to the discharge-opening is accomplished by a system of reversed teeth, which are positive in action.

The deterioration or destruction of cast-iron rakes and teeth has

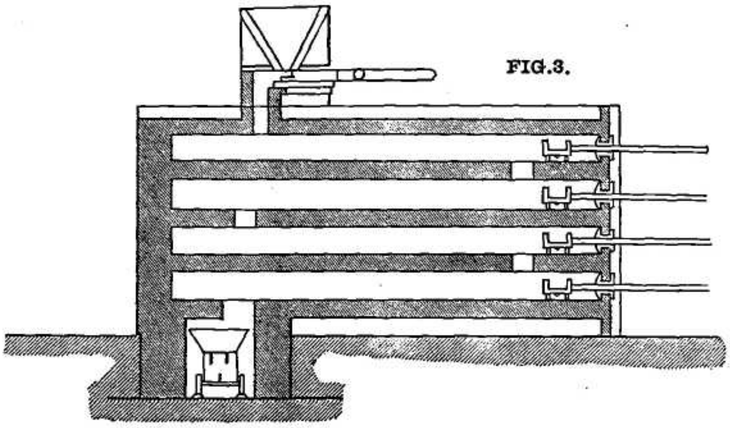


FIG. 3.

been reduced to a minimum by the simple but novel idea of *burying the parts in ore,* which accumulates at the front of the furnace-beds when the rakes are at the position of rest (Fig. 3).

5. Pyrites " smalls," such as are found in Virginia, at the Milan or Capelton mines, carrying 47, 45, and 40 per cent. of sulphur, respectively, can be calcined with two double Spence furnaces, run by one engine at the rate of 15,000 to 20,000 pounds per day of 24 hours, the cinders containing from 1½ to 2½ per cent, of sulphur.

It is claimed that larger amounts of "smalls" containing copper, blende, etc., can be put through, and double the above quantity, where sulphur fumes are passed directly into the air—as would be the case in working auriferous concentrates.

6. Where necessity exists for bringing the sulphur-contents of cinders from iron-pyrites (FeS,) down to ¼ to ½ per cent, to utilize

the iron, or, for the like treatment of rich gold-bearing sulphurets, the result is accomplished by the addition of a fireplace to the lower hearth. This is shown in Fig. 1, although not ordinarily used.

By this means the proper heat is kept in the ores until they are discharged into iron cars, but in general working the ores are " dead " on the lower shelf.

7. The average cost of calcining ores by this automatic furnace is not greater than by any other method at present in use.

The cost of the furnace, complete, with power, is about the same as that of the equivalent grate-bar space in kilns, or equal burning space in the present type of shelf-furnaces.

THE VALLEOILLO MINES, MEXICO.

BY RICHARD E. CHISM, MONTEREY, MEXICO.

I HAVE thought it well to lay before the Institute some account of the Vallecillo Mines, now, I believe, the only paying ones in American hands in northeastern Mexico, including the States of Nuevo Leon, Coahuila and Tamaulipas.

The authentic history of these mines dates from their ownership by an American Company in the year 1851, when they were bought by the Vallecillo Silver Mining Company of New York. They had been worked before by the Spaniards, but had been abandoned for many years, on account of the heavy expense of drainage and the constant incursions of the Indians.

The company commenced work with several well-known New York capitalists among its stockholders, and had a large fund of both money and enthusiasm.

The first point of attack was at a shaft on a mine known as the Jesus Maria, which had the most favorable traditions. Extensive buildings were put up, and two sets of pumps were successively tried. After the second pump, with a steam-cylinder 5 feet in diameter and 10 feet stroke and a plunger 20 inches in diameter, had failed to do more than hold the water, with infinite labor, at the 250 feet level, and after a thorough exploitation of the whole mine above that level had failed to yield more than some $30,000 worth of ore, it was resolved to abandon the effort. Operations were accordingly transferred to the old Dolores shaft, at a point about 2½ miles to the eastward, which had been opened originally by the Spaniards. Here a new *hacienda* was built, and the smaller of the two pumps from the Jesus Maria shaft was used for the drainage.

About this time, was begun a series of experiments in metallurgy, which extended over many years, and embraced nearly every known apparatus and process. The warehouses and yards of the *hacienda* are still crowded with the fragments of many thousands of dollars worth of the most costly machinery, from amalgamating-pans to dry concentrators, while the monumental ruins of reverberatories and upright furnaces have been perfect mines of fire-brick, etc., for some years past. All these remains, together with those of boilers, pumps and general machinery, make up a scrap-heap, wonderful at first sight, and absolutely astounding on closer examination.

Here was employed, about the year 1870, the famous Dr. Stapff of Sweden, since engineer of the San Gothard tunnel; and the plans of a jig of his invention, built for the company, are given in the report of the United States Commissioner of Mining Statistics for the year 1871 (published 1872).

Daring the war of the Rebellion, these mines were in charge of Major Alfred Lowry, a thorough Union man, who shut them down rather than supply lead to the Confederacy. The market, at that time, ruled at a pound of cotton for a pound of lead ; and his patriotism cost the company a considerable fortune. Major Lowry found permanent investment for many thousands of dollars in sinking shafts and in prospecting; but made, I am told, no money for the company. In 1875, he was succeeded by the present superintendent, Mr. John Sutcliffe, in whose hands the property began to pay for itself the next year. In May, 1883, the pump-work was moved from the old Dolores shaft to the new Santiago shaft, 770 feet further east. The whole of this change, including that of the hoisting-machinery, caused a short stoppage only; and the mine paid better last year, and the early part of this, than ever before.

*Situation.**—The Vallecillo Mines are in the northern part of the State of Nuevo Leon, Mexico, about 35 miles a little north of east, from the Villaldama station of the Mexican National Railroad. They are on the eastern side of a range of low, rounded hills, on the western edge of a plateau sloping away to the Rio Grande, at an elevation of about 800 feet above the sea-level.

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* See map to Dr. Frazer's paper on Silver Mines in Nuevo Leon and Coabuila. *Transactions,* vol. xii., p. 537.

From the railway to the mines, the road is level and good, except for about six miles, where it follows the cañon of the Sabinas River through the Iguana mountain-chain. Along this part there are frequent crossings of the river, and the road is rough and liable to be interrupted by freshets. At least 25 miles of the road lies through a fair agricultural country, where supplies in the nature of corn, fodder, lean beef, tomatoes, onions, red pepper and the national beans, are rather abundant. A few hundred yards from the mine is the town of Vallecillo with about 1500 inhabitants. It is dependent on the mine.

Old Workings.—The first signs of mining are seen four or five miles before reaching the works, in the shape of numerous small dumps belonging to prospect-holes in the hillsides. Soon after, we get a distant view of the abandoned buildings of the Jesus Maria Mine; and then the road follows closely the course of the vein to the works, and gives a good chance to inspect the old Spanish workings.

These are a series of pits and galleries, sunk and driven along the course of the vein, so that the workings are practically continuous for about 2\ miles, and the vein is proved to an average depth of 100 feet for the whole distance. In the old times, when every inch of the vein was taken up, and every claim had' its busy workers, this place must have been a small Leadville. The remains of several old smelting-furnaces, with quite large trees growing in their ruins, are still visible.

Besides the main vein-diggings, there are at least two extensive mines on cross-veins. One of these, the Rosario, had the fame of great riches, but was abandoned by the American company years ago, as exhausted. The old Spaniards, before leaving it, had cleaned up everything. Where the vein pinched, they had cleaned it out for some yards by means of rods and wires, until it gave out altogether.

Formation.—The country-rock of this region is a shaly limestone, non-fossiliferous, in nearly horizontal layers, remarkable for the almost entire absence of breaks or faults. The folds are long and gentle, with a general course from northwest to southeast. Some layers of a highly siliceous limestone are found in this region, everywhere conformable to the other variety. I have no doubt that the shaly limestone is much older than that farther to the westward at Villaldama; it dates probably, from about the middle of the Silurian period.

The main Vallecillo vein is undoubtedly a true fissure. It cuts the strata of limestone with a strike of north 40° east (magnetic) and a dip of 56° to the northwest, with an average thickness of about one yard, having a pay-streak of from 6 to 18 inches. In structure, it is irregularly banded, though the upper part is so decomposed that this can not be easily seen : it is, however, quite plain in some of the lower levels. In sinking on this vein, fresh water is met with at a short distance below the surface and down to 150 feet. From that point on, the water is salt, and is met in large quantity. Five hundred grammes of this salt water, evaporated to dryness, gave a residue of about 20 grammes of deliquescent salts.

Mineralogy.—The minerals found are galena, ziucblende, and copper and iron pyrites, the latter in small quantity. The gangue is calcspar, feldspar and some fluor-spar. As the work progresses on the vein, curious alternations are observed in the amount of zinc-blende and galena. The last is present at some points in large bodies, nearly pure. These bodies begin to taper off in each direction to an edge, and a body of zinc-blende appears alongside, growing as the body of galena diminishes, with a layer of a mixture of the two minerals between. Then the blende in its turn diminishes, and the galena increases in quantity ; and so on. Near the surface, the sulphides are changed to carbonates of the two metals ; and these are, at present, left standing, being unsuited to the process now in use for the extraction of the lead.

Fluor-spar replaces the calcspar as a gangue in some parts of the vein, but no amount of heavy spar has yet been found. This is a striking difference from the mines of the Iguana range, farther west, where the gangue is in some places entirely heavy spar.

One of the peculiarities of this mine is the large amount of carbonic acid gas which fills all the abandoned workings, and, in muggy weather, encroaches so upon the drifts and stopes in work, as to necessitate the use of a fan for artificial ventilation.

Workings.—The main working on this vein is the Santiago shaft, This shaft is about 450 feet deep (May, 1884), 8 by 12 feet inside measurement, and has three compartments for pumping, hoisting and the ladder-way. There are three other shafts within the limits of the *hacienda,* namely, the San Juan air-shaft, 370 feet west of the Santiago shaft, the old Dolores shaft, 770 feet west of the Santiago, and the San Vicente shaft, the old main working and draining-shaft of the Spaniards, 1370 feet west of the Santiago. The bottom of the San Vincente shaft is its point of intersection with an incline, heavily and well timbered, which follows down the dip of the vein from a point on the surface near the mouth of the San Vincente shaft. It is difficult to see the motive for opening this incline: it was the work of Major Lowry. We thus have four deep shafts and an incline within a distance of 1400 *feet* along the vein. Two of these shafts and the incline are of no use, and represent so much lost capital.

Besides the above, there are two deep and well-timbered working-shafts in good order, still further westward along the vein. The ore is Paid to be in sight in each of these, so that they only need a force of men and a hoister to commence the output.

The ground worked by the old Spaniards, has its eastern limit about midway between the Dolores and the air-shaft, and extends to a depth of about 160 feet. At the lower edge of this, the moderns have commenced work, and now have five levels, of which the deepest is some 400 feet below the surface. Work has been done on these to a distance of about 1800 feet westward, and 850 feet eastward of the Santiago shaft. The heads of the three lower drifts to the east were considerably ahead of the stoping in May last and were all in ore.

This leaves developed a reserve which, counting from where the Spaniards left off work, and the surface of the ground, is 1700 feet long and on an average 300 feet in depth, and which, therefore, covers some 510,000 square feet of vein. Referring to a map of the mine, now in my hands, which contains data of the production, I find that about 320,000 square feet of vein have produced a little over 200,000 pigs of lead of 62½ pounds each; so that the present reserve should turn out the same rate 320,000 pigs. Making all due allowance for barren ground, etc., it would probably be safe to count on 200,000 pigs from the reserve in sight.

Mining.—The vein-matter in these mines may be characterized as moderately soft and fragile, so that there is not a great use of powder, and the tools do not need much sharpening. Much country-rock has to be taken away, as the vein is nearly everywhere not wide enough for the necessary workings. Constant timbering is required; and the older drifts are much diminished in size by the imperceptible movements of the wall-rock. As there is more or less water all through, the mine is a very dirty one to visit, the passage down the Santiago shaft being especially disagreeable.

The mining captain is a Cornishman, very intelligent, and a master of his business. He was secured by natural selection from the answers to an advertisement in the New York *Herald* asking for "*a* practical miner, who understands timbering and pump-work." He has his son for assistant. They speak only a few words of Spanish, but get along well, with occasional aid from an interpreter. The working miners are all Mexicans. They do all their work by contract, at prices which the mining captain fixes every two weeks.

The contractors for running the levels get from $22 to $30 Mexican, per yard, 8 by 7 feet high and wide, the price varying according to the amount of limestone to be cut through in following the vein. The contractors cut, trim and put in their own timber, carry all ore to the shaft and dispose of the rubbish. They also find their powder, fuse and candles; the mine supplies rough timber at the shaft-mouth, steel and hammers. The drills are given to the miners sharpened. The average progress in drifting is 3 yards a week, for six men twelve hours per day. They can earn, at this rate, a little over $1.25 per day.

For stoping, the prices range from $4 to $6 per yard in length and height, and the full width of the vein. The miners must make a clean separation of the ore from the rubbish, or they are fined. The same conditions as to supplies, moving ore, etc., obtain as in drifting. The rock and ore are brought to the shaft on iron cars which run on a 15-inch gauge road laid with 10-pound iron rails.

Pumping Machinery.—The water is principally handled by a Cornish pump with a 10-inch plunger and 6-foot stroke, capable of throwing out 9,000 gallons per hour at a speed of 6 strokes per minute. The H-piece and valve of this pump are large enough to admit a 20-inch plunger whenever necessary.

Besides the large pump at the bottom of the shaft, there is another and smaller one at about 150 feet down. At this point, the fresh water is caught as it streams from the more superficial strata, prevented from going down the shaft, and transferred by the auxiliary pump to the surface for boiler-feeding, etc. The saltwater from the lower levels is unfit for these purposes, and caused the loss of several boilers before the separation of the waters was made.

At the third level there is another pump which intercepts a large amount of water there, prevents it from going down below, and relieves the main pump of much hard work.

The mine-water is the drainage of the whole country; and when the pumps are at work no water can be obtained within a radius of several miles, except from the Jesus Maria shaft. This latter is, however, too deep for general use.

The pump-engine is horizontal, with 18-inch cylinder and 36-

inches stroke. The fly-wheel weighs at present 10 tons; but its weight can be increased to 20 tons by loading the hollow rim with lead. The cut-off is a variable one, so as to allow the highest range of elasticity in overcoming any sudden resistance. The engine is geared to the pump-crank at the rate of five to one. All the pumping at present is done with about one-fourth the power of the engine; and from 4 to 10 pump-strokes per minute are sufficient to hold the water, or to gain on it rapidly.

Hoisting Machinery.—The hoister at the Santiago shaft was made by Lidgerwood. It has two cylinders, reversing gear and a 5-foot drum with a spiral groove, which will hold 600 feet of 1-inch round wire rope without doubling up. The hoister is run by a little Mexican boy, thirteen years old, who appears to understand the machine thoroughly, and to handle it well.

Boilers.—The steam for pumping and hoisting and also for the jigging and smelting, is supplied from two 70-horse-power boilers, each 12 feet long and 56 inches in diameter, with 46 tubes to each, 3 1/2 inches in diameter. There is also a Babcock and Wilcox boiler of 70 horse-power, as a relay.

, The water used in the boilers passes through a feed-water heater and lime-separator, and the exhaust steam from all sources goes through a condenser, of tubes from an old boiler. The condensed water is used for culinary and drinking-purposes.

Steam-pumps.—Two of these are in use. One is a boiler-feeder, made by Knowles, size 1. The other is size 5 of the same maker, and is used to raise the waste water from the slime-pits, after it has passed through the jigs, and to return it to the tanks at the mouth of the shaft, to be used over again.

Machine Shop.—This part of the establishment is provided with a full outfit of hand-tools, and also a bolt-cutter, a long lathe, a short lathe, a small planer, and a power-drill. All of this machinery is unworn, having been set up only a short time; but it is all old in style. It was sent out here some twenty years ago, and has none of the modern improvements.

Treatment of the Ore.—The ore, as found in the mine and delivered at the mouth of the shaft, may be classified into five kinds, as follows : pure galena; galena and blende; galena, blende and gangue; pure blende; nodules of galena in clay. From one-half to two-thirds of all the ore is lump-galena, which requires no treatment except hand-separation and breaking, to fit it for smelting. The finer portions of this class of ore receive only a slight washing in a circular buddle, and thence go direct to the smelting-hearths.

The mixed ores are roughly sorted at the pit's mouth, and then are removed to the jigging-floor below. The removal is accomplished by piling the ore at the mouths of three pipes, 20 inches in diameter, which radiate from the top of the dump behind the shaft. The ore-piles are then flooded with a body of water, which flushes them through the pipes down to the jigging-floor, and the ore arrives partially washed on a grating at the lower end of each pipe.

On these gratings, the ore undergoes some separation by hand-picking. Large lumps of gangue are picked out and thrown away ; the large pieces of ore are laid aside for crushing, and the fine stuff, up to egg-size, goes to the jigs.

Principles of Separation.—By reference to the list of minerals found in the ore, it will be seen that the problem of separation here presented is a remarkably easy one. The heavy mixture of galena and zineblende is to be first cleaned from the gangue of calc- or fluorspar (both minerals of low specific gravity); then we have to separate the blende and galena, with a fair difference in specific gravity to work upon. The presence of heavy spar would complicate matters more; but, as already noted, this mineral is seldom found with the ores of Vallecillo.

Jigs.—The separation is accomplished at Vallecillo by four intermittent jigs, two fine and two coarse, without any preliminary sizing except the rough hand-picking before mentioned. The results seem to be fairly satisfactory; but a conical sizer, like those used in Pennsylvania for sizing iron-ore, was being erected at the time of my visit.

The coarse jigs separate the gangue from the metallic minerals. They have No. 8 screens, and a stroke of 2½ inches. The fine jigs clean the galena from the blende. They have No. 50 screens, and 2-inch stroke. Each jig is attended by two boys, who get from 18 to 25 cents a day, and a man, who gets 75 cents. They have a task set them which is supposed to be the equivalent of a day's work.

The Stapff jig had originally three pistons, and was designed to be continuous. It was found, however, to use too much water, and was, therefore, altered to a two-piston jig, with a continuous circulation of the water and intermittent action. The water, after passing the screens, is received in an iron pan at one end of the jig. Here it deposits any slime it may carry, and then runs back into the side-box of the jig. From the side-box it is raised by the action of the piston (which has valves like a pump and works underneath the screens), and is made to pass through a second time.

The other jigs have side-pistons. Two of them were built in the machine-shop at the mine. The boxes of these are of boiler-iron. The action of these jigs is about as follows : The jig-box being filled with water, a quantity of stuff is fed in at one end, and distributed evenly over the screens. A number of strokes are then made, at the conclusion of which the finest stuff has fallen through the screen to the bottom of the jig-box. On the screens the minerals are found in. layers, with the galena below, galena and blende next, nearly pure blende above, and particles of gangue above all. The machine is then stopped, and the workman separates the layers with an iron scraper. The gangue is thrown away, the blende goes to its pile, the middlings of galena and blende are reserved for further concentration, and the clean galena is piled away.

The coarse two-piston jigs have the bed divided into two parts, each about 8 feet long by 1½ feet in width, and with the part next the feed-end 2 inches higher than the other, from which it is divided by a partition 2 inches high. The most of the gangue and the larger part of the impure middlings are found in the lowest division.

The finer jigs with three pistons have the bed divided into three parts, of about the same dimensions as the above, and with the same difference in level. Naturally the pure galena is predominant at the feed-end ; the second division receives more middlings, and the third division has the zinc-blende in larger quantity. In these jigs the galena is taken out, the middlings from the second compartment are moved to the first, those from the third to the second, and the zinc-blende is reserved.

Buddle.—The fine stuff which falls through the screens of the fine jigs is removed and washed in a circular buddle. This is a circular pan of iron, 6 feet in diameter, with a rim 6 inches high. It is raised up at one side so as to have a fall of about 6 inches across it, and at the highest point is supplied with a jet of water, which falls a foot or so from the mouth of a 1-inch pipe with a cloth tied over it.

A heap of fine stuff is placed under the jet; the water is turned on, and a boy with brush keeps the heap from guttering, as it slowly spreads out and is borne toward the lower side of the buddle. The action of the water, with careful attendance, effects a partial separation of the galena from the zineblende and whatever small amount of gangue there may be left in the middlings.

Slime-pools.—The slimes from the buddle and jigs are run off to pools, made on the surface of the ground, the bottoms and sides of which are the deposited slimes themselves. As soon as the solid particles settle, the clear water is allowed to run to a sump, whence it is pumped back to the tank above the jigs.

Zinc-blende.—The zinc-blende is dumped in the grounds of the *hacienda,* and has accumulated, during years of working, to an immense extent. The blende in this mine makes up, on a rough estimate, about one-third of the metallic mineral, and will be of great commercial importance as soon as capital can be obtained for the necessary plant for working it.

Amount and Value of Ore-Output.—As neither the total amount of material raised nor the cleaned ore is ever weighed at this mine, it is almost impossible to estimate closely the proportion of cleaned ore to total output. In May, 1884, they were raising some 50 tons of material per day, from which about 10 tons of ore were cleaned up. This ore contains about 72 per cent, of pure lead, and from 25 to 43 ounces of silver per ton. No assays have been made for several years; hence this estimate is more or less guesswork, founded on back-calculations from the market-returns of the lead bullion.

Metallurgy.—The smelting of the galena is accomplished by the American modification of the Scotch hearth-process, the practice being similar to that followed at Joplin, Missouri. The special reason for adopting this process at Vallecillo is that it requires but little fuel. It is, moreover, fairly well-adapted to the ores, and the residues, though apparently rich, are of small amount. The process is not suitable except for pure, or nearly pure, galena ores, and would fail in any place where this fact was not taken into account. At Vallecillo large quantities of carbonate ores have been left standing near the surface, because not suitable to this process, while fuel is said to be at present too scarce for any other.

The heat required is largely furnished by the combustion of the sulphur in the ore. The usual fuel is charcoal; but at Vallecillo this is replaced by wood, with good success.

A disadvantage of the process is the great quantity of fumes, rich in lead and silver, which are continually going off. This loss can be obviated to a great extent by the use of fume-chambers; but at Vallecillo these have not yet been adopted. Another strong objection is that that the residues must always be handled a second time, as they are never poor enough to be thrown away.

Smelting-Plant.—At the time of my visit to Vallecillo, the smelting-plant in use consisted of three "North-American hearths," located near the mouth of the Dolores shaft, some 800 feet from the shaft in present use. A new plant of four hearths was in course of erection at the mouth of the present hoisting-shaft, and is now in operation.

The hearths are like a box about 24 inches square, without a top, and with one side taken away. The walls of the box are of half-inch iron, inclosing a hollow space, in which circulates air or water. The bottom of each box is a lead-bath, holding 900 to 1000 pounds of melted lead, and over the open top of each is a canopy, leading to the stack. Each hearth has three tuyeres, 2 inches in diameter, placed 6 inches above the lead-bath. As the Vallecillo hearths are "air-backs," the blast circulates in the hollow walls before going to the tuyeres, and thus arrives hot at the point where fusion takes place.

The charge floats on the lead-bath, which facilitates the work by making more easy the introduction of the stirring-bars.

The lead which runs from the charge is received on an iron plate or fore-hearth, 3½ feet square, with a groove, 1 inch deep and wide, crossing it diagonally, from the upper to the lower side, and so much inclined that the lead will run off easily into a pot, placed at one of the lower corners, at the end of the groove. A fire is maintained under the pot to keep the lead liquid, and the surface of the molten metal is covered with ashes to prevent oxidation. ,

The three hearths first mentioned are provided with blast at a pressure of about three-fourths of a pound by a No. 4 Baker blower which is run by a separate engine. They use from 10 to 15 horse-power to run the blower for the three hearths; but it could easily supply several more hearths with the same power.

Took.—The hearths are supplied with light, pointed bars for cleaning out the groove of the fore-hearth; heavy bars, 8 feet long, for poking the charge; hoes and shovels, to handle the charge and to pull it out on the fore-hearth when necessary; a perforated ladle, to skim the lead-pot; a ladle, to run the lead from the pot into the moulds, and hooks to pull the bars from the latter. The moulds used hold 62½ pounds each, and have the name of the company at the bottom. They are set in groups of five.

The Working of the Process.—In the working of this process it is easy to distinguish three periods at which the charge undergoes notable changes:

1st. The preliminary or heating-up stage, in which the water goes off, the whole mass becomes red-hot, and the sulphur commences to burn.

2d. The burning sulphur raises the heat to the melting-point of lead; the greater part of the lead finds itself in a reducing atmosphere, and runs out in metallic form, while the rest is oxidized, carbonated, or volatilized with the remaining metals of that kind, that are by this time passing off. It is evidently best at this stage to use as little blast as possible, so as not to blow away the reducing atmosphere, and oxidize or volatilize the lead. It is also necessary to retain the charge at this stage as long as possible.

3d. After the second stage has lasted some time, the heat of the mass has so increased that the ferruginous and earthy impurities of the ore, combining with the litharge formed, commence to sinter and agglomerate to a slag, inclosing the particles of lead as they run out, and finally cementing the whole charge to a mass which sticks to the walls of the hearth. Before this period fairly sets in, the charge should be considerably reduced in bulk by the burning of the sulphur, melting of the lead, etc., and its further progress must be prevented by proper manipulation and by adding a new charge.

Practical Operations.—At the commencement of a heat on one of these hearths, with the hearth cold, some lighted fire-brands are piled against the back-wall, in front of the tuyeres, and a gentle blast is put on. When the lead in the well has been thoroughly melted, and the hearth has attained a red heat, a charge of ore, mixed with the richer slag from the last heat, is put upon the wood and allowed to heat up, being carefully watched and stirred, so as to allow the blast free passage and prevent agglomeration. Soon the lead will be seen to stand out in minute drops all over the pieces of the charge; then the drops slowly join and fall, and the lead commences to roll down the gutter of the fore-hearth in a fiery stream into the pot below. With the first charge, this must be allowed to continue only a short time; almost immediately after the first drops begin to form, the charge must be raked out on the fore-hearth and allowed to cool down. Fresh brands are then placed over the tuyeres, a charge of ore is placed upon them, and the first charge, also mixed with fresh ore, is piled on top of the second. The process goes on as before; the fresh ore seems to swell up and assumes a loose, spongy, earthy look; then the dense white, red, and black fumes commence to roll off; the drops and streams of lead appear;

and the same attention and stirring are necessary to avoid the agglomeration of the charge.

In working with an impure ore, the slag formed must be picked out from time to time and thrown aside, otherwise the burden will get too heavy. With any ore, indeed, this must be avoided ; since otherwise the work is made much harder, more stirring must be done to keep the charge open, and more lead is volatilized or goes into the slag.

Too high a heat will also retard the process by the rapid agglomeration it causes in the charge. When the heat is at the proper point the lead runs out in a brisk silvery stream, and there is no sticking of the charge to the walls of the hearth; but when the heat is too high the lead flows sluggishly; the charge, especially if of impure ore, clings tenaciously to the walls of the hearth, and the constant use of the bar is required to get it off.

Slags.—As already noted, the slags from impure ore will accumulate on the hearth, so as to need removal several times in the course of a heat of some hours. In working pure galena, on the other hand, nearly all the slag stays on the hearth until the end of the heat. What is left at this time is sintered to a mass, which is then broken up and picked over, the rawest parts being saved for re-smelting in the next heat.

After cooling, the slags are examined for shots of lead, and are then thrown on the dump. They are heavy, earthy-looking, puffy and porous—in some pieces, sub-vitreous. They seem to contain a notable amount of iron, and are rich in lead and silver. No assays of them have been lately made, and their exact contents are not known. The slag-bank back of the hearth is small for the time they have been at work, showing that the ore has been of fair purity. Some attempt has been made to work up the slags in a small upright furnace, but the matter has been laid aside for the present.

Lead.—The lead made by this process is of great purity, and very soft; and the brand of this company is favorably known in the English market.

Labor.—The smelting is overlooked by a head-smelter, who gets §3 per day. Each hearth is attended to by two men and a boy. Only one shift is run per day; and a task is given which lasts from four to six hours, according to the ability of the workmen and the class of ore. Each hearth is expected to produce 35 pigs of lead of

62½ pounds each, from 3500 pounds of ore. The ore is not weighed but guessed at from long experience.

The superintendent estimates the cost of smelting each 35 pigs of lead at about $6, subdivided as follows:

Two smelters, at $1 each,	$2 00
One boy,	25
One load of wood,	1 25
Part cost of power,	1 50
Part cost of head-smelter,	1 00
	$6 00

Production, Values, and Profits.—At the time of my visit there were three hearths running, and turning out 105 pigs per day. A considerable reserve of ore was accumulating, as the consumption was less than half the daily product, which would have sufficed for six hearths. With six hearths the production should be 210 pigs per day. The returns from Liverpool give, as *I* am informed, the silver value of the bullion as from 58 to 75 ounces per ton of 2240 pounds. Allowing an average value of C5 ounces per ton of 2000 pounds, of which only 45 ounces are paid for by the smelters, and pricing the lead at 3 cts per pound, we have the following as the market value of the daily product if six hearths were in operation:

13,125 pounds of lead at 3 cts per pound,	$393 75
6½ tons lead give 292½ ounces silver paid for, at $1 per oz.,	292 50
Total United States money,	$657 00

For four hearths, with a product of 140 pigs per day, the return at above rates would be $438.

From these returns must be deducted the cost of mining, concentrating, smelting, and marketing, which I will now proceed to estimate approximately. The expenses per day are calculated as follows:

General staff:

Superintendent,	$15 00	
Bookkeeper,	3 00	
Machinist,	4 00	
Machinist's helper (Mexican),	1 00	
Blacksmith (Mexican),	1 00	
		$24 00

Mining :

Labor.

Underground captain,	$4 00	
Captain's assistant	2 50	
2 pump engineers, at $1 each (Mexican),	2 00	
4 firemen and helpers, at 75 cts. each (Mexican),	3 00	
2 hoist-boys, at 30 cents each (Mexican),	60	
6 surface-men, at 75 cents each (Mexican),	4 50	
50 miners, at $1.25 each (Mexican),	62 50	
		$79 10

Materials.

7 loads of wood for pumping,	$8 40	
Oil, packing, etc	3 50	
Powder and fuse	5 00	
Hammers, steel, and charcoal	3 00	
Candles	5 00	
Wear and tear of machinery (estimated at $21,000 to wear out in five years),	11 75	
Timber, prospecting, and dead-work,	20 00	
		$56 65

Total for mining, $135 75

(This amounts to $13.57 per ton of cleaned ore.)

Concentration :

Labor.

1 jig-boss, at $1 (Mexican),	$1 00	
4 ore-washers, at 75 cents each (Mexican),	3 00	
8 jiggers, at 25 cents each (Mexican),	2 00	
6 carriers and extra hands at 75 cents each (Mexican),	4 50	
		$10 50

Materials.

Wood, 4 loads, at $1.20 a load,	$4 80	
Oil, packing, etc	2 00	
Tools, barrows, etc	2 50	
Dumping waste	8 00	
Wear and tear of machinery ($3000 to be worn out in five years),	1 70	
		$19 00

Total for concentration $29 50

(Per ton of cleaned ore, $2.95.)

Smelting :

Details as before for 1 hearth ; for six hearths, .	$36 00
Wear and tear of plant, machinery, and tools ($4000 to be worn out in five years), .	2 25
Total for smelting,	$38 25
•Total for general expenses, mining, concentrating, and smelting	$227 50

(This in Mexican money is equivalent to $193.37 U. S. currency.)

Marketing:

Freight on 6½ tons from mine to Liverpool, .	$130 00
Commissions, etc., at $3 per ton, . . .	24 00
Total for marketing	$154 00 U. S.
The total expense for mining, concentrating, melting, and marketing would therefore be,	$347 37 U. S.

If we assume the net value of mine, plant, reserves, and rights to be $100,000 U. S., which should earn as a business investment 20 per cent per annum, on account of risks of mining, etc., we should add to the above $55 per day, and the result will be $402.37 U. S., which is the true total daily expense of mine and works.

Subtracting §402.37 from the daily market returns ($657) we have a remainder of §254.63, which represents the net daily profits on a production of 210 pigs per day. This is equivalent to $7600 per month, which would pay off the capital of $100,000 in thirteen months.

According to the above estimates, the net cost of 1 ton of 2000 pounds of lead, laid down in the Liverpool market, is $61.90, or, less the interest on the capital invested, $53.42.

The cost of 1 ton of cleaned ore is as follows :

Mining,	$13 57
Jigging	2 95
Charging to mining and concentration one-half of the general staff charges, or $12, we shall have per ton,	1 20
Total per ton, ...	$17 72 Mex. or $15 06 U. S.

Reserves.—I have already touched upon the question of the reserves on the eastern side of the Santiago shaft, and estimated their amount, as developed up to May, 1884, as perhaps 200,000 pigs of lead.

More important than the actual money-value of this reserve is the assurance, from the appearance of the three eastern headings, of an indefinite extension of the vein on that side.

Turning to the western side, and admitting that the explorations of the Spaniards show the vein to be continuous for at least 2½ miles (of which there is scarcely any doubt), and supposing that the yield of that portion should be even much inferior to the part of which we have data, we would have a calculation leading into the millions as to the value of the extension on that side.

There is, in fact, every reason to suppose that the working of this property on the large scale for both lead and zinc would be exceedingly profitable. I believe, however, that the plans of the present management are quite limited for want of capital.

Water.—The only supply of this necessity at Vallecillo, in quantity sufficient for the uses of the works, is from the mine itself, which, indeed, would be immensely less valuable, or without value at all, if it were a dry one. It is not likely that the present supply of water will be sufficient for works on a large scale. In this case, the abandoned mine of Jesus Maria would furnish about 2,500,000 gallons per day, at an expense of some $50,000 in fitting up the old large pump and constructions necessary, which supply would be enough for an output of many hundred tons daily, and leave a quantity over, which would be very valuable for irrigation.

Or, perhaps, some system of dry concentration might be used, which would do away with the necessity for water altogether.

Fuel.—The present price of a load of wood (about half a cord), at the works, is $1.50, and charcoal, if that were in use, could be had at from $8 to 10 per ton. The supply would be irregular, and not to be depended on for a large production, unless a regular charcoal camp were organized and hauling were done with the mine's own team.

The coke from the Rio Pecos coal, now being opened up along the Rio Grande, would furnish an excellent fuel, but it is to be feared that wagon transportation from the Villaldama station would be too slow, limited, and dear, to allow of work at these mines on a large scale, especially for the zinc industry.

A railroad has been thought to be too expensive, and it has been suggested by one of the parties in interest, that a thorough repair of the wagon-road and the use of a traction-engine, would be the best and cheapest mode of moving the product and bringing in fuel. It is to be hoped that this experiment will be tried in the near future.

Conclusion.—The history and present position of this company forms the best answer to the question so often asked as to the security of American investments in mines in Mexico. This company commenced to mine only a few years after the American invasion of 1847, has remained in full and undisturbed possession through all the changes that have followed, and has met no difficulties from government or people, not easily overcome by good judgment and sense, aided by a knowledge of the peculiarities of the country.

Now, since the railroads have come in, no one need feel afraid to come here and invest in mines, provided the ordinary precautions are taken, which cannot safely be omitted in the United States.

DISCUSSION.

C. KIRCHHOFF, JR., New York City: I understand from Mr. Chism's paper that it is an effort to estimate the possible profits of working the Vallecillo mines, when producing double the quantity of metal actually turned out now, based upon the extremely meagre data obtainable on the spot. Mr. Chism probably does not claim his figures to be anything but an approximation, and they should be criticised only with a full appreciation of their character as a tentative effort. Mr. Chism, however, makes an error in his computations, which is quite independent of the extremely crude manner in which, apparently, metallurgical accounts are kept in Vallecillo.

Mr. Chism estimates the price obtainable for lead at three cents. Since with the quotations of lead in the United States and in England, with the duty on lead in this country, and with the low freights on base bullion from cotton ports to England, the only market open to the Mexican lead is Great Britain, returns must be governed by quotations there. For the greater part of this year soft English pig has been quoted at £11, while soft Spanish has fluctuated between £10 10s. and £11 17s. 6*d.* Taking the highest figure, since the Vallecillo lead is one of the purest brands of bullion known to desilverizers, here or abroad, the lead is worth a little less than 2.4 cents per pound. This difference of 0.6 cent between Mr. Chism's estimate of 3 cents and the actual return of about 2.4 cents per pound would reduce the profits per day on a production of 13,125 pounds by $78.74 per day.

Mr. Chism intimates that he believes it possible that a profitable zinc industry could be established were the capita] forthcoming, with the large accumulations of blende at the mines as a basis. Mexico itself would not furnish a market for the product, and the duty on spelter would exclude it from this country. The English market alone would be left, where the Mexican metal would have to compete with Silesian *at £14* 15s. to *£15* per ton, or §3.25 United States currency *per* 100 pounds. With such questions as the supply of good fuel, of suitable refractory materials, of cheap transportation, and of skilled labor, unsolved (and not likely to be solved, in so remote a locality, except by the most exceptional coincidence of circumstances), the blende will remain a waste product, unless it can be exported as such. The highest price recently paid at Swansea ticketings was *£5 5s.* for a special lot of Minera blende, equivalent to §25 per ton, or about 1.1 cent per pound.

NOTES ON THE PATIO PROCESS.

BY C. A. STETEFBLDT, NEW YORK CITT.

THE *hacienda* Sauceda is one of the largest and finest *haciendas* in the vicinity of the City of Zacatecas, Mexico, and is said to reduce ores by the Patio process more cheaply than any other establishment. It receives its supply of ore from the San Acacio mine. This mine has been for some time, like most of the Zacatecas mines, out of bonanza, and yields, at present, ore of rather low grade. The silver occurs principally as silver-glance, ruby-silver and native silver, associated with pyrites of iron and copper, and some galena and zinc-blende, in a gangue of pure quartz, which takes the form of amythyst whenever the ore is of high grade. All the ore, as it comes from the mine, is broken by hand into small pieces, and sorted before it is delivered to the *hacienda.* Here it is first crushed dry in Chili mills, and then ground wet in arrastras to an impalpable powder. The sulphurets not decomposed in the patio process are separated in the settlers from the tailings and concentrated by hand. By roasting them in a reverberatory furnace with carbonate copper-ores, "magistral" is obtained. All machinery is driven by mule-power.

In the year 1883, the *hacienda* Sauceda reduced 17.726 tons of ore. The average value of the ore was 17.11 oz. silver per ton. Of this, 4.37 *oz.* or 25.5 per cent, were lost. The loss in quicksilver was 1 pound per 7.4 oz. silver extracted. The total expenses of reduction were $8.12, Mexican money, per ton of ore distributed as follows, viz.:

Pulverizing in Chili mills,	$1.03
Grinding in arrastras,	2.06
Salt, from 5 to 6 per cent.,	1.13
Magistral,	0.80
Quicksilver, 1.71 pounds,	0.96
Other items and general expenses,	2.14
Total	$8.12

In considering these results by themselves, as far as the percentage of silver extracted is concerned, one would get an entirely wrong view regarding the perfection of the patio process. It seems that the loss in silver is a more or less constant quantity per ton of ore; *i. e.* it is about the same for poor and for rich ores, whereby the percentage of silver extracted from the latter becomes remarkably high. The following statistics, taken from the books, will illustrate this.

Assay-value of ore. Oz. silver per ton.	Percentage of silver lost.
32.22	10.0 per cent.
.37.00	10.0 " "
42.60	6.1 " "
47.60	5.6 " "
99.60	7.0 " "

These figures are rather a disappointment to those who believe that they can improve the reduction of certain ores in Mexico by the introduction of modern methods. Of course there are many ores that will not yield a high percentage of silver in the patio process.

The same is to be said about the cost of reduction. Modern methods mean the replacing of mule-power by steam-power. In districts void of fuel, like Zacatecas, this is a serious question. So far, the Mexican Central R.R. has not established freight-rates sufficiently low to permit the importation of coal, and it would be a risky undertaking for any mining company to rely upon a temporary concession as long as there is no competition. On the other hand, the cost of the patio process depends largely upon the price of corn. When, in dry years, the crops fail, the price of corn may be four times as high as in normal years. The estimates above are based upon normal prices of corn.

PROGRESS OF THE MANUFACTURE OF SODA BY THE AMMONIA-SODA PROCESS.

BY OSWALD J. HEINRICH, DRIFTON, PA.

SINCE my communication to the Institute at the Baltimore meeting in 1879,* in which I took the lead in emphasizing the importance of a new method in the manufacture of soda, already practiced to some extent in England and on the Continent of Europe, five years have passed. I then referred particularly to the advantages offered in the United States for this peculiar method, by the ammonia process, namely :

1. At the present time, at least, we have but one mine in this country where rock-salt is mined, namely, at New Iberia, La. On the other hand, we have many localities where brine of various degrees of strength, up to that of cold saturation, is obtained in large quantities.

2. We have excellent fuel, in close proximity to most of the brine-centers.

3. Our supplies of pyrites, to use in the manufacture of sulphuric acid, for use in the manufacture of soda by the Leblanc process, are mostly too far from the brine-centers to permit competition in that line with the more favorable conditions existing in England,

4. Unlike our foreign rivals, we have no large and costly plants, erected on the Leblanc plan, which must be abandoned and exchanged for new but cheaper plants, before the ammonia-soda process can be adopted.

5. We have a constantly increasing demand for soda, which is almost entirely supplied by importation.

If slow progress has been made hitherto in this country in the extension of this manufacture (only one plant at Syracuse, erected under the Solvay patent, having as yet been placed in operation), I still feel gratified in saying that developments in England, and particularly on the Continent of Europe, give ample proof of the

* Transactions, vol. vii, p. 294.

correctness of my statements, as recorded in my former paper. At that time, as I then observed, the most adverse criticisms originated with English writers, though Professor Roscoe already admitted that there was doubtless a future for this process, under peculiar conditions. A rapid change has since taken place in that quarter. John Lomas, in his valuable book, *A Manual of the Alkali Trade* (London, 1880, p. 233), closes his remarks by saying, *"and yet, to sum up the whole, in all probability the ammonia-soda, will gradually supersede refined alkali. Its quality cannot be improved, but its cost will be somewhat lowered by the introduction of more perfect mechanical appliances. But soda-ash, crystals and caustic soda will hold their own against the new-comer."*

Agreeing fully with him in the first sentences quoted, I venture to say now, with regard to his latter remark, that the original product manufactured, *i.e.,* an almost chemically pure, anhydrous monocarbonate, is the best material for the manufacture of the bicarbonate. Soda-crystals, and a caustic soda of the greatest strength as well as purity, are thus manufactured from an article originally free from impurities.

Early in 1883, Walter Weldon, an acknowledged authority of the highest rank on questions of practical chemistry, the manufacture of alkalies and kindred branches, renders his opinion in a paper, read before the Society of Chemical Industry.*

"The manufacturers of soda by the Leblanc process have fallen upon evil times. For some time past, their profits have been steadily declining, until now they have disappeared and have been replaced, in many cases, by actual loss. Of twenty-five alkali-works, which were in operation in the neighborhood of Newcastle-on-Tyne, a very few years ago, twelve have been closed ; and of these, no fewer than eight actually dismantled, in despair of it ever again being possible to manufacture soda in them by the Leblanc process, except at a loss, etc.

"In Belgium, the production of Leblanc soda has died out, while in France, Germany and Austria it is only maintained by the aid of import duties and the large demand for the by-product, hydrochloric acid. This deplorable condition of the trade is mainly due to the great increase of the out-put of soda manufactured by the ammonia process, an increase which, though rapid in the past, bids fair to proceed by leaps and bounds in the immediate future."

My personal observations, in 1877, through the districts of the alkaline manufacture of England, and statements then made to me by one of the great industrial leaders of Newcastle, a man whose opinions command the respect of all that know him, confirmed

* *Engineering and Mining Journal,* vol. **xxxv., p. 118.**

already the above reports, my informant himself being one of those who had closed their Leblanc works. Being the owners of rich salt-deposits already developed by boring in Durham districts, his firm has now erected new works, to manufacture soda by the ammonia process.

To follow up this inquiry to the latest date, I refer again to Mr. Weldon. In his address as retiring president of the above society in 1884,* he comes to the following conclusion:

"The Leblanc process is not destined to remain the only means of obtaining hydrochloric acid. Modern industrial chemistry is revolutionizing the methods by which chlorine is obtained from hydrochloric acid, the raw material furnished by and now so vital to the future of the Leblanc process, etc. There seems, therefore, little doubt but that the old soda-process is doomed to a further restriction."

It being now the acknowledged fact, that the soda alone can be manufactured more cheaply by the ammonia process, and with less capital for investment, this restriction must be in favor of the ammonia-soda manufacture, because the soda so made is in general demand.

The annual production of soda throughout the world, during the last eight years, has been, according to Wagner's *Jahresbericht,* as shown below (calculated to Na_2CO_3, produced from common salt).

Name of State.	Production of soda from NaCl in met. tons.			Percentage of total product by ammonia process.
	Total product of State.	Product by Leblanc process.	Product by ammonia process.	
Great Britain, . . .	430,778	428,278	2,500	0.57
France, ...	107,944	107,944	......	
Germany, ...	43,177	43,177	......	
Austria, ...	24,588	24,588	......	
Belgium, ...	5,000	......	5,000	100.00
Total product in 1875, .	611,487	603,987	7,500	1.22
Great Britain, . . .	432,000	380,000	52,000	12.00
France, ...	127,125	70,000	57,125	44.90
Germany, ...	100,500	56,500	44,000	43.80
Austria, ...	40,000	39,000	1,000	2.50
Belgium, ...	8,000	......	8,000	100.00
United States, . . .	1,100	......	1,100	100.00
Total product in 1883, .	708,725	545,500	163,225	23.

* *Engineering and Mining Journal*, vol. xxxviii., p. 101.

This rapid increase must be credited to the enterprising firms of Brunner, Mond & Co., near Norwich, England, E. Solvay, at Couillet, Belgium and Varangeville, Dombasle, France, all working according to the Solvay plan. The first increased their production from 2500 tons in 1875, to 52,000 in 1883; the second, from 179 tons in 1867, to 4678 in 1875 and to 65,125 in 1883.

Such a rapid increase in the product of a single manufacture of twenty-fold, in the course of eight years, is sufficient proof of the advantages of the system, especially when at the same time the product by a former process has decreased during the same period ten per cent in countries where, as in Great Britain, both systems operate in the same neighborhood, while in other countries it has even been entirely obliterated.

About one-fifth of the soda produced in Great Britain is exported to the United States. The increase of importation to this country during the last eight years has been, according to the reports of the Bureau of Statistics in Washington (in tons of 2000 pounds), as shown below:

	Tons.	Value.
1875.		
Bicarbonate of soda,	3,404.841	$ 234,845
Carbonate (including soda ash),	97,875.159	3,860,119
Caustic soda,	19,289.590	1,445,734
Total for 1875,	120,569.590	5,540,698
1883.		
Bicarbonate of soda,	999.466	$ 49,632
Carbonate (including soda-ash),	173,627.010	4,221,899
Caustic soda,	28,865.984	1,255,213
Total for 1883,	203,492.460	5,526,744

If we now turn our attention to another vital objection formerly raised against the manufacture of soda by the ammonia process, namely, the consumption of ammonia and the loss of the chlorine, we shall be able to satisfy ourselves that in this respect progress has been made.

1. With regard to the loss of ammonia, and the fear of a deficiency of supply at reasonable prices to cover such loss, it may be said that if ammonia-soda-works are constructed after a rational plan, with the skill now applied to the making of machinery in a good machine-shop, no greater loss than 1 per cent of ammonia should occur. The loss can only happen by waste or leakage, the ammonia being the intermediate agent for conversion, and being regained from the mother-lye. Taking 3.8 pounds of sulphate of ammonia, at 3 cents per pound, to replace 1 pound of ammonia, the cost will be 8.2 cents or about $1.25 per ton of soda.

To produce the same amount of soda by the Leblanc plan would require 110 pounds of 48 per cent, pyrites at 40 cents per 100 ' pounds (including freight and wastage), or 44 cents per 100 pounds of anhydrous monocarbonate. Suppose 80 per cent of this is regained by working up the soda-waste, according to the very improved methods of Schaffner and Helbig, involving an expense of about 40 per cent of its value. The net result will be a loss of 19 cents; whereas the loss of ammonia for an equal final product made by the ammonia process amounts to only 6¼ cents, or about one-third as much. To recover in Leblanc works the sulphur of the pyrites requires an extensive additional plant, and according to some methods involved even a loss of chlorine.

During the last few years extensive experiments have been made, to furnish a new source of ammonia by utilizing the waste products from coke-ovens and iron-furnaces. These have already been crowned to some extent with success. Large coke-producers have erected plants to collect the ammonia at remunerative prices. Considering the very large amount of coke produced, it is evident that no fear need be entertained but that a constant supply of ammonia can be secured at reasonable rates from the above source. Ammonia-soda-works, which may be so favorably situated as to have their coal supplies near at hand (and such places are fortunately found, particularly in the United States, in close proximity to salt-brine), may even find it advantageous to produce their own ammonia and supply the waste at minimum cost.

2. With regard to the obvious defect in the ammonia-soda manufacture, that it does not utilize the chlorine contained in the brine, we have, at least, this consolation, that experiments, even upon a large scale, have proved that the chlorine may be saved, though it has not yet been done with commercial profit. Seeing such able men in the line of industrial chemistry as Weldon, Gossage, Solvay, Honigmann, Hasenclever, Lunge and others persistently following up this important subject, we may confidently expect an eventual success.

Meanwhile, new subordinate applications for calcium-chloride may come into use, when it can be obtained cheaply. Only lately such has been the case in Italy, where it is now used profitably to extract sulphur, almost pure, and at reduced cost as compared with former methods. The price paid for the calcium-chloride is said to be 9 francs per 100 kilogrammes, or nearly $20 per ton—a very handsome price for a waste-product. When magnesite can be obtained at reasonable prices and cheap fuel is commanded also, a large portion of the chlorine may be obtained and converted into hydrochloric acid. By means of a double reaction, this may also be accomplished if a pure dolomite can be used instead of common limestone.

While it must be confessed that this problem is not yet sufficiently solved, still so able an authority as Professor G. Lunge, admits the possibility of its solution, although, so far, it has not been done with commercial profit. In this respect, local advantages will have some influence, particularly as to the cost of raw materials. But we must not lose sight of the important fact that the source of chlorine, from common salt, natural brines and sea-water, is inexhaustible; and, therefore, its loss is certainly less deplorable than that of sulphur, the sources of which are far more limited. Beside this, the waste calcium-chloride is not obnoxious and detrimental to a neighborhood as soda-waste unquestionably is.

While we are indebted to E. Solvay for having opened the path to success (the enormous increase of his personal manufacture in Europe, amounting to 179 tons in 1866, but 53,400 tons in 1882, being ample proof), other able practical chemists have entered the field also, so that we have now a variety of apparatus, described in foreign journals, as used in Europe to accomplish the same object. It is due to M. Solvay that the first manufacture of this kind has finally been erected in the United States, at Syracuse, N. Y. A man of means himself, he offers sufficient encouragement for other capitalists to invest in this new enterprise, when he ventures to risk his capital in this country, as he had done already in Belgium, France and Germany.

To make clear the peculiar advantages due to this process, I give in Figs. 1 and 2 a sketch of works designed to use the apparatus of M. Gerstenhoefer, patented in the United States, May 3d, 1881.

Fig. 1 represents the ground-plan, its exterior dimensions being 248 by 50 feet, including a mill and packing-room at the lower end, not represented in the figure. Fig. 2 is a longitudinal section. The design represents one "block," which is the smallest works which can be put up to make the manufacture profitable. For larger works, the blocks are grouped together, and by the centralization of the work expenditures in erection and general management will be reduced. One block is capable of producing 8¼ tons in 24 hours.

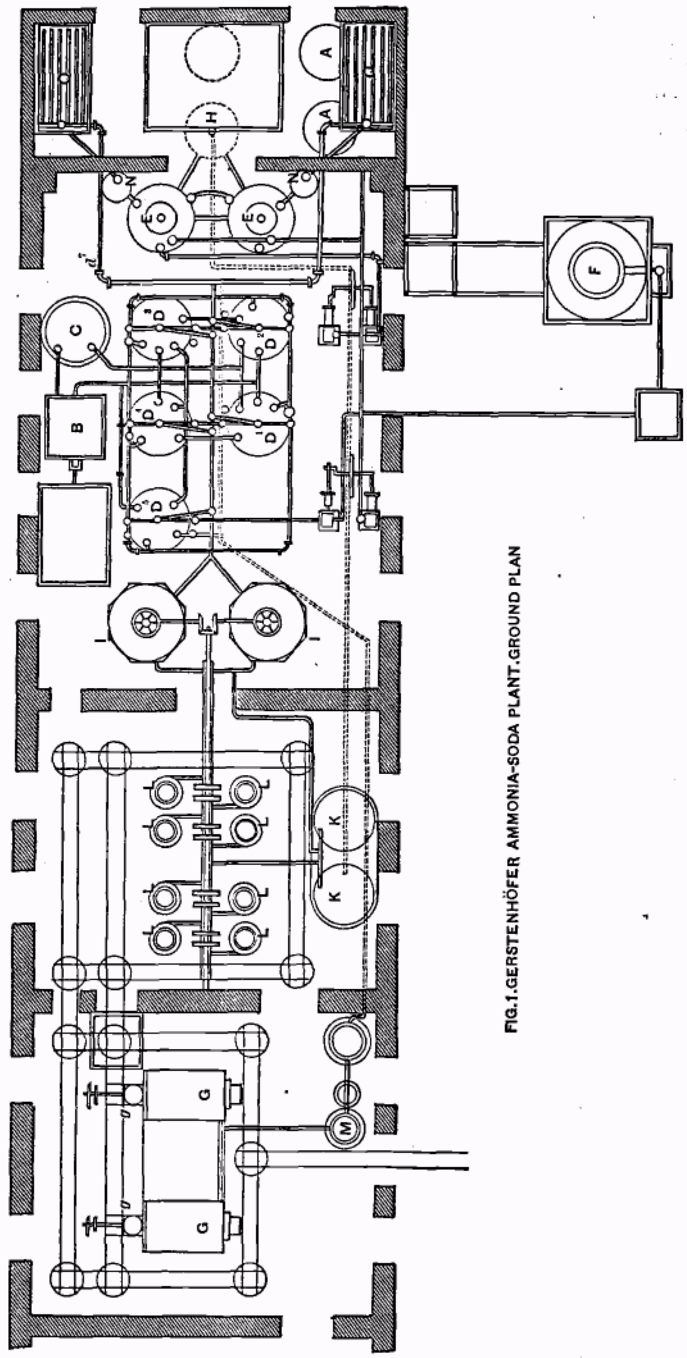


FIG. 1. GERSTENHÖFER AMMONIA-SODA PLANT. GROUND PLAN

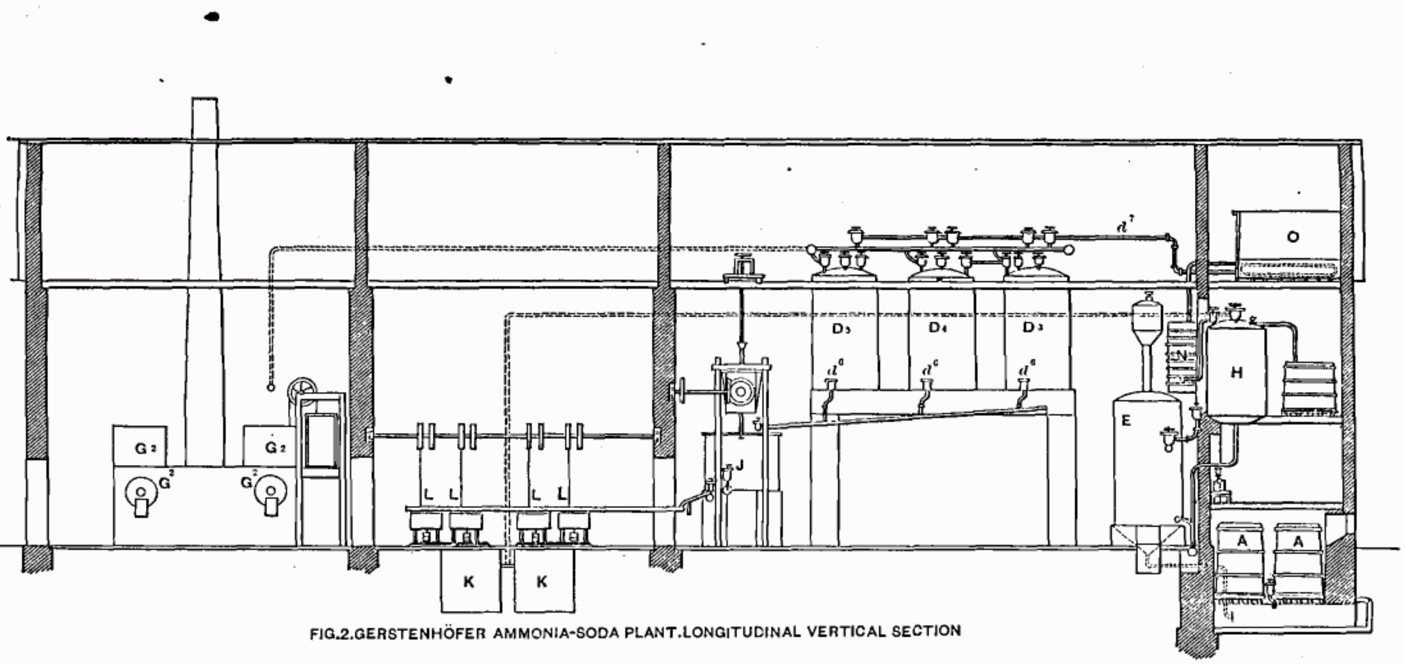


FIG.2.GERSTENHÖFER AMMONIA-SODA PLANT.LONGITUDINAL VERTICAL SECTION

A block consists of 5 separate departments. In the first, we find the brine-tank A, from which the purified brine is forced over to a coke-tower B, supplied with a shower-apparatus. The wasted ammonia gas, if any should leave the next apparatus, passing upwards in this tower, is absorbed entirely by the descending brine. The latter is collected in a reservoir C, and pumped into the universal apparatus D for conversion into bicarbonate of soda. Five of them are used in rotation as described below. Each consists of an air-tight cylindrical sheet-iron vessel D. It is supplied with a three-way pipe, the top branch of which passes through the center to the bottom of the cylinder and connects there with a wider cylinder. The latter is supplied with a large number of perforated pipes for the distribution of the gases.

These converters D_r, D_2, etc., as well as the ammonia-stills E and agitators I, are all placed in the second or converter-department.

The apparatus $D_{l,t}$ D_2, etc., operates in successive periods, thus:

1. Cylinder D_B being charged with brine, receives ammonia gas and sufficient carbonic acid gas to form monocarbonate of ammonia. Cylinders D_2 and D_3 meanwhile act as absorbers of waste gases, being also charged with brine, which has already taken up some of the waste gases. D_4 contains fresh brine.

2. D1 receives now the remaining carbonic acid gas necessary to produce bicarbonate of ammonia, and, by reaction upon the brine, bicarbonate of soda and chloride of ammonia. Meanwhile, D_2 receives ammonia gas, and D_s and D_4 act as absorbers.

3. The first cylinder D, is emptied and cleaned out by means of a steam-pipe, while the reaction and absorption take place in the succeeding apparatus.

4. D_3 receives its balance of carbonic acid gas, while D, is charged again with fresh brine, ending the rotation of the apparatus.

From the converters, the contents are discharged by a line of pipes into the agitators I, of a peculiar construction and closed air-tight. Their purpose is to incorporate the materials still further. Each converter can be brought into communication independently with the brine-pump, the ammonia-still, the lime-kiln F, the calcining apparatus G, or the agitator I. From the agitator the product is transported to the centrifugal machines L, in the third or separating department. Here, by means of centrifugal force, the chloride of ammonia liquor is separated from the precipitated bicarbonate of soda, to a maximum degree. The liquor is collected in closed tanks and forced through a line of pipes to the primary heater H in which bicarbonate of ammonia, to some extent mixed with the chloride, is first expelled. Now, the chloride of ammonia in the still E is converted, by means of caustic lime, into ammonia gas, which is rectified and dephlegmated in suitable apparatus, N and O, whence the ammonia gas reenters the converters D,, etc., to be used again.

The contents of the centrifugal machines are transported to the calcining cylinders G, in the fourth department. They are supplied with proper stirring and transporting tools, attached to a rotary shaft. The cylinders being heated, the small amount of ammonia chloride and half of the carbonic acid is expelled, to enter always the first of the converters in the respective circuit, while anhydrous monocarbonate of 99 per cent, purity remains in the calcining cylinder.

This is transported into a fifth department, the mill-room, and received by the soda-mill, pulverized and packed into barrels ready for shipment.

All vessels and connections being air-tight, so far as a good manufacturer can effect it, the loss of ammonia is prevented. By means of splitting the operation, and first producing monocarbonate of ammonia, the evolution of heat is reduced, the temperature in the converters being further decreased to its minimum by means of refrigerating coils placed within them.

All transportation of brine and gases being effected by pumps or compressor, the chemical reactions are controlled as near as it can be done within the converters. The brine entering the first department will leave the last, six hours afterwards, in the form of anhydrous monocarbonate, ready for packing and almost chemically pure.

To persons familiar with the manufacture of soda by the Leblanc process, it must be evident that the ammonia-soda process requires less manual labor, and that of a less skillful nature, while, at the same time, the raw material, brine, is converted into a marketable product in a minimum period of time.

To compare the financial results of both manufactures, for a like investment of capital, the following estimates are offered, assuming the same locality for the erection of both. The estimates have been worked out in detail, but, for the sake of brevity, only final statements are given.

The Leblanc plant being complicated in its nature, and by its variety of products accommodating itself to the immediate wants of the market to some extent, it is difficult to make a definite calculation as to how this process will be operated, because it may sometimes be of advantage in practice, to force one department according to the temporary demand. As far as possible, impartial statements of average conditions have been aimed at in the following estimates.

The, Leblanc Plant.—Designed to consist of:

One sulphuric-acid works, chamber-capacity 160,000 cubic feet, capable of producing 16,500 pounds sulphuric acid 66° B., with furnaces, condensers and pans, all complete.

Three salt-cake furnaces, 3 tons capacity each, capable of producing 9 tons of dry sulphate, including all apparatus to make hydrochloric acid, to be used for the manufacture of bleaching-powder.

Two soda-furnaces, 4 tons capacity each, heated by regenerators to produce soda-ash.

Six boiling-pans, 6 soda-kettles and 4 lixiviation-tanks for the production of caustic soda.

Two calcining-furnaces, 3 lixiviation-pans, settlers, crystallizing-tanks and all apparatus for making calcined soda and soda-crystals.

Ten stills and converting chambers, for making bleaching powder.

The total, including all buildings, machinery, engines, boilers, furnaces, tracks, pumps, compressors and all other fixtures to manufacture soda by the Leblanc method, all put up in a good and substantial manner, including cooper-shop and other shops for maintaining the works costing the sum of §300,000, exclusive of 5 acres ground necessary for plant and storage-room.

The daily consumption of raw materials for such works would be:

2.8	tons, brimstone	@	$25	$ 70.00
0.2C6	" Chili saltpetre,	@	44	11.70
3.7	" salt	@	3.70	28.67
2.44	" manganese	@	22	53.68
14.5	" limestone	@	1.50	21.75
42.	" coal	@	1.00	42.CO
	Total for materials per day,			$227.80

For labor and other expenditures I estimate:

Labor in total for all work,	$104.	
Repairs,	50.	
Salaries and general management,	32.	
Casks, carboys and incidental expenditures,	60.	
Total for labor, etc., per day,	$246.	246.00
		$473.80
Regained by regeneration of sulphur,	$32.80	
Regained by manganese,	22.00	54.80
After deducting the cost of regeneration,		----------
Total cost of manufacturing products per day,		$419.00

We assume the work to produce

Surplus sulphuric acid of 66° B.	3382lb	at $1.15 per 100lb, .	$ 38.85
Soda-ash of 48 per cent.,	6000 "	" 1.45 " " " .	87.00
Caustic soda at 70 per cent.,	5000 "	" 3.50 " " " .	175 00
Soda-crystals,	3000 "	" 1.15 " " " .	34.50
Bleaching powder,	6300 "	" 1.90 " " " .	119.70
Value of products per day at present prices, . . .			$455.05
Deduct cost of manufacture, ...			419.00
Profit per day, ...			$ 36.05

For 300.working days per annum this small profit would only pay 3.6 per cent. interest, and leave no surplus for redeeming the invested capital or renewing the plant.

Ammonia-soda plant.—We propose here a four-block work on the plan formerly described, capable of producing 33 tons (2000 lbs.) of anhydrous monocarbonate of soda of 99 per cent. purity. The erection of such a work shall also cost §300,000, exclusive of the site, which would require about 2½ acres.

The daily consumption of materials will be:

60 tons of salt (as concentrated brine) at $3.50, . . .		$210.00
34 " " limestone at $1.50, ...		51.00
41 " " coal at $1.00, ...		41.00
0.688 " sulphate of ammonia at $60, ...		41.28
Total for materials per day, ...		$343.28
Labor per day, ...	$247.00	
Salaries and general management, . . .	32.00	
Repairs, incidental expenses, ...	22.00	
520 barrels for packing soda at 30 cts., . .	156.00	
Total for labor, etc., per day, . .	$457.00	$457.00
Total cost of manufacture per day, ...		$800.28
Add 10 per cent. for refunding capital in 10 years and 6 per cent. interest, ...		160.00
Total cost per day, ...		$960.28

The product of this work will be per day:

33 tons anhydrous monocarbonate of soda at $30, . .	$990.00
23 tons of salt regained in the process at $3 profit, . .	69.00
140 lbs. bromine at 20 cts., ...	28.00
34 tons of calcium chloride at $2, ...	68.80
Total daily product, ...	$1155.80
Deduct daily cost including interest and amortization,	960.28
Total daily profit, ...	$195.52

Even if the calcium chloride is altogether disregarded, a net profit of $126.72 is still available. Of this, a proper percentage will be required as royalty for the use of the patent. The above sum yielding a profit of nearly 13 per cent. for dividends, a reasonable royalty can still be afforded, after allowing fully for the redemption of capital and for interest.

This comparison confirms statements so often heard of the deplorable conditions under which the Leblanc process now suffers. Only old works, which have redeemed their capital in former years, may yet weather the rough sea beating against it. New works upon that plan could not prosper, at least in this country, where the cost of the erection of a Leblanc plant is so much higher than in Europe, and where capital demands greater profits. If we desire to manufacture our own soda from salt, we are forced to adopt the ammonia process.

In regard to localities in the United States, we find rock-salt in the States of New York, Virginia, Louisiana, Texas, Nevada and Oregon; strong brine in New York, Virginia and Michigan; weaker brines in the central basin of the United States, Ohio, West Virginia, Kentucky, Pennsylvania, Mississippi, Missouri, Illinois, Indiana, Kansas and Arkansas. It is particularly those weaker brines, in the central basin, with cheap fuel close at hand, which would furnish a favorable opportunity for the ammonia-soda process, where the Leblanc process would find it difficult to meet the higher price of solid salt, indispensable for the latter, while the former can use concentrated brine directly.

A few words may be appropriately said in conclusion to refute the assertion of Mr. Lomas, that monocarbonate of soda, produced by the ammonia process, can not hold its own against crystals and caustic soda produced by the Leblanc plan.

The bicarbonate of soda which leaves the centrifugal machines is not quite free from ammonium-chloride. It is therefore necessary to recarbonate the pure anhydrous monocarbonate. To do so it requires a peculiar treatment, previous to carbonization, which will add no serious expense to the manufacture. It then can be crystallized to produce a perfectly pure bicarbonate.

The same may be said of the caustic soda. It is true that the lye of the bicarbonate produced in the ammonia process cannot be used directly. But the monocarbonate produced can be reduced to caustic soda as well as pure crystallized carbonate of soda produced by the Leblanc process, and used for the production of the purer caustic soda. The raw material used from the ammonia process is not only produced cheaper, but it also furnishes caustic soda of the highest grades and purity, such as is particularly sought for in the manufacture of anilin colors and the finer articles of toilette soap, and this can be manufactured at prices capable of competing with other caustics in the market.

THE SEPARATION OF STRATA IN FOLDING.

BY FRED. *G.* BULKLEY, LEADVILLE, COLORADO.

THAT portion of the geological structure of the Leadville district which rests upon the Archæan is made up of sedimentary beds of Silurian and Carboniferous formation, consisting of many conformable strata of limestones, quartzites, and shales, which have a total present thickness of about five thousand feet. Interbedded with these strata are found, under somewhat fixed laws of regularity, sheets of intrusive igneous rock, varying in thickness from a foot or two to several hundred feet. These consist for the most part of various types of felsite rocks, classed, by the sanction of common and long-continued usage, under the general term of porphyries. Mr. S. F. Emmons, in the abstract of his "Report upon the Geology and Mining Industry of Leadville," says in this connection:

"In their mode of occurrence the type-feature is that of intrusive masses, which are developed on a scale of unprecedented magnitude, and follow certain horizons with remarkable regularity. . . . It is probable that this mode of occurrence of eruptive rocks, viz., as intrusive masses which originally did not reach the surface but were forced up to a certain horizon and then spread out between the beds, is far more common than has hitherto been suspected by geologists. It is difficult to conceive of the conditions under which a fused mass could pry open strata to a width of one thousand feet or more, overcoming the weight of ten thousand feet of superincumbent rocks, and spread itself out in a continuous sheet between the beds to a distance of ten miles beyond the point or line of eruption. That they did exist, however, can be clearly demonstrated in this region. . . . In one single section over fifteen sheets, many several hundred feet thick, were counted between the Blue Limestone and the top of the Carboniferous."

The region here under discussion is made up of a series of great geological folds, the result of dynamic force applied "tangentially to the surface of the earth and in a direction at right angles with the axes of folding," as explained by the generally accepted theory of contraction advanced by Descartes, De la Beche, and others, and discussed by more recent writers on geology.

In a study of this feature of the formation, together with the fact that the intrusive igneous sheets are found *interbedded* with the pre-existent stratified rocks, may be found the material for a theory which will perhaps explain the conditions under which the fused stream of porphyry might have found its place, without discussing the possibility of an upward pressure in the mass itself, sufficiently great to pry open or lift the weight of the superincumbent beds. A formulation of this theory is:

The result of the application of tangential pressure upon rock-beds mill be not only a folding or plication of the beds, but also a tendency to separation in places of the strata composing them.

This may be nicely illustrated by the experiment of pressing together longitudinally one hundred pages of any volume, or as many sheets of paper laid flatly one upon another. In geological folding the principle remains the same, and its application is attended by a like result. In the latter case, however, gravity becomes an important factor.

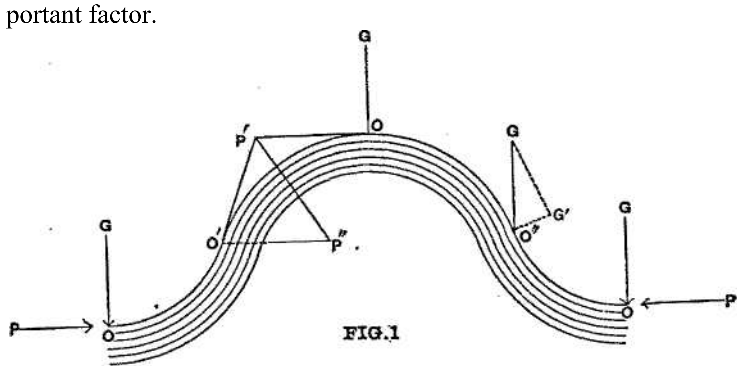


FIG.1

In Fig. 1 an ideal anticlinal fold is represented, produced by the horizontal pressure P P, which force is exerted longitudinally throughout the anticlinal, and its direction is everywhere tangent to the curve of the fold. Thus the resultant P' P" of this force, as applied at O and O', shows an uplift equally applied to all the strata, which is cousequently exerted with increasing effect upon the uppermost sheets, thus causing a tendency to separation of the strata, The force of gravity is represented by G O, G O"; and it is evident that at the summit and at the foot of the anticlinal, as at O O, this *whole* force is exerted in a direction at right angles with the bedding-planes of the structure, its whole effect being exerted to prevent a separation of the strata, while at other points, as midway between the foot and summit, at O", the force thus exerted is much less. A mathematical analysis of the force of gravity at this point shows that *the force exerted at right angles to the planes of stratification is directly proportional to the cosine of the angle of dip,* and is represented by G' O". This, of course, remains true for all points between the foot and summit of the fold. Thus the weight of a thickness of ten thousand feet of sedimentary rock may be estimated at about 875 tons per square foot, which pressure will be exerted at the summit and foot of the anticlinal to prevent a separation of the strata, while if the angle of dip at O" be 60°, the force thus exerted at that point will be but 437.5 tons, so that at the point or line of greatest dip will be the greatest separation of the strata. As a result there will be created fissures or cavities, widest at the point of greatest dip and thinning gradually towards the foot and summit, whose extent, ver-

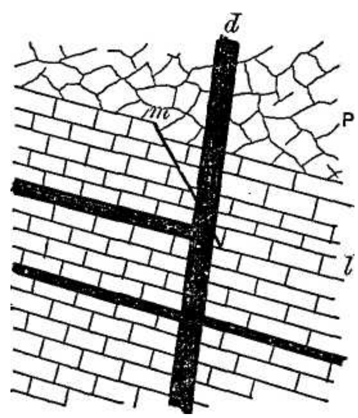


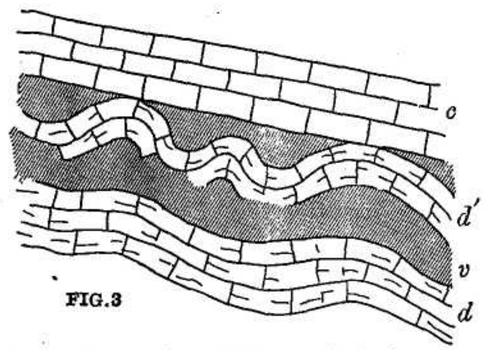
FIG.2
P, White porphyry; *d,* Dyke; *I,* Limestone; m, Fault.

tically and laterally, will depend upon the extent of the folding and upon the thickness of the superposed beds. That the eruption of porphyry at Leadville occurred contemporaneously with and incidental upon the folding is altogether possible (such a theory being borne out by the absence of intrusive sheets in untilted strata); and in the presence of such pre-existent fissures it would naturally fill the latter with its fused mass, and probably, to a great extent, enlarge them, as any upward pressure in the mass itself would most avail where the pressure of gravity is least. This theory gains strength from some corroborative facts revealed by an examination of certain beds of limestone in this region which have been greatly involved in the general folding. In one locality a dyke of gray porphyry, having a thickness of about ten feet, cuts up nearly vertically through lime-strata into an overlying sheet of older white porphyry. Near the point where the dyke passes up through the plane of contact of the two rocks a fault of about ten feet in the lime strata is observed, which extends neither up into the porphyry nor for any considerable depth into the limestone below, where occur several bedded sheets of gray porphyry from one to five feet thick and of considerable lateral extent, injected from and forming a part of the mass of the dyke as shown in Fig. 2.

That the intrusion of the dyke material could have occurred under a sufficient pressure in the mass itself to render possible the creation of the crevices containing these thin lateral sheets is rendered altogether improbable from a consideration of the small size of the dyke; and that the slight local fault existed before its intrusion is proven by the fact that the flow of the older white porphyry conforms precisely with the faulted surface. These crevices must then have existed previous to the dyke, and were naturally filled at the time of its injection. In another locality, on the slope of an anticlinal, successive crevices in limestone exist, from one to six feet thick, lying parallel with the bedding-planes, and filled with ochreous clay and limonite, carried in by and deposited from percolating waters. Here no connection exists with the vent or place of eruption of any igneous rock.

There exists but little room for doubt that the origin of the enclosing crevice of many metalliferous *bed-veins,* properly so called (in contradistinction from those *ore-beds* contemporaneous in their epoch with and forming an integral part of the enclosing rocks), may be referred to a separation of the strata in anticlinal folding.

The Spar lode of Pitkin County, Colorado, is a bed-vein occurring at the plane of contact between a bed of calcite (CaO, CO_2 95 per cent.) above and a bed of dolomite (CaO, CO_2 50 per cent., MgO, CO_2 35 per cent.) below. Here, also, the formation consists of conformable sedimentary beds of the lower Silurian, lower, middle, and upper Carboniferous, and Cretaceous epochs, with interbedded, intrusive igneous sheets; and the vein in question is situated upon the westerly slope of a great anticlinal. It varies in thickness from four to twelve feet, and evidence that it forms the filling of a pre-existent crevice is found in the conditions illustrated by Fig. 3, viz., that, where they are not disintegrated, the uppermost strata of the dolomite are found contorted and folded in short, deep flexures, in local unconformity *(d')*, which could only have occurred within the space of a pre-existent fissure or crevice. The Monarch vein, of Chaffee



c, Calcite; *d*, *d'*, Dolomite; *v*, Vein-material foreign to the walls.

County, and the Combined Discovery vein, of Eagle County, Colorado, present examples of similarly folds. In each of these cases, parts of the crevice remain entirely empty of vein material or other matter, while in the latter instance, a band of aragonite, now about eight inches thick, it still in process of formation upon the hanging wall.

GEOLOGY AND MINERAL RESOURCES OF THE BIO GRANDE REGION IN TEXAS AND COAHUILA.

BY E. J. SCHMITZ, NEW YORK CITY.

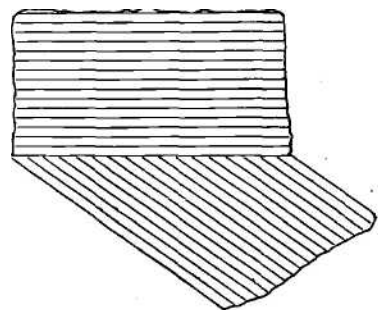
COMING from San Antonio, Texas, and following the Galveston, Harrisburg and San Antonio Railroad westwards, one enters soon the Cretaceous formation, which forms a belt of several hundred miles, extending westwards to the boundary of Arizona and across the Rio Grande into the State of Coahuila, Mexico. The members of this formation are very numerous and in petrographical character very diverse—from a whitish or bluish, slaty, impure limestone to a hard, beautiful blue-and-red striped, and a compact heavy-bedded, yellow-gray calcareous sandstone; from yellow and brownish-yellow calcareous soapstones or marlstones to crystalline limestones full of fossils; from argillaceous to calcareous dolomitic and bituminous marls, slates and bituminous slates, shales and whitish, yellow, blue, and dark sandstones. In regard to the superposition of these members and their classification in groups, it would be very difficult to give a correct opinion, after a short and hasty examination ; but I may name with some certainty the heavy-bedded yellow-gray calcareous sandstones as representing the oldest of the observed Cretaceous strata, while the yellow and brownish-yellow marlstones, the crystalline limestone, the blue and red striped siliceous limestone or calcareous sandstone, and certain dolomitic and bituminous marls belong to the middle Cretaceous. The thickness of these rocks is, in the east part of this formation, about 2000 feet; but further west it is greater.

While the country west of San Antonio is mostly level or slightly hilly and has an elevation of from 400 to 900 feet above the sea, we reach west of Del Rio and Devil's River (stations on the G. H. & S. A. extension) the slope of the Big mountain plateau, which extends in a south-southeast direction through New Mexico, Western Texas and Mexico, the continuation of the Rocky Mountains. A few knobs or mountains are known east of Del Rio. They are of eruptive or volcanic origin, as demonstrated by the basaltic *debris* along their edges.

Mounting the plateau and following the railroad, which runs for about 50 miles alongside of the Rio Grande, we find the elevation increasing by degrees to 3000 and 4000 feet, until we reach the highest point along the road, in Presidio county, 4800 feet above the sea. The rocks of the country have been flat or slightly inclined all the way up to the plateau, and the first disturbance is noticed west of Maxon Springs station, where a yellow-brown, hard sandstone comes up to the surface, bearing a number of coal-seams. This sandstone resembles very much the sandstones found in the Sabinas coal-field, Coahuila, Mexico, of which I shall speak further on. Whether this sandstone is true Cretaceous or not, could not be ascertained either here or in the Sabinas field, since no fossils have been procured; but it may be that it is in both places older than that.

Near Maxon Springs and north of the railroad, one can observe a peculiar profile of the rocks (Fig. 1), highly inclined sandstones and shales being covered by horizontal calcareous rocks, doubtless of Cretaceous age. This profile demonstrates that the country must have been under sea-level after the tilting of the strata mentioned. It is very probable that the elevation of the whole plateau took

FIG. 1.



place in the time defined by the deposition of these sandstones and of the calcareous rocks.

From Maxon Springs westwards to the next station, one can observe these sandstones in less inclined position, or even level while they can also be seen occasionally cropping out between the stations of Marathon and Strobel. Here we enter the southern portion of the Apache Mountains, which has (with the whole plateau) a south-southeast course. Some fair samples of anthracite, reported to come from near the Rio Grande and east of this mountain range, were shown to me at the last station.

The rocks of this range, which is composed of a number of distinct mountains and knobs, are principally sandstones, etc., of Triassic and Jurassic age, and crystalline and eruptive rocks. The occurrences of coal on the plateau, east and west of the Apache Mountains, or in those mountains, are quite numerous; and the character of the coal varies from a lignite to anthracite. Besides the above-mentioned localities, where the existence of coal-beds has been noticed, I may mention the Los Chisos mountains, a district about 60 miles south of Marathon station (these mountains, together with the Sierra de Santiago and Los Corazones, form the extreme southern part of the Apache Mountains); also the coal at Van Horn's Well, north of the G. H. & S. A. R.R., and the Eagle Mountains coal field—the Eagle Mountains being located in El Paso county and the other localities named in Presidio county.

All these coal-occurrences on the high plateau in Presidio and El

Paso county, Texas, and certain others east of the plateau-land in Texas and Coahuila, Mexico—to be mentioned below—represent, apparently, two separate horizons of beds. The upper horizon belongs to the middle and upper Cretaceous, while the lower horizon is older, and is characterized by the yellow-brown, hard sandstones referred to above.

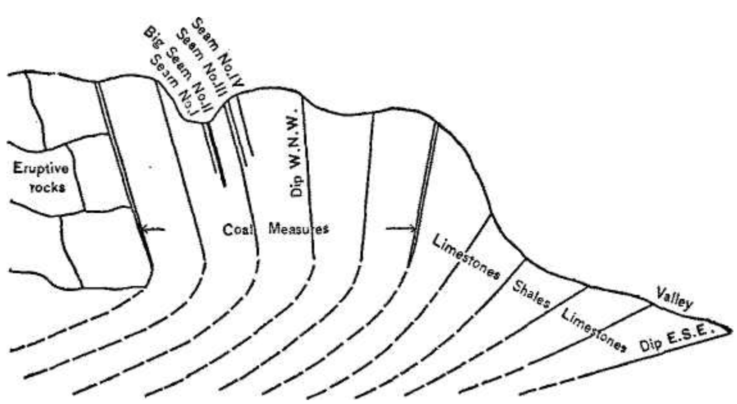
In the present paper I shall treat of such coal-fields only as I have had opportunity to examine with some thoroughness, taking two coal-fields, that of the Eagle Mountains in El Paso county, Texas, and that of the Sabinas in Coahuila, Mexico, as representatives of the lower horizon, and the coal-field near Eagle Pass, Texas, and Piedras Negras, Coahuila, as representative of the upper one.

THE COAL-MEASURES OF THE EAGLE MOUNTAINS.

The Eagle Mines, located on the Eagle Mountains, are about 4½ miles south of Torbet's Station on the G. H. & S. A. extension. The strata at the foot of the mountains dip about 10° east-south-east. Towards the mountains, the dip increases more and more, becomes vertical, and, at the point where the coal-measures come in, inclines towards the west-northwest, as shown in Fig. 2. Near the

FIG. 2.

APPROXIMATE PROFILE OF THE EAGLE MOUNTAINS FROM S.E TO N.W.



mines the strike is from northeast to southwest, and the dip from 55° to 80°.

The coal-bearing rocks, roughly estimated, are about 3000 feet thick, and could be observed for about 1 to 1½ miles in length. The relations of the different coal-outcrops, from the sandstones and shales geologically downwards, are as follows:

1. Outcrops, No. I.	=	Thickness not known.
2. Measures	=	40 feet.
3. Big seam, No. II.	=	From 20 inches to 7 feet (average 3½ feet).
4. Measures	=	About 400 feet.
5. Outcrops, No. III.	=	Thickness not known.
6. Measures	=	100 feet.
7. Outcrops, No. IV.	=	Thickness not known
Measures.		

Of the four veins above mentioned, only No. II. has been developed--namely, by a shaft to the depth of 230 feet. The dip of the vein in the mine ranges from 60° to 80°. In the upper part of the shaft (which could be examined to a depth of 130 feet) the vein shows from 3 to 5 feet of coal and is said to thin out, in some places below, to but 20 inches of coal. The lower 100 feet of the mine was filled with water at the time of my visit, as it had not been worked for about a year. The coal of No. II. is a bituminous coal of fair quality and excellent for cooking purposes. It has a conchoidal fracture. Samples of coal taken about 70 feet below the mouth of the shaft gave the following analysis:

Moisture,	3.537
Volatile combustible matter,	30.843
Fixed carbon,	50.694
Ash,	14.926
	100.000

The coals of the other outcrops are similar to those of No. II.

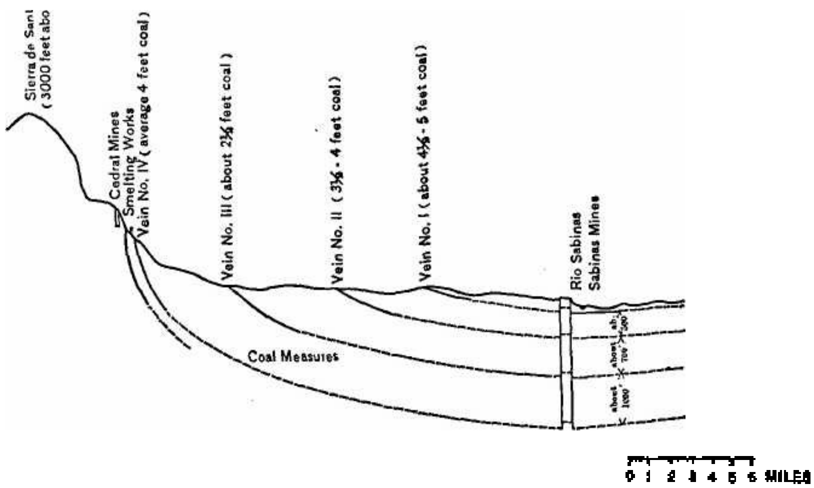
The limestones which underlie the coal-bearing rocks of the Eagle Mountains resemble in petrographical character one of the two limestone groups which form the bulk of the mountain range of the Sierra de Santa Rosa near the towns Santa Rosa and Monclova in Coahuila, Mexico. The limestone group to which I refer is a drab-blue limestone, the strata being irregular in thickness and thinly bedded. It breaks with conchoidal fracture and sharp edges and is exposed at the Eagle Mountains in a thickness of about 2000 feet. Not having succeeded in procuring any fossils from this limestone at the Eagle Mountains, I can only say that the corresponding limestone in the Santa Rosa district is classed as subearboniferous.

The only well-preserved fossil of this limestone was obtained by the writer at the Cerro Mercado (a branch of the Santa Rosa Mount-ain range) near Monclova. This fossil seems to belong to the Blastoideæ and to be identical with the Pentremites.

THE SABINAS COAL-FIELD.

The Sabinas coal-field, which derives its name from the Rio Sabinas, is situated in the state of Coahuila, Mexico. Its area is approximately 2400 square miles, being 40 miles wide and 60 miles long. In width it extends about 30 miles south from the river along the Sierra de Santa Rosa, and about 10 miles north from the river, and in length for about 40 miles west and 20 miles east of the line of the Mexican International Railroad. The position of the strata of coal-field is shown in Fig 3, which gives a profile from

FIG.3. APPROXIMATE PROFILE OF THE SABINAS COALFIELD FROM S.W.TO N.E.



southwest to northeast. It will be seen that the strata on the northern side of the Sabinas river are nearly horizontal, having a slight dip of 2° to 4° towards the south and southwest. On the southern side of the river the strata are also nearly horizontal for about 8 miles or more, with a slight dip towards the north, that is, towards the river. This gives us a basin, the synclinal axis of which is followed more or less nearly by the river. Further south, and everywhere southwest towards the Sierra de Santa Rosa, one can observe the strata of the field more and more inclined towards the river from 15° to 30°, until the lowest strata come up vertical on the lower terrace of the Sierra de Santa Rosa, near the town of that name.

There exist in the coal-measures of the Sabinas field a number of faults, consisting in vertical dislocations of the measures, and forming generally narrow plateaus or mesas, which are elevated from 50 to 100 feet above the plain. One of these is indicated to the left of the Sabinas in Fig. 3. The *debris* covering the breaks of the *mesas* is basalt or more or less altered sandstones of the measures. Such faults or *mesas* can be seen south of the Sabinas river on both sides of the Mexican International Railroad following the river westwards for over 10 miles nearly to Sau Juan Sabinas, and from there turning off in a still more western course towards the Sierra de Santa Rosa. In the southeastern portion of the field, south of the river and east of the railroad, such a *mesa* runs for more than 20 miles parallel with the line of the railroad, and follows the river for over 10 miles eastwards, thus rendering the greater portion of this part of the field one large plateau. Besides these vertical dislocations of the measures, there are several eruptive knobs and mountains to be noticed in the southeastern portion of the field, which are several hundred feet high, and which dislocate the strata.

The rocks of the Sabinas field consist of sandstones and shales. The sandstones are generally pretty hard to very hard, and both heavy- and thin-bedded, and have mostly the characteristic yellow-brown color already mentioned. The surface of the thin layers has often a rippled appearance. The shales are grey and yellowish-white, and show sometimes a thickness of fifty feet. The surface of the field is in many places covered with a thick-bedded conglomerate, consisting mostly of hard limestone and dolomite fragments, of the size and shape of goose eggs, cemented together with a whitish and reddish calcareous matter. Such drift-conglomerate covers the greater portion of the northern field, north of the Sabinas, and it is also noticed to overlie the vertical measures on the first terrace of the Sierra Santa Rosa, near the Cedral mines.

General Profile of the Salinas Coal-field.

This is shown in Fig. 3, and is, in greater detail, as follows:

Whitish, compact limestone of great thickness, forming the Sierra de Santa Rosa, near Cedral mines.

		Thickness in feet.
Exposed near the Cedral mines on the first terrace of the mountain.	Thin bedded bluish limestones and shales, about,	400 to 500
	Sandstone and shales (estimated),	250
	Coal,	0.25
	Interval,	3
	Coal-seam, workable vein No. IV. (two-tenths feet thick), average,	4
	Interval,	5
	Coal,	1
	Clay and clay slate,	35
	Limestone,	5
	Shale,	15
	Sandstone,	2
	Clay and chert,	5
	Sandstone,	3
	Clay slate and black slate,	5
	Sandstone, etc. (estimated),	100
	Interval (estimated) reported to contain one seam of coal,	1000 (or more)
	Coal-seam, workable vein No. III., exposed at the Alomas Cr.,	2.5
	Interval (estimated),	700
	Coal-seam No. II., exposed near Carisa Ranch,	3.5 to 4
	Interval,	15
	Coal,	0.5 to 0.75
	Interval,	6
	Coal,	1
	Interval (estimated),	500
	Coal-seam, workable vein No. I., worked at the Sabinas mines,	4.5 to 5
	Measures,	12
	Coal-seam, irregular,	2
	Measures with two thin layers of coal and drift,	35
	Total, about,	2740

Vein No. IV. was opened at the Cedral mines about four years ago by means of a shaft and slope. Three other openings, respectively one, two, and three miles distant, and northwest of the Cedral mines, have been made on a vein of coal, considered to be identical with vein No. IV. which is thus traced for more than three miles along the side of the mountains. This vein is, as I have already pointed out in the general profile, very irregular in thickness, as is usually the case with vertical or highly inclined coal-seams.

Vein No. III. shows about 2½ feet of coal, its dip being, at the outcrop, 15° N. N.W.

Vein No. II. consists of four different layers, showing together from 3½ feet to 4 feet of coal. They occur as follows:

	Thickness in.hes.
Upper bench (dirty coal),	6
Parting,	0.5
Second bench (better coal),	8
Parting,	0.5
Tbird bench,	12.
Parting,	0.5
Lower bench (best coal),	18.

The dip of No. II. is, at its outcrop, 10° to the north.

Vein No. I has been opened at the Sabinas mines, about a quarter of a mile north of the river, and about 8 to 9 miles east of Sabinas station on the Mexican International Railroad. A number of shafts have been sunk here to prove the extent of this vein, and have explored it more or less for an area about 4 miles in length, and one-half to three-quarters of a mile in width. Mining, which was carried on here during the years 1883 and 1884, will be continued on a large scale, since the mines and adjoining territory have been bought by the Southern Pacific Railroad system. A branch road, running from the Mexican International Railroad at Sabinas station to the Sabinas mines, was finished the first of August, 1884.

The following are the sections of vein No. I., shown in two different shafts. At shaft No. I.:

	Thickness inches.
Upper bench (slaty coal, making good roof),	10–12
Second bench (good coal),	8
Parting (mud coal),	1½–2
Third bench (good coal),	4
Parting (slaty coal),	1½–2
Fourth bench (best coal),	28–34
Good coal,	40–42

At shaft No. III.:

Upper bench (good coal),	8
Shales,	12
Second bench,	9
Parting,	3–4
Lower bench,	42
Good coal,	59

The smaller vein which overlies No. I. seems to be very irregular in its thickness. It is found in some places 2 feet thick, while in other places only 3 to 4 inches of a dirty coal is noticed in its position, or it has given out entirely.

The coals of the Sabinas field are bituminous coals of from fair to very good quality. They are of medium hardness, more or less friable, break in square particles or cubes (block-coal), often showing calcspar on the surfaces of fracture. The coal of No. IV. has a conchoidal fracture, and is very high in ash. It has been tried for coking purposes, and has given satisfaction (except as to ash), and the coal of No. I. will also doubtless make good coke.

I append the following table of the coals of the Sabinas field:

	Locality.	Analyst.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.
Coal from Vein No. I., .	Sabinas mines, Shaft No. I.	E. J. Schmitz.	1.904	20.036	62.714	15.346	...
Coal from Vein No. I., .	Sabinas mines, Shaft No. II.	E. J. Schmitz.	1.372	16.423	68.182	13.023	...
Coal from Vein No. II.,.	Lower bench near Barroteran station.	E. J. Schmitz.	0.836	29.349	50.181	19.634	...
Coal from Vein No. IV.,	Cedral mines.	Chemist of the Cedral mines.	0.450	21.600	45.700	29.100	3.15

Coke from coal of Vein No. IV., made at the Cedral Mines, yielded, according to analysis made at the mines:

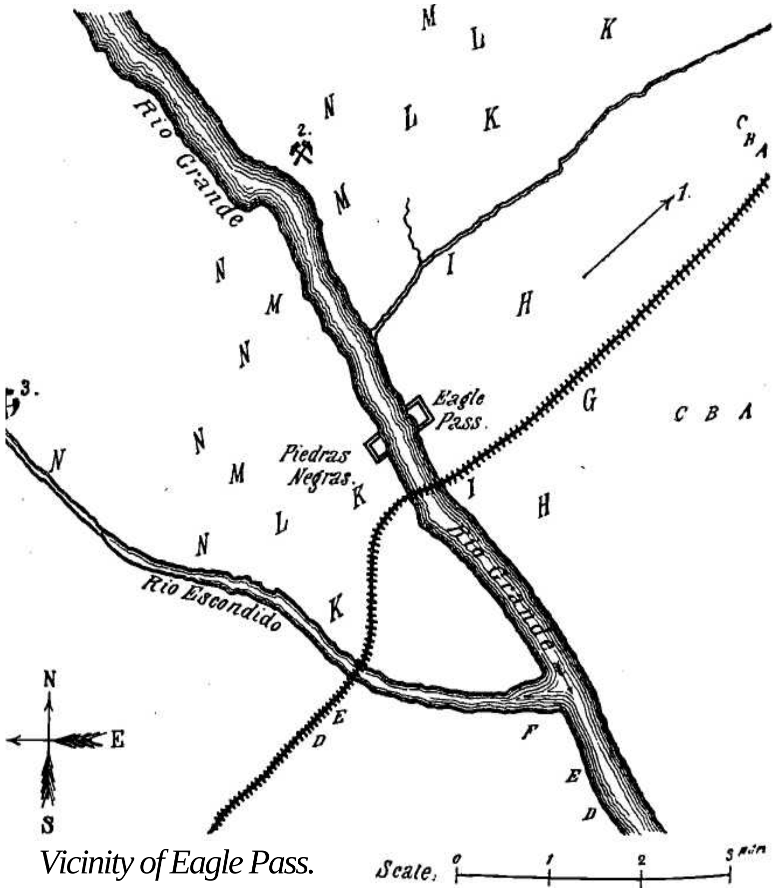
Moisture,	1,43
Fixed carbon,	65.13
Asli,.	31.40
Sulphur,	2.05

THE COAL-FIELD OF EAGLE PASS AND PIEDRAS NEGRAS.

The coal-bearing strata near Eagle Pass, on both sides of the Rio Grande, are known in length for nearly 20 miles, about 12 miles on the American side and 8 miles on the Mexican side, and in breadth along the river for nearly 10 miles. They strike northeast and southwest, and dip under a slight angle(from l°to4°) towards the southeast, so that, northwest and west of Eagle Pass, the coal-seams come up to the surface, while, to the southeast and east, they are covered by a series of rocks about 200 feet thick. Where the coal-seams come to the surface, they are mostly covered by a calcareous drift-conglomerate, exactly like that of the Sabinas coal-field. The higher members of the above-mentioned series of overlying rocks form a low ridge, east of Eagle Pass. Northwest from the out-crop-line of the principal coal-vein of the field (that is, northwest and west of Eagle Pass) the coal-bearing rocks are covered by a series of rocks, similar to that noticed on the east and near Eagle Pass.

The following is a general section of the rocks exposed near Eagle Pass, the coal-measures, so far as developed in the so-called Breckenridge shaft, and the overlying series of rocks capping the hills and the country generally, near and east of Eagle Pass.

FIG. 4.



Vicinity of Eagle Pass.

The letters refer to the outline map, Fig. 4, on which similar letters show the localities where the different strata are exposed. On this map the arrow marked 1 indicates the direction of Breckenridge shaft, which is about five miles from Eagle Pass; the crossed hammers marked 2 and 3, indicate respectively the localities of the Riddle and Hart mine, and of the Eagle mine.

General Profile Near Eagle Pass.

		Thickness in feet.
A,	Limestone (thick, but thickness not known)	
B.	Sandstones, the soft variety is reddish and can be quarried in large plates, the hard variety is greyish blue,	35
C.	Marl (reddish)	5
D.	Bony dirty coal	4
E.	Clay, impregnated with salt,	4
F.	Marl	6
G	Sandstone, slaty with gypsum,	3 to 4
	Limestone with fossil shells (Amomites), bard,	1.5
	Clay slate with fossil shells,	3
	Limestone with fossil shells	2
	Marl, dolomite,	7
	Marl, calcareous,	4
	Limestone, rippled	3
	Limestone, hard silicious,	3
H.	Variegated calcareous sandstones (resembling somewhat *Buntsandstein),*	6
I	Marl, calcareous, containing one stratum limestone with shells one inch thick,	1
	Dolomitic limestone containing brown spar,	1
	Marl, dolomitic,	3 to 4
	Porous clay sandstone,	1
	Marl with magnesia knolls	20 to 25
	Shales containing plant fossils	0.5
	Yellow-brown marlstone not striped (somewhat resembling *Zechstein),*	3
K.	Bituminous slate	6
	Yellow-brown marlstone, striped,	3
	Bituminous slate,	6
L.	Yellow and white sandstones,	40
M	Slate containing one inch of coal,	5
	Bluish sandstone,	30
	Blue slate,	10
	Sandstone,	25
	Black slate and bituminous slate,	20
	Blue sandstone,	10
	Slate and bituminous slate,	1 9
	Blue slate and sandstone,	6
	Hard grey sandstone with fine quartz pebbles, containing a ledge of oolithic iron ore several inches thick,	1
	Sandstone, slate and fire clay,	7
	Slate and one foot of coal (dip S.W.)	2
	Slate, sand, and shales (black)	8

				Thickness in feet.
N.	Coal,	3 feet 6 inches,	The so-called Big seam. 10 ft. 11 in., say,	11
	Slate,	– " 5 "		
	Coal,	2 " – "		
	Slate,	– " 4 "		
	Coal,	– " 6 "		
	Soapstone,	1 " 2 "		
	Coal,	2 " – "		
	Slate and coal,	1 " – "		
	Black slate and clay,			4
	Coal pronounced very good,			1
	Bituminous slate containing fossils and a highly bituminous coal-slate or lignite,			9
	Fine grained blue sandstone without seams,			20
	Blue sandstone,			10
	Slate, dark,			2
	Sandstone and slate with black seams,			3
	Bluish and black sandstones and slates,			10

The section below K was obtained from the Breckenridge shaft, mentioned above, which is about 260 feet deep.

The writer thought at first, after superficial examination of the fossils of this series of rocks, that he could recognize certain fossils of the Triassic and Jurassic period, as *Ceratites nodosus* Han, *Posidoniae,* etc., and as also some of the members of this series of rocks have some resemblance to members of the German Trias *(Muschelkalk* and *Buntsandstein),* he was inclined to accept these rocks as belonging to the said periods, in which case the underlying coal measures also would have been of these or earlier periods. But Prof. Newberry of Columbia College, who was kind enough to look the fossils over, pronounced them middle Cretaceous.

But one seam of workable thickness has been developed as yet in the Eagle Pass field, namely, the so-called Big seam. This was first opened at the Riddle & Hart Mine, about 3 miles northwest of Eagle Pass. It has also been developed on the other side of the Rio Grande, and about 5 miles west of Piedras Negras, on the bank of the Rio Escondido, at the Eagle Mine. This seam is known to cross the Rio Grande about two miles above Eagle Pass.

The Big seam shows, at the Riddle & Hart Mine, the following section :

	Feet.	Inches.
Slaty coal (about),	3	
Coal,		3 1/4
Black slate	-	2
Coal (breaking in blocks),	-	8
Clay slate,	-	2½
Coal (hard, conchoidal fracture),	-	5
Clay slate,	-	1½
Coal (very hard, conchoidal fracture),	3	1½

At the Eagle Mine, on the bank of the Rio Escondido, the seam shows the following relations:

	Feet.	Inches.
Bony coal, with several partings	3	
Coal (of medium hardness, and breaking in cubes or blocks, sometimes having little partings),	1	6
Soapstone,	2	3
Coal	-	3
Parting	-	1½-2
Coal (hard, dull black, beat in seam, conchoidal frac-ture),	2	3
Bituminous slate.		

The character of the coals of this field is very peculiar. The color of the different layers is from gray to dull black, without luster, to the common black of bituminous coals and the pitch-black of certain brown-coals. Some of the coals of the dull colors, as well as of the pitch-black varieties, have partly conchoidal fracture, and partly break in cubes. The coals with the dull color and conchoidal fracture resemble very much the cannel coals. Some of the coals—with the common black color—break in cubes, and resemble somewhat the variety of bituminous coals, known as block-coal. Resin has been observed in most of these coals, but not in the small seams above the Big seam, in the Breckenridge shaft. It may be, however, that the writer overlooked it in those seams. Practical miners claim that resin is the only characteristic mark for the separation of brown coal, or lignite, from the true coal. All coals found in Breckenridge's shaft, which have a cubic fracture, expose occasionally on the fracture-surface crystals of calespar.

The gravity of the different varieties varies greatly.

SILVER AND OTHER MINES.

I have already spoken of the limestone groups of the Sierra de Santa Rosa and other mountain-chains near Monclova, Coahuila, which chains, notwithstanding their distinct names, may be accepted as branches or continuations of the main mountain-stem, that is, may be connected with the Sierra de Santa Rosa to one large range. The longitudinal axis of these Sierras and Cerros is nearly uniform from N. N. W. to S. S. E., the same course noticed on the high plateau in Presidio and El Paso County, Texas, and its mountain chain.

Besides the first limestone group above referred to (the drab-blue limestone), there exists a second group of a more whitish and whitish-blue color, heavy-bedded and of great thickness, which has been noticed principally on the north face of the Sierra de Santa Rosa near the town of the same name. This limestone, which has great resemblance to certain limestones of the lower Silurian is known to be Sub-carboniferous and is very probably identical with the first group, the latter being only in a more metamorphosed state. The ore-deposits of the Santa Rosa district belong to this limestone group.

As it was not the writer's object, when in this region, to report on the silver-mining properties in the Santa Rosa and Monclova district, they will be passed here with slight mention. There are five mines on the northeast side of the Santa Rosa Mountain, the San Juan, San Pedro, Pavilion, San Gertrudis, and Cedral mines, which are only short distances from each other and from the town of Santa Rosa, the Cedral mine being the farthest away—about 8 miles. The ores of these mines are galena, antimonial ores and red and dark carbonates.

Coming from the town of Santa Rosa (*Villa de Musquiz* is the official Mexican name) we reach the San Juan mine by travelling about 2½ miles southwards. The mine and smelting-works are located on a slight descent at the lower portion of the foot of the mountain. This mine, which, like all others of this district, has been worked by the old Spaniards, was abandoned by them on account of the heavy amount of water, which they were unable to control. An old and deep open-cut can be seen on the lower part of the declivity, which it is said was commenced by the Spaniards to drain the mine, but which never has been finished; and a lively little stream of water flows several hundred yards west from the shaft of the mine down from the mountain. This property was bought several years ago by a company from the Southern United States. They removed the water from the mine, built smelting-works and were ready with their preparations, when experience taught them, that it will not do "to sell the skin before the bear is caught." A heavy breakage of water into the mine found the engine and pump too light to do the work. A desperate struggle with the enemy ended with the total ruin of the pump, and being not able to secure stronger machinery, the capital having been expended on the smelting-works and buildings, the company was forced to cease operations.

The other mines are located to the south-southeast along the mountains in the following succession : San Pedro, San Gertrudis, Pavilion, and (several miles distant from the latter) the Cedral Mine. None of these mines are worked to-day except the last. San Gertrudis, Pavilion, and Cedral are owned by Americans. The openings of San Gertrudis and Pavilion are in such ruined condition, and the grounds are so thickly covered with brush and thorn, that it would be nearly impossible to examine them in the present state of affairs. The principal object of raining at the Pavilion is said to have been a blue clay-slate, containing thin leaves of native silver between the layers. This slate seems to belong in position between the rocks of the Sabinas field and the limestones of the mountains.

A vein of coal in vertical position has been opened near the San Gertrudis and Pavilion, in both locations short distances north of the mines. These veins are exactly in similar position as the vein No. IV. at the Cedral Mines and are, therefore, with great probability, considered identical with No. IV.

The ores of the Cedral mine are mostly low-grade carbonate ores with some galena. The vein is somewhat irregular, and has been developed in the old Mexican way, by an irregular slope or shaft following the vein to a depth of one or two hundred feet. A new vertical shaft, which was in course of construction at the time of my visit, is doubtless finished by this time. The smelting-works are located about 1/4 of a mile from the mine, and the coal-mine is only a few hundred yards from the works. A tram-road is running from the foot of a terrace of the mountains, where the mine-opening is located, to the works, which are connected in the same way with the coal-mine. Mines and works have been in operation for over five years, and have met for some years past with good success.

Among other mining properties belonging in these limestone groups, to which the writer paid a brief visit, are to be noticed the Paloma iron-mine and the Potrallios and San Raphael silver-mines. The Paloma mine is about 7 miles southwest of Monclova, located on a spur of the mountains called Cerro Mercado, 3 miles west of the line of the Mexican International Railroad. The ore is a mass of hematite and magnetite of excellent quality. The outcrop on top of the mountain-spur is very thick, but the property has not been developed enough to test its practical value. In case this bed of ore, by further development, proves to be so thick as the outcrop promises it will be of great value as the basis of an iron industry, there being no question as to the ready demand. The Mexican International Railroad connects this property with the coal-mining enterprise near Sabinas Station, in the Sabinas coal-field, bringing coal and iron-ore within a distance of about 60 miles. I may add here, that similar ore is reported to occur on the Sierra de la Gloria, a mountain range opposite Cerro Mercado and a little further south ;

but as I could not visit this locality, I do not know if these reports are correct.

The Potrallios silver-mine is located on the Sierra Potrallios, 18 miles southwest of Castano, and the San Raphael is 2 miles further south. The ore appears in a heavy mass of gneiss, which intersects the limestone of the mountains. The vein matter in both is formed of a weathered whitish mass, containing streaks of quartz and feldspar. The shaft of the Potrallios mine is filled up. From a disinterested source, I received the information that the vein varies from 1½ to 4 feet in thickness. The vein at the San Raphael could be examined in one shaft, and shows a thickness of about 2 feet.

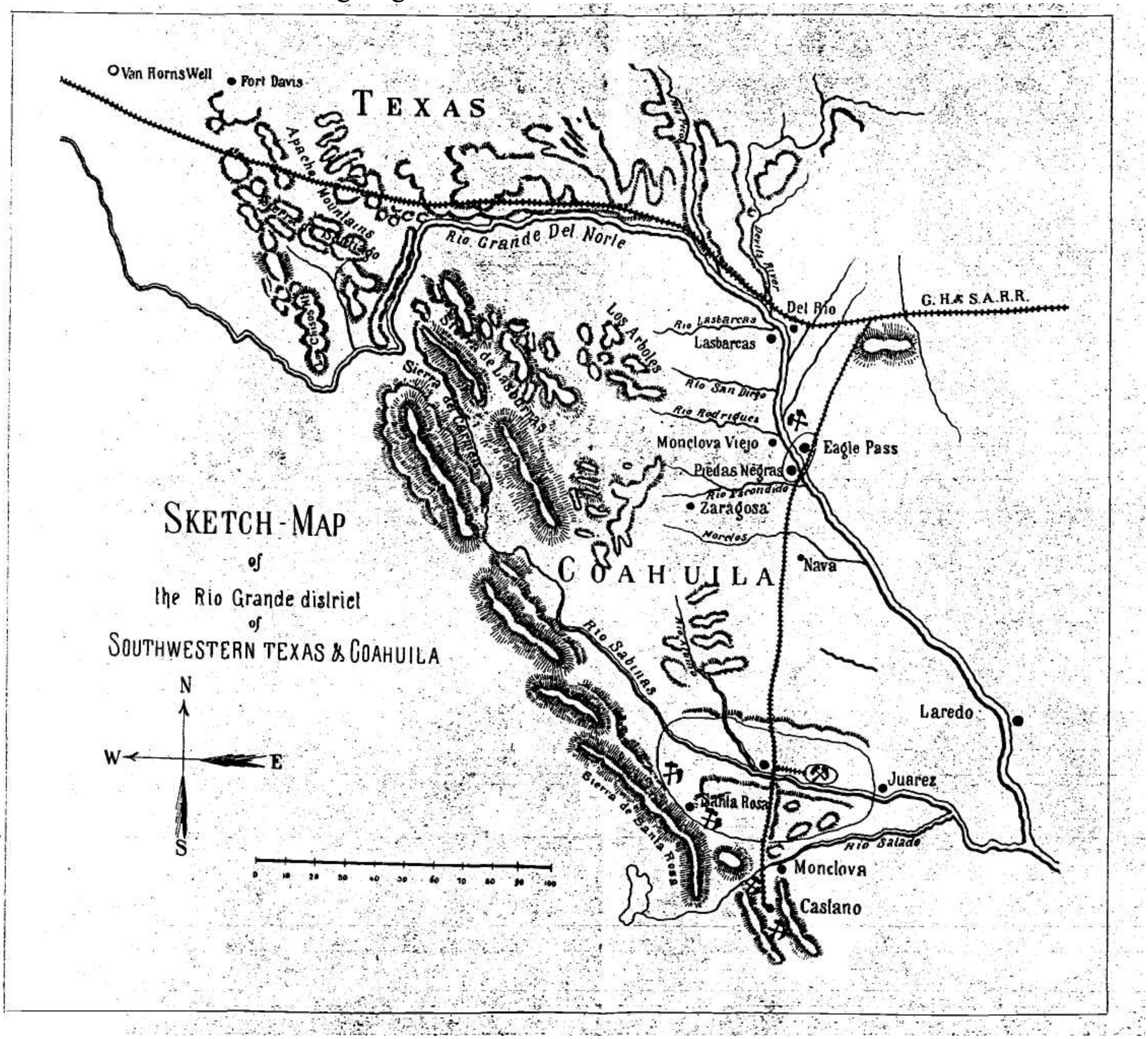
RECAPITULATION.

Recapitulating the results which this little paper has brought forward with regard to the geological periods represented in the region described, we have the Cretaceons, the sandstones, etc. of the lower coal-bearing horizons (Eagle Mountain and Sabinas coal-fields), the Triassic and Jurassic, the Sub-carboniferous and the Azoic formation. Members of the Triassic and Jurassic age can be observed in the southern portion of the Apache Mountains in Presidio County, Texas, where they form a narrow belt in the middle portion of this range of mountains, being bordered by rocks of Azoic age. On the southern side of the Rio Grande, the writer did not meet with any rocks of these periods, but as his examination did not reach any further west than the Los Arboles mountains, he did not enter the continuation of the mountains in which they could be expected. Certain it is that no rocks of these periods or of the Permian can be discovered at the contact of the Sub-carboniferous limestones of the Santa Rosa mountains and the rocks of the Sabinas coal-field (taking it for granted that the rocks of the Sabinas field do not belong in one of these periods).

The formations of this region and their probable thickness, arranged in form of a schedule, will read thus:

1. Cretaceous (commences west of San Antonio) forms the high plateau of Presidio and El Paso County in Texas, and the country on the other side of the Rio Grande to the Sabinas coal-field and the Santa Rosa mountain chain—being the continuation of the Cretaceous belt in Texas and having a south-southeast course. Its thickness being estimated at,...2000-3000 feet.

The sandstones and shales of the Sabinas coal-measures and similar rocks in Presidio and El Paso County, Texas, showing a thickness of about 3000 feet, will increase—if Cretaceous—the Cretaceous rocks to, 5000-6000 feet.


Van Horns Well
Fort Davis
TEXAS
Apache Mountains
Rio Grande Del Norte
Devils River
Del Rio
G. H. & S. A. R. R.
Rio Lasbarcas
Lasbarcas
Los Arboles
Rio San Diego
Rio Rodriguez
Monclova Viejo
Eagle Pass
Piedras Negras
Rio Escondido
Zaragosa
Nordes
Nava
COAHUILA
SKETCH-MAP
of
the Rio Grande district
of
SOUTHWESTERN TEXAS & COAHUILA
N
W
E
S
0 10 20 30 40 50 60 70 80 90 100
Rio Sabinas
Laredo
Juarez
Santa Rosa
Sierra de Santa Rosa
Rio Salado
Monclova
Castano

SCHMITZ.

2. Triassic and Jurassic of the Apache Mountains can be estimated at, 1500-2000 feet.
3. Sub-carboniferous limestones of the Santa Rosa mountain range have a thickness of, ... 5000-6000 feet.
4. Azoic rocks intersect in Texas on the Plateau, the Cretaceous, and in the Santa Rosa mountains in Coahuila, the Sub-carboniferous limestones.

NOTE.—The coal-field of the Eagle mountains, described in the foregoing pages, is not shown on the accompanying sketch-map. It lies in the northwest corner of the area covered by that map, further south than Van Horn's Well, and on the opposite side of the railroad.

THE DETERMINATION OF PHOSPHORUS.

BY JOSEF WESTESSON, CHEMIST OF THE CHESTER ROLLING MILLS, THURLOW, PA.

No question in the metallurgical chemistry of the present day seems to be so difficult to agree upon as the determination of phosphorus in iron and steel. To my knowledge, there are at present at least three different methods in use in the iron laboratories of the United States, viz.: The citric acid method, the molybdate-magnesia method, and the direct molybdate method,—the last-named method having been lately adopted. Each of these methods has its advocates, who take every pains to prove its advantages, and the incorrectness of the others; and much has been written for the purpose of securing the use of a standard method—as yet, however, without any result.

There is no doubt, or ought to be none, that each of these methods gives correct results, when it is carefully conducted and every precaution is taken. But it is not only correct results that we want now-a-days. The demand is great, also, for getting results in the shortest possible time. I think it has been sufficiently proved that the direct molybdate method, the weighing of the precipitate, answers well in both respects. Being a pupil of Prof. Eggertz, I have myself used his method for years until quite recently, as it is described by Mr. Troilius in our *Transactions,* vol. *x.,* p. 166 (but with some slight modifications), and I can safely say that the results of this method agree well with those of the molybdate-magnesia method. I have, moreover, been checked, in a few instances, by some of the leading chemists of the country, and their results have been such as to commend the method I use.

On the European continent, and also in England, the molybdate method is almost exclusively in use. Therefore, the question is there not so much about the superiority of different methods ; researches and experiments tend more to improve the method generally adopted. An important step in this direction has been taken by Dr. Adolph Tamm of Stockholm, Sweden, whose paper on the subject is published in the *Jernkontorets Annaler* of 1883, under the title "Concerning Different Ways of Dissolving Iron for the Determination of Phosphorus by Means of Ammonia-Molybdate." The principal contents of this paper are substantially given below.

When iron is dissolved in nitric acid, the solution acquires a brownish color from humic acids, originating from the carbon in the iron. These humic acids are not destroyed by evaporating the solution to dryness at 212°, or on a water-bath, but continue to give the brownish color after redissolving in nitric acid. The color would, of course, be of no consequence, if experiments had not shown that the humic acids, the presence of which it indicates, prevent the complete precipitation of phosphorus. That such is the case seems to be clearly proved by the facts that the silica and graphite, filtered off from the solution, show no presence of phosphorus; that the filtrate, after a new addition of molybdate and boiling, remains perfectly clear; and finally, that the method which Dr. Tamm recommends, gives considerably higher results. This method, which he has worked with great satisfaction, and the correctness of which he has confirmed by the magnesia method, is the following:

Dissolve 1 gramme of iron in 12 c.c. of nitric acid (1.2 sp. gr.) and boil on a cast-iron plate, down to dryness. Let the beaker remain on the hottest part of the plate—usually at least 200° C.—an hour. Redissolve in strong hydrochloric acid, boil again down to dryness and let the beaker remain another hour on the hottest place,—the second evaporation to dryness for complete separation of silica. Again dissolve in strong hydrochloric acid and remove the excess of acid through evaporation ; add 5 c.c. of water, filter, and add the ammonia-molybdate.

The following table, given by Dr. Tamm, will show the results of both methods. It is to be observed that the higher the amount of phosphorus in an iron, the greater the difference in the results. The old method is marked B, the new method A.

	Per cent. of Phosphorus according to A	Per cent. of Phosphorus according to B		Per cent. of Phosphorus according to A	Per cent. of Phosphorus according to B
Pig-iron, ...	.019	.013	Bessemer steel, . . .	.028	.019
"	.021	.016	Pig-iron.	.029	019
Wrought-iron, . . .	.023	.015	Bessemer steel, . . .	.030	.020
Pig-iron, ...	.024	.015	Pig-iron, ...	.065	.045
"	.024	.016	"	.077	.053
"	.024	.016	"	.078	.055
Bessemer steel, . . .	.026	.018	Wrought-iron, . . .	.109	.080
Pig-iron, ...	.026	.015	Pig-iron, ...	.212	.135
"	.026	.017	"	.222	.141
"	.027	.020	Iron rail, ...	.391	.323
Bessemer steel, . . .	.027	.019	Pig-iron, ...	.410	.260
" " . . .	.027	.019	Iron rail, ...	.541	.433
" " . . .	.028	.018			

That the results obtained by the molybdale method, as it is generally worked, should, according to Dr. Tamm's revelations, be inaccurate to so great an extent, is a very discouraging fact; and the only thing that can console the practitioners of that method is, that the molybdate-magnesia chemists are making the same errors. There are chemists, whom I have made acquainted with Dr. Tamm's method, who believe still less in this method than the old one; and, I dare say, it will be some time before they become convinced. The frequent remark, that the yellow precipitate is soluble in hydrochloric acid, will, in this case, be best disposed of by the words of Fresenius: "The presence of molybdate of ammonia alters the precipitate's deportment to acids ; *only large excess of hydrochloric acid prevents complete precipitation.* " Therefore, the excess of said acid must be removed before adding molybdate. Some hold that the orthophosphoric acid is transformed into pyrophosphoric acid through heating to 200° C. That is true, but they forget that boiling the dried mass in hydrochloric acid brings the pyrophosphoric acid back into the orthophosphoric state. Taken altogether, the objections do not hold good, even if we admit that a trace of molybdic acid sometimes is precipitated along with the yellow precipitate, which, of course, will not have any influence on the final result, this being only 1.63 per cent. of the precipitate. A very essential advantage of this method is, that results can be obtained in less than five hours.

I give below a table of results obtained by myself in the use of both methods. A and B mean the same as in Dr. T.'s table. The precipitates obtained in method A have been redissolved and precipitated with magnesia solution.

	Per cent. of Phosphorus according to			Per cent. of Phosphorus according to	
	A	B		A	B
Pig-iron, ...	.930	.862	Pig-iron, ...	.940	.821
"	1.030	.945	"	.062	.055
"	.715	.674	"	.068	.063
"	.412	.371	Plate steel, ...	.068	.064
"	.477	.447	"	.081	.075
"	.259	.230	"	.082	.072
"	.082	.073	"	.079	.068

AMERICAN MINING MACHINERY IN MEXICO AND CENTRAL AMERICA.

BY F. H. MCDOWELL, NEW YORK CITY.

FOR more than two hundred years Mexico has been enriching the world from her inexhaustible wealth of precious metals. From this source alone, over three thousand five hundred millions of dollars have been poured into the coffers of Europe and America.

During these centuries the wants of the country in manufactured goods have been supplied from the mills and machine-shops of the Old World. English, French and German merchants in Mexico have vied with each other in their efforts to control the importing of these goods from their respective countries. The overthrow of Maximilian, the departure of the French and the restoration of the Republic, largely influenced by the strong stand taken by the United States Government during our own civil war, established a new order of things.

Americans were encouraged to visit the sister republic, examine into the needs of the country, as well as its resources, and interest themselves in the work of development. More recently, under Presidents Diaz and Gonzales, liberal inducements have been extended to American capitalists to build railroads, open mines, erect reduction-works, raise cattle and improve the crude systems of agriculture. The Mexican Central Railway has been pushed south from the Rio Grande to the Capital, and, by its branches and connections, makes the whole mineral belt of the country accessible.

The Reciprocity Treaty, approved at the last session of Congress, will shortly be ratified by the new Mexican Congress, and a fresh impetus will be given to American enterprise in Mexico.

The millions of money which have already been invested are but the beginning of that movement, which will not cease until Mexico has taken that position among the American republics to which her mineral and other resources justly entitle her.

The relations between the United States and the States of Central America are steadily becoming closer; and the Commission, lately appointed at Washington to visit the country, examine into its.resources and report a plan to secure a more extended interchange of products, is likely to open new channels for the introduction and use of American manufactures and the capital necessary to develop Central American industries.

To secure the machinery-trade of these countries, it is necessary, first, to make a careful study of the local conditions under which machinery must operate, and then see to it that no weak or merely experimental devices be allowed to find their way into the new market, to the injury of both maker and user.

As such machinery will be largely used in the mining of ores and the extraction of the metals, I propose to discuss briefly in this paper the character of the machinery which has been used in the past, as well as that which is now being used for these purposes.

The early drainage of the Mexican mines and the removal of ore to the surface was accomplished by cheap peon labor and over pole-ladders, until an increased depth and flow of water made mule-whims and raw-hide ropes and sacks essential to further workings. While these will eventually be replaced by steam-hoists and Cornish pumps, many years must elapse before a genuine revolution in this direction can be effected. Foreign companies have introduced these improved appliances to a limited extent; but the native mine-owners will cling to the old system as long as possible.

For the treatment of ores, however, a much greater interest is being manifested in the American methods. Those of the old Spaniards still in force are crude and laborious, but, as the results have proved, very effective. Wherever it was possible to carry on smelting operations, either through the lead present in the ore or by the addition of litharge, this was the process preferred.

With the rapid encroachments upon the sources of lead and fuel, amalgamation became more generally adopted.

The native furnaces now in use are very crude in construction and limited in capacity, the blast being supplied by man-, mule- or water-power. The resulting lead-bullion is remelted in a *vasa,* built of the same material *(adobe)* as the shaft-furnaces, and the litharge is broken up into a new charge to increase the percentage of lead, the silver being still further refined and cast into bars for shipment to the mints.

The water-jacket furnaces, which have been introduced by American companies, are of the type so favorably known throughout our Western States and Territories, where they have largely increased the bullion out-put. Those giving the best satisfaction are located sufficiently near to the railroad to insure a regular supply of coke.

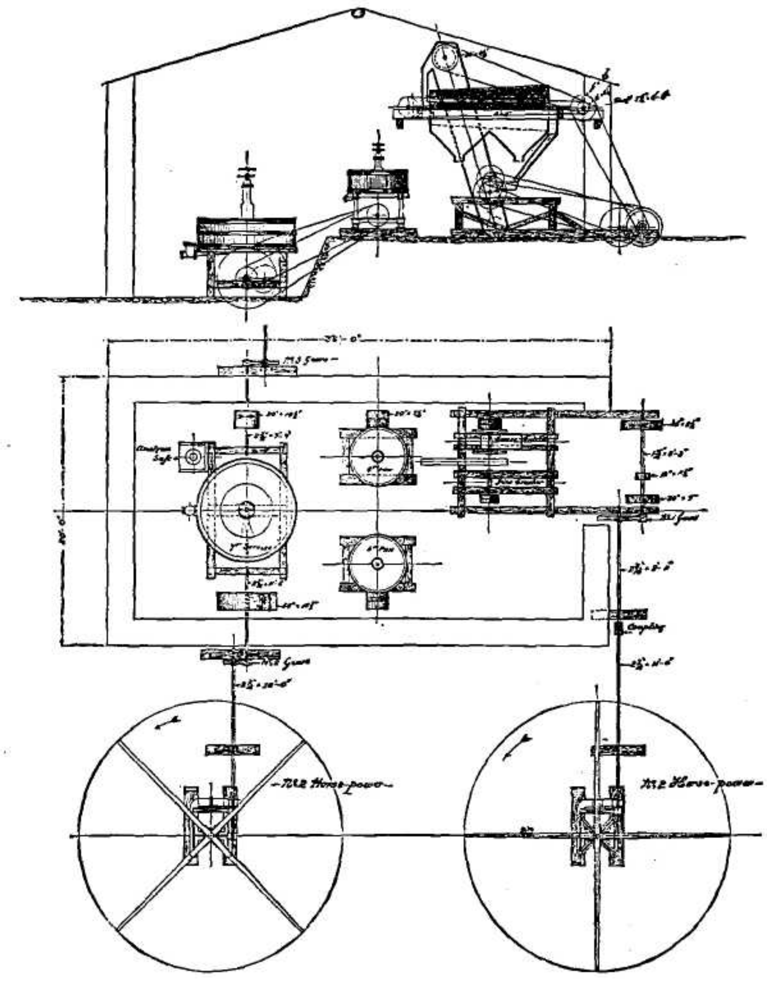
For amalgamation, the ore is broken by hand to the size of a walnut or egg, crushed to powder by the Chilian mill (stone rolls, revolved by mule- or water-power) and finally reduced to pulp in *arrastras* (the simplest form of stone grinding-mills). Where the ores are free-milling, the *arrastras* are frequently used for amalgamation also. Refractory ores go to the *patio,* and are worked over repeatedly by hand or by driving horses through the heaped-up pulp. This operation requires from one to five weeks, according to the season of the year; chemicals being added with quicksilver from time to time until the whole is ripe for washing, when it is removed in regular charges to the settlers. These are commonly deep wooden tubs, into which is run a stream of water. Natives wade through the pulp, up to their necks in mud, gradually separating the earthy matter from the amalgam. The former runs off, while the latter is collected and retorted, the distilled quicksilver being used over again, and the silver cast into bars. Particularly rebellious ores go through the roasting furnace before reaching the *patio;* but this is avoided wherever possible, on account of the high price of fuel.

So much of the labor of treating ores by these processes devolves upon mules and horses, that one of our most eminent mining engineers has said that the price of corn controlled the cost of all the mining and metallurgical operations of the republic.

To design machinery to accomplish the same results with much greater economy and dispatch would appear to be a very simple matter, until the complicated conditions under which it must operate are considered.

Many mining camps are accessible only on foot or horseback; the machinery, in such cases, must be made in light sections for mule transportation. In some districts fuel cannot be obtained; here we are obliged to utilize mule- or water-power. In others, where fuel can be obtained and water for steam is abundant, the quantity of mineral and organic matter held in mechanical suspension or in solution is so great, that boilers scale and deteriorate very rapidly. In still others, owing to the altitude, the difference in temperature between the days and nights, the bad water and food and the small number of foreigners present in the raining districts, it becomes a difficult matter to retain competent mechanics. Most

FIG. 1.



of the mines are located so far from the base of supplies in the United States, that long delays can only be prevented by carrying a very complete stock of supplies. Machine-shops being few and poorly fitted up, a little repair-room connected with each plant becomes an almost essential feature.

It remains, therefore, to study the conditions of each locality before selecting or designing the machinery best adapted to the work in hand. This should not only be extremely simple in construction and operation, but readily repaired in case of wear or accidental breakage. Wherever possible, the prominent features of the native appliances should be copied, mules, water or steam being simply substituted for hand-power. In this connection, it would be well to note the historical fact, that our system of amalgamation is largely a natural out-growth of the old Spanish system, modified to meet the requirements of our times.

In no other way can the labor of the country be gradually educated up to a full appreciation of the advantages to be conferred by the use of modern mechanical devices, and a sudden revolution avoided. It is by natural and easy gradients, that the native mill-men can be carried from hand-crushing and Chilian mills, to the California stamp, the Cornish rolls and the crushing machinery of more recent construction.

While the latter are gradually encroaching, and with reason, upon the domain of the stamp in this country, that device has played so important a part in our metallurgical operations, and has become so thoroughly established at all our important centers of mining, that we can neither expect to drive it out of the United States at short notice, nor prevent its introduction upon a considerable scale into neighboring republics.

There have been shipped into Mexico nearly one thousand of our American stamps, more than one-half of which are now at work. These, with but few exceptions, have gone into the hands of foreign companies, the natives weighing carefully, and at their leisure, the advantages claimed, and only purchasing when the results have proved perfectly satisfactory.

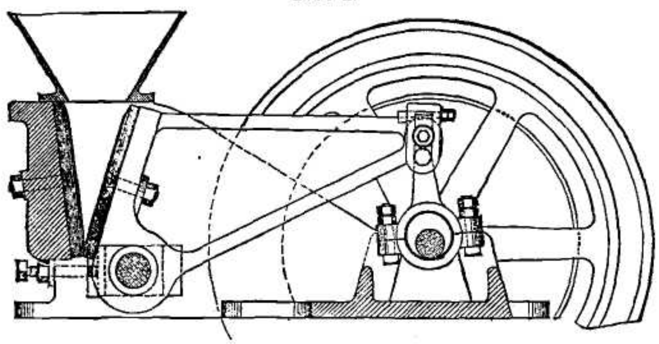
As the adoption of American processes and machinery means the abandonment of very large and costly reduction works, the Mexicans prefer to make their changes very gradually. In some cases, rock-crushers, operated by steam or horse-power, have been introduced to aid the Chilian mills in reducing the ores; in others, settlers of American manufacture have been added to increase the capacity of works, and in still others, the crude retorts of home construction have been replaced hy our iron barrel-retorts.

A type of mill which is being received in Mexico with considerable favor, is illustrated in Fig. 1. It will be noted that both the crushing and amalgamating machinery are driven by horse-power.

Fig. 2 shows the construction of the crusher to which the ore is fed dry as it comes directly from the mines or after a short exposure to the atmosphere. In crushing this to pea- or nut-size, a considerable percentage is reduced to a forty-mesh fineness.

This is removed by a revolving screen, and the remainder is elevated to a fine-crusher of similar construction to the first, with much longer jaws. The product from this machine passes by the elevator, as before, into the same screen, and a small percentage of coarse is returned to the fine-crusher for a second passage.

FIG. 2.



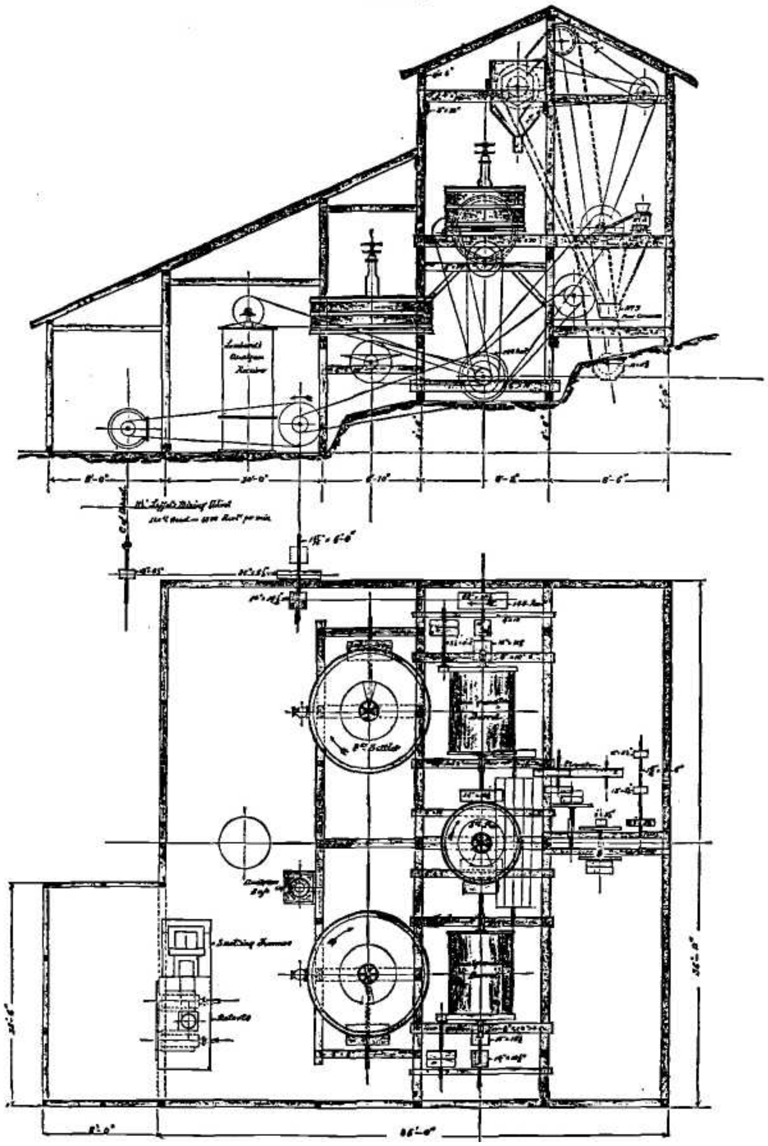
The storage-bins are arranged to discharge directly into the amalgamating-pans. These are the regular combination-pan, now universally adopted throughout the gold and silver districts of the United States. The amalgamating process is so familiar to the members of the Institute, that it does not require to be dwelt upon here.

This style of plant goes to districts where, on account of the high price of fuel, the absence of water, or the difficulties of transportation, steam-power is unavailable.

At Pinos, in the state of Zacatecas, where one of these mills is located, coal can not be delivered for less than thirty dollars per ton; wood is worth about one-half cent per pound, and the water carries more or less mineral. The cost of working ores in this district by the *arrastra* process, varies from $15 to $25 per ton, and is accompanied by considerable loss. The new process effects a saving of about fifty per cent.

Another type of mill is illustrated by Fig. 3. One of these has been sent to the Paraiso Reduction Company of Honduras. Like most of the mills which have been sent to Central America, it was sectional in character, the pieces being limited to two hundred and fifty pounds in weight. The mill is a combination-plant to treat

FIG. 3.



both gold and silver-ores. For this reason, amalgamation is effected in both the revolving barrels and the pan. The crushing-machinery

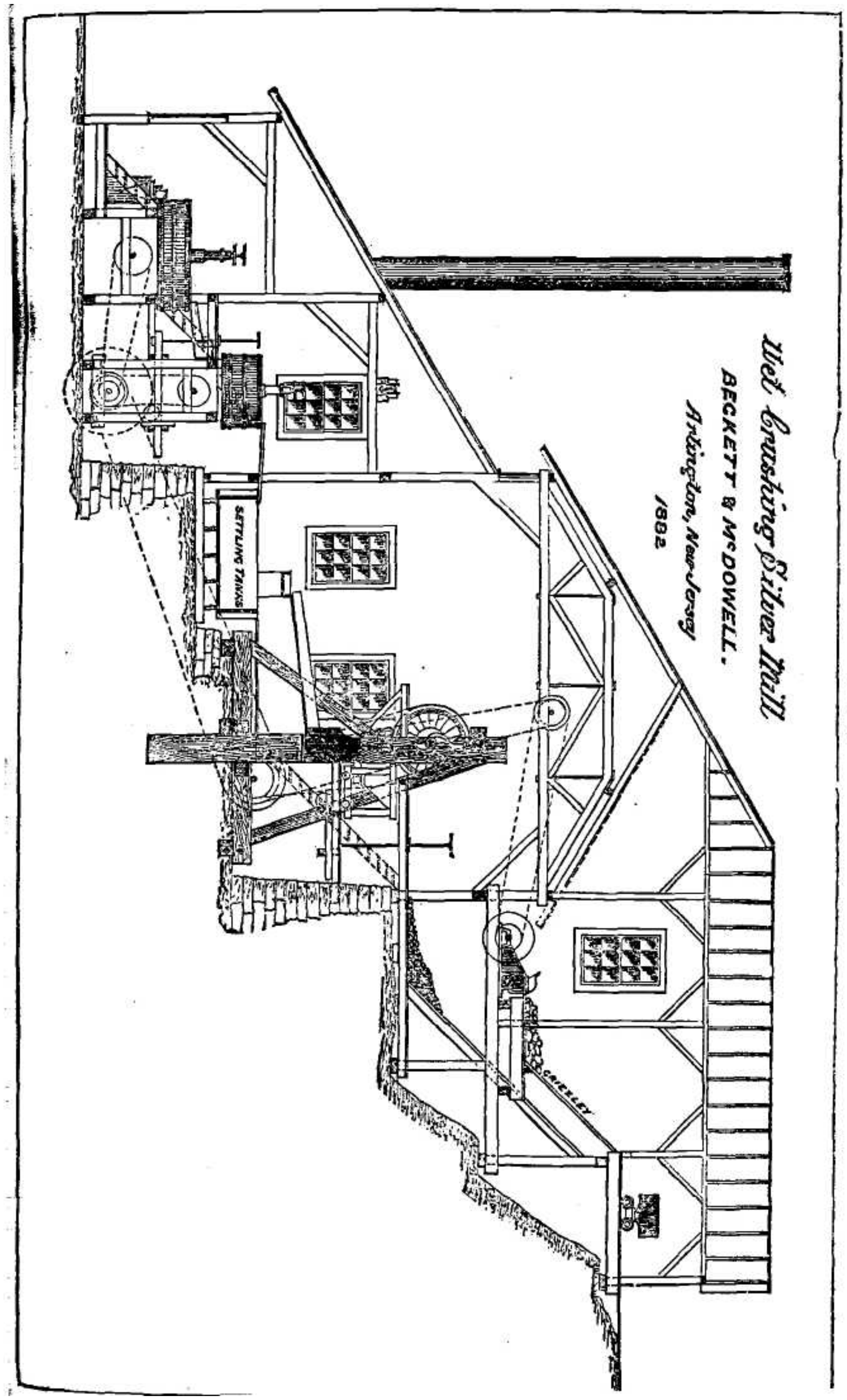

Wet Crushing Silver Mill
BECKETT & McDOWELL.
Arlington, New Jersey
1882
SETTLING TANKS

FIG. 4.

is of the same style as that previously described. This system insures a much finer product than that produced by stamp-mills, and makes pulp much more rapidly. The tailings from the settlers pass through the Lombard amalgamator and concentrator. This consists of a number of revolving disks made slightly conical, and an equal number of stationary copper plates of like form, inclosed in an iron shell. The material is passed repeatedly from centre to periphery and back again, until it has left the last plate, when it is carefully washed in such a manner as to save any quicksilver amalgam or precious metal which may have escaped in the previous operations.

Another type of mill is that shown in Fig. 4. Among others, the works of the Negociacion de Cerro de San Andreas were built after this plan. They are located on the main line of the Mexican Central Railroad at the City of Zacatccas. The mill of this company does not differ materially from the regular pan-amalgamation mill of the West. Owing to the high price of firewood (one-half cent per pound), the mill was built with fifteen stamps and only two pans, the greater part of the crushed ore. going to the *patio*.

Since the completion of the railroad and the shrinkage *of* the price of fuel by fully one-third, the pan-capacity has been increased.

The results obtained in working refractory ores have been very satisfactory, and fully forty per cent. better than those secured by the old Mexican methods. Eighty-five per cent. of the assay-value is saved in the pans, and some seven per cent. more from the tailings on concentrators.

The value of the latter is also beginning to be appreciated, not only in dressing low-grade ores, that have accumulated on the mine-dumps for over a century, but in working tailings as they come directly from the mill or as they have resulted from the Mexican operations. The more refractory ores pass through the same process as free-milling ores, after they have been roasted and chloridized.

Among the most noted machinery-plants in Mexico are those of the Sonora Mining Company, the Santa Eulalia Mining Company, the Cusihuriachic Mining Company, the Gabilana Mining Company, the Jocuistita Mining Company, the Parral Mining and Milling Company, the Santa Barbara Mining Company, the Sombrerete Mining Company, the Cinco Senores Mining Company, and the El Oro Mining Company.

These are treating almost every variety of gold and silver-ores, and with such success, that they are being copied into the plans for new works, which will be erected during the next decade.

The saving in time and cost of treatment which will be effected by these plants, will increase the demand for American machinery until it will be as universally employed as throughout the mining districts of the United States.

TEE ELECTRICAL ACTIVITY OF ORE-BODIES.

BY CARL BARUS, PH.D., U. S. GEOLOGICAL SURVEY, WASHINGTON, D. C.

INTRODUCTORY.

THE present paper is a revision, with changes and additions, of my contribution to the "Geology of the Comstock Lode and of the Washoe District," G. F. Becker, Geologist-in-charge ; Monographs U. S. Geological Survey, III., Washington, 1882, and is communicated to the Institute by permission.

The experiments were made at the instigation and under the general direction of Professor Becker, who had for some time given detailed attention to the possible electrical activity of ore-bodies. The physical work was intrusted to me.

About a year or more ago, I read in the New York *Times* that the eminent English electrician, C. E. Varley, had patented a new "divining-rod," by the aid of which the position of ore-bodies is said to be discoverable from observations made on the surface of the earth. I have not seen since that time any account of this apparatus, or any mention of results obtained by means of it. But this may be due to the fact that the literature of mining engineering is not conveniently at my disposal. The nature of the problem would at first sight seem to suggest the voltaic induction-balance. It is to me, however, inconceivable that an instrument based on Professor Hughes' balance, one of the forms of which is A. G. Bell's apparatus for discovering the position of a bullet in the body of a patient, could be, even under favorable circumstances, of assistance to the prospector in his search for ore.

There is another method which has been proposed, and in the case successfully employed for the discovery of ore-bodies. This is the magnetic method due to R. Thalen. It is primarily applicable to bodies of iron-ore. Possibly it may admit of an extension to electrically active ore-deposits. Thalen made a minute magnetic survey over a considerable area, in the Swedish iron-districts. He found that the lines of equal magnetic intensity, in the vicinity of the ore-deposit, contracted to two sets of closed curves, disposed with reference to two very satisfactorily indicated *foci.*

It was the object of the geologist-in-charge, Professor G. F. Becker, to have similar work conducted over the region of the Comstock lode, in Nevada. The plan would have been that of making measurements of the intensity of terrestrial magnetism at a sufficient number of points of a line of survey passing normally across the strike of the lode. From the coordination of a number of such series of measurements it was hoped that some indication of lode activity might possibly be discernible. But the results obtained galvanometrically, from observations made in the lode itself, dictated the abandonment of this project.

A second scheme of investigating the variation of magnetic intensity along a vertical passing from the surface downward was also frustrated. The Yellow Jacket mine, the shaft of which had reached a depth of 3012 feet, would have afforded good facilities for this purpose. But just at this time a remarkable subterranean reservoir of water was struck, **the** efflux from which filled the available shafts to a height of about 600 feet, making them temporarily inaccessible. I was obliged, therefore, to abandon the magnetic method of investigation altogether.

The method which I propose to discuss in the following pages is thoroughly different from either of these. As regards age, also, it is by far the most venerable, and for this reason comes to us in a form incomplete and crude. This method considers the ore-body as *a source of electrical current,* and then from a study of the nature and conditions of this flow, endeavors to arrive at certain specific effects, referable only to the ore-body.

In 1830, R. W. Fox communicated to the Royal Society a paper which contained the results of a careful experimental study of the possible electric activity of ore-bodies. From this time until 1844, the matter was discussed with some enthusiasm by Fox and Hen wood, in England, von Strombeck and Reich, in Germany. After the publication of Reich's second paper (1844), however, further research seems to have been altogether abandoned ; at least I have not, with some pains, been able to find anything that has a bearing on the subject.* This is all the more remarkable, as the general line of

* See also, *Revue des Pi-ogrès récentes de l' Exploitation des Mines, etc.,* par M. Haton de la Goupillière, Ingen, en chef des Mines, Professeur, etc.," in the *Annales des Mines,* t. xvi., p. 6, 1879.

investigation had already assumed a promising course. It, would also have been supposed that Thalen's * work must have given the matter a new impetus.

With the present paper (undertaken at the suggestion of Mr. Becker †) the question of a relation between local currents and ore-bodies is, as it were, resuscitated, so that a general review of the development which it had attained previous to its abandonment seems pertinent.

Brief Review of the Work of Previous Investigators.

Fox,‡ in his original experiments, secured electric contact with the vein by wedging copper plates against it. These were put in connection with a galvanometer by copper wire. Earth-currents, if present, entered the wire at one end, passing through the galvanometer and finally back into the earth at the other.

As a general result of his investigation, Fox found that the intensity and direction of the currents bore no relation to the cardinal points, but could be explained by a consideration of the distribution of ores.§ Between two points of a continuous vein on the same level no current was observable; but when the points tapped were on different levels, or when there intervened between them an area of barren rock (horse), or when two apparently distinct veins were connected, the effect was invariably decisive. At times the currents were so powerful as to throw the needle of his by no means delicate galvanometer (3¼-inch needle in twenty-five turns of wire), several times around the circle. After enumerating a number of facts with reference to the relative position of the veins, Fox remarks that " many of the phenomena referred to, bear a striking resemblance to common galvanic combinations, and the discovery of electricity in veins seems to complete the resemblance." In other parts of this paper, however, he expresses the opinion that "mineral veins and internal heat are connected with electric action," and, moreover, anticipates greater effects with increasing heat and depth.

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* R. Thalen; v. de la Goupillière, *I. c:* "On trace des Iignes d'égale intensité, qni dans le voisinage d'un gîte prennent une forme caractéristique consistent en deux systémes de courbes fermées, concentriques, autour de deux foyers assez nettement indiqués."

† First Annual Report, U. S. Geological Survey, 1880, p. 46.

‡ R. W. Fox, *On the electro-magnetic properties of metalliferous veins in the mines of Cornwall.* Phil. Trans., ii., p. 399, 1S30.

§ Galena, copper, and iron pyrites were the ores met with.

The experiments of von Strombeck* were made at Werlau and Holzappel on a large vein, in which quartz, blende, galena, copper-pyrites and tetrabedrite occurred in irregular distribution, and are distinguished by the care with which all known sources of error were avoided. Contact was secured by drilling into the vein holes 2 to 3 inches in depth, into which the ends of the wire, spirally wrapped and held in position by a cork, were inserted. In other respects the method of experimentation was identical with that of Fox. Von Strombeck made a large number of experiments, but was unable to detect any traces of electric excitation, and, consequently, concludes that Fox's results are not applicable to veins generally, and that, even in Cornwall, the matter requires further consideration. Strombeck's difficulty is obviously the want of contact. Even with the improved galvanometer of the present day, such a device would be unsatisfactory.

In 1834, Fox again resumed his experiments, with special reference to the objections which had been raised against the validity of his results. † It having been mooted that the currents observed might, in some way, owe their origin to the copper contact-plates, he showed that by replacing these by plates of zinc the results remain unaltered. This was the case even when terminals of copper and zinc were used simultaneously. It was, moreover, immaterial whether the contact was produced by plates or whether the ends of the wire only were pressed against the vein. By inserting a copper-zinc couple into his circuit, Fox found that its effect was, in some cases nearly, in others decidedly, overbalanced by the lode currents. Finally, in the interval of four years which had elapsed between these and his former experiments, the direction of the currents had remained unchanged.

In a subsequent paper, Fox‡ endeavors to classify minerals with reference to their electrical properties. A table of conductivities is contained in his original paper.

In the Skeers lead mine, near Middleton, Teasdale, Durham County, Fox § obtained but feeble currents; at the Coldberry mine,

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* A. v. Strombeck, *Ueber die von Herrn Fox angestellten Untersuchungen in Bezug avf die electro-magnetischen Aeusserungen dar Metallgänge.* Karsten's Archiv., vi., 431,1833.

† R. W. Fox, *Account of some experiments on the electricity of the copper vein* in *Huel Jewel mine.* Rep. Br. Assoc., 1S34, p. 572.

‡ R. W. Fox, *Note on the electric relations of certain metals and metalliferous minerals.* Phil. Trans., i., 39, 1835.

§ R. W. Fox, *Report on* some *experiments on the electricity of metallic veins, etc.* Rep. Br. Assoc. Adv. Sc, p. 133, 1837.

in the same locality, they were absent altogether. Lead mines do not, in general, give evidence of electrical action comparable to that of copper mines—a circumstance which Fox refers to the positions of their ores in his scale.

Kenwood's* experiments were made on a larger scale (at times as much as 600 fathoms of copper wire were employed), but otherwise, in a way analogous to that of Fox, and contain a thorough corrob-oration of the results of the latter. He, moreover, insists that currents are only obtained in the case where the points tapped are in vein matter, being most decisive for copper pyrites, vitreous and black copper-ore, galena and blende; that between points in barren rock, electrical action is altogether absent. After a number of theoretical considerations—to which the paper is largely devoted—he concludes that the currents are probably of thermo-electric origin, that they are certainly purely local. Hen wood's theories are of little interest, as they are without a quantitative foundation. He knew little about thermo-electrics, and on the whole, I fear, rather ran a-slough in the dangers of speculative enthusiasm.

Some time after, all of Fox's experiments were again repeated and the results confirmed throughout by Reich.† Although the heating of one of the points of contact, in the case where both were applied to the same vein, produced a decided thermo-electric effect, quantitatively this was so small as to furnish grounds against Henwood's hypothesis. Reich is convinced that Fox's currents are hydro-electric phenomena. When an ore point was connected with one of rock, the currents were not only much smaller—probably on account of the greater resistance in this case—but when plates of copper and zinc were used together as terminals, a commutation of these invariably produced a corresponding change in the direction of the current.

In Fox's last paper ‡ on the subject, the effect of the contact-plates is again carefully considered. But even with one terminal of zinc, the other of copper, "the current continued to deflect the needle from 50° to 60°, notwithstanding that any action between the copper . . . . and the zinc . . . . if it had existed, would have been in the opposite direction and have tended more or less to counteract the

* W. J. Henwood, *Sur lea courants électriques observés dans lea filons des Cornuailles.* Annales des Mines [3], xi., p. 585, 1837.

† F. Reich, *Notiz über elektrische Ströme auf Erzgängen.* Pogg. Ann., xlviii., p. 287, 1839.

‡ R. W. Fox, *Some experiments on subterranean electricity, made at Pennance mine near Falmouth.* Phil. Mag. [3], xxiii., pp. 457 and 491, 1843.

influence of the actual current." The galvanometer referred to consisted of forty-eight turns of brass wire wrapped around a 2-inch needle, on a pivot. The lode-current, in a case observed, was found to remain constant for a period of eight months. Toward the end of the paper, mention is made of experiments in which one or both terminals were in rock. In this case, the results were similar to those of Reich, "there being still a tendency to deflection." The exchange of terminals of different metals also produced a change in the direction of the current.

In the next year, Reich * published his second paper, undertaken with the especial object of studying more closely the currents probably existing in the rocks surrounding the vein. His idea was that lode currents are produced by the contact of the different ores in the deposit, that the rock which separates them more or less completely one from another, performs the function of the liquid of an ordinary galvanic couple. *As* Fox's method of obtaining contacts with the earth was inapplicable, Reich had holes (12 inches deep) drilled in the rock, into which dilute sulphuric acid was poured. Strips of copper foil plunged into the acid and connected with the ends of a copper wire, completed the circuit. Currents were obtained when at least one point was near ore; they were completely absent when both points were in barren rock. Though the deflections of the needle ranged from 2° to 30°, they seemed to obey no general law. The results are, moreover, difficult of interpretation, because the needle does not discriminate between high and low grade, or between base and noble minerals,† the deflection being a function of both the quality and the quantity of the electrically active material. Reich's mode of operation was derived from a consideration of the currents of a galvanic cell in action. The paper ‡ is interesting, and the reader's attention is specially called to it. I shall have occasion to consider it again below. The reader is finally referred to the *Proceedings* Roy. Soc. Lond., iii., p. 128, 1832, and iv., p. 317, 1841, which were not at my disposal.

From 1830 until 1844, therefore, the papers in hand offer little more than a criticism of Fox's original investigation. In 1844, with

* F. Reich, *Versuche über die Aufsuchung ron Erzen mittelst des Schweiger'schen Multiplicators.* Berg- u. hüttenmänn'sche Ztg. [3], p. 342-346, 386-390,1844.

† The terra " mineral" wherever used throughout this paper is intended to refer to those of the heavy metals only—to those, in short, in which we may expect to find metallic properties.

‡ See, also, B. v. Cotta, *Erzlagerstätten,* vol. i.

the publication of Reich's second paper, in which the idea that if local currents due to ore-bodies are present at all, they must be discoverable in the rocks, was the basis of research, a second step may be considered as having been made. It is to be regretted that in none of the papers is there even an attempt toward fully describing the phenomena quantitatively. Generally, conclusions are drawn from the deflection of a galvanometer-needle without sufficient consideration of the very probable variation of the resistance of different circuits. The experiments are, moreover, made individually, not in series or with reference to any definite, pre-organized plan. Insomuch, however; as most of the work was done when methods of. electric measurement were still in their infancy, these matters are not to be mentioned to the disparagement of the authors. In fact, the reader is surprised at the breadth of view usually taken, at the cautiousness with which hypotheses are stated, and at the number of details and chances of error which are considered.

HYPOTHESIS UNDERLYING THE PRESENT INVESTIGATION.

There can be little doubt that the hypothesis which ascribes to ore-currents a hydro-electric origin is perfectly correct. Fox and Reich themselves found, in the case of terminals of copper and zinc used together, the points tapped being in rock, that currents resulted, the direction of which changed with an exchange of the terminals. I have actually measured the electro-motive force in action under these circumstances (see pages 432,434), and found it of the same order as that produced by combining these metals with a liquid in the form of a galvanic element. If, then, there are also ores which possess the electric properties of metals—and that this is the case Fox * went to some trouble to show—the possibility of ore-currents due to hydro-electric action follows as an immediate consequence. These currents will, in general, have an origin analogous to those technically known as "local action " in batteries, while at times, they may even be due to the occurrence of a complete natural battery. Thermo-electric hypotheses are unnatural, inasmuch as with the temperatures at our disposal, even in the Comstock lode, it would be necessary to assume values for thermo-electric power which, in comparison with those of known substances, are abnormally large. Such a speculation is,

* R. W. Fox, Phil. Trans., i., p. 29, 1835.

therefore, remote, artificial, and forced, and, in cases where there is a better hypothesis, deserves only very secondary consideration.

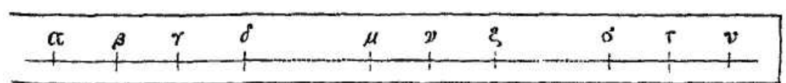
Suppose now, that in connection with an ore-body, with reference to which experiments are being conducted, electric action actually does occur. In the consideration of these currents; we are at once confronted by the important fact, that, inasmuch as electric action has been going on for an indefinite period of time, the currents must have become constant both in intensity and direction, and that therefore, the equipotential surfaces corresponding to this flow, will have fixed and probably well-defined positions.

In view of the fact that, with most geological readers, the consideration of electric phenomena will be merely an incidental matter, it may be well to be more explicit than would otherwise be necessary. By far the greater number of electrical phenomena can be explained by regarding electricity as of the nature of an incompressible fluid. The analogy is, in fact, very complete, and extends even into further detail than need be noticed here. We speak of a liquid as having a tendency to flow from a higher to a lower level; of electricity, as flowing from an equipotential of greater to one of lesser value. In the former case, the " levels " are approximately spheroidal surfaces —"geoids"— parallel to the 'normal surface of the earth; in the latter they are also closed or extend to infinity, may be quite simple or exceedingly complex. In order to exhibit the topography of a country in detail, it may be represented graphically by the aid of a series of equidistant earth-levels. In electricity, the analogous problem is similarly solved, those surfaces being chosen for which the potential value from surface to surface increases by a definite amount. In other words, therefore, the electrical potential at a given point, is its electrical state cônsidered with reference to its power of communicating electricity to another point. The locus of all points at the same potential, is an equipotential surface. Furthermore, neither " potential " nor " level" necessarily implies the existence of electricity or matter, respectively, at a given point. They merely offer a means by which a flow can be conveniently and tersely described.

If a reservoir, the water in which is constantly at a level, p, be joined by a pipe with one in which the water-level is constantly q (both p and q being measured vertically upwards from some fixed datum, and $p>q$), the quantity of liquid traversing any right section of the pipe in the unit of time would (other things being equal) be dependent on the dimensions of the latter and upon $p—q$. If a point on an equipotential of the value p be connected by a thin wire with a point on one of the value q, analogous remarks may be made with reference to the quantity of electricity (1) flowing through any right section of the wire in the unit of time. Now it is upon I that the deflection of a magnetic needle surrounded by a coil of wire, the plane of the winding being vertical and parallel to the needle (other things being equal) depends; whence it follows, even if the same arrangement of coil and needle were used throughout, that the deflection just mentioned would contain an incidental element; in other words, that it depends upon the means which have been adopted to effect the connection between the equipotentials p and q.

Returning to the problem in hand, it will be found that the mere measurement of deflections would be of but little avail. An effort must be made to determine the values of p and q at the points tapped by the ends of a wire. These quantities, moreover, are particularly significant, inasmuch as the potential at any given point in the vicinity of the ore-body depends, principally, upon the nature and distribution of the electrically active ore-matter, and of the rock-surrounding it, or wholly on conditions fixed by nature. Hence, instead of seeking for the ore-body itself, an attempt will be made to add to

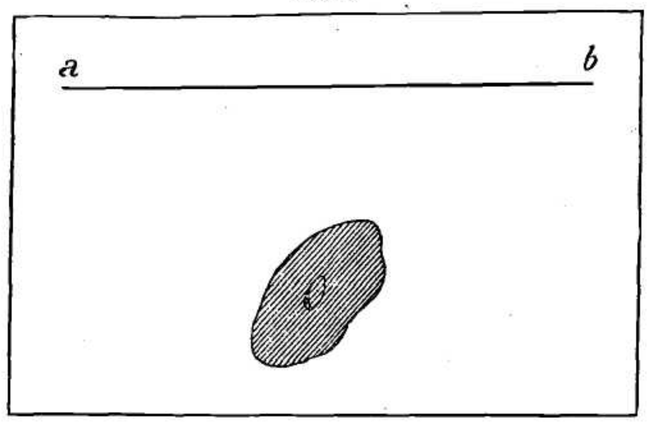
FIG. 1.



the few clews available to the prospector, by investigating some characteristic variation of the potential at consecutive, similarly disposed points, as indicating proximity to it. But what has been said of p and q applies equally well to p—q, which latter quantity is, moreover, easily measurable, either directly (electrometrically, or by certain galvanometric methods) or indirectly, by the determination of the magnitude of deflection of the needle described above, under *known* conditions. p—q is technically called electromotive force.

To an observer, the equipotentials are accessible for measurement either on the surface or in those places where drifts penetrate into them. Let a, *v, u,* Fig. 1, be a line lying either upon or within the surface of the earth. Suppose the electromotive forces be measured between a point *a,* and consecutive points ß, *y, ?, ?, ?,* . . . . *?, T, U,* . . . , taken at convenient, approximately equal distances apart. The points ?, v, ?, ... are supposed to be near the ore-body, whereas *a, ß, y,* . . . . *?, T, u,* are remote from it. As I shall frequently have to refer to the point *a* in contradistinction to the remaining points ,ß, y, ?, ... ?, *T*, *u,* it will be well to refer to the former under the name of *permanent contact (P.C),* while to any of the others, the name *temporary contact (T.C.),* will be applied. Then the electromotive force (?) between the permanent and any temporary contact . in general, will vary with the distance between these points. Supposing this distance to increase from zero (in which case the permanent and temporary contacts coincide) to the value it has at any remote point, u, then as a field of electrical activity is encountered in the neighborhood of ?, *v, ?*, the electromotive force, regarded as a function of distance, must pass through a single maximum or a minimum, or a number of them. It is, therefore, toward a characteristic variation of this kind, that we must look in endeavoring to define a position of greatest proximity to the ore-body. Analogously, though less generally, we may state that the increment of potential due to a given increment of distance will increase as we approach

FIG. 2.



the ore-body. This is probably the idea which Reich had in mind, and to which he must have come had he followed his line of argument into its consequences.

I will add here that local circumstances did not permit me to pass linearly *through* an ore-region. I had to content myself with a progress from the latter into barren rock.

The following analogy will give to this topic all desirable perspicuity. Let *ab* represent the surface of the earth. Let *0* be an area (body in section) of constant high temperature beneath it. Suppose

this body to have been in place for an indefinite period of time, so that the thermal distribution has become stationary. Let the problem be that of finding the body from observations made at the surface.

The mode of operation to be adopted is sufficiently obvious. Commence at some point *a* and take earth-temperatures at a sufficient number of points along a line *ab* until some point *b* is reached. If we plot the distances traveled over as abscissæ, and the corresponding values of earth-temperature as ordinates, we shall obtain a curve showing a maximum over the hot body *0*.

Or more generally: Let the given area of the earth's surface under which the ore-body is supposed to lie, be surveyed thermally. At each point of this surface (supposed for convenience to be level or horizontal) let an ordinate be erected of a length proportional to the temperature at that point. The upper ends of these ordinates will then make up a second (imaginary) surface, coextensive with the first, and expressing the thermal distribution over the area surveyed. Then it is obvious that the presence and position of **the** hot body will be indicated by a *hillock* in the imaginary thermal surface, and that a vertical let fall from the summit of the same must pierce the body.

To plot the contours of this imaginary surface topographically, we would trace the horizontal projection of its intersection with a series of horizontal planes having a fixed distance apart. If we desire to exhibit it thermally, we consider its intersection with a series of iso-thermals having a fixed interval of temperature apart. If, finally, the body were an electrically active ore-deposit, an analogous surface would express the *electrical state* at each point of the territory electrically surveyed. To exhibit this in detail as before, we make use of a series of equipotentials having a fixed difference of potential apart. In short, replace temperature by potential, isothermal by equipotential, and the thermal method will apply to the latter instance at once, only that in the case of electrical excitation we have to do with circumstances vastly more complex; with a body, as it were, in part hot and in part cold, or, we may say, a body over which heat is irregularly distributed.

The remarks just made with reference to the surface of the earth, are true also for any imaginary line or any imaginary plane lying in it, and sufficiently near the hot body. To make the case general, however, we should have to investigate the isothermals as themselves surfaces, in their actual position and contour. In the case of the hot body, for instance, these surfaces would at first completely envelop it, beginning with the surface of the body itself; subsequent ones would intersect the surface, and finally they would merge into the normal isothermals of the earth. From a similar point of view do we regard, in the case of a more detailed study, the equipotentials surrounding and intersecting an electrically active ore-body.

Now, practically, the normal isothermals are planes, parallel to the surface of the earth. It is not without propriety, therefore, that we may call that basin-shaped region, within which the iso-thernials are distorted in such a way as finally to envelop the hot body, a region of thermal activity or disturbance. The thermometric measurements discussed, enable us to discover the position of the hot body readily, in so far as we have practically increased its actual size to that of the region of sensible thermal disturbance. The analogous remark with reference to the electrically active ore-body is this: an electrical survey offers facilities for the exploitation of mines by *virtually increasing the actual size of the ore-body, to the field of sensible electrical excitation,*— more accurately, by increasing the actual size of the ore-body by the field of electrical excitation not in coincidence with it.

EXPERIMENTS MADE IN SOME OF THE MINES OF THE COMSTOCK.

Experiments were commenced in the Consolidated Virginia and California and the Ophir Mines, the line at times extending into Union and Mexican ground.

From the work of the earlier investigation, I was naturally led to expect currents due to electromotive forces of considerable magnitude, and as a consequence was satisfied with a method of obtaining contact with the vein, in which the electromotive force due to the terminals alone was not greater than a few hundredths of a volt. Bright steel gads, to the tops of which pieces of thick copper wire had been firmly fastened, were especially convenient for this purpose, as they could be expeditiously driven into the vein or again withdrawn from it. These gads were from 8 to 10 inches long and about 1 inch in diameter at the head, from which they tapered gradually to a point. As it would repeatedly be necessary to use them in places where the earth was naturally moist, the question arose whether it might not be desirable in all the experiments to moisten the rock around the gads at once. Accordingly, two sets of experiments, the results of which are contained in Tables I. and II., were made, the former above the surface, the latter below.

TABLE I.—*Experiments made on the South side of Bullion Bovine.*

(Gads driven into quartz seams between walls of diorite, about 10 feet apart. Seams naturally somewhat moist.)

Gads dry.					Gads wet.				
No.	Position of the gads.	W.	ε.	Direction of the current.	No.	Position of the gads.	W.	ε.	Direction of the current.
1	I, II	7,600	0.03	+	1	II, I	1,560	0.01	+
2	II, I	6,300	0.09	+	2	I, II	1,260	0.02	+
3	I, II	4,300	0.01	—	3	II, I	1,280	0.02	+
4	II, I	4,500	0.06	+	4	I, II	1,200	0.01	+
5	I, II	3,700	0.00	—	5	II, I	1,210	0.01	—
6	II, I	3,400	0.01	+	6	I, II	1,200	0.01	—
7	I, II	3,200	0.00	+	7	II, I	1,230	0.01	+
					8	I, II	1,240	0.01	—
					9	II, I	1,240	0.04	+

TABLE II.—*Experiments made in the Consolidated Virginia and California Mines,* 1750 *level.*

(Gads driven into rock, as free from mineral matter as possible, about 8 feet apart.)

Gads dry.					Gads wet.					Date.
No.	Position of the gads.	W.	ε.	Direction of the current.	No.	Position of the gads.	W.	ε.	Direction of the current.	
1	II, I	6,000	0.04	+	1	II, I	550	0.03	—	Sept. 24, 1880.
2	I, II	3,700	0.04	+	2	I, II	500	0.03	—	Sept. 24, 1880.
3	II, I	2,800	0.02	+	3	II, I	450	0.01	—	Sept. 24, 1880.
4	I, II	2,200	0.02	+	4	I, II	400	0.02	—	Sept. 24, 1880.
5	II, I	1,870	0.02	—	5	II, I	380	0.01	—	Sept. 24, 1880.
6	I, II	1,380	0.01	+	6	II, I	390	0.01	+	Sept. 25, 1880.
7	II, I	1,030	0.03	+	7	I, II	270	0.03	+	Sept. 25, 1880.
8	I, II	1,060	0.01	—	8	II, I	280	0.01	+	Sept. 25, 1880.
					9	I, II	260	0.03	—	Sept. 25, 1880.
					10	II, I	270	0.01	—	Sept. 25, 1880.

Two suitable positions in rock free from mineral* matter having been selected, the gads were driven and the circuit completed.

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* See note, page 422.

Measurements of resistance and electromotive force were then made. The gads were now exchanged and the measurements repeated, and so on. The relative position of the gads to an observer facing them is indicated in the second column of the tables. Resistance (W) in ohms and electromotive force (E) in volts, are given in the third and fourth columns, respectively. The last column shows the direction of the current, arbitrarily called " + " when flowing in one way, and " — " when flowing in the opposite way.

The results are highly in favor of wet gads. In this case a very marked diminution of resistance is effected without increasing the values of e. The direction in which e acts follows no observable law, probably being conditioned by the electrical difference of the gads and by effects of polarization due to the introduction of a Daniell.

TABLE III.

(Plugs about 10 feet apart in moist clay seams, repeatedly exchanged as indicated.)

Copper plugs, wet.			Zinc plugs, wet.		
No.	Position of plugs.	ε.	No.	Position of plugs.	ε.
1	I, II	+0.02	1	I, II	+0.02
2	II, I	+0.02	2	II, I	+0.02
3	I, II	+0.01	3	I, II	+0.03
4	II, I	+0.02	4	II, I	+0.01
5	I, II	+0.02	5	I, II	—0.01
6	II, I	+0.02	6	II, I	—0.01
7	I, II	+0.01	7	I, II	+0.00
8	II, I	+0.02	8	II, I	+0.01
9	I, II	+0.01	9	I, II	+0.01
10	II, I	+0.02	10	I, II	+0.00

Analogous experiments were also made with copper and zinc. These metals were used in the form of strips cut from sheets. Each strip was bent around the small end of a slightly conical stick of wood about one foot in length. The plug was then firmly driven into a hole previously drilled for the purpose, in such a way as to force the metal into thorough contact with the rock. Table III. gives the results, the notation being the same as that used in Table I.

Steel plugs are therefore not greatly inferior to those of copper or zinc in cases where a few hundredths of a volt are believed to be of minor importance; whereas, on the other hand, their use for the purpose in view is attended with much convenience. It was found, however, that great care had to be taken in keeping them bright, as otherwise the electrical difference between the gads themselves was apt to rise to many times the value given above. It was also necessary to maintain a thorough contact between the ends of the metallic circuit and the gads.

Great difficulty was encountered in avoiding leaks in the copper wire connecting the plugs with the galvanometer. At first, wire covered with a double thickness of cotton and waxed was employed, but proved to be wholly inadequate. Even gutta-percha wire scarcely offered as complete an insulation as was desired in the hot and damp atmosphere of the Comstock, when laid in long lines in the ordinary manner. After testing a number of devices, it was finally found sufficient to *suspend* the wire from silk or waxed cotton threads, care being taken to prevent it from anywhere touching either rock or timbers. This plan of swinging the line was adhered to throughout, in spite of the loss of time frequently occasioned thereby. In short, the rule was finally adopted of arranging all the connections just as though the experiments contemplated were to be made with frictional electricity.

The galvanometer used in these experiments, was an ordinary instrument with an astatic needle, capable of measuring intensities as small as 0.0001 in Weber's electromagnetic scale *(mg. mm. see.)* with certainty. Readings were made directly, the needle swinging over a graduated arc.

For the measurement of electromotive forces, a method of compensation was first employed. But in the course of the investigation it was found absolutely necessary to abandon all complications and to reduce the method of research to the utmost simplicity. This will be evident to the reader when he remembers that the heat of the mines is such as to cause profuse perspiration, and make the body of the operator a conductor; that it was desirable to make the first observations near or on the vein—hence in the busiest part of the mine—so that expeditious manipulation was extremely important; that, finally, the time during which exposure to high temperatures can be endured with safety is itself necessarily limited. A simple method, analogous to one of consecutive substitution of two elements in the same circuit of large resistance, was therefore adopted. If e and E denote the lode electromotive force and the electromotive force of a normal element, respectively, i and I the intensities due to the action of e and $E \pm e$ in the same circuit, we shall have, approximately,*

$$\frac{e}{E \pm e} = \frac{i}{I}, \text{ or } e = E \frac{i}{I \mp i}.$$

Intensities were measured by the aid of the galvanometer above described, the instrument having been carefully calibrated at the outstart—an operation which was frequently repeated during the course of the experiments, i and I could both be determined in the same circuit without inserting auxiliary resistances.

By way of example, some of the results obtained in the mines of the Comstock lode will now be cited. The plan has been indicated in a foregoing paragraph. It will be remembered that a permanent contact placed conveniently in one end of the network of drifts, is successively connected with points in positions of sufficient interest to justify measurement. In the tables, unless otherwise stated, P. *C.* is to be understood as coinciding with point I. The second column contains the distance, in feet, of the points tapped below the level of the mouth of the shaft as a datum. "Distance" and "bearing" refer to the imaginary lines connecting P. C. (I) with the remaining points of the series. An exception is, however, made in Table VI., where the data contained in corresponding columns give the horizontal distance and bearing of the lines joining consecutive points. e, the lode electromotive force, is expressed in volts, and is taken as positive when it acts in the direction *P. C.*—>. Earth—> *T. C.*

From a comparison of Tables I. and II. with Tables IV., V. and VI., it appears at once that the electromotive forces due purely to chemical difference and polarization of the terminals are of the same order as the data expressing the electric activity of the Lode. The latter, therefore, can serve no other purpose than that of affording information as to the magnitude of the forces to be determined. To assure myself as to the certainty of this conclusion, I made a measurement of the electromotive force (E) obtained by using terminals

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* Approximately, because, in the case when the lode electromotive force acts alone, we have not a true circuit, in the ordinary sense. Between the holes, both in the earth and in the wire, the direction of the current is the same. But since the resistance of the rock, passing from the hole into the earth, diminishes rapidly (see page 469), the former may be considered, with a degree of accuracy sufficient for our purpose, as acting through the same resistance as does the normal element, subsequently inserted.

TABLE IV.—*Experiments made in the Ophir Mine.*

(Steel gads.)

No.	Level. Feet.	Points.	Distance.	Bearing.	*l.*	Remarks.
1	2,000	I	0	....	+0.00	In quartz seam; barren.
2	2,000	II	116	S. 55° E.	+0.02	In clay seam.
3	2,000	III	170	S. 20° E.	+0.01	In quartz seam: old stope; low-grade ore.
4	2,000	IV	415	S. 42° E.	+0.02	In quartz seam; new stope; ore.
5	2,000	III, IV	260	S. 55° E.	+0.01	
6	2,300	I	0	....	......	In clay seam.
7	2,300	II	230	N. 19° E.	+0.04	In small quartz seam; barren.
8	2,300	III	370	N. 19° E.	+0.01	In small quartz seam; low-grade ore.
9	2,300	IV	415	N. 29° E.	+0.05	" " "
10	2,300	V	470	N. 38° E.	+0.02	In quartzose clay.

TABLE V.—*Experiments in the Consolidated Virginia and California Mines.*

(Steel gads.)

No.	Level. Feet.	Points.	Distance.	Bearing.	*l.*	Remarks.
1	1,750	I	0	Points nearly vertically one above another.	+0.00	All points in the vein; ledge very broad; low-grade ore in quartz gangue.
2	1,750	II	20		+0.09	
3	1,750	III	60		+0.01	
4	1,750	IV	100		+0.08	

TABLE VI.—*Experiments in the Ophir and Mexican mines.*

(Copper terminals.)

No.	Level. Feet.	Points.	Distance.	Bearing.	*l.*	Remarks.
1	2,000	I	0	....	+0.00	In small quartz seam; barren.
2	2,300	II	0	....	+0.02	" " "
3	2,300	III	100	S. 19° W.	+0.03	" " "
4	2,300	IV	100	S. 19° W.	+0.04	" " "
5	2,300	V	100	S. 19° W.	+0.04	In large quartz seam; low-grade ore.
6	2,300	VI	80	N. 29° E.	+0.03	" " "
7	2,300	VII	85	N. 38° E.	+0.04	In quartzose clay.

of copper and zinc conjointly, and found, as a mean of three experi. ments,

$$e = 0.82.$$

In consequence of polarization, the current speedily diminished in strength, so that all the phenomena are identical with those which would be'obtained in the laboratory. The effect of polarization in distorting the true value of the lode currents was frequently noticed but it would be superfluous to repeat these data here.

It is necessary, therefore, in order to obtain satisfactory results, to apply all the refinements that have been developed for problems of this character. In making an attempt of this kind in the mines on the Comstock, however, unusually great difficulties would be encountered. At the outstart, the fact that the observer is compelled to operate with wet hands must be considered as prejudicial to delicate physical experimentation. But there is a more fundamental difficulty.

It will be remembered that the ore of the Comstock lode is argentite accompanied by gold, probably in the metallic state, finely disseminated in quartz. At the time of the experiments the mines, without exception, were working in comparatively barren parts of the vein, so that there was actually more mineral possibly possessing electrical properties (iron pyrites, etc.) in the rocks than ore in the ore-stopes. In such a case the term "ore-body" is scarcely applicable at all.

The result of circumstances of this kind, regarded from an electrical point of view, can be expressed as follows: Either there will be no electric action at all, as we may consider each little granule of ore or pyrite to be surrounded by an insulating envelope of either quartz or country rock—whether the latter be considered as an insulator or an electrolyte is immaterial—or the whole district, vein and rock, is to be regarded as the field of electric action; in which case an equal difficulty occurs, inasmuch as within the limited space open to the observer, the variation of potential will be inappreciable. In short, from the peculiar distribution of mineral matter, electric excitation is not local in comparison with the space accessible for experimentation.

The unusual difficulty with which a correct interpretation of results would be attended, not to mention the loss of time occasioned by the fact that, in consequence of the heat, experimentation cannot be long continued, finally induced me to abandon the matter at the Comstock altogether—at least until definite results could be obtained in a more favorable locality.

EXPERIMENTS MADE AT THE RICHMOND MINE, EUREKA DISTRICT, NEVADA.

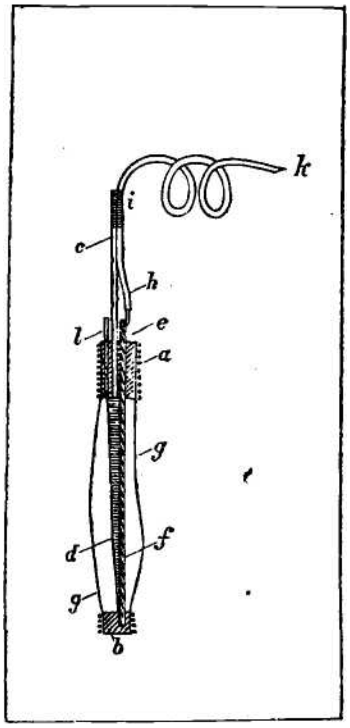
In determining to make the study of local currents a part of the programme of the work to be done under his charge, Mr. Becker had selected both the Comstock lode and the Eureka district as available localities in which to test the applicability of an electrical method as an aid to prospecting. The former is a fissure vein, in which the ore, comparatively free from base material, is scattered irregularly through a quartz gang' e. At Ruby Hill, Eureka, the ore is principally plumbic carbonate and sulphide, and oxide of iron—the whole containing more or less silver and gold—occurring, moreover, in huge, apparently isolated masses in limestone. In most of the cases, fissures containing vein-matter and connecting the chambers have been traced. The facilities offered for the prosecution of the investigation by the Eureka deposits were therefore, to all appearances, unusually great. The immense ore-bodies in sight were furthermore at a mean distance of not more than 400 feet from the surface, and a series of electric surveys could easily be carried out over, through and under them. Finally, it appeared not at all improbable, inasmuch as the ore-bodies in places extend to within 100 feet from the surface, and are in fact, to some extent, above the mean surface of the surrounding country,* that local electrical currents might actually be detected on the surface itself. In consideration of this encouraging prospect, due pains were taken to work up all the experimental details with corresponding care.

Apparatus.—Above all things, it was necessary to devise some method of obtaining electric contact between the ends of the metallic circuit and the rocks, which would be free from the difficulties met with in the Comstock. Metallic plates, etc., used *alone,* are objectionable (see page 468); but it is clear that through the intervention of a suitable liquid, effeets.of polarization, etc., can be avoided. The following contrivance, based on the well-known excellence of amalgamated zinc in a zinc sulphate solution, for the purpose in question, was finally adopted.

* Being in Ruby Hill, an elevation of some hundreds of feet above the extensive plain partially surrounding it.

Into a large cork a, 1 to 1½ inches in diameter, Fig. 3 (longitudinal section), is inserted a strip of amalgamated zinc, *ef,* about one-half inch broad, to the top of which, *e,* a gutta-percha covered copper wire, *hik,* is soldered. Throughout the greater part of its length it

FIG. 3.



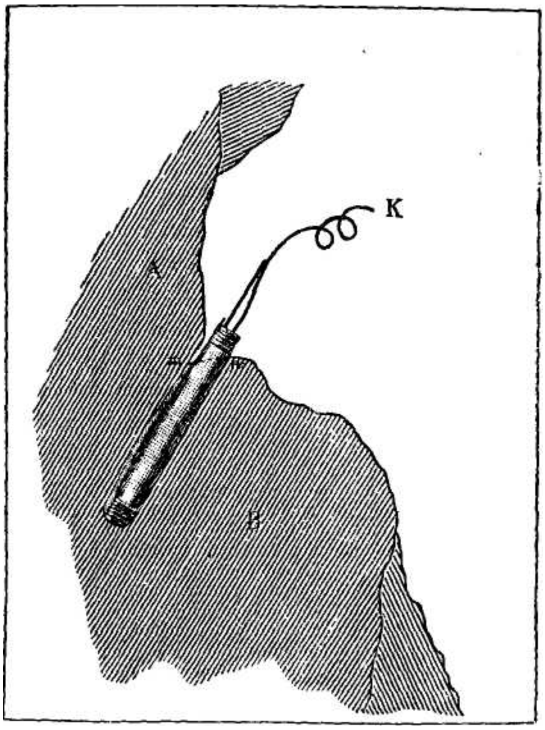
Terminal, longitudinal section.

rests against a stick of wood, *cd,* cylindrical above at *c,* which end is to be thrust through a perforation in the cork *a,* but wedge-shaped below, *d.* At *i* the wire and stick are firmly tied together. A smaller cork, *b,* secures the lower end of both zinc and stick. The whole is surrounded by a piece of beef-gut, *gg* (free from salt), tied to the corks *a* and *b,* as shown in the cut.

Into the bag (6 to 10 inches long) thus formed is poured a solution of zinc sulphate, the wooden plug *I* being for this purpose removed and a small funnel inserted. On replacing the plug the terminal is ready for use. The object of the stick is to obviate accidents due to breakage of the zinc, this material becoming very brittle by amalgamation.

Fig. 4 represents the terminal in place. A suitable hole, 6 to 9 inches deep, and 1 to 1½ inches in diameter, is drilled into the rock or vein,.at an angle of about 30° with the vertical, and filled with a solution of sodic sulphate or water; whereupon the bag is introduced as shown in the figure. The dotted line mn indicates the level of the outer liquid.* Solution of sodic sulphate was at first used, because it increases the conductivity and is not acted upon

FIG. 4.



Terminal in position.

appreciably by the rock (limestone). It was found, however, that ordinary water, which had previously been placed in contact with zinc for some time, so as to precipitate all dissolved matter which might act upon it, was far preferable (see page 467). When not in use, the bags were preserved in a glass vessel containing a zinc sul-

* The solution poured into the hole will be referred to throughout this description as the "outer liquid."

phate solution; during the observations, however, they were transported from place to place in jars containing water.*

The electromotive force between two similar bags placed in the same external liquid was seldom found to be greater than 0.005 volt, usually much less and tolerably constant (see page 472); whereas the electromotive force of polarization, due to the action of a Daniel] under circumstances actually met with in the mines, a number of data being in hand, was in no case as large as 0.001 volt, in the experiments cited falling below this limit. Out of curiosity, the bags in a particular instance were filled with water instead of zinc sulphate, when an electromotive force of polarization of 0.020 volt was obtained.

Gutta-percha-covered wire No. 19, of excellent quality (Tillotson & Co., New York), was used almost exclusively, the whole circuit, nevertheless, being suspended in air from threads, as in the Corn-stock. In the long circuit on the 600-foot level it was, however, necessary to employ cotton-covered wire for part of the liue, the supply of the other being insufficient. This could be done without disadvantage, as follows: A hollow cylinder of gutta-percha, stripped from the end of wire covered with this substance, was bent in the form of a loop, Fig. 5, and kept bent in this way by a thread passed through its interior and tied. The cotton-covered wire used *(a b* in 6gure) was passed through this loop, suspended by the other end of the thread.

A case in which gutta-percha-covered wire trailed on the ground a distauce of about 1000 feet, was made the subject of measurement. The leak was quite perceptible; the insulation offered, however, was about 1,000,000 ohms.

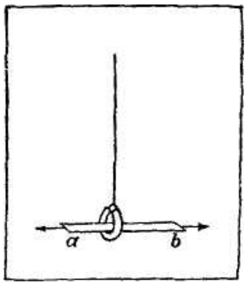
In extending the line from point to point, Reich's plan offers great convenience. For this purpose, the wire is wrapped on a light wooden reel, but in such a way that the inner end also remains accessible. The outer end being in connection with the measuring apparatus, enough wire is uncoiled to reach the desired hole, and a connection (contact-bag) between this and the inner end of the wire is then made. In the damp atmosphere, the reel soon became saturated with moisture, and, in spite of the insulation of the wire, care had to be taken to insulate the reel also.

For the measurement of intensity, I was fortunate in securing a magnificent instrumeut, made for me after the Wiedemann pattern, by

* It was desirable during the observation to have the outside of the bag as free from zinc sulphate solution as possible.

Mr. Wm. Grunow, of New York. This instrument is exceedingly convenient for the purpose, as by an adjustment of the coils, the sensitiveness can be varied over a very wide range. Readings were made with telescope, mirror, and scale. In the adjustment adopted, currents as small as $\frac{2}{10^8}$ webers could still be detected with certainty.

FIG. 5.



Method.—The simple method of consecutive substitution for the measurement of electromotive forces$\left(e = E\frac{i}{I \mp i}\right)$ —inasmuch as while there were no reasons for abandoning it there were a great many in its favor—was adopted here, as in the Comstock. The coils of Gru-now's galvanometer could easily be so placed as to enable the observer to measure with sufficient accuracy both the lode-current and that due to the latter and the normal electromotive force conjointly, without making any change at the instrument or inserting auxiliary resistances. By means of an inclosed mercury commutator, the current in the galvanometer could be reversed and the deflection thus doubled. All intensities *(i* and i) were determined as a mean of five consecutive commutations—not that it was desirable or necessary to increase the accuracy by such a process, but because it appeared essential not to hurry the measurements and to test the constancy of the current as appearing in the five data obtained. Errors from condensation of moisture on the commutator, were avoided by excluding the latter entirely from time to time, the measurements being made by simply connecting the wires with clamp-screws.*

As a matter of especial importance, it will be necessary to consider a scheme of operations by which discrepancies, due to extraneous

* The commutator used was made of wood boiled in linseed oil, and supported on three conical feet of wood boiled in wax and resin. The holes, moreover, were coated with a thick layer of wax (see page 481). Whole sets of observations had to be discarded on account of the insufficient insulation of an earlier apparatus.

causes, can be eliminated as completely as possible. In the experiments, the following order of observations was adopted and rigidly adhered to throughout:

1. Measurement of the apparent intensity of the lode current (i').
2. The same, with the terminals exchanged (i'').
3. Measurement of the current produced by the normal element and lode conjointly (I).
4. With the battery left in place, the circuit is broken at the temporary contact; no deflection must ensue (E supposed to be acting *with* the lode electromotive force).

If a mean of the intensities derived from the first and second operations $[i = \frac{1}{2}(i'' + i')]$ e taken, the intensity of the current (i) due to the lode only will be obtained. That due to differences in the amalgamated zincs is thus eliminated. In by far the greater number of experiments three exchanges were made, so that the first and third positions of the terminals were identical. Analogously, then,

$$i = \frac{1}{2}\left(i'' + \frac{i' + i'''}{2}\right).$$

The fourth operation in this scheme insures the perfect insulation of the circuit between the *T.* 6'. and the galvanometer. The part between the latter and P. *C.*—the two being always placed in close proximity, this partial circuit, moreover, remaining fixed—is tested once for all before commencing the experiments.

It is often desirable, before inserting the Daniell, to determine whether the circuit is in order and without a break. This may be easily accomplished by touching with the finger a copper part of it, so that a secondary circuit, *T. C.* wire, galvanometer, wire, body, earth, *T.* C, or P. C. wire . . . . body, earth, P. *C,* is produced, respectively. The electromotive force acting in this case, is that of zinc-copper, but in consequence of the very large resistance of the finger-contact, the current, though distinctly perceptible, is too weak to produce any appreciable polarization.

In spite of all these safeguards, however, a close inspection of the observations still revealed discrepancies which had not been avoided. Accordingly, the method of procedure was still further improved by the following additions: To eliminate as much as possible the effect due to the terminal bags, a variation was introduced, by which the results from different bags could be compared. Four of these, *A, B, C,* and *D,* were generally employed, which, when combined, two and two, in the manner shown in the diagram, gave three separate and distinct, values for the lode electromotive force e. The electromotive force between any two bags, A and B, is represented by $A \mid B$, between A and C by $A \setminus C$, etc.

Holes.	P. C.	T. C.	Electromotive force.	P. C.	T. C.	Electromotive force.	P. C.	T. C.	Electromotive force.
First series, .	A	B	$e \pm A \mid B$	B	A	$e \mp A \mid B$	A	B	$e \pm A \mid B$
Second series,	A	C	$e \pm A \mid C$	C	A	$e \mp A \mid C$	A	C	$e \pm A \mid C$
Third series, .	A	D	$e \pm A \mid D$	D	A	$e \mp A \mid D$	A	D	$e \pm A \mid D$
	Original position.			First exchange.			Second exchange.		

After the second exchange, the bags again have their original position with reference to the holes. The corresponding measurements, therefore, check one another, while from their mean any linear variation of their own electromotive force is eliminated. Each series gives a value for e. With this method of triple measurement, the series was completed by determining all the electromotive forces between P. *C.* and each of the *T. C's,* starting with the one nearest P. C. and ending with the most remote. After this the whole set was again repeated, starting, however, with the extreme *T. C.* and finishing with the one nearest P. *C.* The two sets, therefore, form a symmetrical series, and from the means of all the values corresponding to a particular *T. C,* any change which may have taken place in the hole P. *C.* (see page 471), as well as in the electromotive force of the Daniell, may be regarded as practically eliminated. A comparison of the two sets, moreover, affords a good criterion of the constancy of the currents as well as of the trustworthiness of the results obtained in general.

Besides the electromotive force, the resistance of the different circuits was also measured, being an item of interest. The values usually ranged between 2000 and 3000 ohms, though at times they went as high as 20,000, or as low as 700 ohms. Almost the whole resistance of the circuit is encountered by the current in passing from the wire into the rock, and from the latter back again into the former. In other words, the resistance of the layers of rock immediately surrounding P. *C.* and *T. C.* is so large, that in comparison with it, that of the rest of the circuit (never greater than 20 ohms) can be completely neglected. The total resistance is, therefore, essentially the sum of two terms, corresponding to the holes, respectively. Suppose now, that in a circuit P. *C. (T. C.)* these partial resistances are w and

r, respectively; in a circuit $P.\,C.\ (T.\,C.)'$, w and r' respectively; then it is found, experimentally, that

$$\left.\begin{matrix} w + r = a, \\ w + r' = b, \\ r + r' = c, \end{matrix}\right\}, \text{ whence } (s = a + b + c), \left\{\begin{matrix} r = \frac{s}{2} - b, \\ r' = \frac{s}{2} - a, \\ w = \frac{s}{2} - c. \end{matrix}\right.$$

These points have been described in considerable detail, being of such Importance that without them the results reached would be illusory. I was twice obliged to discard whole sets of experiments because one or the other of the disturbances set forth had found their way into the results in the most insidious manner. It is true that Fox actually used uncovered wire; but it must be remembered that the currents obtained by him were abnormally large. Moreover, I am convinced that the currents found by Fox, when connecting two different points in rock, were entirely due to, and that those of Reich were largely distorted by, discrepancies of the kind discussed in this paragraph.

Relative Position of the Ore-bodies.—Before proceeding further, it will be necessary to give the reader some general notion as to the disposition of the ore-bodies of the' Richmond mine. It will be convenient, and fully sufficient for the present purposes, to consider them with reference to a horizontal and a vertical projection. The former will be given with the different sets of observations which are to follow. For the latter, I am indebted to Mr. R. Rickard, superintendent of the Richmond Mining Company, without whose cordial cooperation it would have been impossible, in the time allotted, to carry out these experiments. To Mr. Rickard are also due the following details and sketch.

In Fig. 6, the horizontals passing across the diagram represent the levels in feet below the shaft-mouth as a datum. Different ore-bodies are differently shaded, the attached numbers depending upon the date of their discovery. The sketch is intended to illustrate the relative positions of the ore-bodies one to another only, as seen from the extreme north.

Chamber No. 11 begins on the 200-foot level and continues to the 500-foot level.

No. 12 is a continuation of No. 11, beginning on the 500-foot level and ending 70 feet below this level.

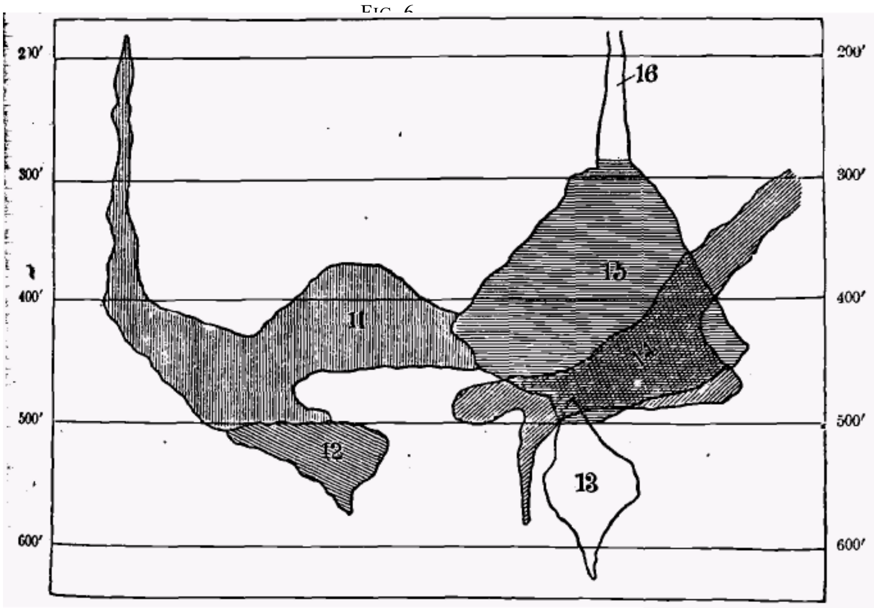
No. 16 commences 50 feet above and runs 70 feet below the 200-fbot level-bottom of present workings.

No. 15 commences on the 300-foot level and continues to the 500-foot level.

No 14 begins 58 feet above the 400-foot level and continues to within 50 feet of the 600-foot level.

No. 13 begins at the 500-foot level and continues 50 feet below the 600-foot level.

FIG. 6



Vertical section through ore-bodies.

Chambers Nos. 13, 14, and 15 are all connected and form one ores body. No. 16 will undoubtedly connect also with these three, so that in fact Nos. 13, 14,15, and 16 are but lobes of one and the same huge deposit.

The greatest horizontal extent of these bodies is between the 400 and 500-foot levels, the plan showing the following dimensions:

N. to S., ...	520 feet.
E. to W., ...	600 feet.

No. 7 extends from the 400-foot level to 50 feet below this level. No. 10 begins 20 feet above and ends 50 feet below the 400-foot level, and is exhausted. No. 13 also is partially exhausted.

East of the clump of ore-bodies of the Richmond Company are those of the Eureka Consolidated Company, which are also of unusually large dimensions, the ore being the same in every respect.

Experiments on the 500 *and* 400 *Levels.*—These series of measurements were made with the intention of observing the variation of potential met with in passing through the ore-body, the line of electric survey beginning and terminating in points as far distant from it as was practicable.

The plan of the position of the drifts on the 500 and 400-foot levels relative to the ore-chambers, so far as is necessary for the present purposes, is given in Fig. 7, on a scale of 1/3000. Starting with the shaft at *m,* the drifts are represented by broad black lines. The main drift on the 400-foot level, passing from a point between VIII. and IX. on the 400-foot level in an approximately semicircular path toward the shaft has, as well as others, been partially or wholly omitted. Instead of giving an outline of the horizontal projection of the ore-bodies themselves, it was thought preferable to represent rather the position and extent of the actual workings. On the map, chamber No. 11 is designated by *ab,* No. 12 by *CD, N*os. 13 and 14 by *rS,* and No. 15 by *tg.* The position of chambers Nos. 7 and 10 is only indicated. Smaller patches of ore also occur at *n,* between the 500 and 600-foot levels, and at *P,* above and below the 500-foot level.

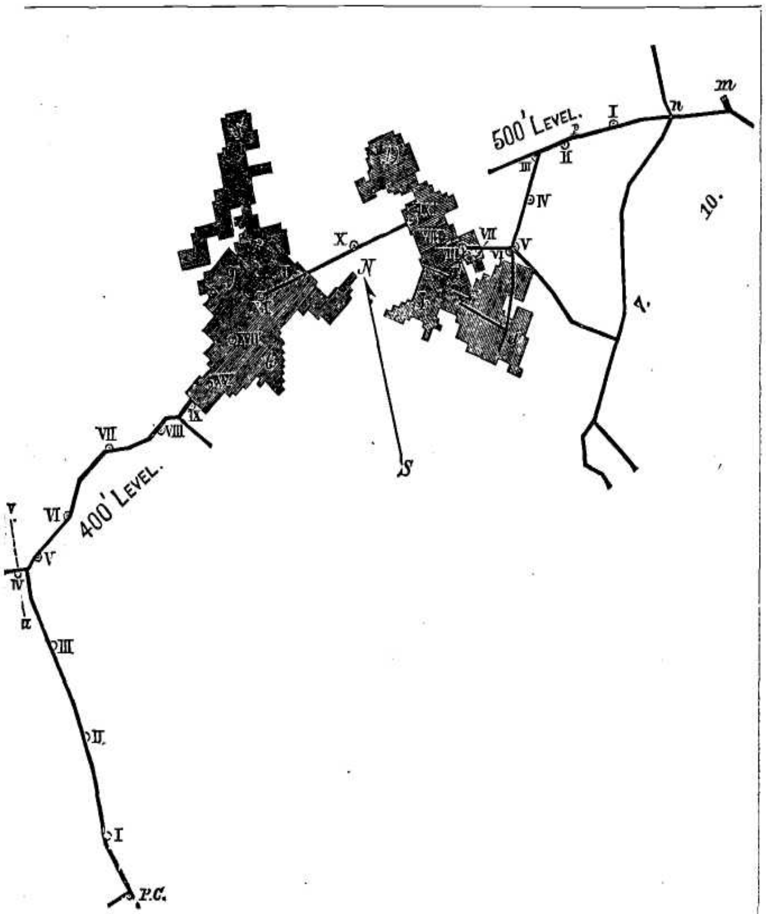
The line *uv,* on the 400-foot level, marks the position of a contact between shale and limestone. It may be, moreover, remarked that the shale of the west country intersects the 400-foot level on a line approximately parallel to the drift between P. *C.* and No. IV.

Unfortunately, local circumstances rendered it absolutely impossible to make this survey in a single continuous series, however desirable such a method of procedure would have been. But this was accomplished indirectly by selecting a permanent contact both on the 400 and on the 500-foot levels, and carrying the two lines of measurement onward to the same intermediate point. The differences of potential thus obtained from two fixed points, respectively, can then be converted by a simple method of reduction into those which would have been obtained had all the electromotive forces been measured from one and the same P. C.

1. On the 500-foot level the permanent contact was placed in chamber No. 12, in calcareous earth stained with iron, its position coinciding nearly with the letter *C* in the plan of this chamber (Fig. 7, *C. D.).* The points selected as *T. C.'s* are designated on the map by small circles, to which Roman numerals are annexed, and extend from I.,

near the shaft *m* on the 500-foot level, in a more or less broken line to *XV.,* in chamber No. 15, about 30 feet below the 400-foot level. The following table will describe them more completely. Column 2, in Table VII., contains the points, some of which, to prevent confusion, were omitted on the map; column 3, the depth of each below the mouth of the shaft, taken as zero. . " Distance " refers to

FIG. 7.



Plan of the 400' and 500' levels. Scale 1/3000

the length of the lines joining consecutive points for which data are given.* The figures under " bearing" are to be similarly under-

* The points for which no data are given are distributed through various parts of chambers 12 and 15, in positions for which it was difficult to make measurements.

stood. (S. 81° W. refers to the line I. III.; S. 26° W., to III V.; N. 67° W., to V. IX., etc.) It appeared unnecessary to give more than the bearings of the main lines of direction on which the points approximately lie. The figures included under " resistances " are the means of two determinations of this quantity made for each of the points. They express the sum of the resistances of the rock surrounding *P. C.* and the *T. C.* specified. The original results were always greater than those made at a subsequent time; this from the fact that the rock in the neighborhood of *P. C.* and *T. C.* became, during the progress of the experiments, gradually more saturated with moisture.

TABLE VII.

No.	Points.	Level. Feet.	Distance. Feet.	Bearing.	Resistance. Ohms.	Remarks.
1	P. C.	500	......	....	......	Ferruginous, calcareous earth, in chamber 12.
2	I	500	0	Origin.	3,620	Hard, fissured limestone.
3	II	500	84	....	1,480	Limestone, compact, porous, moist.
4	III	500	39	S. 81° W.	1,550	" " "
5	IV	500	55	....	1,660	" " "
6	V	500	69	S. 26° W.	1,670	" " "
7	VI	500	13	....	970	Limestone, very porous, near contact of chamber 12.
8	VII	500	47	....	2,090	Ferruginous earth.
9	VII'	500	......	....	850	Red ocher, near bunch of ore, . } Chamber No. 12.
10	VIII	500	......	....	1,520	Ferruginous earth, ... }
11	IX	500	101	N. 67° W.	1,590	Pocket of lead carbonate ore in limestone.
12	X	500	101	....	5,560	Hard, impervious limestone and calcspar.
13	XI	500	94	....	3,720	Hard, solid limestone.
14	XI'	490	......	....	2,240	Ferruginous earth, with galena, ... } Chamber No. 15.
15	XII	480	88	S. 80° W.	3,590	Black iron ore, loose, dry, ... }
16	XIII	460	......	....	2,620	Ferruginous earth, with galena, ... }
17	XIV	450	......	....	1,990	Ferruginous earth, without galena, ... }
18	XVI	450	......	....	1,140	Large breast of lead carbonate ore, ... }
19	XVII	440	......	....	6,260	Ferruginous earth, very dry, ... }
20	XV	430	123	S. 37° W.	990	Large breast of lead carbonate ore, ... }

The results of the measurements of electromotive force between *P. C.* in chamber 12 and the consecutive *T. C.'s* are given in Table VIII. The general method of obtaining them has already been described (see page 440). Intensities *(i)* are given in absolute electromagnetic units *(C. G. S.);* electromotive forces (e) in volts, and are arbitrarily considered positive when the potential of *T. C.* is the greater, or when the lode current flows

$$T.\ C. \longrightarrow \left\{ \begin{matrix} wire \\ earth \end{matrix} \right\} \longrightarrow P.\ C.$$

It will be remembered that, throughout, four terminal bags, *A,B, C, D,* were used. The results obtained with AB are given in Series *I.,* where, moreover, *i'* is the intensity observed with the bags *A* and *B* in any particular position (say *A* in hole *P. C,* and *B* in *T. C)* *i"*, the intensity observed when the bags are *exchanged {B* in hole

TABLE VIII.

First Series.

No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$	No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$
1	I	+ 16	− 10	+ 13	+ 1	11	X	± 0	− 25	......	− 7
2	II	+ 41	− 26	......	+ 1	12	XI	− 35	+ 5	......	− 6
3	III	− 61	+ 56	......	± 0	13	XI′	+ 41	− 46	......	± 0
4	IV	+ 46	− 41	......	± 0	14	XII	− 49	+ 5	......	− 8
5	V	− 33	+ 71	− 30	+ 3	15	XIII	− 25	− 25	......	− 6
6	VI	+ 89	− 66	+ 102	+ 2	16	XIV	− 5	− 12	......	− 2
7	VII	+ 59	− 39	+ 56	+ 2	17	XVI	+ 35	+ 10	......	+ 3
8	VII′	+ 7	− 57	+ 10	− 2	18	XVII	− 0	− 3	......	− 1
9	VIII	+ 35	− 41	......	± 0	19	XV	+ 112	+ 95	+ 121	+ 11
10	IX	− 117	− 41	......	− 13						

Second Series.

No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$	No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$
1	I	+ 8	− 12	......	− 1	11	X	+ 2	− 28	......	− 7
2	II	+ 30	− 26	......	± 0	12	XI	− 38	+ 25	......	− 6
3	III	− 53	+ 33	......	− 2	13	XI′	+ 49	− 56	......	− 1
4	IV	+ 39	− 46	......	− 1	14	XII	− 43	+ 12	......	− 6
5	V	− 31	+ 61	− 33	+ 2	15	XIII	− 16	− 33	......	− 6
6	VI	+ 71	− 33	+ 102	+ 3	16	XIV	− 13	± 0	......	− 1
7	VII	+ 39	− 26	+ 43	+ 2	17	XVI	+ 53	− 10	......	+ 2
8	VII′	± 0	− 57	− 5	− 3	18	XVII	− 3	− 2	......	− 1
9	VIII	+ 36	− 49	......	− 1	19	XV	+ 82	+ 115	+ 110	+ 11
10	IX	− 120	− 38	......	− 13						

Third Series.

No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$	No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$
1	I	+ 12	− 13	+ 15	± 0	11	X	− 5	− 25	......	− 8
2	II	+ 38	− 34	......	± 0	12	XI	− 26	− 8	......	− 6
3	III	− 33	+ 33	......	± 0	13	XI′	+ 44	− 49	......	− 0
4	IV	+ 33	− 31	......	± 0	14	XII	− 51	+ 11	......	− 7
5	V	− 11	+ 46	− 11	+ 3	15	XIII	− 20	− 28	......	− 6
6	VI	+ 97	− 62	+ 105	+ 2	16	XIV	− 8	− 11	......	− 2
7	VII	+ 54	− 34	+ 57	+ 2	17	XVI	+ 36	+ 10	......	+ 3
8	VII′	+ 10	− 59	+ 5	− 2	18	XVII	− 0	− 3	......	− 1
9	VIII	− 26	− 46	......	− 1	19	XV	+ 103	+ 118	+ 99	+ 11
10	IX	− 95	− 46	......	− 11						

Fourth Series.

No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$	No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$
1	I	+ 7	± 0	......	+ 1	9	IX	− 84	− 57	......	− 11
2	II	− 26	+ 25	......	± 0	10	X	− 20	− 31	......	− 14
3	III	+ 8	− 8	......	± 0	11	XI	− 31	− 16	......	− 9
4	IV	+ 16	− 16	......	± 0	12	XI′	+ 2	− 11	......	− 1
5	V	+ 57	+ 28	......	+ 7	13	XII	− 25	− 15	......	− 7
6	VI	+ 116	+ 66	+ 79	+ 8	14	XIII	− 31	− 30	......	− 8
7	VII′	+ 33	+ 16	......	+ 2	15	XIV	− 28	− 0	......	− 3
8	VIII	+ 8	+ 15	......	+ 2						

Fifth Series.

No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$	No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$
1	I	+ 7	− 7	......	± 0	8	IX	− 79	− 61	......	− 11
2	II	− 23	+ 20	......	± 0	9	X	− 21	− 31	......	− 14
3	III	+ 16	− 13	......	± 0	10	XI	− 31	− 18	......	− 9
4	V	+ 56	+ 23	......	+ 6	11	XI′	+ 2	− 18	......	− 2
5	VI	+ 105	+ 51	+ 84	+ 7	12	XII	− 20	− 18	......	− 7
6	VII′	+ 36	+ 13	......	+ 2	13	XIII	− 38	− 20	......	− 7
7	VIII	+ 0	+ 10	......	+ 1	14	XIV	− 16	− 15	......	− 3

Sixth Series.

No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$	No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$
1	I	+ 0	+ 8	......	− 1	8	IX	− 72	− 72	......	− 11
2	II	− 25	+ 26	......	± 0	9	X	− 25	− 31	......	− 15
3	III	+ 26	− 26	......	± 0	10	XI	− 26	− 20	......	− 8
4	V	+ 56	+ 20	......	+ 6	11	XI′	+ 3	− 23	......	− 2
5	VI	+ 102	+ 51	+ 90	+ 7	12	XII	− 26	− 16	......	− 7
6	VII′	+ 34	+ 21	......	+ 2	13	XIII	− 26	− 25	......	− 7
7	VIII	+ 15	+ 18	......	+ 2	14	XIV	− 5	− 25	......	− 3

P. C, and *A* in hole *T. C);* finally, *i"*, the observed intensity when the bags again have their original position. *e* is the corrected lode electromotive force between P. *C.* and the *T. C.* specified. Series *II,* contains the corresponding results with the bags *A* and *C;* Series *III.*, with *A* and *D.*

Finally, Series I., *II.* and *III.* were obtained in surveying from point *I.* to *XV.*, series *IV.*, *V.* and VI., on the other hand, on returning from *XV.* back to *I.*

In these experiments, a solution of sodic sulphate was used as an outer liquid.

TABLE IX.

No.	Points.	Level. Feet.	Distance. Feet.	Bearing.	Resistance. Ohms.	Remarks.
1	P. C.	400	0	Origin.	......	Red clay selvage.
2	I	400	100	....	2,890	Black, fissured limestone, dry.
3	II	400	140	....	1,040	White calcareous pulp, very moist.
4	III	400	139	....	1,820	Gray limestone, compact, dry.
5	IV	400	85	N. 7° W.	710	Shale, very moist.
6	V	400	37	....	2,050	Gray, fissured limestone, dry.
7	VI	400	88	....	1,760	Limestone, compact.
8	VII	400	94	N. 49° E.	2,740	" "
9	VIII	400	89	....	1,280	Quartzite, very wet.
10	IX	400	68	....	1,820	Bunch of lead carbonate ore in limestone.
11	X	430	37	N. 71° E.	1,030	Large breast of lead carbonate ore, chamber 15.

2. On the 400-foot level, the permanent contact was placed in a ferruginous clay-seam, toward the southern end of the drift, and observations were made in a northerly direction from this point. The temporary contacts have been designated on the map, Fig. 7, as in the previous case. Point X., of the present survey, coincides in position with XV. of the line on the 500-foot level. The following table (IX.), in which full statements of the position, etc., of the points are contained, will be intelligible without further description. As before, the bearing of the main linear loci only have been determined, the data referring to the lines joining the consecutive points, for which figures are given. Resistances, as above, are mean values for the circuits P. C., *earth, T. C, wire,* P. *C,* and are essentially of the resistances of the layers of rock surrounding *P. C.* and *T. C.* . The results of the measurements of electromotive forces between P. *C.* and I.—X. are contained in Table X. They are given in a

way entirely analogous to that adopted for the 500-foot level, and no further explanation is necessary. Intensities are expressed in electromagnetic measure *(C. G. S.),* electromotive forces in *volts.* Water was used as an outer liquid.

No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$	No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$
					First Series.						
1	I	+ 22	+ 41	+ 35	+ 11	6	VI	+ 125	+ 93	+ 116	+ 19
2*	II	− 7	− 52	− 67	− 62	7	VII	+ 56	+ 50	......	+ 15
3	III	+ 54	+ 52	+ 61	+ 10	8	VIII	+ 34	+ 43	± 0	+ 4
4	IV	− 49	− 145	− 45	− 7	9	IX	+ 4	− 6	......	± 0
5	V	+ 0	+ 2	+ 9	+ 1	10	X	− 30	− 56	− 21	− 4
					Second Series.						
1	I	+ 22	+ 39	+ 34	+ 10	6	VI	+ 118	+ 88	+ 116	+ 19
2*	II	− 26	− 56	− 73	− 62	7	VII	+ 60	+ 45	......	+ 15
3	III	+ 65	+ 43	+ 63	+ 10	8	VIII	+ 15	+ 37	+ 4	+ 3
4	IV	− 71	− 130	− 67	− 7	9	IX	− 4	+ 9	− 6	± 0
5	V	+ 8	± 0	+ 13	+ 1	10	X	− 63	− 62	− 37	− 6
					Third Series.						
1	I	+ 87	+ 30	+ 50	+ 11	6	VI	+ 138	+ 82	+ 140	+ 21
2*	II	− 9	− 47	− 26	− 37	7	VII	+ 67	+ 37	......	+ 15
3	III	+ 77	+ 30	+ 80	+ 10	8	VIII	+ 4	+ 28	+ 6	+ 2
4	IV	− 73	− 160	− 52	− 8	9	IX	+ 4	− 6	+ 13	± 0
5	V	+ 11	− 7	+ 22	+ 1	10	X	− 13	− 73	− 0	− 4
					Fourth Series.						
1	I	+ 41	+ 22	+ 43	+ 9	6	VI	+ 140	+ 88	+ 142	+ 20
2	II	− 76	− 142	− 88	− 13	7	VII	+ 76	+ 58	+ 84	+ 19
3	III	+ 86	+ 56	+ 82	+ 13	8	VIII	+ 52	+ 13	+ 45	+ 4
4*	IV	− 118	− 130	− 120	− 183	− 10	9	IX	± 0	− 21	− 2	− 2
5	V	+ 35	− 15	+ 34	+ 1	10	X	− 30	− 56	− 24	− 5
					Fifth Series.						
1	I	+ 39	+ 28	+ 41	+ 9	6	VI	+ 108	+ 108	+ 104	+ 19
2	II	− 91	− 130	− 112	− 13	7	VII	+ 60	+ 71	+ 62	+ 18
3	III	+ 87	+ 62	+ 82	+ 14	8	VIII	+ 19	+ 41	+ 4	+ 3
4*	IV	− 153	− 45	− 49	− 220	− 8	9	IX	− 15	− 9	− 22	− 2
5	V	+ 7	+ 6	+ 0	+ 1	10	X	− 52	− 34	− 50	− 5
					Sixth Series.						
1	I	+ 45	+ 22	+ 49	+ 9	6	VI	+ 134	+ 78	+ 121	+ 18
2	II	− 67	− 130	− 80	− 12	7	VII	+ 80	+ 45	+ 76	+ 17
3	III	+ 82	+ 50	+ 82	+ 13	8	VIII	+ 58	+ 4	+ 45	+ 3
4*	IV	− 91	− 108	− 112	− 168	− 9	9	IX	+ 7	− 28	+ 4	− 2
5	V	+ 24	− 15	+ 21	+ 1	10	X	− 13	− 67	− 11	− 4

The values for electromotive force contained in Tables VIII. and X. are now to be referred to one and the same origin. For this purpose it will be convenient to select a point having an extreme

*In these cases three consecutive exchanges of the terminals were made, their positions in Nos. 1 and 3 and in Nos. 2 and 4 being the same.

position. Point I., 500-foot level, is of this kind. As there is no means of assigning an absolute value to the potential of this point, it may be arbitrarily called *zero,* in which case the electromotive force between it and any succeeding point will be identical with the potential of the latter. In the following table (XI.) the potentials of all the points on the 400 and 500-foot levels have been calculated, that of No. I. (500-foot level) being zero. The values obtained from the different series are designated by indices (e', e'', e''', e^{iv}, e^{v}, e^{vi}). e_1 is the mean of the first three, e_2 of the last three; and e the mean of all the series.

Table XI.

No.	Points.	Level. Feet.	$e' \times 10^3$	$e'' \times 10^3$	$e''' \times 10$	$e_1 \times 10^3$	$e^{iv} \times 10^3$	$e^{v} \times 10^3$	$e^{vi} \times 10^3$	$e_2 \times 10^3$	$e \times 10^3$
1	I	500	+ 1	− 1	± 0	± 0	+ 1	± 0	− 1	± 0	± 0
2	II	500	+ 1	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
3	III	500	± 0	− 2	± 0	+ 1	± 0	± 6	± 0	± 0	± 0
4	IV	500	± 0	− 1	± 0	± 0	± 0	......	......	± 0	± 0
5	V	500	+ 3	+ 3	+ 3	+ 3	+ 5	+ 6	+ 6	+ 6	+ 5
6	VI	500	+ 2	+ 3	+ 2	+ 2	+ 8	+ 7	+ 7	+ 7	+ 4
7	VII	500	+ 2	+ 2	+ 2	+ 2	......	......	......	......	+ 2
8	VII′	500	− 2	− 3	− 2	− 2	+ 2	+ 2	+ 2	+ 2	± 0
9	VIII	500	− 0	− 1	− 1	− 1	+ 2	+ 1	+ 2	+ 2	± 0
10	IX	500	− 13	− 13	− 11	− 12	− 11	− 11	− 11	− 11	− 12
11	X	500	− 7	− 7	− 8	− 7	− 14	− 14	− 15	− 15	− 11
12	XI	500	− 6	......	− 6	− 6	− 9	− 9	− 8	− 9	− 7
13	XI′	490	± 0	− 1	± 0	± 0	− 1	− 2	− 2	− 2	− 1
14	XII	480	− 8	− 6	− 7	− 7	− 7	− 7	− 7	− 7	− 7
15	XIII	460	− 6	− 6	− 6	− 6	− 8	− 7	− 7	− 7	− 6
16	XIV	450	− 2	− 1	− 2	− 2	− 3	− 3	− 3	− 3	− 3
17	XVI	450	+ 3	+ 2	+ 3	+ 2	......	......	......	......	+ 2
18	XVII	440	− 1	− 1	− 1	− 1	......	......	......	......	− 1
19	X* or XV	430	+ 11	+ 11	+ 11	+ 11	......	......	......	......	+ 11
20	IX or XVIII	400	+ 15	+ 15	+ 15	+ 15	+ 13	+ 13	+ 13	+ 13	+ 14
21	VIII or XIX	400	+ 19	+ 18	+ 17	+ 18	+ 19	+ 18	+ 19	+ 19	+ 18
22	VII or XX	400	+ 30	+ 30	+ 36	+ 30	+ 34	+ 33	+ 32	+ 33	+ 32
23	VI or XXI	400	+ 35	+ 34	+ 36	+ 35	+ 35	+ 34	+ 33	+ 34	+ 35
24	V or XXII	400	+ 16	+ 16	+ 16	+ 16	− 17	+ 16	+ 16	+ 16	+ 16
25	IV or XXIII	400	+ 8	+ 8	+ 7	+ 8	+ 5	+ 7	+ 6	+ 6	+ 7
26	III or XXIV	400	+ 25	+ 25	+ 25	+ 25	+ 28	+ 29	+ 28	+ 28	+ 27
27	II or XXV	400	+ 10	+ 10	+ 11	+ 10	+ 2	+ 2	+ 3	+ 2	+ 7
28	I or XXVI	400	+ 26	+ 26	+ 26	+ 26	+ 24	+ 25	+ 25	+ 25	+ 25
29	P. C. or XXVII	400	......	......	......	......	......	......	......	......	+ 15

Table XII. has been prepared to show the character of *e* as a function of distance (see page 452). In it e has the same signification as in the preceding table. Under *distance,* however, is given the length, in feet, of the imaginary line joining Point I. with the point to which the datum refers. The data included under *bearing* also refer to this line. Current numbers have been given to the points on the 400-foot level. (See "Points," Table XL).

* To facilitate the construction of Fig. 8, current numbers have been given to the points on the 400-foot level. The new numbers are given with the original ones.

TABLE XII.

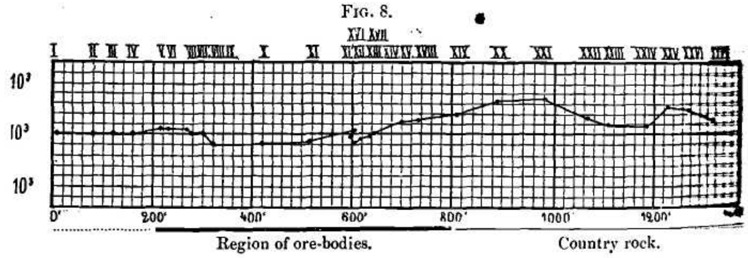
No.	Points.	Level. Feet.	Distance from I.	Bearing.	$e \times 10^3$	No.	Points.	Level. Feet.	Distance from I.	Bearing.	$e \times 10^3$
1	I	500	......	Origin.	± 0	16	XIV	450	635	S. 72° W.	— 3
2	II	500	84	S. 82° W.	± 0	17	XVI	450	600	S. 69° W.	+ 2
3	III	500	123	S. 81° W.	± 0	18	XVII	440	640	S. 75° W.	— 1
4	IV	500	158	S. 63° W.	± 0	19	XV	430	700	S. 72° W.	+ 11
5	V	500	216	S. 58° W.	+ 5	20	XVIII	400	735	S. 72° W.	+ 14
6	VI	500	228	S. 54° W.	+ 4	21	XIX	400	805	S. 71° W.	+ 18
7	VII	500	268	S. 60° W.	+ 2	22	XX	400	890	S. 73° W.	+ 32
8	VII'	500	275	S. 64° W.	± 0	23	XXI	400	980	S. 71° W.	+ 35
9	VIII	500	300	S. 70° W.	± 0	24	XXII	400	1,066	S. 71° W.	+ 16
10	IX	500	318	S. 77° W.	— 12	25	XXIII	400	1,108	S. 70° W.	+ 7
11	X	500	420	S. 78° W.	— 11	26	XXIV	400	1,228	S. 65° W.	+ 27
12	XI	500	515	S. 78° W.	— 7	27	XXV	400	1,184	S. 59° W.	+ 7
13	XI'	490	595	S. 78° W.	— 1	28	XXVI	400	1,276	S. 54° W.	+ 25
14	XII	480	600	S. 79° W.	— 7	29	XXVII	400	1,332	S. 51° W.	+ 15
15	XIII	460	610	S. 79° W.	— 6						

Discussion of the Results Obtained in the 400 *and 500-Foot Levels.* From a comparison of the resistances of circuits between different holes, as contained in Tables VII. and IX., we find that in cases of fissured, of tough and impervious, or of dry rock or earth, this quantity inclines toward a maximum ; whereas, on the other hand, whenever the material is porous or moist, minimal values are obtained. It is to be remembered that under ground, from the exceedingly damp atmosphere, as well as from infiltration of water, the rock forming the walls of the drifts is throughout very moist, and at the surface of the latter, at least, nearly saturated. Hence it follows that the conductivity of the rock is largely, if not wholly, due to the presence of moisture in its pores, and is therefore electrolytic. This matter, which is of importance, will be repeatedly referred to hereafter.

Intensities.--In Tables VIII. and X. the intensities of the currents observed in the different circuits have been very fully given, both because the present measurements are the first of the kind made, and because the character of the data furnishes an important criterion of the validity of the subsequent results derived from them. From an inspection of the tables, it is, moreover, obvious that an exchange of terminals in measurements of this kind, however tedious and laborious in case of long circuits, is indispensable. The intensities V and i''', which are measured with the bags in the same position relatively to the holes, are usually very nearly of the same value, from which i'' generally differs, frequently having even the opposite sign.

Potential.--Between the values of e for the first three, and for the last three series, there is usually a good agreement. The means (e_1 and e_2) of these series, however, often show a lack of accordance which is greater than was expected. The discrepancies occur principally in the results obtained on the 500-foot level, and it was at first thought that they were largely to be referred to the fact that a solution of sodic sulphate was used as an outer liquid in the holes. In No. 11, Table XI., for instance, this liquid, instead of soaking into the rock, as usual, remained in the hole, gradually becoming concentrated by evaporation. In the repetition of the experiment, therefore, the exterior liquids in *P. 0.* and X. were not of the same concentration, so that a discrepancy would not seem remarkable. Subsequent experiments, however, hardly corroborated this supposition. Another large difference occurs in the case of No. 27 of the same table. But for this hole it was impossible to obtain constant results, though the experiments were many times repeated. I am at a loss to account for this fact.

FIG. 8.



Earth potential and distance, Richmond mine, 400 and 500-foot levels. The horizontal line represents distance, the ordinates represent earth-potentials.

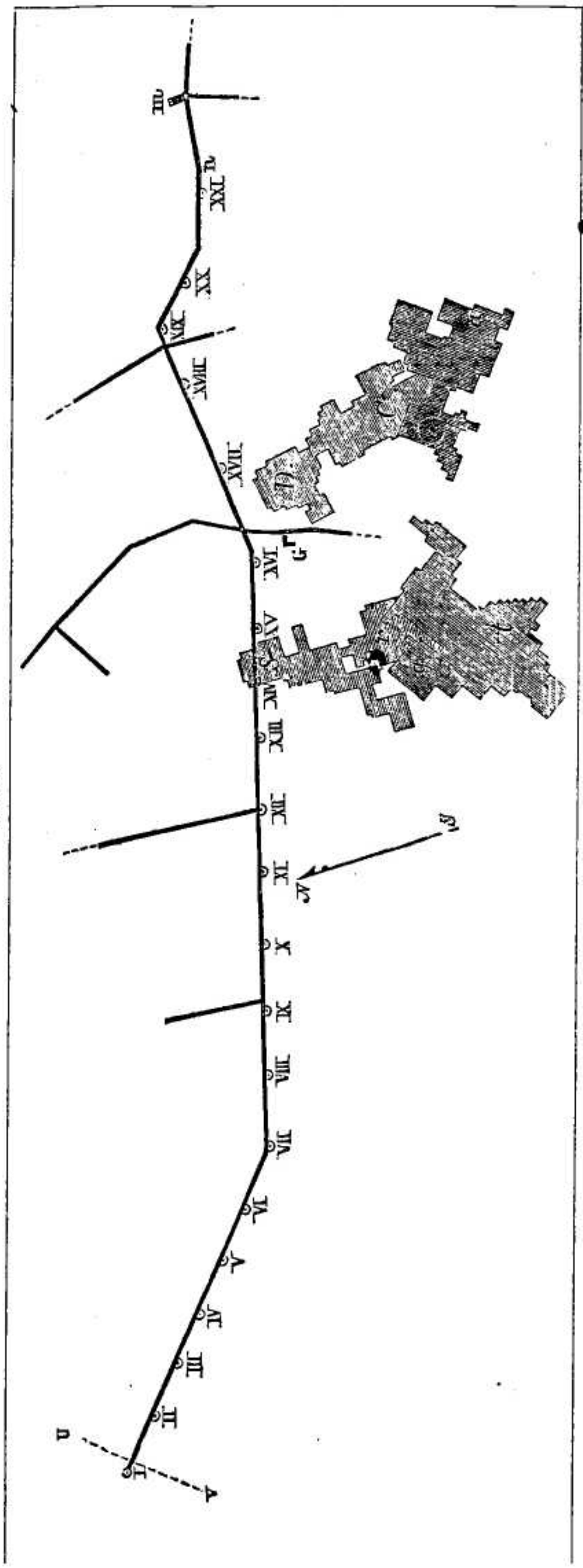
The actual relation between potential and distance, will, of course, be exceedingly complex, and it would be little short of a waste of time to endeavor, with the data at command, to arrive at an empirical form for this function. On the other hand, a graphic representation of the change of potential due to a corresponding change of distance is certainly desirable. Accordingly, I have discarded more elaborate mathematical means, and have represented the relation in question by the following simple plan : If all points of the 400 and 500-foot levels be joined by straight lines with Point I. on the 500, the horizontal projections of these will lie within a sector whose center is at I. and whose bounding radii subtend an angle of 31° approximately. It should be noted (Table XII.) that on passing through the ore-bodies the variation of bearing is much smaller; that it is large both for points near I., where the actual length of arc subtended, however, is small, and for points on the 400-foot level, where, though the actual length of arc subtended is large, as all points are remote from ore, a smaller change of potential may be expected. Bearing in mind, therefore, that our object is merely to represent in a systematic way the potential of consecutive points, a curve may be constructed by representing the linear distance of any point from I. as abscissa, the corresponding potential as ordinate. In this way, Fig. 8 was obtained. From an inspection of the curve it appears that the ore-body is in general at a lower potential than the points remote from it.

Here it must be remarked that only the extreme points on the 400-foot level (XXVII., XXVI., etc.) can, so far as known, be considered actually distant from ore. In the vicinity of Points I., II., etc., 500-foot levels there are not only the streaks of ore, *n* and *p* (Fig. 7), but also chambers 7 and 10, and still further east the large ore-bodies of the Eureka Con. Mining Company. This has been indicated by the dotted line in Fig. 8.

The variation of potential is irregular, however--even more so than, with the rough method of delineation, we would have anticipated--and its amount is small. In fact, it will be seen that certain unavoidable errors might conspire to produce an almost equivalent change. From results of such a magnitude, in short, no prediction as to the occurrence of ore or electro-active material would be justified. Not to mention minor matters, the survey described suffers from a serious objection, due to the fact that a temporary contact in progressing from I. to XXVII. passed through a great number of varieties of rock, and therefore, also, probably through a great variety of absorbed liquids, holding more or less saline matter in solution. In such a case the electromotive force due to the contact of these liquids would seem to come into play. As the matter will again be discussed, I will add here only that electric effect thus produced cannot, *a priori,* be regarded as negligible. Furthermore, the preference given to Point XV., in using it alone as a basis, for the coördination of the results of the surveys on the 500 and 400-foot levels, is to be criticized. It was intended to use several consecutive points for this purpose; but in each case local interferences prevented. As a whole, however, the results are sufficiently interesting to justify further and more careful investigation.

Experiments on the 600-foot level. Results.--This series of measurements was made with the intention of observing the variation of potential encountered in passing across the ore-body, without actu-

Fig. 9.



Plan of 600-foot level, Richmond mine. Scale $\frac{1}{3000}$.

ally getting into it. Care was also taken to place all the points, so far as practicable, in rock of the same variety, and to remove the ends of the line of survey as far from the. ore-body as possible.

The plan of the position of the drifts on the 600-foot level, relatively to the ore-chambers, is given in Fig. 9. As before, the points tapped are distinguished by little circles, to which Roman numerals are annexed. *P. C.* in this case coincides with Point VIII., and is in porous limestone. The great ore-bodies have been lettered as in Fig. 7. Ore is also found at *G,* above and below the 600-foot level, and at *n* above it. *UV is a* line of contact between the shale of the west country and limestone. Table XIII. exhibits more exactly the disposition, etc., of the points. It will be intelligible without further explanation. *(Cf.* Table IX., p. 448.)

TABLE XIII.

No.	Points.	Distance. Feet.	Bearing.	Resistance. Ohms.	Remarks.
1	I	0	....	1,580	Shale, moist.
2	II	76	S. 49° E.	2,350	Limestone.
3	III	77	S. 49° E.	1,750	"
4	IV	65	S. 49° E.	3,110	"
5	V	75	S. 49° E.	4,015	"
6	VI	70	S. 49° E.	4,420	"
7	VII	87	S. 52° E.	6,300	"
8	VIII	94	S. 74° E.	......	"
9	IX	85	S. 74° E.	2,480	"
10	X	71	S. 74° E.	5,150	"
11	XI	91	S. 74° E.	3,420	"
12	XII	80	S. 74° E.	4,170	Limestone, faintly stained with iron.
13	XIII	90	S. 74° E.	3,480	Limestone.
14	XIV	75	S. 74° E.	3,200	"
15	XV	78	S. 74° E.	9,490	Limestone, with calcareous spar.
16	XVI	79	S. 74° E.	15,950	Limestone, hard, impervious.
17	XVII	127	N. 72° E.	3,440	Limestone, stained with iron.
18	XVIII	118	N. 85° E.	3,380	Limestone.
19	XIX	72	N. 85° E.	2,525	Pocket of ferruginous earth in limestone.
20	XX	74	S. 49° E.	3,275	"
21	XXI	121	S. 42° E.	4,965	Limestone.

The results of the measurements of electromotive forces between VIII. (P. *C.)* and *T. C.'s* are contained in Table XIV. The nomenclature being the same as that used above, the meaning of the data will be at once apparent. As before, four terminal bags *A, B, C,* and *D,* were used. Intensities are given in electromagnetic units (C. *G. S.),* electromotive forces in volts ; and are arbitrarily considered positive when the potential of *T. C.* is greater than that of *P. C.* (Point VIII.); or when the current travels

$$T.\ C. \longrightarrow \left\{ \begin{matrix} earth \\ wire \end{matrix} \right\} \longrightarrow P.\ C.$$

The experiments were made in continuous series, starting with Point I. in the extreme west, in shale, and ending with XXI, near the shaft, in limestone. Water, which had previously been kept in contact with zinc, was used as an outer liquid.

Table XIV.

No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$	No.	P. C. connected with—	$i' \times 10^8$	$i'' \times 10^8$	$i''' \times 10^8$	$e \times 10^3$
					First Series.						
1	I	− 172	+ 16	− 189	− 16	11	XII	− 69	− 95	− 78	− 33
2	II	+ 43	− 64	+ 36	− 3	12	XIII	− 98	− 127	− 112	− 40
3	III	+ 81	− 105	+ 60	− 3	13	XIV	− 150	− 157	− 153	− 48
4	IV	+ 64	+ 65	+ 64	+ 17	14	XV	− 50	− 57	− 59	− 57
5	V	+ 52	+ 45	+ 50	+ 20	15	XVI	− 52	− 60	− 41	− 93
6	VI	+ 21	+ 9	+ 21	+ 6	16	XVII	− 88	− 105	− 93	− 30
7	VII	+ 9	+ 9	+ 12	+ 5	17	XVIII	− 170	− 198	− 169	− 57
8	IX	+ 9	− 10	+ 9	± 0	18	XIX	− 71	− 79	− 76	− 17
9	X	− 24	− 24	− 17	− 11	19	XX	− 55	− 76	− 59	− 18
10	XI	− 50	− 53	− 60	− 17	20	XXI	− 53	− 67	− 47	− 29
					Second Series.						
1	I	− 172	+ 0	− 193	− 16	11	XII	− 76	− 93	− 79	− 33
2	II	+ 40	− 55	+ 38	− 2	12	XIII	− 103	− 122	− 144	− 40
3	III	+ 55	− 108	+ 53	− 5	13	XIV	− 160	− 153	− 152	− 48
4	IV	+ 64	+ 71	+ 62	+ 18	14	XV	− 55	− 59	− 60	− 59
5	V	+ 47	+ 43	+ 50	+ 19	15	XVI	− 50	− 55	− 43	− 90
6	VI	+ 17	+ 10	+ 19	+ 6	16	XVII	− 98	− 102	− 96	− 31
7	VII	+ 12	+ 5	+ 10	+ 5	17	XVIII	− 169	− 182	− 177	− 55
8	IX	+ 9	− 9	+ 5	± 0	18	XIX	− 81	− 72	− 81	− 18
9	X	− 24	− 28	− 21	− 12	19	XX	− 60	− 69	− 64	− 17
10	XI	− 52	− 57	− 50	− 16	20	XXI	− 67	− 64	− 53	− 30
					Third Series.						
1	I	− 172	− 3	− 165	− 17	11	XII	− 72	− 103	− 79	− 34
2	II	+ 33	− 38	+ 21	− 2	12	XIII	− 107	− 134	− 110	− 41
3	III	+ 40	− 83	+ 36	− 4	13	XIV	− 160	− 167	− 152	− 50
4	IV	+ 65	+ 71	+ 62	+ 18	14	XV	− 55	− 57	− 62	− 59
5	V	+ 47	+ 34	+ 48	+ 17	15	XVI	− 62	− 57	− 47	− 96
6	VI	+ 19	+ 9	+ 17	+ 6	16	XVII	− 91	− 100	− 95	− 30
7	VII	+ 9	+ 5	+ 9	+ 4	17	XVIII	− 167	− 182	− 176	− 54
8	IX	+ 10	− 19	+ 10	− 1	18	XIX	− 79	− 71	− 76	− 17
9	X	− 22	− 34	− 17	− 12	19	XX	− 64	− 69	− 65	− 18
10	XI	− 48	− 71	− 48	− 18	20	XXI	− 64	− 62	− 64	− 30
					Fourth Series.						
1	I	− 79	− 98	− 78	− 11	11	XII	− 83	− 86	− 81	− 27
2	II	− 0	− 19	− 9	− 3	12	XIII	− 96	− 105	− 95	− 35
3	III	− 12	− 31	− 21	− 4	13	XIV	− 138	− 146	− 141	− 46
4	IV	+ 48	+ 52	+ 59	+ 19	14	XV	− 69	− 71	− 72	− 59
5	V	+ 36	+ 38	+ 43	+ 15	15	XVI	− 65	− 69	− 64	− 95
6	VI	+ 14	+ 14	+ 7	+ 5	16	XVII	− 72	− 95	− 69	− 30
7	VII	+ 7	+ 7	+ 7	+ 4	17	XVIII	− 148	− 143	− 143	− 52
8	IX	± 0	− 14	− 5	− 2	18	XIX	− 55	− 78	− 57	− 18
9	X	− 22	− 21	− 17	− 11	19	XX	− 60	− 84	− 60	− 21
10	XI	− 41	− 47	− 43	− 16	20	XXI	− 52	− 55	− 53	− 26
					Fifth Series.						
1	I	− 84	− 83	− 96	− 11	11	XII	− 84	− 84	− 86	− 37
2	II	− 12	− 10	− 12	− 3	12	XIII	− 102	− 103	− 103	− 36
3	III	− 24	− 16	− 36	− 4	13	XIV	− 143	− 141	− 145	− 46
4	IV	+ 48	+ 59	+ 55	+ 19	14	XV	− 69	− 72	− 69	− 59
5	V	+ 33	+ 43	+ 38	+ 15	15	XVI	− 59	− 71	− 59	− 93
6	VI	+ 10	+ 14	+ 7	+ 5	16	XVII	− 74	− 95	− 65	− 30
7	VII	+ 5	+ 9	+ 5	+ 4	17	XVIII	− 145	− 145	− 136	− 52
8	IX	− 9	− 2	− 12	− 2	18	XIX	− 60	− 76	− 64	− 18
9	X	− 22	− 21	− 21	− 11	19	XX	− 67	− 76	− 62	− 20
10	XI	− 47	− 43	− 40	− 16	20	XXI	− 43	− 55	− 69	− 27
					Sixth Series.						
1	I	− 86	− 90	− 98	− 12	11	XII	− 84	− 86	− 84	− 37
2	II	− 16	− 12	− 24	− 3	12	XIII	− 110	− 105	− 105	− 37
3	III	− 36	− 21	− 38	− 5	13	XIV	− 138	− 152	− 138	− 47
4	IV	+ 47	+ 62	+ 59	+ 20	14	XV	− 72	− 72	− 72	− 59
5	V	+ 31	+ 41	+ 36	+ 15	15	XVI	− 60	− 71	− 64	− 93
6	VI	+ 14	+ 7	+ 14	+ 5	16	XVII	− 76	− 93	− 74	− 31
7	VII	+ 7	+ 7	+ 9	+ 4	17	XVIII	− 136	− 141	− 141	− 51
8	IX	− 24	+ 0	− 16	− 3	18	XIX	− 65	− 78	− 72	− 19
9	X	− 19	− 22	− 21	− 11	19	XX	− 67	− 76	− 60	− 19
10	XI	− 52	− 45	− 43	− 17	20	XXI	− 43	− 50	− 67	− 28

A comparison of the values of *e* obtained is given in Table XV. The plan is analogous to the above.

Table XV.

No.	Points.	$e' \times 10^3$	$e'' \times 10^3$	$e''' \times 10^3$	$e_1 \times 10$	$e^{iv} \times 10^3$	$e^{v} \times 10^3$	$e^{vi} \times 10^3$	$e_2 \times 10^3$	$e \times 10^3$
1	I	− 16	− 16	− 17	− 16	− 11	− 11	− 12	− 11	− 14
2	II	− 3	− 2	− 2	− 2	− 3	− 3	− 4	− 3	− 3
3	III	− 3	− 5	− 4	− 4	− 4	− 4	− 5	− 4	− 4
4	IV	+ 17	+ 18	+ 18	+ 18	+ 19	+ 19	+ 20	+ 19	+ 18
5	V	+ 20	+ 19	+ 17	+ 18	+ 15	+ 15	+ 15	+ 15	+ 17
6	VI	+ 6	+ 6	+ 6	+ 6	+ 5	+ 5	+ 5	+ 5	+ 6
7	VII	+ 5	+ 5	+ 4	+ 5	+ 4	+ 4	+ 4	+ 4	+ 5
8	VIII	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
9	IX	± 0	± 0	− 1	± 0	− 2	− 2	− 3	− 2	− 1
10	X	− 11	− 12	− 13	− 12	− 11	− 11	− 11	− 11	− 11
11	XI	− 17	− 17	− 18	− 17	− 17	− 16	− 17	− 17	− 17
12	XII	− 33	− 33	− 35	− 34	− 37	− 37	− 37	− 37	− 35
13	XIII	− 40	− 40	− 41	− 40	− 35	− 36	− 37	− 36	− 38
14	XIV	− 48	− 48	− 50	− 49	− 46	− 46	− 47	− 46	− 48
15	XV	− 57	− 59	− 59	− 58	− 59	− 59	− 59	− 59	− 59
16	XVI	− 93	− 90	− 96	− 93	− 95	− 93	− 93	− 94	− 93
17	XVII	− 30	− 31	− 30	− 31	− 30	− 30	− 31	− 31	− 31
18	XVIII	− 57	− 55	− 55	− 55	− 53	− 52	− 51	− 52	− 54
19	XIX	− 17	− 18	− 17	− 17	− 18	− 19	− 19	− 19	− 18
20	XX	− 18	− 17	− 18	− 18	− 21	− 20	− 19	− 20	− 19
21	XXI	− 29	− 30	− 30	− 30	− 27	− 27	− 28	− 27	− 29

Table XVI., finally, contains the data necessary for the approximate representation of earth potential as a function of distance. By arbitrarily assuming the potential of Point VIII. as zero, the final means in Table XV. are identical with the potential of the points to which the data refer. The third and fourth columns of Table XVI. contain the length and bearing of the imaginary lines joining I. with the succeeding points.

Table XVI.

No.	Points.	Distance from I.	Bearing.	$e \times 10^3$	No.	Points.	Distance from I.	Bearing.	$e \times 10^3$
1	I	0	Origin	− 14	12	XII	850	S. 61° E.	− 35
2	II	76	S. 49° E.	− 3	13	XIII	935	S. 63° E.	− 38
3	III	153	S. 49° E.	− 4	14	XIV	1,010	S. 64° E.	− 48
4	IV	220	S. 49° E.	+ 18	15	XV	1,080	S. 64° E.	− 59
5	V	295	S. 49° E.	+ 17	16	XVI	1,160	S. 65° E.	− 93
6	VI	365	S. 49° E.	+ 6	17	XVII	1,280	S. 68° E.	− 31
7	VII	450	S. 50° E.	+ 5	18	XVIII	1,380	S. 70° E.	− 54
8	VIII	540	S. 54° E.	± 0	19	XIX	1,450	S. 71° E.	− 18
9	IX	615	S. 57° E.	− 1	20	XX	1,510	S. 70° E.	− 19
10	X	685	S. 58° E.	− 11	21	XXI	1,630	S. 70° E.	− 29
11	XI	775	S. 60° E.	− 17					

From the results in Table XIII. for the resistance of different circuits, similar conclusions to those on page 35 are deducible. Wherever the structure of the rock and coexisting circumstances are favorable to the absorption of moisture, there we also find minimal values for this quantity. Unusually high values were obtained for the holes XV. and XVI. But the rock at these points was so tough and tenacious that the miners complained of the slow progress made in drilling.

Remarks analogous to the above are applicable to the present values for intensity on this level.

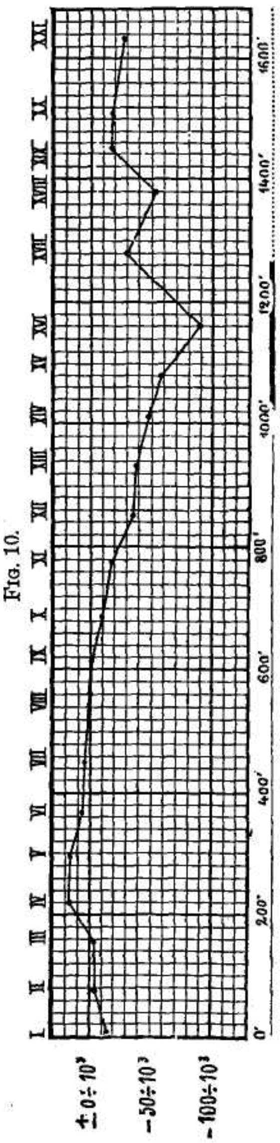
The results for earth-potential in Table XV. harmonize much better than those for the preceding levels. The individual values in the two series, as well as the means of the series themselves, are in fair accordance. This might be ascribed to the fact that the holes were mostly in rock of the same variety, and that strong salt solutions were discarded in completing the contact between the terminal hags and the earth.

By a method of procedure similar to that already employed the relation between potential and distance may be represented graphically. It will also be seen from an inspection of Table XVI., that the considerations involved in constructing Fig. 28 are more pertinent in this case, as the main drift itself is more nearly linear. Laying off potential as ordinate, distance as abscissa (Table XVI.), Fig. 10 is obtained.

Both Fig. 8 and Fig. 10 demonstrate the remarkable result, that the region of ore-bodies coincides with a region of low potential. This is all the more striking, as in the first case the ore-bodies are approached from barren rock (400' level), taking in general a northerly course. In the second, the course of survey, while passing toward the ore-region, was mainly in an easterly direction. The two lines of survey may, roughly speaking, be said to be at right angles to each other. In one case, moreover, the sequence of points tapped intersects the ore-bodies, whereas in the other it remains exterior to them throughout its whole extent.

Comparing the results of the two surveys, the indications on the 600-foot level are found to be much the more pronounced ; in fact, they transcend values which can be accounted for as an aggregate of incidental errors. It may be remarked here, that it is a very improbable chance which would place the region of greatest electrical disturbance in coincidence with the region of ore-bodies, if the latter were without influence in producing the former. There in no reason, apparent, why the part of the main drift on the 600-foot level, between Points I. and X., should not be just as active as that between Points X. and XXI., unless it be that these points lie nearest to ore,

Fig. 10.



Country rock. Region of ore-bodies.
Earth-potential and distance, Richmond Mine, 600-foot level.

and, consequently, that we are here rapidly approaching the seat of an electromotive force.

Chambers No. 14 *and No.* 15 *connected electrically.*—In the survey on the 400 and 500-foot levels, two ore-bodies, Nos. 12 and 15, were indirectly connected, but the indications obtained were much smaller than was anticipated. It appeared desirable, therefore, to test this matter still more carefully by connecting the huge ore-masses in chambers No. 14 and No. 15. Accordingly a P. C in a large breast of ore (lead carbonate) in chamber No. 15 was placed successively in contact with three different points at a distance of about 100 feet one from another in chamber No. 14. Each of these was also in ore, the first in lead carbonate, the second, in lead carbonate and earthy sulphide, the third, finally, in a mixture of carbonate, sulphide and ferruginous earth. Table XVII. contains the results of the electrical measurements. A single set of observations, with one exchange for each, was made.

TABLE XVII.

First Series.					*Second Series.*					*Third Series.*				
No.	P. C. joined with—	$i' \times 10^8$	$i'' \times 10^8$	$e \times 10^3$	No.	P. C. joined with—	$i' \times 10^8$	$i'' \times 10^8$	$e \times 10^3$	No.	P. C. joined with—	$i' \times 10^8$	$i'' \times 10^8$	$e \times 10^3$
1	I	−16	− 3	− 6	1	I	−18	− 2	− 6	1	I	−11	− 8	− 6
2	II	− 8	−10	− 7	2	II	− 7	−10	− 6	2	II	−11	−10	− 7
3	III	−10	−13	− 7	3	III	−11	−13	− 7	3	III	−11	−13	− 7

In considering these results, it is strikingly apparent that the evidences of electric action are almost altogether absent. It is true that in all probability, chambers Nos. 14 and 15 are but parts of one and the same large ore-mass, but in the place where the experiments were made they are to some extent, at least, locally disconnected. The results lead to the inference either that the ore of both chambers is remarkably similar in character, so as to present no appreciable electric difference, or that it is here without electrical properties altogether (earthy), the field of electric action being confined to certain definite parts of the ore-deposit. (See also page 474).

Experiments on the surface.—Encouraged by the results on the 600-foot level, I thought it not impossible, inasmuch as the ore extends in places to within 100 feet from the surface, while vestiges of croppings, etc., still remain, that currents might also be observed on the surface itself.

A line of points lying in general in a north-and-south direction, and at distances of about 100 feet apart, was chosen, the object being to extend the electric survey from shale free from ore, in the north, over Ruby Hill and the large ore-bodies in its interior, to quartzite in the south, also more or less free from ore. It was hoped that in this way a passage through a field of electrical activity might actually be made. Unfortunately, the work was interrupted by a heavy snow-storm and accompanying frosts.

P. C. was placed about half-way up the hill in compact limestone. Point I. is the most northerly of the series, and remote from ore; Point IX. approximately over the Richmond ore-bodies. The results are contained in the following table, *e* is the mean of a single triple set. The potential of P. *C.* Point VI.) is arbitrarily put equal to zero.

TABLE XVIII.

No.	Points.	Resistance.	$e \times 10^3$	Remarks.
1	I	17,000	— 20	*Débris;* lowest point.
2	II	14,000	— 30	" "
3	III	13,000	— 30	" "
4	IV	13,000	— 10	" "
5	V	13,000	— 10	Shale.
6	VI	....	±.0	Limestone (P. C.).
7	VII	150,000	+ 10	" "
8	VIII	40,000	+ 20	Limestone; highest point.
9	IX	20,000	+ 40	" "
10	X	25,000	+ 50	" "

In the table the unusually high values for the resistances of the circuits, P. C, earth, *T. C,* are a striking feature. This may be due either to the compact and impervious structure of the rock (the drill making very slow progress), or, as the experiments were made in the early spring, to the possibility that the moisture in the rock was still frozen. In either case, however, the supposition that the conductivity of the rocks is principally due to the presence of moisture in their pores receives fresh support.

The values for earth-potential again exhibit a marked variation in passing toward the ore-deposit. But unlike former cases, the passage from points remote to those nearer the ore-region is one from lower to higher potential. As nothing is known about the distribution of potential with reference to ore-bodies, this is not to be regarded as at variance with former results. Not overmuch reliance, however, must be placed on the values of *e* in this table. They were obtained under unfavorable circumstances, and not checked, as in the former cases.

According to Mattenci,* a difference of potential exists between points at a different level, in virtue of this fact alone. "Ce courant est ascendant dans la partie métallique du circuit; son intensité augmente à mesure que les lignes sont plus longues, et que la différence de niveau entre ces extremités est plus grande." But in the present case the direction of the. current is not the only opposite of this, but the electromotive force continues to increase even in greater ratio after the highest point of the series has been reached. We have, therefore, not to do with such effects as Matteuci observed. The reader is further referred to page 470.

REPETITION OF SOME OF THE EXPERIMENTS AFTER AN INTERVAL OF ABOUT ONE HUNDRED AND THIRTY DAYS.

The preceding experiments are to be regarded as incomplete in two particulars. In the first place, the data are the results of but a single method of measurement, the application of which is not immediately evident; in the second, no criterion of their constancy in point of time has, as yet, been obtained. The additional results now to be given were obtained on the 600-foot level of the Richmond mine, all the former holes (points tapped), with the single exception of No. 1, being used over again. In place of the latter, this having become inaccessible, a fresh hole, about 25 feet to the east of the old one, but also in shale, was drilled.

The experiments were made after an interval of more than four months from the time at which the original data were obtained.

From an inspection of the magnitude of the electromotive forces contained in the foregoing tables, it will be seen that they fall well within the scope of a good electrometer. Such an instrument, properly protected against the moisture of the underground air, would have been most serviceable for the purpose. Unfortunately, one could not be obtained in time for the work. The following methods were therefore resorted to:

In the first place the greater part of the data were checked by the old method given above. This, it will be remembered, was chosen because of its simplicity and the comparative ease with which any

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* Ann. de Chim. etde de Phys. (4), t. x., p. 148, 1867.

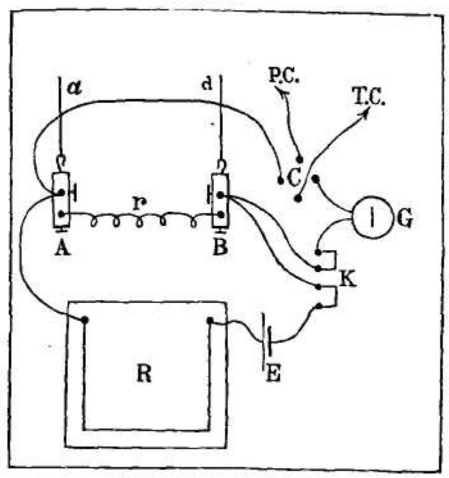
fault in the connections could be ascertained. The potential of the same holes was also measured by a method in which the electromotive force is expressed in terms of the increment of the reciprocal of intensity of current, and the corresponding increment of the resistance of the circuit, to which the former is due. In order to vary the resistance at pleasure, a rheostat was introduced. If the resistances w_1 and w_2 correspond to the intensities i_1 and i_2, respectively, we have

$$e = \frac{w_1 - w_2}{\frac{1}{i_1} - \frac{1}{i_2}},$$

where *e* is the electromotive force to be measured.

Finally, the whole of the experiments formerly made on the 600-foot level were again repeated by a zero method. Here great care had to be taken to effect the complete insulation of all parts. This was accomplished in the manner previously indicated, by suspending

FIG. 11.



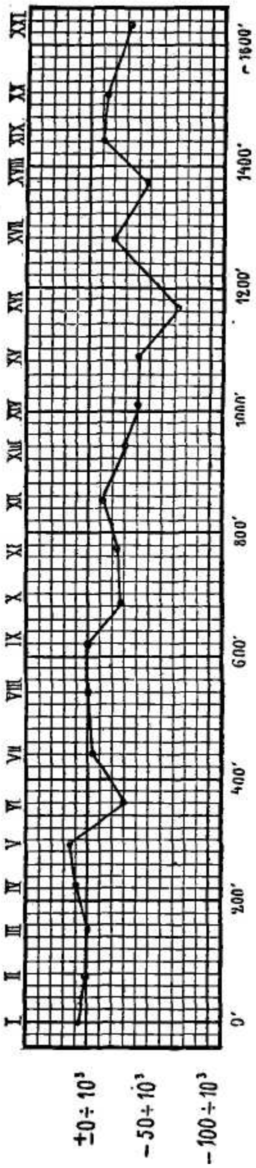
Disposition of apparatus.

the terminal wires, as well as all the connections, from threads. The accompanying diagram, Fig. 11, will show how this was done. *A* and B are clamp screws, suspended from the threads *a* and *d,* respectively, *R* (rheostat) is the large, *r* the small resistance, *K* a double key, *C* a commutator, *G* the galvanoscope. For a current zero in the latter (the effects due to the normal element *E* and the lode electromotive force compensating each other in *G),*

$$e = E\frac{r}{R + r}.$$

The resistance *r* was wrapped on a small piece of wood and the whole subsequently boiled in paraffine. The body of the key *K*, and

FIG. 12.



Earth-potential and distance, Richmond mine, 600-foot level (new results).

that of the commutator C were similarly prepared, being boiled in linseed oil, and the mercury cups covered internally with a thick coating of wax. Moreover, the wires of both in passing through the wood were additionally insulated from the latter by a covering of gutta-percha; the ends only being uncovered and communicating with the mercury in the cups. In consequence of these precautions it was found that this comparatively complicated method could be employed in these wet drifts with complete success, and the adjustments having once been made, it proved to be nearly as expeditious as either of the other methods.

As the result obtained is derived from an expression which is independent of the resistance of the circuit, the method could be used with advantage in studying the manner of variation of potential in passing, as it were, continuously from any *T. C.* to the next. But the actual observations will be more appropriately cited in connection with another topic (see page 472).

It will be remembered that in the former experiments four contact bags were used throughout, which were so combined as to give three independent values for the electromotive force to be measured. The result thus obtained, however, being usually so nearly identical, it was thought that this precaution might be safely dispensed with. Two contact bags only, therefore, were employed. In all other respects, however, the former plan (see pages 440, 441) was rigidly adhered to, with such slight variations, of course, as the different methods rendered necessary.

The following table, containing the potential of the consecutive points on the 600-foot level—that of No. VIII. being arbitrarily put equal to zero, as before—will be intelligible without much further explanation. The results of the different methods are arranged in parallel columns, and in the order in which they were described. For the sake of comparison those obtained on the former survey are also added, and a final column shows the difference between the two.

The results obtained by different methods present throughout a fair agreement, when it is remembered that errors amounting to a few thousandths of a volt are introduced by circumstances beyond the observer's control. Between the mean of the new and the mean of the former results, there are a number of annoying discrepancies. In part, though by no means wholly, these are due to a difference in the values of the standard electromotive force employed in the two cases. With the knowledge at present available it would be of little use, however, to attempt to assign reasons for the remaining variations. A matter of greater importance is that the general character of the curves, as derived from the two series of results, is essentially the same.*

TABLE XIX.

No.	Points.	$e \times 10^3$, determined—			$e \times 10^3$, mean.	$e \times 10^3$, old value.	$\delta(e) \times 10^3$	Remarks.
		By old method.	With rheostat.	By compensat.				
1	I′	.....	.....	+ 7	+ 7	− 14	....	New and old holes do not coincide.
2	II	.....	.....	+ 1	+ 1	− 3	− 4	
3	III	.....	.....	+ 1	+ 1	− 4	− 5	
4	IV	.....	.....	+ 12	+ 12	+ 18	+ 6	
5	V	.....	.....	+ 15	+ 15	+ 17	+ 2	
6	VI	.....	.....	− 30	− 30	+ 6	+ 36	
7	VII	− 3	.....	− 4	− 4	+ 5	+ 9	
8	IX	− 1	− 1	− 1	− 1	− 1	± 0	
9	X	− 29	− 25	− 31	− 28	− 11	+ 17	
10	XI	− 25	− 25	− 25	− 25	− 17	+ 8	
11	XII	− 13	− 12	− 14	− 13	− 35	− 22	
12	XIII	− 30	− 23	− 24	− 29	− 38	− 9	
13	XIV	− 39	− 39	− 40	− 39	− 48	− 9	
14	XV	− 41	− 40	− 47	− 43	− 59	− 16	
15	XVI	− 72	− 75	− 76	− 74	− 93	− 19	
16	XVII	− 15	− 15	− 23	− 18	− 31	− 13	
17	XVIII	− 48	− 47	− 50	− 48	− 54	− 6	
18	XIX	− 8	− 13	− 7	− 9	− 18	− 9	
19	XX	− 14	− 13	− 14	− 14	− 19	− 5	
20	XXI	− 31	− 32	− 39	− 34	− 29	+ 5	

UNAVOIDABLE ERRORS AND MISCELLANEOUS CRITICISMS.

Moisture in the rocks.---By far the most serious difficulty encountered in endeavoring to interpret the results obtained, is that due to the difference of potential of two liquids in contact. The conductivity of rocks is as has been seen, largely, if not wholly, to be ascribbed to the presence of moisture in their pores. This moisture unquestionably holds saline matter in solution. Moreover, it is altogether probable that the solution in one rock of a particular structure is, in general, different from that in another of different structure and many hundred feet distant from the former, even if the composition of both is essentially the same. In tapping tow points at some distance apart, by the aid of two metals (plates or gads) supposed identical in every respect, two members of the continuous sequence of solutions contained in the rocks are, in fact, put in metallic contact. The difference of potential thus obtained would be that due to the resultant action of the series of liquids included between the points. This electromotive force is, however, principally dependent on the extreme members of the series, *i.e.,* those at the points tapped; and in the present investigation it was hoped that the dis-

*Compare Figs. 10 and 12

crepancy thus arising might be very largely eliminated by putting the same liquid in both holes, and by exchanging not only the metallic terminal—amalgamated zinc—but also the terminal solutions (zinc sulphate). Hence the "bag" form of the terminal.

It was thought not superfluous to test the matter with the aid of the contact-bags themselves; all the more as it would thus appear to what extent the results obtained with the latter are trustworthy. The two liquids, whose electromotive force was to be measured, were separated from one another by a porous septum of animal membrane. As in the mines, the terminal bags were exchanged. In passing them out of the first liquid into the second, care was taken to wipe off the liquid adhering to the outside. If now, e be the electromotive force of the two solutions in contact, and e, that due to the difference between the zincs alone, in the first position of the bags A and B (A in water and B in the liquid to be tested), the apparent force would be

$$\varepsilon \pm e;$$

in the second position of the bags (B in water and A in the liquid to be tested),

$$\varepsilon \pm e;$$

the connections themselves remaining unaltered. A mean of both measurements gives e; half the difference, e. The following are some of the results:

Remarks.	$\varepsilon \times 10^3$	$e \times 10^3$
Both bags in water, ...	1.0	0.2
Bags alternately in solution of Na^2SO^4 and in water, ...	1.0	2.8
Both bags in water, ...	2.8	0.4
Bags alternately in salt solution and in water,.	3.4	2.2
Both bags again in water, ...	3.4	0.6
Both bags in water, ...	3.0	+ 0.4
Bags alternately in Zn SO^4 solution and in water, ...	3.6	− 0.4

It will be seen that in the different sets e is fairly constant. The value of e is small, as anticipated, notwithstanding that nearly concentrated solutions were used. In the case of zinc sulphate e is practically zero, as it should be, the bags themselves containing this solution.

The following table contains analogous experiments made in the mines. Holes IX. and X., 600-foot level, were put in contact. Measurements were made by a zero method:

Remarks.	$e \times 10^3$
Water in both IX. and X., ...	— 28
Water in X., concentrated brine in IX., . .	— 27
Concentrated brine in both IX. and X., . .	— 27

Two other holes similarly treated gave :

Remarks.	$e \times 10^3$
Brine in one only,.	— 14
Brine in both, ...	— 17

Apparently, therefore, large discrepancies are not produced in this way.

Of course all these experiments are only intended to furnish estimates as to the probable magnitude of disturbances of an analogous kind, which may possibly have influenced the data given above.

Mr. E. Kittler * has recently commenced a new study of the question of potential difference due to the contact of liquids. From a large number of careful experiments he finds electromotive forces between them far exceeding, as a rule, those met with in the measurements of earth currents here described. These forces, however, obey the law of Volta's potential series.

From all these considerations, it seems to follow that in the present investigation the discrepancies due to the presence of different liquids in the rocks have been eliminated to a great extent. Certainly their effect can hardly be estimated as much greater than a few thousandths of a volt. It is obvious, moreover, that the use of simple metallic contacts (plates and gads) is under all conditions unsafe. To this is to be added the fact that metallic plates are never identical in their electrical properties, and that their difference (as large effects of polarization are also included therein) cannot be eliminated by such a process of commutation as was employed.

The phenomenon of conduction of rocks being essentially hydroelectric, the determination of the thermo-electric power earth-copper, for which it was at first thought the high temperature on the lower

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* E. Kittler: *Ueber Spannungsdifferenzen,* etc. Wied. Ann., xii., p. 572, *et seq;* 1881.

levels of the Comstock lode, in comparison with those at the surface, would offer excellent facilities, has no further interest. No attempt of this kind was therefore made.

If the hole drilled for the reception of the terminals be regarded as a cylinder with a hemispherical base, the directrix of the former as tangent to the sphere corresponding to the latter, and its axis as normal to the plane face of the drift, approximate values may be derived for the specific resistance of the rock met with. Let h be the height of the cylinder, a the common radius of both the latter and the hemisphere. Let r be the radius of any similar figure, the axis of whose cylinder and center of hemisphere coincide with those of the hole. Finally, lot a be the specific resistance of the rock, or the resistance in ohms between opposite faces of a cubic centimeter.

The elementary resistance of a shell at the distance r from the . axis and of the thickness dr, is then

$$dw = \frac{\sigma}{2\pi} \frac{dr}{r(r+h)},$$

and, therefore, the resistance of the layer of rock between coaxial and concentric figures, the inner radius being a, the outer r, is

$$\left[w \right]_a^r = \frac{\sigma}{2\pi h} \, l \frac{(a+h)r}{(r+h)a},$$

the symbol $[w]_a^r$ being used to express the resistance of the layer of rock between the similar surfaces just defined. If r is allowed to increase to infinity approximate values for a can be determined from the data given, above for the resistance of circuits, and the known dimensions of the holes. In this way it appears that the mean value of this quantity was about

$$\sigma = 40{,}000,$$

whereas values as high as 500,000 and as low as 20,000 were met with. From the invariable presence of moisture, however, these figures possess only minor interest.

If the resistance of layers of rock between consecutive similar surfaces be compared, the same notation being again employed, in round numbers:

$$\frac{\left[w \right]_{10}^{\infty}}{\left[w \right]_a^{10}} = 0.6; \quad \frac{\left[w \right]_{100}^{\infty}}{\left[w \right]_a^{100}} = 0.07; \quad \frac{\left[w \right]_{1000}^{\infty}}{\left[w \right]_a^{1000}} = 0.007, \text{ etc.}$$

all dimensions being expressed in centimeters, and a being 1.2 cm.; whence it follows that the resistance of coaxial and concentric layers decreases, though hardly as rapidly as might be desirable. In point of fact, however, the convergence is more rapid than this approximate calculation indicates. A drift may with greater accuracy be regarded as a cylindrical tunnel, into the sides of which the contact holes have been drilled, with their axes at right angles to that of the drift. Now, it is obvious that as r (in the former signification) increases, the value of dw will, in this case, decrease more rapidly than in the previous one ; this because the superficial area of the infinitesimally thin shell increases much more rapidly. The actual analysis, however, is unnecessary here. The points of greatest interest have already been sufficiently illustrated by what precedes.

Earth-currents.—A second important consideration relative to the causes which might have produced discrepancies in the present investigation is the effect to be described to earth-currents. Although numbers of experiments have been made in different parts of the world as to the magnitude and direction of such currents, I am unable to estimate their effect in this case, especially as the constants for the currents probably vary with the position of the field of observation on the surface of the earth. Most observers have availed themselves of telegraphic connections between points very many miles apart. Mattenci,* I believe, was the only one who laid a carefully insulated line especially for this purpose, and it is to his investigation that we can with greatest ad vantage refer, Yet, though his points were at a distance of six kilometers apart, the currents obtained, so far as can be seen, were certainly not much larger than those here recorded. If, however, the variation of potential in the above experiments were due to some normal, non-local cause, it would be fair to assume a linear change of potential with distance throughout the comparatively small area in which the experiments were made. Such is by no means the case. In fact, some of the largest variations observed occur within distances of a few hundred feet, while elsewhere a range of 1000 feet is without marked alteration of potential. It is probable, therefore, that earth-currents have not perceptibly affected the results.†

* Ch. Matteuci: *Sur les courante électriques de la terre.* Ann. d. Chim. et de Phys. [4], t. iv., p. 177, 1865; *ibid* [4], t. x., p. 148, 1867.

† Temporary disturbances, such, for instance, as are due to atmospheric induction, are obviously without influence in the present case. Inductive action, moreover, it hardly to be expected from the clear, dry air of Nevada.

Drill-holes.—The angular and somewhat irregular curves (Figs. 8, 10, 12) might give rise to a suspicion that the difference of potential observed is in some way to be ascribed to the accidental condition of the holes themselves. *A priori,* therefore, the presence of little pieces of steel, worn or broken off from the drill, crystals of iron pyrites, particles of ore, etc., in the walls of the hole should not be disregarded. That such material is, however, entirely without disturbing effect will be seen from the following experiments.

In a particular case the intensity i1, obtained by connecting two holes in the ordinary rnauner was

$$i_1 = 101 : 10^8.$$

A thin strip of platinum was subsequently introduced into one of the holes and firmly pressed against its sides. The intensity i_2 then measured proved to be

$$i_2 = 99 : 10^8;$$

or, practically, the same as before. An effect due to the platinum was therefore absent.

Two holes, about 18 inches apart, were drilled into solid rock and connected as usual. The measurements made for difference of potential, by the original method, gave, in four successive experiments, different bags being used for each,

$$1)\ e = +1 : 10^3$$
$$2)\ e = -1 : 10^3$$
$$3)\ e = \pm 0 : 10^3$$
$$4)\ e = \pm 0 : 10^3,$$

or zero, as from the proximity of the holes it ought to be.

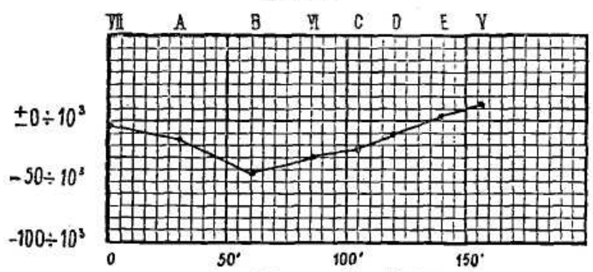
Finally, the potential of a number of points lying between Nos. V. and VII., on the 600-foot level of the Richmond mine, was determined. A zero method being used, it was only necessary to put the terminal bags in contact with the rock at the points chosen, by allowing them to recline against the wall. Care was taken to prevent any part of the copper wire from touching it. Two points, *A* and *B,* were thus established between VII. and VI.; three *C, D,* and *E,* between VI. and V. The following table gives the results, the potential of No. VIII. being put equal to zero, as before:

TABLE XX.

No.	Points.	$e \times 10^3$	Distance from VII.	Remarks.
1	VII	− 4	0	Drill-hole.
2	A	− 15	30	
3	B	− 44	60	
4	VI	− 30	87	Drill-hole.
5	C	− 23	105	
6	D	− 9	120	
7	E	+ 2	140	
8	V	+ 15	157	Drill-hole.

In Fig. 13 these results are graphically represented. It appears, notwithstanding the different kinds of contact at V., VI., VII., and at *A, B, C, D,* that the progress of the curve in passing from VI. to V. is continuous. The experiments, therefore, failed to detect

FIG. 13.



Potential of Intermediate Points.

any specific action due to the holes. Nos. V., VI., and VII. were especially chosen, because, as will be seen from a comparison of Figs. 10 and 12, this part of the curve presents a curious and well-pronounced anomaly, the newer results differing very remarkably from the earlier. It. was natural to suppose that, in the time which had elapsed between the two series of measurements, hole No VI. had in some way been interfered with. The results just cited, however, preclude such a supposition. Even larger masses of metal seem to be without marked effect. Between the date of the older and that of the newer observations, for instance, a track had been laid from the vicinity of the hole No. 1 to No. XV.

Terminal-bags.—There occur a few cases in my notes in which, though in every other respect the behavior was normal, different resuits were obtained for the same hole at nearly the same time, by employing different bags, viz. :

IV. $e = 0:10^3$ VII. $e=2:10^3$
$e = 2:10^3$ $e=6:10^3$
$e=5:10^3$

These cases are rare, however, and their effect is of minor importance. More worthy of consideration are the successive differences of potential due to the bags alone when employed for a long period of time. The quantity referred to has already been considered on page 467, under the symbol e. It may be readily derived from the tables for intensity. The following table (XXI.) probably contains good examples of its consecutive states, the data given be deduced from those for the holes I.-XIV. on the 600-foot level. If the bags are called *A, B, C, 3D,* the electromotive force e between A and B may be conveniently represented by *A* *B,* between *A* and *C* by *A* | *C,* etc. The values of e, as derived both from the direct and return series, are given in the (able, the latter being primed. Heavy black lines across the table indicate either that the bags were refilled or that the experiments had to be temporarily discontinued.

TABLE XXI, containing $e \times 10^8$.

No.	Points.	A | B	A | C	A | D	A′ | B′	A′ | C′	A′ | D′
1	I	− 17	− 16	− 15	− 1	± 0	± 0
2	II	− 12	− 11	− 8	− 2	± 0	+ 1
3	III	− 16	− 15	− 11	− 1	+ 1	+ 1
4	IV	± 0	+ 1	+ 1	± 0	+ 1	+ 2
5	V	− 1	− 1	− 3	± 0	+ 1	+ 1
6	VI	− 2	− 2	− 2	+ 1	+ 2	− 3
7	VII	± 0	− 2	− 1	± 0	+ 2	± 0
8	IX	− 2	− 2	− 3	− 1	+ 1	+ 3
9	X	− 1	− 1	− 4	± 0	± 0	− 1
10	XI	± 0	− 1	− 3	− 1	± 0	± 0
11	XII	− 4	− 3	− 5	− 1	± 0	± 0
12	XIII	− 4	− 2	− 4	+ 2	± 0	+ 1
13	XIV	− 1	− 1	− 2	− 1	+ 1	− 2

The successive values of e are not constant, though in the majority of cases they are so small as to be immaterial. At times, however, values sufficiently large to be important are reached. An exchange of terminals is therefore indispensable, especially as experiments will usually be sufficiently extensive to involve interruptions. The gradual variation observed in the value of e can most probably be referred to a corresponding change in the concentration, etc, of the solution (zinc sulphate) contained in the bags. It is hardly probable that it is due to polarization, or a change in the surface of the amalgamated zinc strips. It is interesting that, in spite of the fact that for the holes I., II., and III. the electromotive force between the bags in the direct and return series differs largely, the load-currents deduced from the two sets of data are practically equal. (See Table XV).

Wire.—In the above experiments especial care was taken to prevent errors due to leaks in the wire. The galvanometer was sufficiently delicate to register a fault of this kind of 5,000,000 ohms resistance with certainty. As has been mentioned, every leak introduces an electromotive-force zinc-copper ;* hence the great necessity, notwithstanding the fact that the latter must act through a very great resistance, of avoiding them.

General remark.—The opinion has already been expressed that the field of electric excitation is confined to particular parts of the ore-body. That this should be the case is not surprising, as the conclusion has already been reached that contact between different kinds of material is necessary for the production of currents. In the connection made between chambers No. 14 and No. 15, as well as in the survey on the 400 and 500-foot levels, the ore actually met with was principally lead carbonate, at times stained with sulphide and ferric oxide. Now, disregarding the sulphide, which is here very unfavorably associated, more pronounced electrical properties can hardly be ascribed to the remaining constituents of the deposit than to the surrounding rock itself. For, judging RDM physical properties, cerussite may be regarded as an insulator with as much right as calcine, earthy lead-carbonate as limestone. In fact, it seems to follow that the feeble, though none the less positive, reaction observed on the 600-foot level is already partially obscured when the line of points on the 500-foot level is reached, and would, perhaps (other things being equal) be equally obscured on the 700-foot level. I am also inclined to infer that the currents observed on the surface are not

* For we have the closed couple: Copper (of wire); liquid (moist earth, etc.); zinc (of bag).

due, or, rather, not immediately due, to the deeper ore-bodies (Nos. 11,12, 13,14,15, etc.), but to the deposits, also of considerable size, occurring in what are known as the Lizette Tunnel workings. The entrance to the latter is on a level with the mouth of the shaft, and the ore-masses are distributed in a vertical range from point I. to a level even above point X. of the surface survey. These ore-bodies, throughout their extent, are comparatively near the line of holes used in the surface survey. It is, moreover, quite probable that an intimate connection exists between these and the large group of ore-bodies below.

In consideration of the statements made in the foregoing paragraph, and allowing as accurately as possible for discrepancies, the results thus far reached may be regarded as agreeing well with the fundamental hypothesis.

CONCLUDING REMARKS.

On reviewing the results described it is strikingly evident that the electromotive forces met with are invariably small, very frequently, indeed, actually at the limit of the accurately measurable. It is true that the electrically active material was probably galena, which, as Fox long ago observed, is unfavorable for observations like the present. It is a question, however, whether results much larger than these will generally be obtained. I cannot believe, for instance, that Reich's earnest appeal for general research in the direction of electric prospecting has been altogether disregarded. There is much more to lead one to infer that many undertook the study of the question, but disappointed with feeble reactions and discordant results abandoned the matter altogether. Reich, at the end of his last paper, gives a list of the apparatus desirable, which, however, except where the action is so intense as it was found to be in Cornwall, and to a lesser extent at Freiberg, would certainly be insufficient.

Nor can my experiments be said to have finally settled the question as to the availability of an electrical method of prospecting. But allowing the researches of Fox and Reich proper weight, results such as those contained in the above pages, certainly give the highest encouragement to further research in this direction.

The variation of earth-potential encountered along any line of electrical survey with distance, when expressed graphically, appears as a broken line possessing certain distinct characteristics. I proved, however, that the progress in the values of earth-potential observed in passing from one point of a drift to another, is continuous, and that therefore the potential-line in the diagram, however sinuous, never suffers a break of continuity. It follows that we may regard the curves obtained as containing an unknown disturbing effect, superimposed on the decidedly larger electrical effect attributed to the ore-bodies. I infer that in any extended line of electrical survey, besides the large field of excitation due to the ore-bodies, very many smaller fields distributed throughout the mine are constantly encountered and intersected.

The study of the electric activity of ore-bodies should be carried out on a broader basis than was possible in the present case, to reach the best results. A single line of survey, or the investigation of the variation of potential in a single drift, is far from sufficient. The endeavor should be made to map the equipotentials as surfaces traversing the whole mine, carefully considering their position and contour relatively to any ore already in sight, and their change of form on leaving it. The inferences to be drawn herefrom would certainly compare in value with those of a purely geological character, even though dependence must be placed on the latter for a complete interpretation of the results.

Furthermore, it will be desirable to carry out Fox's original idea, namely, of investigating the electrical properties of ores and those minerals of the heavy metals which are usually found associated with them; not that the results of such an investigation could ever furnish a clew as to the kind of material to which an observed electric effect is due (it is here that our knowledge of the locality must aid us), but that the *class* of ores, in prospecting for which an electric method would be peculiarly applicable, could thus be defined. The knowledge we possess of the conductivity and the position of ores in the electrical scale is largely the result of experiments made a long time ago. Recent observers have made but few quantitative additions, and even these—probably from improperly chosen methods—are frequently discordant.

The method which has been described seems to me especially worthy of consideration from the fact that by means of it an electric survey, made on the surface, may detect not only the presence but also the approximate position of ore-bodies under ground. With such an end in view we have only to repeat an earlier consideration with a little more definiteness. The experiments should be extended over a large area, and the potential at all portions of the surface determined. Suppose, now, that at each point of the projection of the latter on a fixed horizontal plane, a vertical line is erected, of a length proportional to the earth-potential at this point. The ends of all such lines together make up a second imaginary surface, coextensive with the first, which will represent the electric state graphically at each point of the territory over which the survey has been carried.

The effect of normal earth-currents would then express itself in the progress and contour of the imaginary surface as a whole, and would not destroy its regularity. If its extent is not too large, this surface will probably be a more or less inclined plane. As it has been observed that earth-currents are not constant, even for short periods of time, the latter is, moreover, to be regarded as slowly oscillating, more or less parallel to itself, about a certain temporarily fixed position of equilibrium. But it is probable that the limiting positions of the plane are so near to one another that for this purpose they may be regarded as coincident.

Local action, however, in contrast to the foregoing, would probably manifest itself locally in the imaginary surface, as a hillock or depression. It is to such anomalies that the attention would subsequently be directed, the electric activity of ore-bodies, differences of potential of liquids in contact, and Matteuci's effect (mentioned on a preceding page) constituting the salient points to be considered. In the interest of expeditious work all measurements should be made electrometrically, the lines of survey radiating from a central point *(P. C.)* the potential of which is arbitrarily taken as zero.

The prosecution of the experiments described in this chapter was aided by the cordial cooperation of Messrs. Patton, Lamb and Ballard, of Virginia City, and Messrs. Rickard, Westcott, Harris and Bryan, of Eureka, Nevada. The work is also indebted to Professor Michie, of West Point, for the loan of a Rowland magnetometer made by Mr. William Grunow, of New York.

TEE IR0N-M1NES OF PUTNAM COUNTY, N. T.

BY ARTHUR F. WENDT, N. Y. CITY.

IN 1697 King William the Third granted unto his well-beloved suhject Adolph Philipse, a certain tract of land, now known as Putnam County, N. Y. At the death of Adolph Philipse the land descended by inheritance to his nephew, Frederick Philipse. In 1754 his surviving three children partitioned the surface into nine parcels and divided them equally amongst themselves, but reserved the mineral rights which they held in common.

Thus, at this early period in the history of the colonies, the existence of valuable deposits of iron-ores in Putnam County seems to have been a matter of common knowledge. Yet it is only within the last five years that the county has become a prominent producer of iron-ore.

Desultory mining had been carried on before that period at the Sump, Croft, and Tilly Foster mines, but only a limited output was achieved, and few of our iron-masters suspected the existence of an abundance of good ores only forty miles from New York harbor.

The accompanying map shows the location of those deposits of ore which are now generally known, and have been worked to considerable extent. Without doubt there are many more still awaiting the miner's pick, for no systematic exploration has ever been attempted within the borders of the county.

Geologically, the occurrence of the ore is a counterpart of that of the New Jersey and Lake Champlain magnetites. The country-rock, and even the physical geography, are identical. Many small lakes dot the surface of the county. It is from these and their tributary springs and streams that the metropolis derives its far-famed Croton water. Abrupt hills divide the lakes and ponds. Some of the lakes, notably Lake Mahopac, are on the crest of hills, and are fed by subterraneous springs.

The prominent mines of the county, in the order of their productiveness, are the Tilly Foster, Mahopac, Croton Magnetic, Sump, Croft, and Island mines. Of these, the first two are at present the only producers, and are quite exceptional in their nature. In fact they are the only ones of their kind in the Appalachian range, if not in the world.

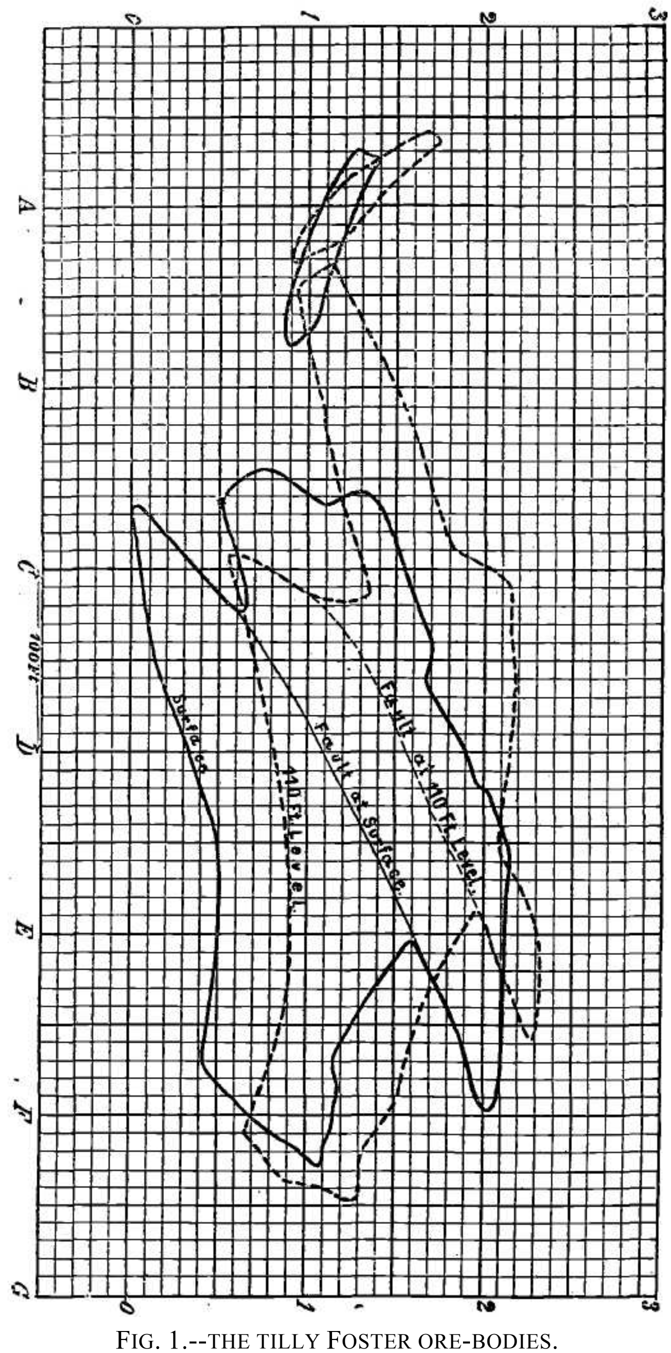


FIG. 1.--THE TILLY FOSTER ORE-BODIES.

The ore-bodies are large chimneys or lenses of magnetite, approaching two hundred feet in thickness, and respectively three hundred and four hundred feet long.

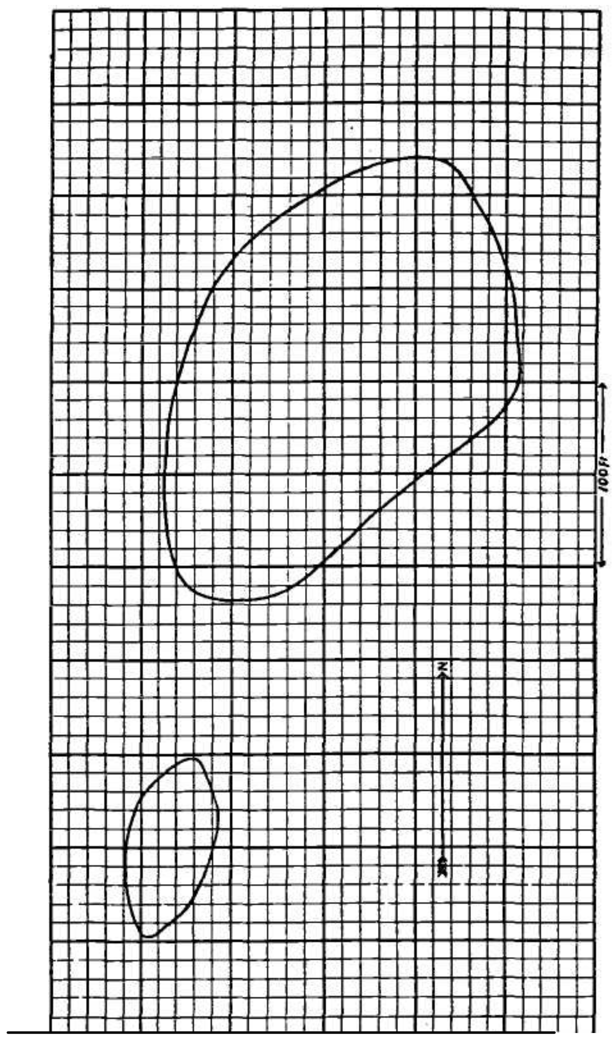


FIG. 2.--THE MAHOPAC ORE-BODIES.

The strike of both ore-bodies is northeast, conformable to the country-rock. The dip of the Tilly Foster is about 60°, and that of the Mahopac is somewhat flatter. The Tilly Foster has a small chimney on the northeast, and the Mahopac has one southwest of the main ore-body.

Horizontal sections of these ore-bodies are shown in the accompanying diagrams.

The Tilly Foster (Fig. 1) assumes its singular shape by reason of a fault which has cut the ore-body diagonally, and thrown it about ninety feet. Originally, without doubt, the section of the Tilly Foster was very similar to that of the Mahopac mine. (Fig. 2.) But it is not only in the shape and size of the ore-bodies that these mines are remarkable. The ore itself has unusual peculiarities. It is a magnetite with a gangue of the rare mineral chondrodite. The chondrodite usually occurs in fine yellow or brown grains, interspersed throughout the ore. Perfect crystals are seldom found.

Some beautiful ruby-red specimens of this rare mineral have been 'obtained associated with dolomite, enstatite, and sometimes with chlc-rite. Magnesia minerals, in fact, form the only gangue of the ore. As these are all quite fusible, and there is no free silica present, the remarkable effect of the ore in increasing the product of a blast-furnace is readily accounted for.

From a paper by Prof. Dana, on the Tilly Foster chondrodite, I extract the following analysis of this mineral, made by Mr. G. W. Hawes, of the Sheffield Scientific School.

Silica,	34.10
Magnesia,	53.17
Ferrous oxide,	7.17
Alumina,	.48
Fluorine,	4.14
Total,	99.06

The mineral is substantially a double silicate and fluoride of magnesia and iron. It melts in the flame of a candle.

A destructive analysis of an average sample of Tilly Foster ore, made by Mr. O. D. Allen, of the Sheffield Scientific School, gave the following result:

Fe_2O_3,	48.24
FeO,	22.67
MnO,	.17
MgO,	13 20
SiO_2,	12.67
Fe,	50.64
P,	.019
S,	.050

Average samples of shipments to the Bethlehem Iron Company gave:

	I.	II.
Iron,	46.76	47.43
Silica,	10.22	12.69
Phosphorus,	.028	.027

Average of thirty commercial samples, from sale of the ore, yielded 47.8 per cent, metallic iron.

It will be noted that the aggregate amount of the bases is greater than the total of silica, and hence the ore is almost self-fluxing.

Mahopac ore is even more basic, and also richer in iron, as the following average analysis of samples just taken from 12,000 tons of ore, by Andrew S. McCreath, will show:

Sesquioxide of iron,	52.018
Protoxide of iron,	22.885
Bisulphide of iron,	.026
Protoxide of manganese,	.186
Oxide of copper,	none
Alumina,	3.078
Lime,	1.450
Magnesia,	10.065
Titanic acid,	trace
Carbonic acid,	.251
Sulphuric acid,	none
Phosphoric acid,	.028
Hydroscopic moisture,	.048
Combined water,	.758
Silica,	8.780
Alkalies and fluorine,	.427
Total,	100.000

Equivalent to:

Metallic iron,	54.225
Metallic manganese,	.144
Sulphur,	.014
Phosphorus,	.012
Phosphorus in 100 parts iron,	.022

An aggregate of nearly 15 per cent, of bases against only 8¾ per cent, of silica makes the ore absolutely self-fluxing. Only a lime-addition for ash in the fuel is requisite in the burden of a furnace. Mahopac ore is, without exception, one of the purest mined in the United States, and is lower in phosphorus and sulphur than any native ore in the market. Pig-iron made from it alone need contain only .03

per cent, of phosphorus, and would permit, in the manufacture of steel rails, a considerable addition of pig classed outside of the Bessemer limit.

The question of working the mines and supporting the roof of these enormous ore-bodies has proved a very troublesome one. Especially is this true of the Tilly Foster mine, where the ore has been torn asunder and shattered by the fault already referred to. The common method of leaving a floor of ore to support the hang-wall resulted in an enormous cave which ruined the mine and rendered it unprofitable for over two years.

Taught by dear experience that such a system of support was quite inadequate to the requirements, Mr. A. Cosgriff, the superintendent of the mine, introduced the present system. Thus far this has answered its purpose, and it will, with proper modifications, answer in the future.

The system in use is to sink the main incline on the dip of the foot-wall and cut a station every hundred feet; then to run a wide drift along the foot-wall to the ends of the ore-body. From this drift rooms twenty-four feet wide, with intervening twenty-foot pillars of ore, are turned towards the hanging-wall. A plan and an elevation of a level thus arranged are sketched in Fig. 3.

Each room is raised up to within fifteen or twenty feet of the room above, leaving a floor of ore of that thickness extending over the whole area of the mine. Enough ore is left in each room to allow the miners to stand thereon and reach the solid stope overhead. Only the surplus is withdrawn from day to day, as the work progresses. When the room has been stoped out, the broken ore lying in it is drawn and the room is abandoned.

All work is done by contract, the breaking of ore being paid by the fathom. Each set of contractors is furnished and charged with a drill, and the powder, fuse, steel, etc., consumed. A reasonable charge is made for compressed air used. No attempt at sorting the ore is made underground. The whole of the material broken is hoisted to the surface, dumped into cars and there carefully sorted. The waste usually exceeds 25 per cent. Owing to the intimate and irregular mixture of ore and rock in the vein sorting on the surface has been found to be the only feasible system.

By the method pursued a very large proportion of the vein, estimated at over one-half, remains to support the mine, as pillars and floors. At the time of writing there are supposed to be over a million tons of ore thus developed and in sight in the Tilly Foster mine. To recover this enormous quantity of ore, the excavations or rooms are now being filled with masonry, laid in cement. Upon the completion of these artificial pillars the iron-ore pillars and floors will be removed. The cost of this proceeding, although very large, will not, it is thought, be prohibitory; and the ease and safety with which the ore can subsequently be removed will, in a large measure, recoup the outlay.

In the Mahopac ore-body, the lean ore and vein-rock are fortunately stratified parallel with the ore-body, and it does not become necessary to mine the whole width of the vein. The mine practically assumes the shape of four beds of clean ore, from ten to fifty feet wide, superimposed the one upon the other. Practically, all the rock remains underground and admirably answers the purpose of pillars. Overhead stoping is used only in part, the aim being to raise up a small stope to the level overhead and then widen out and stope downwards. Development work consists, as at the Tilly Foster, in an incline; but here the similarity ceases. From the foot of the Mahopac incline a cross-cut is run towards the hanging-wall, and from this cross-cut low rooms are turned off, both right and left, on the different ore-bodies. By this system a very small amount of dead work becomes necessary. The breaking of the ore, tramming, hoisting, etc., is all done on contract. Sorting is done at the surface, but from the nature of the ore-body, there is not nearly as much waste as at the Tilly Foster, and consequently the sorting is comparatively inexpensive.

The Tilly Foster mine has produced, in the twenty years of its operation, upwards of three-quarters of a million tons of ore, and has shipped as much as 60,000 tons in a single year. The Mahopac mine, first opened by the writer a few years ago, has shipped over 60,000 tons of ore, notwithstanding all the ore had to be carted some four miles to the railroad. This drawback is now on the point of being remedied by the completion of the Mahopac Falls Railway, connecting the mine with the New York City & Northern Railway, and affording outlets to New York harbor via High Bridge on the Harlem River, and via the New York and New England to Fishkill on the Hudson. Once at tidewater or on the Hudson, many railways are available to transport the ores of Putnam County to the Pennsylvania furnaces.

The Croton Magnetic Iron Ore Company's property is tributary to the Harlem Railway, with which it is connected by a wire-rope tramroad.

An ore-deposit entirely different from the Tilly Foster or the Mahopac has been developed on this property. Magnetic attraction extends over an area of one hundred feet wide, and nearly seven thousand feet long. Over this area the gneiss rock is impregnated with particles of magnetite.

The workable ore is not, however, above ten or fifteen feet wide.

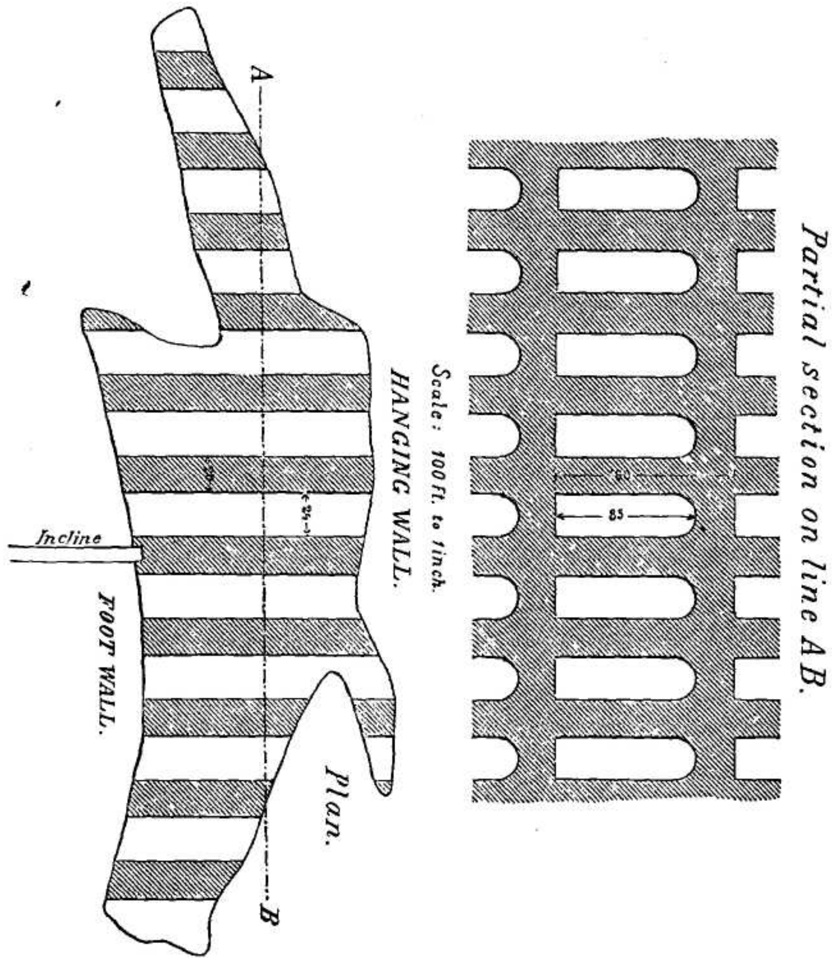


FIG. 3.—METHOD OF WORKING THE TILLY FOSTER STILE.

Usually it follows a pretty well defined hanging-wall. The ore forms an exceptionally long and continuous bed, somewhat resembling the noted Chateaugay mines near Plattsburgh. The vein strikes N. 20° E. and dips very steeply (almost vertical), towards the southeast. Openings have proved the ore-body to a length of 2600 feet. Four levels about 75 feet apart have developed the ore to a depth of 160 feet below, and 200 feet above the adit level.

Regular shipments of the Croton Magnetic Company's ore were first made in the summer of 1880. All told, they do not sum up over 35,0G0 tons. The mine is now idle, owing to the general depression in the iron trade. Analysis of the ore shipped in 1883 resulted as follows:

Fe_2O_3,	47.17	49.74 Fe.
FeO.	21.52	
MnO,	.51	
Al_2O_3,	8.55	
CaO,	2.10	
SiO_2,	18.93	
P,	.21	
S,	.52	

The ore makes a strong forge iron and, if used in admixture, a good foundry pig. Of course it is outside of the Bessemer limit both in phosphorus and sulphur.

The four levels opened on the vein give extensive faces for working the property.

It has been customary to work these faces or stopes by the ton. From 50 cents to 75 cents was the usual contract price per ton of ore broken and delivered outside of the mine on the weigh-scales above the sorting-floors. The ore as mined is quite lean : about one-half has to be wasted to sort it up to a yield of 50 per cent. Much of the waste is, however, recovered by passing it first through a large crusher, and over a picking-table, and then through a complete concentrating-mill. This mill was described by the author in a paper read before the Institute at the late Chicago meeting (*Transactions*, vol. xiii., p. 35).

Concentrations of the ore contain by analysis :

Metallic iron,	65.
Silica	3.
Phosphorus,	0.08

In the paper referred to, the author mentioned the remarkable elimination of phosphorus in the concentrating process, undoubtedly due to the separation or washing away of the apatite in the gangue.

The separated or concentrated ore has heretofore been all shipped to the furnaces in admixture with the sorted lump-ore. No attempt has been made to work it up into blooms, as is usual in the Lake Champlain district.

The market for Croton ore has been principally in the Lehigh and Schuylkill districts of Pennsylvania. With the rates of freight now-ruling to these points, via the Harlem Railroad, no sales can be made, even were the ore sold for less than two dollars per ton at the mines ; and the property is condemned to enforced idleness until such time as the Iron market revives, or a demand is created nearer to the mines.

Possibly, in time, the transportation companies may, in their wisdom, decide that carrying ore at a low rate of freight is preferable to not carrying it at all. But iron miners hardly expect this much to-be-desired event to occur a very great while before the arrival of , the millenium.

The Mahopac Island mine is a portion of an irregular and (for this country of great ore-bodies), a small bed of ore, extending from Petrie Island on Lake Mahopac, under the lake and about a mile in a southeast direction.

A picked sample of the ore showed by analysis :

Metallic iron,	56.33	per cent.
Manganese,	0.102	"
Silica,	9.020	"
Alumina,	7.090	"
Lime,	1.970	"
Magnesa,	0.620	"
Sulphur,	0.128	"
Phosphorus,	0.049	"
Titanium,	Trace.	

A fair average of the sorted ore will not yield over 50 per cent, of iron. The ore-bed is quite irregular. Practically it must be considered a succession of lenticular masses, rarely exceeding 6 feet in width. Each mass will have to be mined by itself, as drifts through the rock, from ore-body to ore-body, would often be too expensive. No large amount of ore has been shipped from the mines. The little that has been shipped has gone to Cold Springs via Harlem and Hudson River Railroads. The property is idle at present, and likely *to* remain so until iron interests experience a material advance.

The Croft mine, connected by a narrow-gauge railway with

Peekskill, has been worked many years. The ore occurs as a series of lenticular masses, often joined by narrow strings. The vein reaches a width of 15 feet in places, and has been explored and exhausted some 200 feet or more on its dip. While the Peekskill furnace was in operation, the ore from the Croft mine formed a large portion of its burden. Lately the furnace and mine have been idle. An average analysis of a large sample taken by the writer showed 51.2 per cent, of metallic iron. A complete analysis of a sample rather better than the average, made by Dr. T. M. Drown, in November, 1880, gave the following result:

Fe_3O_4,	80.87
FeO,	0.66
MnO,	0.36
Al_2O_3,	0.71
CaO,	2.48
MgO,	4.24
SiO_2,	3.61
PO_5,	.055
S,	0.16
TiO_2,	none

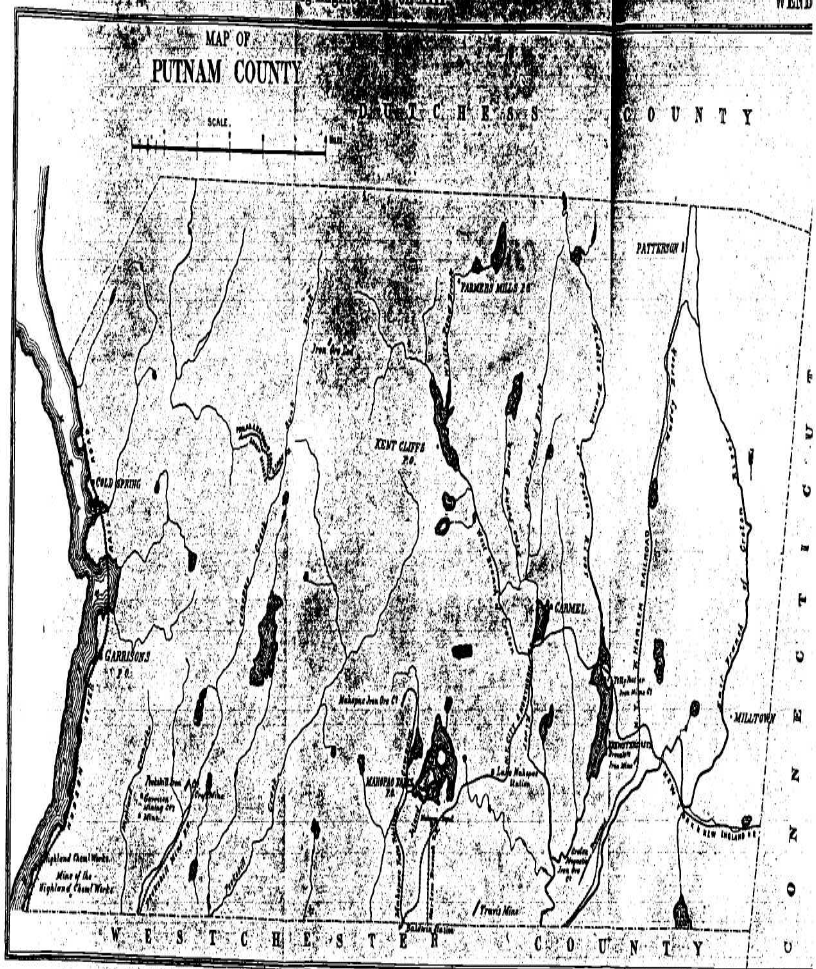
Equivalent to:

Metallic iron,	59.06
Phosphorus,	.024

The ore is, as the analysis indicates, of fair quality, and fit for Bessemer purposes if used in admixture.

Sulphur sometimes varies considerably, and hence it is not possible to use a large percentage of the ore in a Bessemer mixture.

The mines known as the Sump mines are owned by the Philadelphia and Reading Goal and Iron Co. Common report places the cost of the property to the company at a very high figure. Work has been prosecuted spasmodically at these mines. Whenever a boom in iron occurs, some money is spent, but to little advantage, as the property has no railway outlet for the ores, and cannot possibly be profitable till this is secured. The Croft Mine Railway could be extended to the Sump mines at no prohibitory expense, and a market on the Hudson would then be open.


MAP OF
PUTNAM COUNTY
SCALE.
DUTCHESS COUNTY
PATTERSON
FARMERS MILLS P.O.
KENT CLIFFS P.O.
COLD SPRING
GARRISONS P.O.
CARMEL
MILLTOWN
MAHOPAC FALLS P.O.
Highland Chem'l Works
Mine of the Highland Chem'l Works
Travis Mine
WESTCHESTER COUNTY
CONNECTICUT

EXPERIMENTS WITH A STRAIGHT OR NO-BOSH BLAST-FURNACE.

BY W. J. TAYLOR, CHESTER, N. J.

IT is, perhaps, more important to put on record the particulars of experiments that are decided failures than those that are successful, as those of the latter class are certain to live, while the former may be lost sight of in a short time, and repeated by others. To this end, I propose to give the particulars of a straight or no-bosh furnace just tried at the Chester (New Jersey) works, chichi was such a decided failure as to leave no doubt of the plan being wrong, and determining the necessity of a bosh of some kind, as of old.

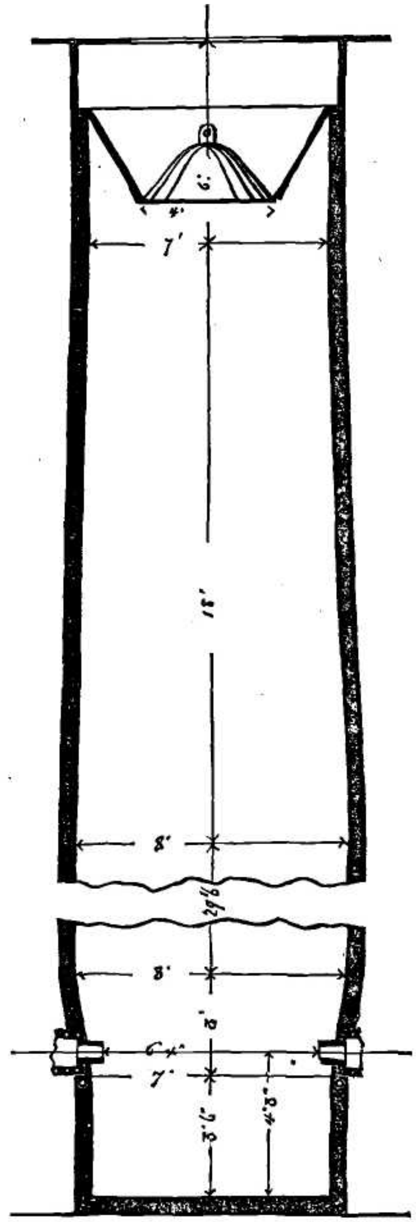
Some experiences during the past year led me to suppose that the bosh or belly of a furnace was unnecessary, and that the contraction of the walls toward the bottom for the stock to wedge in, in its descent, facilitated dirty walls and scaffolding; hence, irregularity and high fuel. I concluded, however, that a very shallow bosh for a skew-back support to the stock would be necessary, and that the proper place for this was in the tuyere-section, beginning just below the tuyeres and ending just above them, where there is nothing in the solid state but fuel, which is consuming, and no slipping or travel of stock takes place. The cubical capacity of a furnace of this design would necessarily be much less than in the old style, unless it was made very much higher. But I assumed that the loss of room for reduction could be overcome by making the size of the ore and stone charged much smaller, so that the gases would act more quickly. The next point was, what should be the size of the shaft, crucible, tuyere-circle, and tunnel-head for a given quantity of air?

My first design was 12 feet diameter of shaft for 7000 feet of air, with a 9-foot crucible and 8-foot tuyere-circle. This I soon reduced to 8-foot shaft diameter, which I concluded was large enough for economical work, if regular travel of the stock on the walls could be maintained. I consulted with a number of experienced furnace-men and furnace-engineers, and the plan was well thought of by many of them; and, as I had also some offers of financial aid from them toward the risk of trying the experiment, my firm concluded to make the trial in its Chester furnace, which was 13 feet by GO *feet,* blowing 7000 feet of air maximum. The furnace was lined accordingly, the shaft 8 feet for 36 feet up and drawn to 7 feet at the stock-line, bell 4 feet, crucible 7 feet, tuyere-circle 6 feet 4 inches, all as shown in cut. The lines of the lower part of the furnace for 14 feet above the tuyeres were held by vertical water-pipes 7 inches apart, with 8 inches of brick inside, and one horizontal pipe just underneath the tuyeres. The furnace was filled about in the usual way—fuel, half coke and half anthracite—and fired at 8 A.M., July 17th. Burned well by fanning with the engine, and blast was put on and bell closed at 2 P.M. Commenced blowing with 3400 feet of air through four 5-inch tuyeres. The oven (Weimer suspended pipes) had been well fired with wood, and the heat came up well, but the gas was thin and cold from the start. Pressure light, less than one pound for the first hour, but went up normally, and stock settled pretty regularly until about 6 P.M., when very decided irregularities commenced. Pressure very high at times, no gas, and stock not settling. Temperature of blast at 6.30 P.M was 600 degrees. From this time, for the next five hours, the furnace could only be eased by throwing off the blast, when the pressure would tighten, gas come and stock settle occasionally. On throwing on blast at 11.16 P.M., burst one of the pipes in oven and stopped 29 hours for repairs. Oven had been fired, and heat came up rapidly on starting Saturday morning, 19th, at forty minutes past 3 A.M. Pressure 2 pounds with 3400 feet of air, and a small quantity of gas soon made its appearance at boilers and oven. Stock did not settle, however, and pressure soon went up, which was again relieved by throwing off blast. In this way the furnace was nursed until about 11 A.M., when stock settled well, and matters looked encouraging. Filled 7 tons coke as blanks, and got first flush of cinder at cinder-notch at 3.15 P.M. Continued to work fairly well until 3 A.M. Sunday, when we cast five beds poor white iron. Furnace then tightened up, and gas disappeared. At 7 A.M. exploded five cartridges of giant powder in the center of the furnace about 13 feet above the tuyeres. This, together with throwing off the blast, and not filling for a time when the stock settled, gradually brought the furnace into working shape again, but only for making a small quantity of white iron, even with the low burden of one to one. On Monday, 21st, opened four test-holes in walls 3 feet above the tuyeres and found stock quite cold—only red-hot—next to walls for about 2 feet in all round. This stock, consisting mainly of fuel, was principally fine, and appeared to be moving, but very slowly compared with the center. We also opened holes 13 and 20 feet above the tuyeres, and found practically the same conditions—cold stock, but not specially fine, next to walls for about 2 feet. This showed only 4 feet in diameter or one-quarter of the area of the furnace for active work, and explained the whole trouble, and also proved that straight walls would not prevent accumulations on them, or perhaps scaffolding. We then blew the furnace down to within 4 feet of the tuyeres when the walls cleaned themselves, and test-rods showed greatest heat next to walls; but, in filling up again, the old troubles reappeared, stock settled irregularly, and by jumps particularly when the furnace was nearly full. The accumulations on walls over tuyeres were the same, iron nothing but white, unless blanks or very light burden was working, and even then we could make nothing better than gray forge.

After working in this irregular way for a few days, we blew down again; and, when a little more than half-way down, found the stock active and hot on walls, and we commenced filling up again. First 12 hours put in 18 tons of blanks with a slag and limestone burden only, then 20 tons blanks in next 12 hours with slag and scrap, but after putting on a light ore-burden, three-quarters ore to one fuel, and before furnace was full, the old troubles came back, and we decided to blow out.

The duration of the blast was 16 days, and the product was 30 tons gray forge, 20 tons mottled, and 76 tons white iron, total 126 tons plus the scrap, which was perhaps 20 tons more than was used. Stock used was 295 tons coal, 134 tons coke, 365 tons ore, 175 tons stone. Of course, much of the cinder was high in iron also, and was saved. These results were so decidedly unsatisfactory that they seemed almost accidental, and it was, therefore, concluded to make another trial before abandoning the plan entirely, by blowing in a little differently. The furnace was again carefully filled, using a little more wood and considerable furnace-slag with the blanks and charges. No slag had been used in the first filling. Blast was again put on August 13th, after burning well for 13½ hours natural draught, starting with 3300 feet of air blown through 3-inch instead of 5 inch nozzles. In 4 hours the furnace was in precisely the same conditions as in the first blast at the end of 4 hours' blowing; and, as the following 24 hours were only a repetition of the first blast in all respects, notwithstanding the changes made in blowing-in, it was decided to blow out at once, as there could be no doubt then that the plan, at least if not a success, was a successful failure.

My thanks are due, for support and assistance in the trial, to



many members of the Institute, among whom I wish to name particularly Mr. Hartman, of Philadelphia, Mr. Rader, of Sheridan, Mr. Cook, of Warwick, Mr. Firmstone, of Glendon, and Mr. Boyer, of Columbia.

DISCUSSION.

JOHN M. HARTMAN, Philadelphia, Pa. (who read the paper, in the absence of the author): This experiment was a failure. The paper was written by Mr. Taylor at my request, and I told him I would like to read it. Of course, we dislike to record our failures, but the information communicated in this instance may prove valuable in pointing out that which is to be avoided in the future.

R. W. RAYMOND, New York City: I did not notice in the paper itself any attempt to explain the cause of the failure. Mr. Taylor does not seem to have undertaken to deal with the theory of the matter at all, and, before Mr. Hartman considers his duty done, I think he ought to give us any ideas that he may have upon the cause of the failure. I see nothing in the lines of this furnace *a priori* to prove that it should, in the lapse of such a very short time after blowing-in, come into a condition such as is described in Mr. Taylor's paper. It has been a great puzzle to me, why this should be so. Although the conclusive result of the experiment is plain enough, it fails, of itself, to explain not only why it should happen, but also why it should happen so quickly, and, we may say, so much more quickly than would have been the case in a normal blowing-in with the ordinary furnace-lines.

W. F. DURFEE, of Bridgeport, Conn.: I do not know that the suggestion that I am about to make will explain satisfactorily the cause of failure of this furnace, but the fact is one that is well known, that, if a cylindrical tube of moderate diameter (in fact, if everything is proportioned to the size of the tube, it may be a very large tube) be filled with sand and placed vertically, it will be almost impossible to force the sand out of the tube by pressure applied at the lower end. The tendency of this dry sand is to pack or, so to speak, form inverted arches or domes of the particles of sand, which have their abutment on the side of the tube, and the friction there is so great under the pressure as to prevent the expulsion of the sand. A practical application of that idea is of very frequent occurrence in blasting. It is not unusual to omit the old-fashioned method of tamping with brick-dust and clay, and simply pour in dry sand above the powder-charge, and, in lieu of any forcible compression, to compact it by thrusting in a tapered pine stick, as the sand is poured in, thus insuring its settlement upon the charge. In this case, it may not be at all impossible, it seems to me, that the stock in the furnace should have formed itself into a series of domes, in the central or lower part of the furnace, their abutments being the sides of the furnace, and the frictional resistance there being sufficiently great, under the pressure of the superincumbent materials, to prevent the stock descending or coming within the influence of the heat below. I do not know that this is a satisfactory explanation, but it seems to me that such a state of facts might cause the failure of such a furnace.

EDGAR S. COOK, Pottstown, Pa. : During the trial of this experiment, I visited Chester, at the request of Mr. Taylor. When I arrived, the furnace was working very cold; the stock was settling regularly, but the iron was not properly separating from the cinder. Instead of making pig-iron, the furnace was producing a slag heavily charged with iron in chemical combination, that is, similar to mill or finery cinder. There was some metallic iron thrown out also, along with the slag. All the conditions indicated that the burden of ore was being melted, without previous preparation, the oxygen not being removed. The reduction-space was probably not sufficient to permit complete deoxidation of the ore, or the gases were not rich enough to do the work in the small space and short time allowed; consequently, the iron passed off with the slag.

While I was there, Mr. Taylor decided to treat the furnace as a cupola, and commenced to fill nothing but fuel, furnace-slag and scrap-iron. When this mixture came fully to work, the furnace became very hot, making a liquid, gray cinder. The furnace soon worked full size, settled regularly and evenly, and melted rapidly. An experiment was tried of passing rods through the walls a few feet above the tuyeres. This showed that the furnace was as hot on the walls as in the center. This mixture was filled for about 12 hours, the proportion of furnace-slag and scrap-iron, however, being gradually increased, until to 1 pound fuel there were 2 pounds slag and scrap. The ash of the fuel was carefully fluxed with limestone. During this time all the conditions appeared to be normal. The engine was run with the average number of revolutions, 36 to 40 per minute ; pressure was regular; tuyeres were bright; stock settled regularly; cinder continued fluid, showing no iron beyond that usually found in good gray cinder. A cast of gray pig-iron was made, and everything seemed favorable enough to permit again filling the regular ore-mixture. It was hoped that the heating-up had removed any remnants of the scaffold that might have previously formed on the walls above the tuyeres.

Shortly after the ore-mixture came fully to work, the cinder changed; ore-material settled on the walls, reducing the active working-size of the furnace ; the ores were not properly reduced, and the furnace soon became cold, making white pig-iron and fining cinder. Just previous to the filling of the ore-burden, I was obliged to return home. I had had, from the beginning, but little faith in the commercial success of the experiment, and was convinced that, if the furnace did not work satisfactorily after pursuing the course described, it was only a waste of time and money to continue it longer. As the after-results showed no improvement on those previously obtained, Mr. Taylor decided to blow out.

It is possible that, with a larger furnace, the results obtained from straight lines would not have been so disastrous, since more room would have been allowed for reduction, even if there had been accumulations on the walls. The furnace, however, was built to suit the capacity of the engine and boilers, assuming that the walls would work clean, leaving it fully 8 feet in diameter. My experience would prove that this diameter above the tuyeres is sufficiently large for 7000 cubic feet of air per minute, so far as the melting part of the operation of the furnace is concerned. Anything larger would probably require an increased consumption of fuel. The experiment of Mr. Taylor proved that more room was required above for the proper reduction of the ore, and that straight boshes, or rather no boshes at all, do not offer any guaranty against scaffolding or accumulations on walls. It would thus appear that the angle of bosh usually adopted, 70° to 80°, does not necessarily incline a furnace to form scaffolds. Even as built, I believe Mr. Taylor's straight furnace would work, provided from 2 to 3 tons of coal were used to 1 ton of iron, but from the result of the two trials it is evidently a failure, so far as concerns the making of iron with an economical consumption of fuel. This may be due not so much to shape of furnace, as to the dimensions employed. Here arises the seeming necessity for boshes. A comparatively confined space at and directly above the tuyeres is required to concentrate and intensify the temperature, with the least expenditure of fuel; while, still higher, a considerable enlargement seems essential to afford room for the proper reduction of the ore and free circulation of gases.

Generally speaking, I think the first six months are the most troublesome part of the blast. After a furnace has been in blast for six months or a year, and has been worked up to its capacity the boshes become melted away, and practically we are then working furnaces without any boshes, owing to loss of brick-work and enlargement of furnace. In such cases, for a distance of 10 to 15 feet directly above the tuyeres, the boshes are all melted away, so that the lines are nearly vertical,--the only slope or inclination being beyond the region of intense heat, probably about 5 feet from the top of the bosh downwards. For instance, the Warwick Furnace, after being in blast 3 years and 9 months, is, today, essentially in the shape of Mr. Taylor's furnace. The boshes for 13 feet above the tuyeres are practically straight. The next 5 feet, to the top of the bosh, show an inclination of probably 80°.

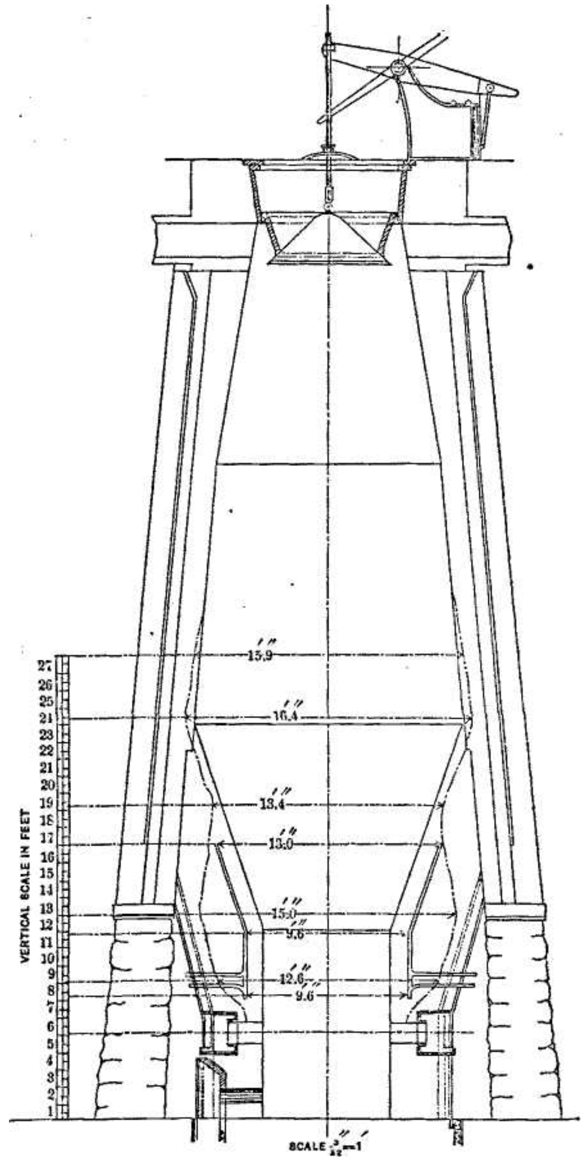
It was a knowledge of these facts, taken in connection with the irregularities that usually attend the commencement of a blast, while the bosh is supposed to be in the shape as built, that probably suggested to Mr. Taylor the idea of building a furnace without any bosh at all, in the hope that this would reduce or entirely remove the danger of scaffolding.

One of the most valuable lessons taught by his experiments, is that a straight furnace will scaffold, and, therefore, that boshes, as ordinarily constructed, are not the cause of scaffolding under other conditions.

I have here a sketch of the shape of the Warwick Furnace as we think it is now--after having been in blast three years and nine months--making in that time about 77,000 tons of iron, and with every prospect of running six months or a year longer.

To obtain the internal diameter or shape of furnace while in operation, we drilled a number of holes through the shell of the furnace. A series of holes--one above the other at about equal distances--was drilled and the thicknesses of the walls thus obtained were laid off on the original drawing of the furnace. By this method we approximated the present working shape.

In the diagram, the full line shows the furnace as blown in December 15th, 1880; the broken line, its size and shape, July, 1883. The figure shows also the location of the vertical series of water-pipes encircling the furnace. Constant streams of water circulated through these coils from December, 1880, to May, 1882, and prevented the furnace from enlarging beyond 9½ feet diameter. We were obliged to stop using these coils in May, 1882, owing to the breaking of the elbows connecting the horizontal feed and discharge-pipes with the upright coils. These pipes were of great value to us ; and we regretted the necessity of discontinuing their use. As soon as the



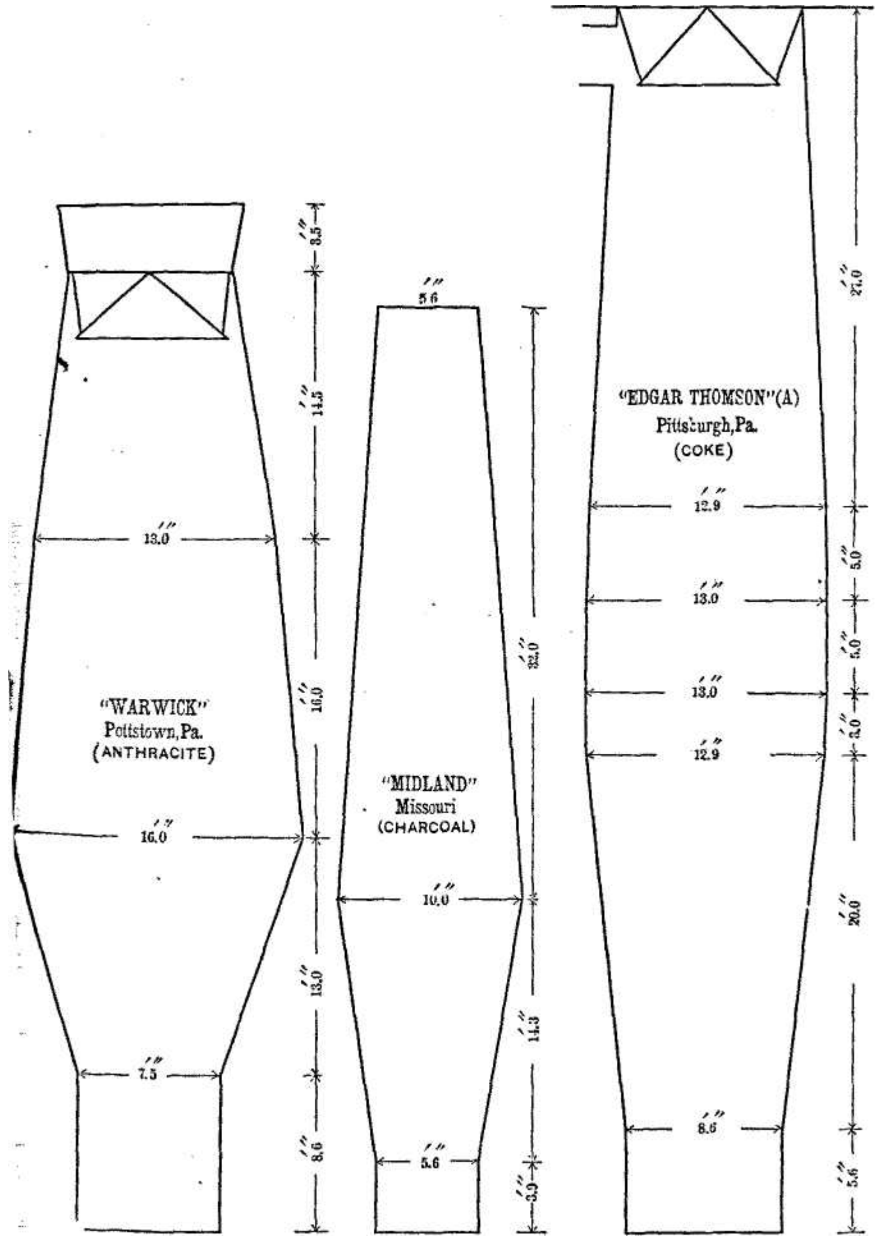
WARWICK FURNACE.

pipes were burnt off, the furnace rapidly enlarged to the size shown by the dotted lines. Since about June, 1882, the furnace has been working its own repairs, filling up and cutting away. At the level of the tuyeres we think the diameter is about 14 feet where, originally, it was 6½ feet. A few feet above the tuyeres, we found the diameter to be 12½ feet instead of 6½ feet as built. For a distance of 13 feet above the tuyere center, the walls are nearly vertical. Between tuyere-center and mantle--a distance of 7 feet--we found the thickness of bosh-walls to be only six inches. These measurements were first taken in July, 1883. A second trial made a week ago--August, 1884--proved the walls to be of the same thickness as the year previous. The economical working of the furnace depends upon the internal diameter. At the largest diameters the work is not economical. It is only when the furnace has filled up with finely divided ore, in a state of oxidation most likely, thus reducing the size of the furnace probably to 10 feet or 11 feet diameter, instead of 13 feet or 14 feet, that the furnace does the most economical work, producing from 450 to 475 tons of iron per week, and on one occasion running as high as 507 tons per week, and with a fuel-consumption of 1 ton, 3 cwt., to 1 ton, 5 cwt. per ton of iron.

This accumulation on the walls is generally in a perfectly unfused condition, resembling a heavy red-hot flue-dirt. When it is partially cut away, the production is not very much affected, but an increased consumption of fuel is required. If, however, the enlargement becomes too great, the furnace loses heat, becomes cold, falls off in yield, and can only be restored to economical working again by the process of filling up and becoming smaller in size. Our average yield of iron per week for the last two years is from 425 to 435 tons. For the last year the average is probably 450 tons per week.

The measurements given, were made when the furnace was doing fairly well, but not the best work.

JOHN BIRKINBINE, Philadelphia, Pa.: When we examine the great variety of shapes which have been and are used to determine the lines of blast-furnaces, and notice how greatly they differ, and yet are informed that almost all of them have given satisfactory results, we need not be surprised if success, partial or complete, attends very material alterations in the forms of those with which we are familiar. When we compare the shape of some of the old charcoal-furnaces, having high crucibles and flat boshes, with the shape of some of the newer charcoal or coke-furnaces having steep boshes running directly from the bottom of the furnace, we find a greater change in shape than is noticeable between the form last named and that which was proposed by Mr. Taylor and his associates. The accompanying

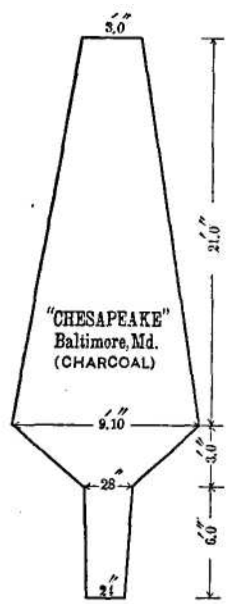


sketches will illustrate this point.

The various shapes here shown are all those of successful blast-furnaces using different fuels. The Warwick and the Edgar-Thomson " A " furnaces have made exceptionally good records, both as to output and as to fuel-consumption.

Data concerning the Warwick furnace will be found in vol. ix., page 58, and concerning the Edgar Thomson "A" furnace in vol. viii., page 349, of our *Transactions.*

It would appear on general principles, that, if we could steepen the bosh from 10 inches to the foot, as shown in the charcoal-furnace, *to* say 2 inches to the foot, as shown in the coke-furnace, and secure



improved results, we could also reduce the batter from 2 inches to the foot to a vertical line and have corresponding advantage. But the boshes of a furnace are important features of the lining. Instead of retarding the flow of a stock, they facilitate it.

Mr. Durfee has probably indicated the fault of straight furnaces where the proportionate size of the material bears the relation to the height and diameter of the furnace that grains of sand bear to tubes of a certain diameter; and it is possible that with a furnace of larger diameter better results might have been obtained; but to secure those results, additional height of furnace would have been required to prepare the stock for smelting and increased activity of combustion would have been necessitated in a larger hearth. Under these circumstances it seems doubtful if success will attend the use of straight furnaces. But we should certainly recognize the candor and frankness with which Mr. Taylor and those who are associated with him in these experiments, and who have borne the expense of them, . have given the Institute the benefit of their experience. We always learn more from failure than from success; and the presentation of this paper may be the means of saving other gentlemen from investing money in what may likewise prove "successful failures."

MR. DURFEE : Following out my original suggestion or thought in regard to this furnace, I would add that it may not be impossible, if a furnace on the principle of this one were constructed on a larger scale as regards its diameter, that quite different and more favorable results might be obtained. If the diameter were considerably larger, that tendency to the packing of stock and consequent resistance to its descent would be very much less. I do not think I have faith enough in the idea to cause me to spend any money to carry it out; but, at the same time, I think I can see that a condition such as I have supposed would not be as liable to occur in a furnace of a larger diameter in which all conditions would be much more favorable to successful working than in the case of the furnace under discussion.

JOHN M. HARTMAN, Philadelphia, Pa.: We are limited in the size of that furnace, and had not the means to enable us to build a new plant, so we did the best we could. The blowing-capacity and stove-capacity would not permit a furnace of larger size; that is, I mean a tuyere-circle of larger area. It is now a pretty well-established fact that the area of the circle enclosed by the noses of the tuyeres governs the production of the furnace. That being the case, we were limited.

In reply to Dr. Raymond, as to my own views of the matter, I will make a brief and plain statement. First, let us take this furnace with straight walls, with the water-pipes just back 9 inches from the face of the walls, and the water circulating up and down rapidly. Now a blast-furnace is a curious thing. It will chili and nip before you know it. After firing, the wood must be consumed before live coals appear at the tuyeres. It takes some little time to get the coal down to the tuyeres. On this occasion, about five hours after blowing in, the eccentric-pin on the blowing engine slipped and caused a shortstop. I noticed on starting up again, that the pressure had increased 2 pounds. I watched that closely. A few minutes after that, the crank-pin got hot; the engine was stopped; and then the pressure went up to 7 ponnds on starting. Each time, there was an addition to the pressure that was quite remarkable. Now let us refer to a furnace in its normal condition. As the matter presents itself to my mind (and I speak only so far as my observation is concerned), from the tuyeres up for a certain distance, there is simply a bed of live coal, nothing else. From the top of this bed of live coal for 18 or 20 inches up, is a certain area in which the ore and stone that have come down are undergoing transformation from a solid to a liquid state. Whenever the furnace is stopped, the weight of the mass of stock above this zone settles down on it and squeezes the pasty material hard against the walls. The circulating water abstracts the beat from this pasty material and sets it firmly against the walls, for, say, a distance of 12 to 18 inches out from the walls.

With this water abstracting the beat from the walls, it rapidly forms an obstruction. You will understand that I do not say that the water-pipe was wrongly placed in the walls; I simply give you my observations in the matter.

For fast driving, some cooling devices must be resorted to to save the brick. I prefer thin walls with a bosh-jacket of boiler-plate, and rely on the cooling influence of the air.

DR. RAYMOND: I think Mr. Hartman will agree that a fundamental cause of the production of furnace-accretions in the iron blast-furnace, is the irregular passage of the gases and the carrying of the heat up along the walls in such a way as to semifuse the stock that is not fully reduced, and to carry the smelting zone in an irregular way up in the furnace, so that the stock, instead of coming clown and melting in the zone of the tuyeres, melts higher up, because channels are formed through which the hot gases rise and overheat the stock above. If that be, as it has heretofore been accepted to be, the main cause of the formation of certain varieties (I may say of the most frequent varieties) of scaffolds in blast-furnaces, then Mr. Durfee's suggestion seems to be contradicted by it. And certainly it is a matter of experience with a great many of us that we do not mind the packing of stock against the walls of the furnace if it is kept open in the middle and the gases rise through the middle; but we do mind very much the formation of channels in the stock, through which the hot gases ascend along the walls of the furnace, instead of diffusing themselves through the furnace. It seems to me that the first thing we have to apprehend is an irregular ascent of gases. Anything that prevents the proper diffusion of the gases through the furnace and promotes an excessive ascent of gases on the walls so as to carry the heat higher up when we want it below and defeat us in our purpose of maintaining what Dr. Wedding once called "a normal condition of health for a blast-furnace, as for an individual, viz., a cool head and warm feet"—anything that defeats that condition is likely to produce these accretions or scaffolds. That they are not due to pressure of stock against the walls in blast-furnaces, I am very positive; and, in regard to that, I would suggest to Mr. Durfee that this pressure against the walls is certainly greater in a bosh-furnace than in a furnace without a bosh. This friction of anything like sand in a tube—that is, the friction due to gravity—is greater against the walls of the tube if they are contracted at the bottom than it is if the walls are vertical.

We have here, also, the condition of varying sizes in the stock, so that if they roll apart from each other in charging, we have variable density in the stock and the clanger of formation of gas-channels. Through these, the hot gases rise unequally, burn coal above, and increase the difficulty. The unreduced half-melted stock, enclosed sometimes in sintered masses of lime and coal that cannot be got at by the oxygen of the gases, begins to form these hard rings, and the trouble can scarcely be got at afterwards, except by blowing down.

MR. DURFEE: I am disposed to agree with Dr. Raymond in the great body of his remarks. I should not expect any such state of facts as that which I first suggested to exist in a furnace of double the diameter of the one described in the paper before us. But I think that this furnace was so small in diameter, in proportion to its height, and that its condition was so nearly that of a perfectly cylindrical tube, that such a state of facts as I have supposed might possibly account for its failure. I do not say that the failure is thus accounted for; but I think that the conditions I have named had something to do with it. If the diameter of that furnace had been doubled, I do not think that the conditions experienced would have existed at all.

MR. HARTMAN: In regard to the passage *of* air, its getting on one side or the other, of which Dr. Raymond speaks, that would not form a ring. It would form a scaffold on one side; but the other side of the furnace would he clear.

DR. RAYMOND: A scaffold forming on one side very often extends around the furnace. I think I saw one instance of that in one of Mr. Fritz's furnaces in Bethlehem, in which a ring formed symmetrically around the whole furnace and bottled it up. If, in this case, to avoid the difficulty which Mr. Durfee suggests, the furnace had been made bigger with the same blowing-engine, it would have bottled itself up notwithstanding the new conditions. When a furnace has too large a diameter for the quantity of air supplied by the blast, I think the tendency is to contract the working dimensions inside.

Finally, I wish to observe that there is, to my mind, a great difficulty in regard to all the suggestions that have been made, so far as they attempt to explain the failure of a straight furnace. If they were correct explanations, why should a furnace run successfully, as Mr. Cook has told us (and as we all know from our practical experience) after the boshes have been cut away ? The mere fact that they were once there, certainly is no reason for supposing that they exert, after their destruction, a mysterious wholesome influence. As to Mr. Durfee's suggestion, there is an additional argument against it. If the packing of stock against the walls had been the cause, the trouble would have shown itself as well when fuel, slag and pig were charged as when the charge was ore.

MR. DURFEE: Of course such a result as the one which Dr. Raymond has suggested would have happened if the furnace had been larger and the blast had been made the same. I supposed, of course, that the blast would be in proportion to the increased size of the furnace; if the furnace had been increased.

THE PRESIDENT : Is it not possible to exaggerate the practical lessons of it, and to mistake the failure of that furnace, under the circumstances illustrated and described, for a failure of the principle, which, I presume, would never have been experimeutally worked out if it had not commended itself theoretically to the gentlemen who put their money into the experiment? It is very often a mistake to place too much dependence upon the teachings *of* crude experience. An experiment is tried and fails; and basing one's ideas upon that fact, it is very natural to conclude that the experiment cannot succeed under the conditions, whereas somebody else, working under different conditions, follows the same idea and accomplishes it. Can Mr. Hart man answer whether that is possibly true?

MR. HARTWAN: After a general talk over the matter, it was thought by all hands that we would have met with more success if there had been a larger furnace. That was felt. The question comes up in this way : When a furnace is driving rapidly, you want to get a body of fuel close to the tuyeres, have it well heated up, so that it shall always be coming down before the tuyeres intensely hot, and thus give the tuyeres no chance to blow cold; because the interior heat of a furnace is very high compared with the heat of the entering blast, even if it is at the figure at which Mr. Taylor had it. It strikes me that one requisite is a good large body of coal in close proximity to the tuyeres, and acting as a sort of regenerator, so that when it arrives at the tuyeres they can burn it up quickly. The larger diameter we have always felt would be more successful; but whether it would really prove a commercial success is a question.

NOTE ON A FIRE-BULKHEAD.

BY CHARLES M. ROLKER, NEW YORK CITY.

IT is now three years ago that I wrote a paper on the fire which broke out in October, 1880, at the Chrysolite mine, Leadville, Colorado, of which I was at that time manager. The paper was read by title at the Harrisburg meeting in 1881, and was accompanied by plans and sections fully illustrating it. It was written to invite a general discussion of the course pursued in the management of that fire, since the various fragmentary and sometimes prejudiced or inaccurate newspaper accounts were not suitable to base judgment on. The paper I offered, gave the facts as they appeared in the contemporaneous record which I had kept. At that time, a difference of opinion had arisen with an adjoining mine, as to possible damages entailed through the fire; and a law suit was talked of. In view of these circumstances, the President of the Chrysolite Company advised a temporary withdrawal of my paper. Somewhat later I withdrew it entirely, because of the unlooked-for delay in arranging the controversy referred to. It has now, indeed, been amicably settled; but the lapse of time has deprived the matter of much of its immediate professional interest.

To the urgent request of some of the members, that I should, at least, give a description of the fire- and gas-proof bulkheads employed, I yield with some hesitation, since I lay no claim whatsoever to originality in these devices, and therefore question the value of such a paper.

The fire originated by accident, in the Chrysolite, a mine comprising extensive and more or less irregular workings, containing immense quantities of timbering, but partially packed with waste rock or earth. This class of mines is numerously represented at

Leadville, Colorado, at many points in Utah, at Eureka and Virginia City in Nevada, etc. Moreover, the Chrysolite is connected by underground workings, for more than a thousand feet east of the seat of the fire, with adjoining properties, which have numerous shafts. The neighboring mines are situated on higher ground, the hill rising in an easterly direction; but they are worked to practically the same underground level.

The ore-deposits of Fryer Hill occur as shallow and more or less flat deposits. The deepest ore-occurrence in the Chrysolite was, at the time, one hundred and fifty feet below the collar of the main hoisting-shaft, and it varied from that, to 66 feet from the surface, where the only covering to the ore consisted of *detritus* and grass-roots.

The ore-occurrence in the adjoining mines, was very similar, barring local synclinals and anticlinals. The felsite, where it overlies the ore, is finely fissured. In the Chrysolite, ore had been repeatedly mined up to the *detritus,* and it had been allowed to cave in, thus establishing more or less connection between the surface and the underground workings.

Considering the rise of the hill to the east, and the fact that the fire started near the extreme west workings, at the foot of Fryer Hill, it is apparent that an immediate joint action on the part of all the connected mines, was not alone desirable, but imperative, in order to control the draft.

Unfortunately, we were not able to agree upon harmonious action. As a consequence, the fire was eventually drawn over a stretch of 400 feet of stoped-out ground, in places 30 to 33 feet high, and averaging, probably, 15 to 18 feet in height, by 35 to 40 feet in width. The system of timbering in this mine is the square-set, Comstock style, varying, however, from that of the Comstock in having no diagonal members. Instead of these, the open square sets are filled with "cribbing," the sticks being 8- by 8-inch timbers; and according to the pressure and the importance of keeping the ground open, we employ solid cribs (each a solid mass of timbers) and open cribs (those in which space is left to fill in any waste that may be encountered). The stopes through which the fire swept had some open sets, partly cribbed and filled solidly with waste; others, solidly cribbed; others, partly cribbed and but partially filled; and again, others, neither cribbed nor filled. The waste-filling of these timbered stopes was not a systematic one in any direction, but was the result of the local waste which was encountered in mining the ore. This made the approach to the fire, which, within the first few hours, communicated the flame to these cribs, extremely difficult, and even impossible, without a proper regulation of draft.

When it became apparent that harmonious action would not prevail, the necessity arose for the Chrysolite to isolate the best ore-bearing portions of the mine from the fire and from the adjoining mines, in such a way as to permit our extracting the ore; moreover, this had to be done promptly, since those parts of the mine were in imminent danger. I, then, of course, abandoned the plan previously tried, of putting up temporary air-stoppings, such as wooden doors (the cracks calked with cotton-waste soaked in tallow), plain earth-dams, etc. Readily constructed, permanent dams had to be built under sorely trying circumstances. Earth-dams packed wet and up to 10 feet thick, would let the carbonic acid gas through almost as though they did not exist. The stop-doors, calked by an old sailor, looked as if they were on fire, so rapidly did the smoke and gas work through the calked cracks. In places, on account of the carbonic acid gas and smoke which were drawn through by the eastern openings, men could work but five minutes at a time behind these temporary barricades, though they were supplied with fresh air by a No. 4½ Baker blower.

Dr. A. Serlo *(Bergbaukunde,* 3d edition, page 328) quotes from the *Berggeist,* and advises the covering of stoppings, on the side facing old works which generate gas, with a coating of asphaltum, to prevent the oozing through of gas.

The stoppings I adopted, were placed in gangways, drifts and winzes leading to stopes, either on fire, or in imminent danger of fire, but inaccessible, owing to the manner in which they had been filled and timbered. These stoppings consisted, first, of a temporary stop-door, introduced to weaken the current of smoke and gas. This was simply made of inch-boards, cut to proper lengths and nailed to the posts and caps of a drift-set, selected as near to the fire circumstances would permit. The cracks were calked with cotton-waste soaked in tar. Behind this door, earth or clay was filled in solidly for say 4 feet, more or less, the drift-timbers being left in. It is well to moisten the earth or clay and beat it down. A plain board wall was nailed back of this tamped mass against another set of timbers, to keep it in place. Tin's formed the complete temporary stopping, which, aided by a bountiful supply of fresh air, was generally found a sufficient protection to permit the erection of the permanent stopping and bulkhead behind it. The latter was intended to prevent the spread of the fire itself, as well as the dissemination of gas and smoke throughout the remainder of the workings. To show the necessity of something more thorough and permanent, I may mention that a tamped earth-stopping, 10 feet long, proved in sufficient, even at the distance of a thousand feet from the seat of the fire, to exclude the gas from a neighboring mine.

To effect a safe, permanent stopping, remove all drift-timbers for a distance of from 25 to 50 feet. This is done quickly, by cutting the posts nearly in two, with an axe; cutting out or loosening the blocks and wedges, as far as this can be done; boring in the ends of the posts and caps auger-holes of the requisite number and size (according to the size of the timbers and the pressure upon them), to admit cartridges of giant-powder, to blast the timbers out. As many of the cartridges are fired simultaneously as the nature of the ground will allow. Mud-sills and all fragments of timbers are removed, and the now untimbered drift is filled in with waste or earth, the finer the better. It is well to wet the ground frequently in order to pack the fine waste and to keep the drifts cool. Whenever a sufficient length of drift has thus been freed from its timbers and has been filled in with waste, to insure the safety of the adjoining works, the final gas-bulkhead is put in. The length of the earth-dam is, of course, a matter of judgment, depending on the size and proximity of the stopes, as well before as behind the dam, and the combustible material in them ; in other words, on the supposed intensity of the coming fire and the consequent likelihood of its spreading.

Preparatory to putting in the gas-bulkhead, the place in the drift where it is to be erected is trimmed down to a section as nearly rectangular as possible. If the time permits, it is best to cut into the sides of the drift, say, from 4 to 6 inches, so as to get a shoulder. In the bottom a similar channel is cut, which connects with the sides. Should a place be chosen as a site for the bulkhead where a drift-set has been standing, part of the bottom-cutting and often some side-cutting can be utilized. In case no side-cutting is resorted to, the old mud-sill can be utilized, as a bottom-piece, after lagging its shoulders. The extended mud-sill or bottom-excavation is then partly filled with tar and the foundation or bottom piece of timber is laid in it. Proper care, must, of course, be exercised to lay the bottom-piece level, and to insure this, whatever piece of timber is used for it, its top and bottom should be dressed. On this bottom-piece a wall is built up, with such timbers as are at hand, dressed on two sides. I found 4 by 6 inches or 6 by 6 inches, of sawed sticks, a very convenient size. As the binding material for the wall, tar is used; and to give additional stability, each stick is spiked to the lower one. The top-pieces are simply hammered in, but they have similar tar coatings; and the last one may require dressing and fitting underground. Holes, due to irregularities of walls or roof, can be filled in with clay or cement, if it is at hand. When the wall is completed, the entire face, clay and all, is covered with a thick coat of tar.

Instead of these wooden bulkheads, brick or stone walls may, of course, be built, and any little openings at the top or ends may be filled in with cement. But often, this material may not be on hand in sufficient quantities; or it may be much more expensive than the wooden bulkhead. Again, it will require longer time underground, to build a stone or brickwall, than such a wooden wall; and the wooden wall has the further advantage that nearly all pieces can be cut and prepared above-ground, with plenty of elbow-room and with as much dispatch as desired. Any good miner can prepare for, and build, such a wall, while he may not be able to lay a good brick or stone wall. The blacksmith shop can turn out the desired spikes. I used eight of these bulkheads, with earth-dams from 25 to 50 feet long, free of timbers, and a temporary stopping in front of these; and in no case did any gas work through, or the fire spread beyond the temporary stopping. We mined for months behind the bulkheads, completely cut off from all connecting adjoining mines and from the fire, while neighbors, who resorted to other means, could not enter their mine on account of gas.

I may finally remark, that this fire was not put out in the beginning, hose in hand (with an upcast away from the attacking force and a downcast supplying the fresh air) because the fire originated, as indicated, in the west workings at the foot of Fryer Hill, while the connecting shafts stood east of it and on higher ground; these were either not kept continuously sealed or were insufficiently sealed, so that they drew the smoke and gas east into the face of any attacking party. A southern shaft, on which a stack was built, was used as an upcast for a limited period. The mine was not flooded because the district did not supply water enough to flood.

Carbonic acid gas was not used to extinguish the flames, because the Chrysolite itself could not be hermetically sealed, owing to the surface caves mentioned above, which had caused numerous cracks extending from the underground work to the surface. Again, the rock itself had numerous cracks and fissures in it, which, the deposit being a shallow one, would admit air and leak gas. Finally, the use of carbonic acid would have involved the filling with gas of all the connected adjoining mines.

Steam was injected in the hope of checking the flames, but, where used for this purpose, proved of little use except to cool the ground. In the immediate neighborhood where the steam had l>een discharged, we afterwards found the lower part of the timbers not burnt, but the fire had burnt the top part and crept and spread along the roof.

The mine-shafts were closed up as tight as possible, by putting in scaffolding (for some, as much as 16 feet down the shafts) and packing dampened earth on top. to stop air-currents and to confine to the mine, as much as possible, the carbonic acid gas generated by the fire. The two last principles, combined and practiced, not alone by us, made the fire die out of itself, but not until seven months after we were working and extracting ore from our isolated portion of the mine.

Our experience showed that the heat retained in a smoldering stope, long after it had ceased to give signs of active combustion, was sufficient to cause a rekindling of the fire as soon as fresh air was admitted. Even when, after the lapse of months, we cautiously penetrated into the burnt district, the heat of the ground was almost insupportable.

NOTES ON THE RHODE ISLAND AND MASSACHUSETTS COALS. *

BY ARTHUR B. EMM0NS, PH.D., LL.B.. NEWPORT, B. I.

HAVING been in the management of a company which has been exploring with a diamond drill during the past year in Rhode Island and Massachusetts, with a view to finding workable anthracite coal of a better quality than has been hitherto found, I have collected a certain amount of material which seems to have some scientific interest (though in this respect it is unfortunately incomplete), as well as a possible value to any one who may be tempted to follow oat a similar line of investigation.

The following are the analyses of the coal from the Portsmouth

* This paper was communicated to the Secretary at the Philadelphia Meeting, September, 1884 Mr. Eminous was elected a member at the Annual Meeting, February, 1885.

Mine, Portsmouth, E. I., made by Dr. F. A. Gooch and Mr. B. T. Putnam :*

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Water	5.12	0.52	3.18	2.25	7.62	7.96	8.76	10.27	10.47
Volatile combustible	6.49	6.31	4.43	6.46	5.42	4.95	7.23	5.99	5.83
Carbon	71.04	76.23	75.97	79.59	74.40	76.22	70.24	67.50	66.95
Ash	17.35	16.94	16.42	11.70	12.56	10.87	13.77	16.24	17.05
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur	0.216	0.224	0.258	0.64[illegible]	0.2[illegible]	...	...	...	...
Ash	Red	Red	Red	Red	...	Red	Red	...	...
Fuel ratio $\left(\frac{\text{Carb.}}{\text{Vol. Comb.}}\right)$	10.94	12.08	17.14	12.32	13.72	15.39	9.71	11.26	11.48

I. Bottom of shaft, north side, thickness of seam 3 feet 11 inches.
II. Bottom of shaft, south side, thickness of seam 2 feet 7 inches.
III. South side, 50 feet from bottom, thickness of seam 6 feet.
IV. South gallery, 370 feet from bottom, upper ¾ of 6-foot seam.
(Analyses I., II., III., and IV. are from samples taken across the width of the seam.)

V. The average of seven analyses made from samples taken at intervals along the length of a 6-.foot drill-core, cut out of what is known as the " Back Seam," at about 90 feet below the mouth of the Portsmouth Mine.

VI. and VII. The single analyses of this series showing the maximum and minimum percentages of carbon and ash.

VIII. and IX. Samples taken from two lots, of several tons each, of freshly mined coal used in other experiments.

The ash of the above sample No. 1 contained:

SiO_2,	49.49
Fe_2O_3,	8.40
Al_2O_3,	19.00
CaO,	15.21
MgO,	4.82
MnO,	0.32
SO_3,	2.72
	99.96

* It should be stated here that Analyses I., II., III., and IV. were made during the prevalence of a northwest wind, or dry condition of the atmosphere, though the conditions were not specially noted ; and that Analyses VI., VII., VIII., and IX. were made during a damp period, or a southwest wind, which, in Newport, is frequently accompanied by fog.

The Portsmouth coal possesses the striking peculiarity (hitherto unnoticed in anthracite coals, or, I believe, in any coals) of quickly taking up a large percentage of water under a moist condition of the atmosphere, and as readily parting with it under a drier condition of the atmosphere. This is shown by the following interesting experiments conducted by Dr. Gooch.

A sample of Portsmouth coal, the same as that used in one of the first four of the above analyses, powdered and exposed for twenty-four hours in the balance-room during the prevalence of a northwest wind, contained, after exposure, water amounting to 0.65 per cent of its weight when dried at 115° C.

	Water, per cent.
The dried (at 115° C.) coal took up during 24 hours' exposure in the balance-room, while the same wind was blowing, of its own weight, ...	0.15
After 16 hours exposure over water it had taken up, . .	8.46
" 24 " " " . .	9.72
" 61 " " " . .	12.64
" 85 " " " . .	12.67

The percentage of water fell:

	Water, per cent.
After 24 hours' exposure over H_2SO_4 to, ...	1.38
" 48 " "	0.54
" 138 " "	0.64

A similar sample was wet thoroughly, dried with filter-paper, and exposed twenty-four hours in the balance-room during a northwest wind. Its content of water in terms of coal dried at 115° C. amounted to 0.75 per cent.

	Water, per cent.
A sample of the drill-core from Portsmouth (same as analyses V., VI., and VII.), moistened thoroughly, dried with paper, and exposed twenty-four hours during a northwest wind, contained, in terms of material dried at 115° C., .	0.81
The dried coal took up, during 24 hours' exposure in balance-room, ...	0.22
It took up over water, in 16 hours, ...	8.96
" " " 24 "	10.32
" " " 61 "	12.88
" " " 85 "	13.80

The coal contained of water, expressed in terms of itself dried at 115° C:

	Per cent.
After 24 hours' exposure over H_2SO_4, ...	0.85
" 48 " "	0.53
" 138 " "	0.46

A sample of the same piece exposed in the balance-room *without wetting,* contained of water 0.72 per cent of the weight of the coal dried at 115° C.

A sample of the same piece exposed in the balance-room without wetting or drying in the air-bath, contained of water, expressed in terms of itself dried at 115° C.:

	Per cent.
After 16 hours' exposure over water, ...	11.45
" 21 " "	13.26
" 37 " "	16.77
" 61 " "	16.91
" 85 " "	16.87
" 109 " "	16.85

The content of water expressed in percentage of coal dried at 115° C.:

	Per cent.
After 24 hours' exposure over H_2SO_4, fell to, . . .	1.84
" 48 " " " . . .	0.83
" 138 " " " . . .	0.71

For the sake of comparison, a piece of Pennsylvania anthracite was taken from the cellar and similarly treated.

As it came from the bin, it contained of water 4.69 per cent of the weight of the coal dried at 115° C.

	Water, per cent.
Powdered and dried at 115°C., it contained, ...	4.42
After 26 hours' exposure over water, ...	5.91
" 75 " "	6.34
" 144 " "	5.10

A similar piece (*i. e.*, not powdered), exposed over water without previous drying in air-bath, contained, in terms of weight of coal dried at 115° C.:

	Water, per cent.
After 30 hours' exposure over water, ...	5.38
" 80 " "	5.67
" 150 " "	5.69
" 23 days' " "	5.38

A piece of Cumberland bituminous coal contained, as it came from the bin (the sample was powdered), in terms of the coal dried at 115° C., ...	1.33
After 26 hours' exposure over water, ...	1.93
" 75 " "	2.06
" 144 " "	1.95

A sample of Montana bituminous coal contained, in terms of its weight after drying at 115° C.,	1.00
After 16 hours' exposure over water,	1.80
" 24 " "	1.78
" 61 " "	1.68
" 85 " "	1.73
After 24 hours' exposure over H_2SO_4,	0.86
" 48 " "	0.56
" 138 " "	0.64

A. specimen of lignite from Mouse River (Dakota), belonging to the Northern Transcontinental Survey, was found to be as hygroscopic as the Portsmouth anthracite.

A sample moistened thoroughly, dried with paper, and exposed twenty-four hours in the balance-room under a northwest wind, contained, in terms of its own weight after drying at 115° C, 13.83 per cent, of water.

Exposed in the balance-room, after drying at 115° C, during the prevalence of a northwest wind, it contained:

	Per cent.
After 24 hours,	6 9 4
" 48 "	7.38
" 64 "	7.11

Placed over water, it contained:

	Water, per cent.
After 16 hours,	20.93
" 24 "	22.19
" 61 "	22.63
" 85 "	22.57

Exposed over H_2SO_4, it contained :

	Per cent.
After 24 hours	13.43
" 48 "	11.14
" 138 "	10.50

The surprising fact that the percentage of water in the Portsmouth anthracite may vary ten to fifteen per cent., according to the hygrometric condition of the atmosphere, not only suggests an interesting line for future investigation, but also raises a feeling of distrust of the coal-analyses hitherto published, and makes the desirability more than ever apparent of having some standard method in coal-analyses, as for example that adopted by Dr. Gooch, of drying the sample for analysis at 115° Centigrade or that adopted by the Pennsylvania Geological Survey of drying at 225° Fahrenheit, so that different analyses can be understandingly compared—besides making a special test of the coal as to its hygroscopic properties. That the method in almost universal use in coal-analyses, of exposing the sample in the laboratory for twenty-four hours before analyzing, may lead to untrustworthy results, is shown by the foregoing analyses Nos. I., II., III., IV., compared with VIII. and IX. All these analyses were made before the hygroscopic properties of the Portsmouth coal were suspected ; and all the precautions hitherto supposed to be necessary to obtain accurate results were observed. The samples from which analyses VIII and IX. were made, were taken from the same seam, and within a hundred feet or so from the point where the samples were taken from which analyses I., II., III. and IV. were made; and there is no reason-for assuming that there can be any particular difference in the coal from the several points. The striking difference between these two sets of analyses of practically the same coal, is due to the fact that analyses I., II., III. and IV. were, by chance, made during a period of dry atmosphere, while analyses VIII. and IX. were made during a period of damp atmosphere.

The Mouse River Lignite from Dakota, shows that the Portsmouth coal is not an isolated instance of this hygroscopic property ; and the fact that the lignite had been analyzed in regular course with numerous other specimens, without this peculiarity having been noticed, renders it, to say the least, not improbable that this peculiarity will be found where it is not now suspected, among coals, the analyses of which are already known.

The two following analyses by Mr. Putnam, were made from drill-cores, cut from what was assumed to be the same seam of coal at different depths, at West Mansfield, Mass., in the neighborhood of the old Hardon Mine. The first was cut at a depth of about 90 feet, and the second at a depth of about 850 feet.

	I.	II.
Water,	1.02	308
Volatile combustible,	3.76	6.22
Carbon,	74.24	79.68
Ash,	20.97	11.02
	99.99	10000
Sulphur,	0.56	
Ash	Red to light reddish brown	Purplish red
Fuel ratio $\left(\frac{\text{Carb.}}{\text{Vol. Comb.}}\right)$,	19.74	12.81

Analysis I. is the average of five analyses, made from samples taken at intervals along the length of the core. After drying at 115° Centigrade, this coal took up 2.69 per cent of water, after 24 hours exposure in a saturated atmosphere, *i.e.,* over water.

Of the following two analyses, No. I. is that of the ash of No. II. above; and No. II. is of a sample taken near the above coal-sample No. I., but not the same sample.

	I.	II.
SiO_2,	49.18	75.11
Fe_2O_3,	11.25	13.05
Al_2O_3,	11.41	7.46
CaO,	19.48	2.22
MgO,	3.39	0.98
MnO,	0.55	0.19
SO_3,	5.06	1.11
	100.32	100.12

A sample of coal from the bottom of the shaft of the old Cranston mine, southwest of Providence, analyzed by Dr. Gooch, gave the following results:

Water,	0.24
Volatile Combustible,	4.49
Carbon,	82.20
Ash,	13.07
	100.00
Sulphur,	0.34
Ash,	Brown
Specific Gravity at 15° C.,	2.209

The sample used in the above analysis was dried over sulphuric acid. As received, the sample contained 0.67 per cent of water, reckoned upon the weight of the coal dried at 115° C. After exposure during 48 hours over water, it contained 3.52 per cent of water.

An elaborate comparative test of the Cranston coal with Lackawanna coal was made at the Providence water-works about the year 1874. Some of the records of this test are still preserved at the office of the City Engineers at Providence. From these it appears that the evaporative power of the Cranston coal was found to be 72 per cent of that of the Lackawanna coal.

In 1875, a diamond drill-hole was sunk in Seekonk, Bristol Co., Mass., by the Seekonk Coal Mining Co., to the depth of 705 feet. At 691 feet, a seam of anthracite, 8 feet 11 inches thick was alleged to have been cut. This coal is referred to by A. L. Holley in his paper on *The Iron-Ore and Anthracite Coal of Rhode Island and Massachusetts.** The drill-hole is genuine, and the geological record of the core is probably correct in every respect except the coal (the core is still extant); but no coal-core was ever cut in the hole, and the coal-core exhibited as having been so cut, was cut at the top of the hole from a piece of coal brought on to the ground for that purpose. The fraud was very skilfully perpetrated and was known to only three persons, the manager (since deceased) and two employees, who at the time supposed that the core was being cut for an innocent purpose; and to this day, most of the stockholders still have firm faith in the supposititious coal-seam at the bottom of the Seekonk bore. I feel called upon to publish these facts, as this same coal-core has been made the basis of at least one swindling operation since that time and is still in existence.

Although not strictly related to the foregoing, I would add, that in boring through seams of coal with the diamond drill, we found great assistance in overcoming the tendency to crumble, and thus in preserving the coal-core, by reversing the flow of the water from the pump. That is, instead of causing the water from the pump to pass down through the drill-rods, as is usual, and returning through the drill-hole and casing outside the rods, we forced it down outside the rods, and let it return through the rods. This was accomplished by attaching a stuffing-box to the end of the casing, turning a length of the drill-rod true, so that with the stuffing-box it would make a water-tight joint, and then introducing the water from the pump into the casing below the stuffing-box. In this way, the pressure from the pump on the top of the core was relieved, and all the fine material from the core was more easily preserved.

THE DEEP RIVER COAL-FIELD OF NORTH CAROLINA.

BY DR. H. M. CHANCE, PHILADELPHIA, PA.

HAVING an opportunity of exhibiting specimens of coal from two beds in this field to the members of the Institute, I desire only to

* *Transactions,* vol. vi., p. 225.

give a few facts bearing directly upon the locality from which these specimens were obtained, reserving for a future paper a full description of this, and also the Dan River field.

The specimens were obtained at Farmville, one mile and a half from Egypt and about one quarter of a mile from the Deep River. The coals occur in a series of dark carbonaceous slates, shales, and fire-clays, with bands of phosphatic black-band iron-ore. These shales form the middle member of the Triassic (Mesozoic), the upper and lower members consisting of red sandstones and shales, with some coarse conglomerates.

They dip from 10° to 35° in a southeastwardly direction, the average dip being from 20° to 30°. They present only one outcrop, the dip throughout being monoclinal.

Coal has been found for a distance of 25 to 30 miles along the outcrop, the most northeastwardly locality being near where the Deep and Haw rivers converge to form the Cape Fear River; and this locality is but a short distance from Farmville.

The North Carolina Department of Agriculture recently determined to have these fields thoroughly explored, in order to determine the extent, thickness, and quality of the coals. I assumed charge of this work in July last, commencing work in Farmville, where I have found five beds of coal lying close together. From the top of the uppermost to the floor of the lowest, the measurement is not more than 40 or 50 feet.

Only two *of* these beds are of workable thickness, viz.: the upper bed, containing three feet of good coal, and the lowermost, which is about 22 to 24 inches thick.

The upper bed shows the following section :

Slate roof.	
Coal, good,	3 ft. 0 in. to 3 ft. 2 in.
Blackband and slate,	1 " 8 " to 3 " 0 "
Coal, poor, slaty,	1 " 0 " to 2 " 0 "
Fire-clay floor.	

Analysis of the upper bench made by the State chemists give:

	I.	II.
Moisture at 115° C.,	1.79	1.95
Volatile combustible matter,	29.56	30.54
Fixed carbon,	58.30	58.47
Ash,	7.46	6.85
Sulphur,	2.89	2.19
	100.00	100.00

These results show uniform composition ; for No. I was made from picked lumps, while No. II was an average of lump and slack, made from a heap containing two or three tons.

I opened the lower bed at two places by shafts, respectively 18 and 28 feet deep, and from the latter mined about one hundred tons, which was shipped to Raleigh for use under the steam-boilers at the State Exposition. It is undoubtedly a strong steam-coal, but is somewhat high in sulphur.

The analyses of this coal are as follows:

	III.	IV.	V.	VI.
Moisture at 115° C.,	1.71	1.36	2.15	1.32
Volatile combustible matter,	28.66	28.71	28.88	26.87
Fixed carbon,	60.59	51.24	52.56	50.04
Ash,	5.35	14.51	12.69	14.69
Sulphur,	3.69	4.18	3.72	7.08
	100.00	100.00	100.00	100.00

No. III. Picked lump coal obtained at depth of 18 feet.

No. IV. Average of several tons obtained at depth of 28 feet.

No. V. Average of several tons obtained at depth of 18 feet.

No. VI. Lump coal picked from coal mined at depth of 28 feet.

These analyses furnish some food for thought. How are we to account for the analysis showing 3.G9 of sulphur and only 5.35 of ash ? I am satisfied the fault is not in the selection of this sample, at least, since I have reason for special confidence in it. The high ash percentages in Nos. IV and V, I regard with suspicion, as the coal in burning does not indicate the presence of nearly so large a percentage, and the samples may be at fault; and the sulphur percentage in No. VI is undoubtedly accidental. Averaging the first three analyses No. III, IV and V, we may safely assume the sulphur at about 3.86.

The close agreement of the volatile matter percentages in Nos. III, IV and V, is also remarkable in the presence of such marked variations in ash.

The physical character of this coal is similar to that of a true coal-measure coal. It has a well developed columnar structure, is hard, bright and black, *and with very little pyrites,* burns with a strong flame, and cokes slowly, not commencing to coke until highly heated,

The upper bed is much more friable, readily breaking down into fine slack, and cokes quickly and thoroughly.

I hope shortly to communicate to the Institute the results of an examination into the mode of occurrence of the sulphur in this coal;

for it is evident that only a small portion is in combination with iron as pyrites. The amount of pyrites is so small that it is difficult to detect its presence. From the appearance of the coal I should not estimate the sulphur in combination as pyrites at more than one per cent. The analyses above given were made by Mr. Battle, of the State Agricultural Department.

AN IMPROVED LANGEN CHARGER.

BY FRANK FIRMSTONE, EASTON, PA.

IN a paper read at the meeting in Cleveland, Ohio, in 1875,* I showed that as a result of changing from open-topped to close-topped furnaces at the Glendon Iron Works, there had been a decided falling off in regularity of working, which we attributed to the very different distribution of the materials in the new method of filling.

Subsequent experience has, on the whole, confirmed the opinions then expressed, and in 1881 we decided to try the modification of the Langen charger, shown on the accompanying drawings, thinking by its use to approximate to the distribution obtained by dumping the barrows at six equidistant points in the circumference of the open-topped furnaces.

The top of the furnace is closed by a ring-shaped "bell," as we still call it, the outside of which is cylindrical and rests by the turned lower edge on the bored seat of a " loose ring," supported by the lower part of the hopper. The inside of the bell is an inverted frustrum of a cone, the central opening in which is closed by a cylindrical plug, which is prolonged into a pipe to carry off the gas. †

This center-plug is connected by rods and chains to sectors on the ends of a forked lever, to the other end of which is attached, by a wire rope, the piston-rod of the blast-cylinder used in opening the top. The rods connected to the center-plug pass loosely through the apexes of triangular frames, to the other angles of which the bell is attached ; it thus being suspended by four points when the top is open.

When the materials are dumped out of the barrows into the hopper, a part is thrown over the crest of the bell into the space between it

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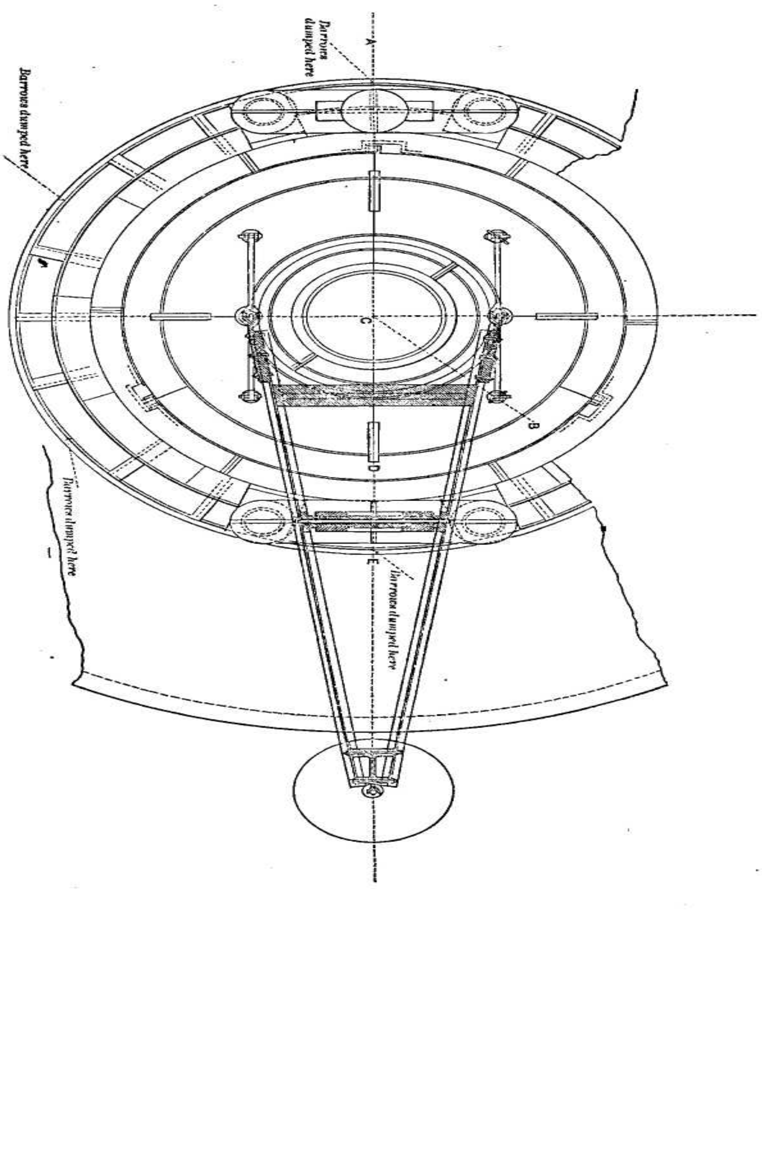
* *Transactions,* vol. iv., p. 128.

† There is, of course, no difficulty in taking off the gas through side-flues below the bell, as in the usual arrangement; but I prefer the central gas-pipe, even at greater complication and expense, especially with brick furnaces.

FIG. 2.



PLAN AND HORIZONTAL SECTION OF LEVER
GAS-PIPE REMOVED

and the center-plug, the rest going into the space between the bell and the hopper ; but owing to the considerable circumference of the latter, six heaps are formed opposite the six dumping points, which do not touch one another, and thus imitate a feature of the open-top filling which I considered, when the paper of 1875 was written, as one of the important differences between it and the double bells then used.

When the piston in the cylinder descends, the center-plug, being directly connected to the lever, is raised, and the material in the center of the bell slides into the furnace; but the bell remains on its seat until the large nuts on the hanger-rods strike the apexes of the triangles, when it also is raised.

When the piston has made its full stroke, the center-plug and bell occupy the position shown by the dotted outlines.

The central gas-pipe has a ball-and-socket-joint where it is connected to the horizontal pipe which joins it to the down-comer; and the joint between the horizontal pipe and the latter is made in the same way.

The horizontal pipe, as shown by Fig. 1 (Plate), rests at its inner end on a lever, to the other end of which is attached a counter-weight so adjusted that the gas-pipe is raised three or four inches (turning on the joint connecting it with the down-comer) when the center-plug is lifted to open the top of the furnace. When the center-plug descends, the female joint on top of it strikes the flange on the gas-pipe and draws it down with it, raising the counter-weight until the center-plug is seated on the bell, by which means a good joint is made at both top and bottom of the center-plug, without any exact adjustment of the height of the lower end of the main gas-pipe being necessary.

The female joint on the center-plug is bored to a hollow cone, and the male joint on the end of the gas-pipe is slightly rounded to approximate a spherical surface; but the angle of the cone must be steep, as shown ; since otherwise the male joint will fail to center itself properly, and the joint will leak. The details are shown in Fig. 3.

The center-plug is the largest single piece which is likely to require renewal, and it can easily be taken to the top of the furnace on the hoist—a point which it is well to bear in mind in settling the dimensions of the hoist and the several castings to be used on top of a furnace. For the same reason, the bell is made in four segments, united by internal and external flanges and bolts, and the loose ring is made in three parts, the external flanges of which fit into pockets in the hopper, made to receive them, as shown on the vertical section and plan, Fig. 4.

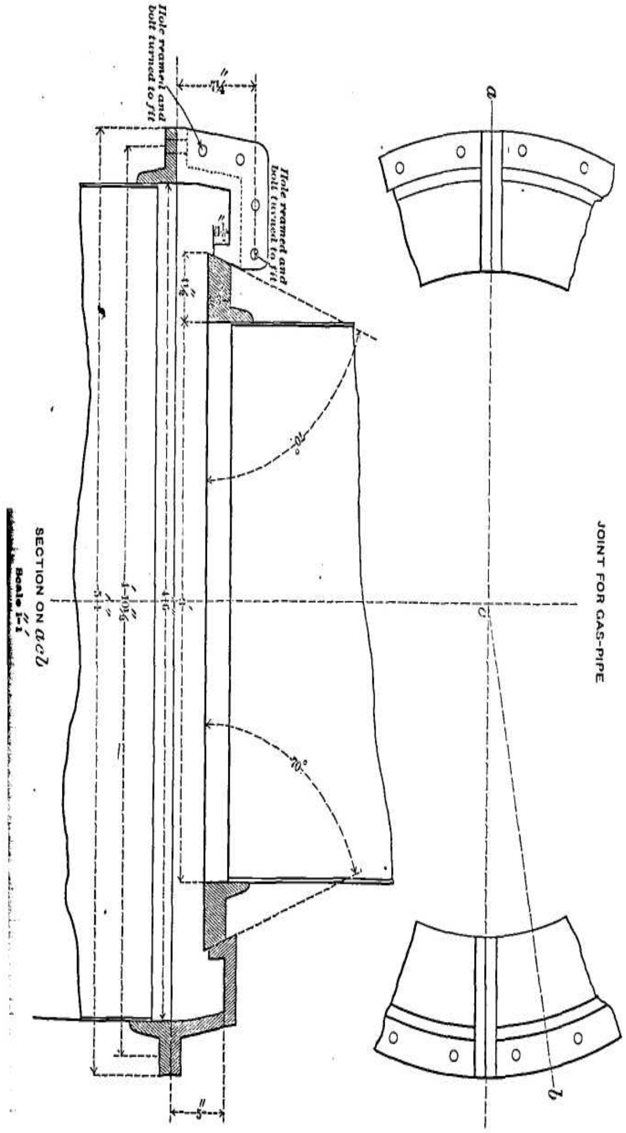
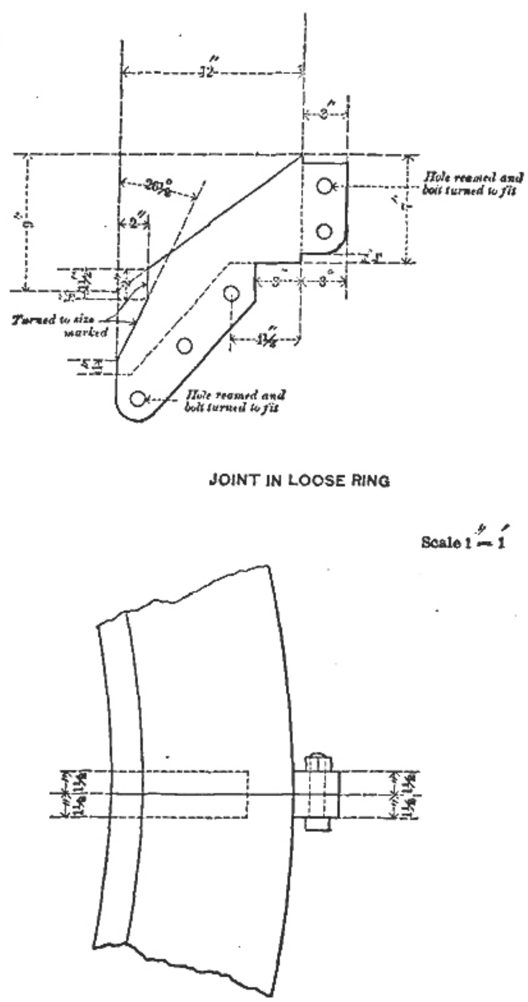


Fig. 3.
JOINT FOR GAS-PIPE

The blast-cylinder for raising the bell is made with a heavy piston, and is double-acting, whereby its size is only about half that of a single-acting cylinder to do the same work, and the double action is very convenient when using the lever to lower a new bell into place.

Fig. 4.



In the chargers first made, the seat for the bell was formed on the upper surface of the loos ring, and the material in the hopper, in sliding into the furnace, passed over the turned surface and soon wore it out of truth opposite the dumping-points, so that a ring would not make a joint with the bell at the end of six months' use; but by dropping the seat below the line of the hopper, and making it pretty steep, as shown on the drawings, all of the coarse stuff, and most of the fine, shoots over it without touching it, and nothing can remain on it except it be in the state of semi-fluid mud. By this construction, the joint, to all present appearances, will last indefinitely.

The most important dimensions in designing such a charger are the diameter of the furnace at the height at which the top of the materials is to be kept, and the diameters of the loose ring and central opening in the bell at the place where the stock leaves them (9 feet 5 inches and 5 feet, 6 inches in the charger shown on the drawing). The distance from the rim of the hopper to the crest of the bell, and the depth of the latter below the wheeling-plates on the top of the furnace, also influence the proportion of material delivered by the barrows into the center of the bell.

In the first charger tried, the diameter of the opening in the loose ring, was 9 feet, 9 inches, and that of the inside opening in the bell, 6 feet, 6 inches. With these dimensions, there was no improvement during a six months' trial over the results with a double bell during a preceding blast; but upon reducing the central opening to 5 feet, 6 inches, and lowering the crest of the bell 3 inches, the production at once rose from 300 tons to an average of 365 tons per week, with an important saving in fuel, and regularity equal to anything we have ever attained. Subsequent trials on three furnaces show that the sizes shown on the drawing must be nearly correct for our materials.

The incidental advantages of the Langen plan over the various modifications of the cup-and-cone are considerable. The bell can be quickly raised by the cylinder so that skids (wrought-iron beams are best) can be slipped tinder it, and it can then be drawn out and a new one slipped in and lowered into place. By having the new bell put together beforehand, the change can be made in less than two hours.

There is no strain on the bolts, etc., except when the top is open, and then it never exceeds the weight of the bell and center-plug; while with the cup-and-cone, part of the weight of the material comes on the hanging-arrangements, in addition to the weight of the bell, and they are always under strain. Even should the hanging-arrangements fail in the Langen, neither the bell nor the center-plug can fall into the furnace. Moreover, the bolts, etc., can be renewed at any time, without taking the blast off the furnace or making any special arrangements to keep the bell shut while doing it. To facilitate this, it is best to give a slight preponderance to the inner end of the lever.

The material is shot into the furnace and the top is again closed rather more quickly than with the cup-and-cone or the double bell; but the opening is so great when the bell is raised that the loss of gas is perhaps greater than with the usual plans.

One of the most serious troubles is that the distribution is bad when the top of the material is low in the furnace, while this seems to make less difference with the cup-and-cone or double bell. Hence, diligent and regular filling is of great importance; and this it is not always easy to get.

DISCUSSION.

DR. R. W. RAYMOND, New York City: While we think that we have, at the Durham Iron Works, a double bell which possesses all the advantages enumerated by Mr. Firmstone, and others of its own, we have been, by our experience, somewhat weakened in the notion that the details of the bell and hopper are all-important as to the running of the furnace. We find that when we follow what might be called the modern method of high-pressure and larger quantity of blast—in other words, of rapid running—coupled with large units of charge, the slight variations in the filling, formerly deemed influential, do not seriously effect the operations at the tuyeres. When our double bell was out of order, so that the inside bell could not be used, we went on charging with the outside bell, and there was no difference down below for a week or so, during which this condition lasted.

MR. FIRMSTONE: I do not think a fair argument can be based on the facts in that case, because important changes were made in the Durham furnace and practice, including a change in the character of the fuel, namely, the introduction of a considerable percentage of coke. But fuels will not save the working of a furnace if it is not treated properly in other respects. It is true that furnaces may become unmanageable in less than a week; yet, unless the case was very bad, I should not expect decisive effects permitting a conclusion on a single week's result.

As to the sensitiveness of furnaces to the methods of charging, I can mention that, it being necessary to experiment with this apparatus in order to get the proper dimensions, we diminished the inside diameter of that bell by attaching sheet-iron to it. Things went very well until, through carelessness of the fillers, that wrought-iron wing (indicating on blackboard) was broken loose on one side. • This increased the diameter of the inside of the bell on that side by six inches, so that the material was delivered practically, on one side, six inches nearer the center of the furnace than it was on the other. As a result of that, we had one week of exceedingly bad working. As it was impossible to repair the wrought-iron immediately, I had it knocked off. The result was that as soon as the material was charged uniformly and came down, the furnace improved and began working splendidly. Then I put on a new piece of wrought-iron; and as a result we had an appreciable gain of economy in the consumption of fuel. I may be blinded somewhat by excessive zeal in this matter; but, in that case, I am of the belief that I was able to see a difference that resulted from a change of the diameter of the bell by six inches. That being the case, I think that the operations of the furnace at Durham, referred to by Dr. Raymond, were dependent upon exceptional conditions, and hence that they were not conclusive.

EDGAR S. COOK, Pottstown, Pa.: In the Warwick furnace, of which I am the manager, we have never had any experience with the double chargers. That which has been used is simply a plain bell. It is a seven-foot bell, with a stock-line ten feet in diameter; the furnace being fifty-five feet high and fifteen and a half feet bosh and the distance between the bell and the in-wall being about eighteen inches on each side.

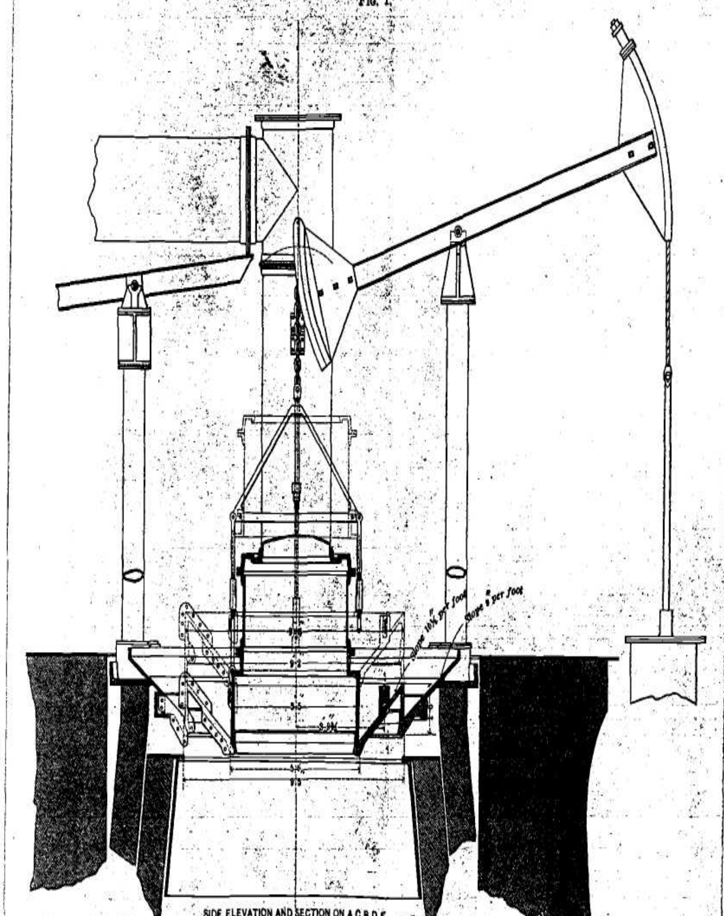
We have now been in blast for about three years and nine months. Our stock is very fine and different from that spoken of by Mr. Firmstone. It is made up of fully seventy-five per cent of fine packing material. We have been using about one-fourth of coke, and the furnace is working with pretty fair regularity, making, on an average, I suppose, from 425 to 450 tons of iron per week. In the summer of 1881, the furnace was working somewhat irregularly, and, in the hope of overcoming this irregularity, we substituted a five-foot, in place of a seven-foot bell. This change did not overcome the difficulty as we hoped. The result was decidedly other than beneficial. The production of the furnace with the five-foot bell was reduced fully fifty tons per week, and the coal-consumption was increased from three to five cwt. per ton of iron. After running this bell for about nine months, to give it a fair trial, we took it out and replaced it with a seven-foot bell again. The change in the bells, while it did not affect the working of the furnace particularly did very materially affect the economical results. As soon as we replaced the seven-foot bell, the product of the furnace increased • fifty tons per week and finally one hundred tons per week; and the fuel consumption was reduced from five to three cwt. again, thus coming back to our former figure. It would thus appear that, with the same furnace, essentially the same stock and the same management, the size of a bell has a very material effect upon the economical results and, it may be added, upon the working of the furnace.

JOHN BIRKINBINE, Philadelphia, Pa.: The two features in proportioning a blast-furnace stack which require the most careful consideration are in the region of the tuyeres and at the top of the furnace. This, of course, refers to the stack-construction and not to the hot-blast engine, boilers, etc. The proportions of the top and the arrangement for supplying stock to it are second in importance only to the proportions of the crucible and the arrangement of tuycres, cinder-notch, etc. I cannot agree with the statement that the size of stock entering the tunnel-head and the method of distribution is unimportant, but am convinced that if any one will make an investigation of the thirty or forty furnaces in the United States which have been doing extraordinary work, it will be found that in at least eighty per cent of the number very close attention is given to the preparation of material in the stock-house. I am convinced that the good results obtained at most of the other furnaces which do not attract so much attention are largely due to work upon the stock before charging. In fact, I am convinced that one dollar well expended in the stock-house, brings two dollars out of the furnace tapping-hole.

There is, of course, a difference in the treatment of various ores, but it is hardly to be expected that we will get as good results when part of the ore is as large as the size of a fist, and another part as large as one's head, as we will get when the sizes are more uniform; and, similarly, the difference in size of coal, particularly of anthracite, has a material effect upon the working of the furnace.

The form of bell shown by Mr. Firmstone, while possibly well adapted to his furnace, might not be advantageous if placed on a furnace of smaller size where the proportion of parts would be diminutive. Some furnaces appear to be obtaining good results while working open-top, and, in one instance, where I represented the owners, the lessee was permitted to arrange the furnace to work with

FIG. 1.



SIDE ELEVATION AND SECTION ON A C B D E OF PLAN open-top, provided a bell and hopper were kept ready for use is required. This was done; but for two years the plant has been in operation with open-top. The lessee seems satisfied with its results, and, the owners are receiving good compensation based upon the weekly out-put. There is no question in ray mind, however, that the arrangements for distributing stock into the top of the furnace and the necessity for properly preparing and selecting it beforehand have much to do with its successful operation ; and the merits of various forms of bells and hoppers for charging apparatus may well command our attention.

THE SIEMENS PATENTS FOB IMPROVEMENTS IN GLASS-FURNACES, WITH SUGGESTIONS FOR THEIR USE WITH NATURAL GAS.

BY B. SILLIMAN, NEW HAVEN, CONN.

THE remarkable outflow of natural gas recently developed in Western Pennsylvania, and along the valley of the Ohio and its tributaries, has called attention to an important series of patents for improvements in glass-furnaces and the manufacture of glass, which the brothers Siemens have made since 1872. The basement-patent of this series, is No. 127,806 of the U. S. Patent office, and is of date June 11th, 1872. This has been followed by eleven other patents (including one re-issue), all for improvements in glass-furnaces, or methods of manufacture, of which the latest is of date July 11th, 1882. Nine of these patents were issued in 1880-82. The following is the list, of these patents, in order of dates, viz.:

1872. June 11th. No. 127,806 (U. S. office), Improvement in glass-furnaces; 17 sheets drawings, 5 pages text. This is the basement-patent.

1877. April 17th. No. 189,800. Improvement in the manufacture of glass; 3 sheets drawings, 2 pages *text.* Boats and floating vessels swimming in the liquid glass of the tank-furnace. Re-issued in 18S0. *q. v.*

1880. April 27th. No. 226,934. Furnace for annealing and tempering glass.

" July 13th. No. 229,846. Glass-melting-furnace.

" August 3d. No. 230,668. Glass-melting-furnace; 4 sheets drawings, 2 pages text.

1880. August 3d. No. 230,668. Glass-melting-furnaces; 3 sheets drawings, 1 page text.

" October 19th. No. 2:13,566. Furnace for melting, refining, and working cut-glass; 3 sheets drawings, 2 pages text.

" October 19th. No. 9,418 (re-issue of No. 189,800). Manufacture of glass, boats, and floating vessels.

1881. June 14th. No. 242,S45. Manufacture of glass; 5 sheets drawings, 2 pages text. Floating vessels and boats of three compartments, and their use in the tank.

1882. March 7th. No. 254,572. Melting, refining, and working out glass.

" April 18th. No. 256,748. Glass-melting-furnace; 4 sheets drawings, 2 pages text.

" July 11th. No. 261,054. Construction and method of working glass-melting-furnaces.

The fundamental idea upon which all the Siemens glass-patents are based, is found in the cardinal fact, before overlooked, or not availed of, that in the melting or fining of glass, there is an important difference of density in the product in the successive stages of the process, the fine glass being the denser, and falling by gravity to the bottom of the pot, while the less refined glass floats on the surface of the denser glass, bearing with it the "scum" or "stone," so called, imperfectly melted material, and impurities fatal to the beauty and homogeneity of the finished product. The Siemens brothers, with characteristic sagacity, have seized on this fact, and have developed out of it an entirely new system of glass-furnace and glass-manufacture, as described in their patents.

This invention involves the use of a pot or tank for the continuous melting of glass and other vitreous substances, provided with three compartments, so arranged as to communicate with each other in such manner, that the raw material is introduced in one compartment, from the lower part of which the melted material is caused to flow into the top of the next compartment, whence it passes into the bottom of the third compartment, from which it is worked out. These tanks are so constructed that the compartment into which the raw material is introduced is open to the direct action of the flame, while the working-out compartment is protected from this direct heat, and is consequently maintained at a lower temperature, such as is essential to the proper temper of the metal for working-out, and also is conducive to the comfort of the workmen. The construction of the furnace also permits the regulation of the heat in the separate parts of the furnace, by the adjustment of the gas and air-ports, so as to cause the flame to play, at will, transversely over the three compartments.

All that part of the foundation patent of 1872 *(No.* 127,806), which relates to improvements in the gas-producer has no relation to our present purpose, since the flow of natural gas relieves the manufacturers of all the annoyances and difficulties connected with the gas produce of the regenerative furnace.

It is well, as illustrating the development of the fundamental ideas of the inventors, to copy from their basement-patent a few figures showing how, starting with the old form of glass-pot, modified as here described, we pass later to an entirely different form of apparatus for the same purpose, in which the old pot disappears, and the fundamental idea is generalized.

Not to run the risk of failing fully to state the inventors' views, we will quote a paragraph or two from the 1872 patent, with the figures to illustrate the text. The numbers of the drawings (4 to 14 in the patent) have been changed in the quotation to prevent confusion in the present paper, other drawings being hereinafter given:

"By our present improvement we render the process of glass making a continuous and more uniform one, and we construct the glass-pots or tanks with three separate compartments, in one of which the materials are introduced continuously, or at short intervals, and from which the materials, as they melt, are caused to flow into the next compartment, where the operation of melling is completed, and whence the glass flows into the third compartment, where it is worked out continuously. To produce this circulation of the melted glass through the three compartments, advantage is taken of the gradually increasing specific gravity of the glass, as the melting-down thereof proceeds. By this means a stratification according to the condition of the mass is effected, allowing of its being subjected to different temperatures, corresponding with the particular stage of preparation at which the several portions thereof have arrived.

"Figs. 1 to 11 of the drawing show the application of the invention to glass-pots. Fig. 1 shows a plan of the pot; Fig. 2 a sectional plan on line 5 5 of Fig. 3, the latter being a vertical section on line 6 6 6 of Fig. 2. Fig. 4 is a vertical section on line 7 7, and Fig. 5 a vertical section on line 8 8 8, of Fig. 2.

"The pot is constructed with three separate compartments, A. B, C, of which A serves to receive the raw materials, and communicates with the intermediate or clarifying compartment B, by means of the aperture a, and the vertical passage *b,* while the compartment B communicates with the third or working-out compartment C, through the aperture c, at the bottom. The compartments A and B are open to the direct action of the flame, while the compartment C is closed in at the top, in order to protect it from such direct action of the flame, and it is provided with a nozzle, *d,* which projects through the working-aperture of the furnace, and through which the glass is worked out in a similar manner to ordinary glass-pots.

Fig. 1.

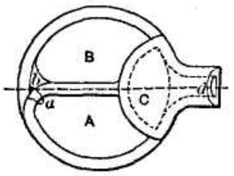


Fig. 2.

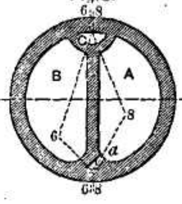


Fig. 3.

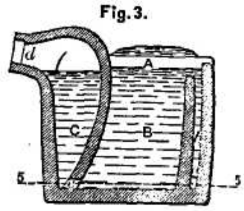


Fig. 4.

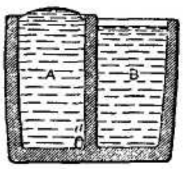


Fig. 5.

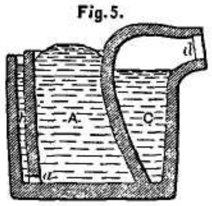


Fig. 6.

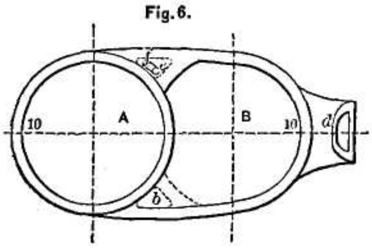


Fig. 7.

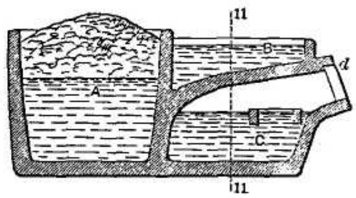


Fig. 8.

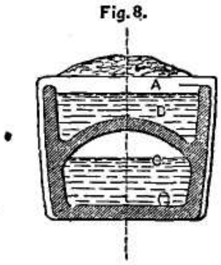


Fig. 9.

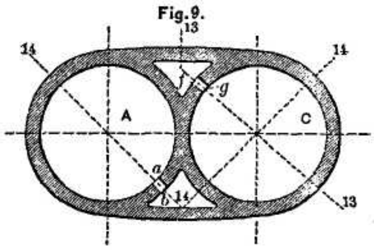


Fig. 10.

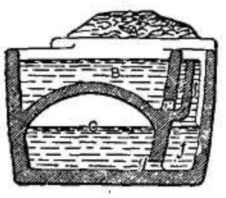
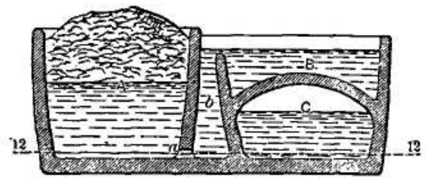


Fig. 11.



"The two uncovered compartments, A and D, serve for the melting-down and clarifying of the melted glass supplied to the working compartment in the following manner: The raw materials are introduced in small quantities into the compartment A, which, as shown in the drawing, is maintained as nearly as possible in a filled condition. As the materials melt they will, by virtue of their increasing gravity, accumulate in the bottom of the compartment in such manner that the perfectly melted particles will be situated quite at the bottom, while the portions that are in a less perfectly melted condition will be stratified above the same, according to the degree of heat which they have attained. As the melting-down proceeds, the lowest stratum in the compartment will pass through the aperture *a* into the channel *b,* in which it will rise, and eventually flow over into the compartment B. As this compartment fills, a stratification of the material similar to that in A will take place, the most perfectly clarified and densest portion of the glass sinking to the bottom, while that which is less clarified and charged with air bubbles will remain in the upper part, until by the action of the furnace heat it becomes clarified in its turn, and is caused, by the continued entrance of fresh material from the passage *b,* to sink to the bottom, thereby forcing the lower stratum through the aperture *c* into the compartment C. As the lower part of the glass-pot is cooler than the upper part, the compartment B serves both to clarify the glass in the upper part and to cool the same down in the lower portion, in which cooled condition the glass consequently enters the compartment C ready for working out. All three compartments are thus always filled with glass in different stages of preparation, the level of the glass being, however, different in each compartment, as shown on the drawing, corresponding with the respective differences of the mean specific gravity of the several contents.

" It will be understood from the foregoing that in proportion as the glass is worked out of the compartment C, fresh material must be charged into the compartment A, which operation is effected by the glass-blower, who also from time to time skims the surface of the glass in the compartment B, in order to remove impurities or imperfectly melted particles. By this improved construction of glass-pots it is rendered possible, while maintaining the furnace-heat at one uniform temperature, to effect the four different operations which are requisite for the perfect manufacture of glass—namely, the melting-down of the materials, the clarifying of the melted mass, the cooling-down thereof, and the working-out of the cooled mass.

"Figs. 6 to 11 show a modified form of the above described improved glass-pot, Fig. 6 being a plan of the same. Fig. 7 is a vertical section on line 10 10 of Fig. 6; Fig, 8 a section on line 11 11 of Fig. 7; Fig. 9 a sectional plan on line 12 12 of Fig. 8; and Figs. 10 and 11 are sections, respectively, on lines 13 13 13 and 14 14 14, Fig. 9. The general arrangement of the pot is the same as in that just described, the raw material being introduced into the compartment A, from which the melted glass passes into the compartment B, where it is clarified, and whence it descends into the closed compartment C, where it is worked out. The compartment B is, however, here formed over the compartment C, the melted material being caused to pass from A, through the aperture *a* and channel *b,* into B, from the bottom of which first it ascends through the apertures *c* and the channel *e,* and then flows over into the space *f*, communicating at bottom with the compartment C through the aperture *g.* From the arrangement of the passages *e f* it will be seen that, though the compartment B is raised entirely above the level of the glass in C, yet the glass will flow only into the latter compartment in precisely the same measure as it flows from A into B. In both the above-described arrangements of glass-pots the working-out-compartment C, in place of being formed by a fixed partition in the compartment B, may be constructed as a loose com partment, in the form of a deep ring floating in the melted glass in the compartment B, so as to reach nearly to the bottom of the latter, through which ring the melted glass will rise from the compartment B in the same manner as is the case with the fixed compartment C."

The mode of arranging these glass-pots in the regenerative furnace will be readily understood without any detailed description.

The principal advantages resulting from this construction of furnace, glass-pots, and tanks, are: First, an increased power of production in the furnace; as the full melting heat may be employed without interruption, in place of the intermittent action of furnaces as before constructed. Second, an economy in working; less labor being required for carrying on the operation than in the ordinary process. Third, greater durability in the pots and tanks, owing to the uniform temperature to which they are subjected ; and Fourth, much greater regularity of working, and more uniform quantity of the products by the continuous method of manufacture.

Without reproducing several large drawings it is impossible to give here the detail of the tank-furnace in three compartments, which is the generalized form of the special three-compartment pots already described, and accomplishes on a very large scale what is done in the smaller pots, the gas- and air-ports being so arranged along each side of the tank as to cause the flame to play transversely across the same; allowing of the proper adjustment of heat in each compartment. All this, it will be readily seen, is a remarkable advance over anything before known in the construction of furnaces for glassmaking.

An important development of the fundamental idea already considered followed in 1877, and again more maturely in 1881, July 14, in the invention of floating vessels of fire-clay, swimming like boats upon the surface of the molten sea of glass, in the large tanks, and gathering their charge of refined glass by force of gravity in their vessels, sometimes of three compartments, but not always so; these segregating vessels transporting their load of fine glass to the working-out holes in the sides of the furnace, and delivering it there as wanted by the workmen.

This general statement requires illustration, which is best drawn from Patent No. 242,845, June 14, 1881. From this we will copy two or three figures which are essential to the understanding of the description. This patent is the individual production of Mr. Frederick Siemens, of Dresden, and his description of his invention is so concise that it is hardly possible to condense it without loss of clearness. He says his invention consists in providing a floating vessel for continuously fining and working out glass, with an upwardly projecting transverse partition to prevent the melted glass within the fining compartment of the floating vessel from flowing

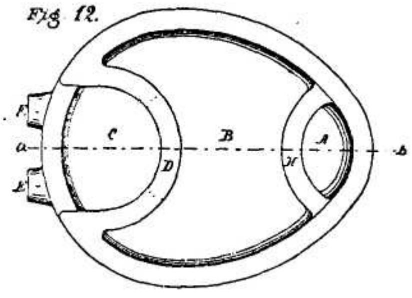


Fig. 12.

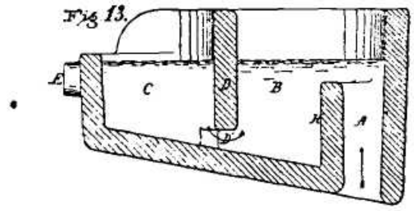


Fig. 13.

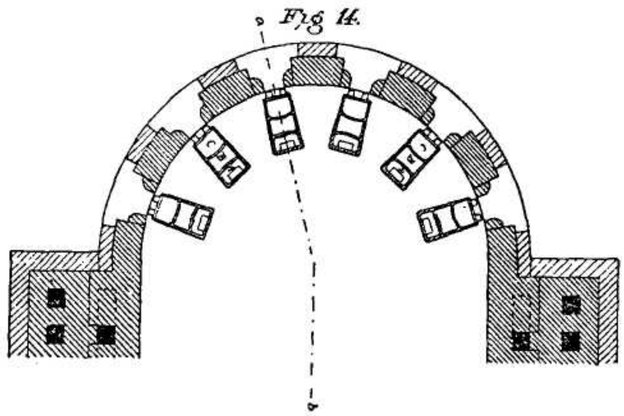


Fig. 14.

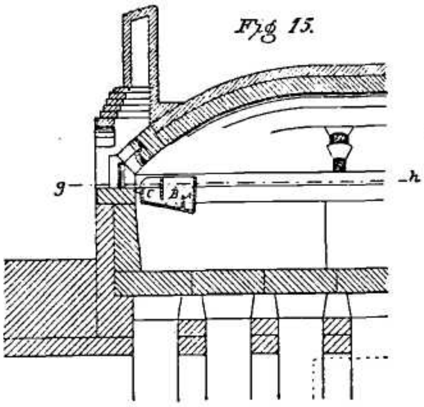
back into the tank. This floating vessel is also provided with studs or horns, forming a fender, to keep the vessel away from the wall of the tank, and to prevent the fused material from the roof of the furnace, or grating-holes, from falling into the refining-vessel. Mr.

Siemens goes on to say (the numbers of the drawings, 1 to 4 in the original, being changed in this quotation to prevent confusion in **the** present paper):

"In the accompanying drawings corresponding parts are designated by the same letters. Figure 12 is a plan of a refining floating vessel. Fig. 13 is a longitudinal vertical section taken on the line a 6 of Fig. 1. Fig. 14 is a plan, in horizontal section, on the line *g h,* Fig. 15, of the tank of a glass furnace, showing the refining vessels floating on the metal. Fig. 15 is a vertical section of the same, taken on the line *a b* of Fig. 14.

"The floating vessel made use of in my process of continuously melting, fining, and working out glass is constructed of fire-clay or other suitable material, and may be of any size or shape, several being shown in the patent which may be deemed desirable or best adapted to the work for which it is used. It is provided with three communicating compartments or receptacles arranged in relation to each other, as shown in the drawings. The first of these compartments, A, is a receiver, into which the metal flows from the tank. The second, B, is a refining-chamber, and

Fig 15.



the third, C, is a working-out compartment. The refining-vessel is made to float in the metal of the tank in such a manner that the first compartment is supplied through holes at or near its bottom with glass taken at the lowest practicable depth below the surface of the material in the tank—that is to say, at the point at which the metal is sufficiently liquid to flow into it, the hottest metal being at the upper surface, over which the flame plays, and gradually diminishing in temperature toward the bottom. The vessel may be adjusted to the desired level at its supply-end by a greater or less thickness of those parts which project above the metal, or by means of loose bricks placed upon the vessel.

"The receiver or first compartment, into which the metal flows from the tank, is separated from the refining chamber or second compartment, B, by a partition or dam, H, rising from the bottom of the floating vessel, and the base thereof is provided with one on more apertures openings, or spouts, of any size or shape which may be deemed desirable for the admission of the metal, the use of spouts enabling the metal to be drawn from another point in the tank than that in contact with the floating vessel. By the observation of well-known laws and methods for regulating position of floating bodies, the vessel may be so constructed and floated that this opening in the bottom of the first compartment will occupy the most desirable location for withdrawing the best material from the tank, or the vessel may be weighted, if necessary, as already described, so as to be adjusted to this point.

"The working-out compartment, C, is separated from the refining-chamber by the cross-partition D, having an opening, D, at the bottom thereof for the passage of the refined glass from the compartment B. The object of the partition H is to prevent the refined glass within the floating vessel from finding its way back into the tank, and thus, in conjunction with the partition, D, cause the working out compartment to be supplied only with the most refined glass from the refining-chamber. The size of the latter will depend upon the kind of glass to be worked out. Thus when window-glass or large objects requiring the withdrawal of great quantities of glass at a time are to be produced, the refining-compartment may be of greater capacity than when bottle-glass is required, or two or more vessels may be employed from which glass may be gathered successively.

"The refining-compartment should be subjected to the full heat of the furnace, if all the glass which reaches it is to be thoroughly refined therein ; otherwise the metal therein may be skimmed from time to time for the removal of imperfectly fused glass.

The worked-out compartment, C, is sometimes provided with a hood, in order that the refined glass may be sufficiently cooled therein for gathering, and (hat the workmen may be protected from the direct action of the flame while gathering the glass.

" The working-out end of the floating vessel is provided with studs or horns E, at or near the upper edge, serving as fenders to keep the said vessel from contact with the side of the tank, to which it might otherwise adhere, owing to the cooling of the material next the side of the tank, and thus also preventing fused material from the roof or sides falling into it. "With the assistance of these fenders no difficulty is experienced in keeping the floating vessels in position in the tank, as the flow of the glass causes them to press slightly against the sides of the tank nearest their respective working-out holes. Advantage is taken of the gradually increasing specific gravity of the glass during the process of melting and fining, in order to produce the required circulation of the melted glass through the compartments of the floating vessel. By means of the passage, A, in the bottom of the vessel, the best material in the tank, free from floating impurities, is admitted into the first compartment, through which it rises until it flows over the top of the partition or dam, H, into the refining-chamber, B, wherein a stratification of the metal takes place, the most perfectly clarified and dense portion of the glass sinking to the bottom of the compartment and forcing the lower stratum therein through the passage, D, into the working-out compartment, C, the refined metal being prevented from flowing back into the tank by the cross-partition or dam, H.

"By the use of floating vessels, as thus described, the melting down of the materials, the clarifying, the cooling of the melted glass, and the working-out of the glass may be effected continuously while maintaining the furnace-heat at a uniform teurperture, without the use of division-walls in the tank.

"Vessels, as above described, may be also used in pots, and such pots may be worked as tanks with the hottest flame playing continuously over the surface of the material contained in them."

This patent of 1881 quite supersedes the partial one of April *7,* 1877, re-issued in 1880 in which boats and rings of various forms were used with only two compartments; although these do excellent service, and were very successfully used, especially in the form of floating rings, in the furnace for melting, refining, and working-out glass, patented October 19, 1880, No. 233,566.

In this last-named patent we find a quite novel device described consisting of bars or girders of fire-clay, floated on the surface of the molten glass in the tank, and so secured in position as to divide the upper stratum of the molten matter into compartments. The imperfectly melted or impure material is thus kept at the supply end of the tank, and only the more thoroughly melted and pure matter is permitted to flow towards the working out end by passing downward and under these floating bridges. These bridges or girders are made quite separate from the tank, and are floated into position and secured in place by dowels or wedges of fire-clay introduced for that purpose through openings in the roof of the furnace. In order to assist the vertical circulation of the molten matter, floating rings of refractory material in greater number than required for gathering the glass, may be employed at the working-out end of the tank, and from these rings, near each working-hole, the glass to be worked should be gathered. These rings are renewed, as are the girders, as they dissolve or wear away in the molten metal. A glance at the figures accompanying this patent will render this device clear, if the description fails to do so, but these figures are too large to introduce into our paper. This mode of construction, designed to secure the effectual development of the original idea of the basement-patent of 1872, is as simple as effectual, and well illustrates the fertility of invention so characteristic of Charles William Siemens, whose individual patent it is.

The subsequent patents of 1882 relate to various forms of melting-and refining-furnace, of which that of July 11, 1882, is, perhaps, the mast important, claiming the advantages of a greater depth in the molten mass in the tank. This patent was issued to Frederick Siemens, of Dresden. After describing his invention, with reference to the accompanying drawings, he thus sums up the reasons which have led him to adopt the present construction, and the advantages derived from it.

"The tank, D, is made over eighteen inches in depth for the following reasons: In continuous-melting tanks shown in former patents, the surface of the metal subjected to the action of the flame was made considerable, in order to permit of the reactions taking place in the upper portion of the current travelling towards the working-holes. These dispositions appeared indispensable, for the lower portion of the metal in the tank is chilled by contact with the bottom, which is kept actively cooled by circulation of air to prevent leakage of the glass through the joints. By increasing the depths of the tanks to a sufficient degree while maintaining an active circulation of air beneath, the metal under treatment is maintained quite fluid to a depth of about eighteen inches, and it has been found not only possible, but advantageous, to reduce the surface-metal subjected to the action of the flame, for the reason that the reactions among the particles occur in this case, during their descent from the higher to the lower zones of fluid metal. This is particularly the case in bottle-glass furnaces, in which the finest glass always remains in the lowest zone, whence it is, according to the new arrangements, gathered by means of the floating vessels or other suitable means. In the fusion of window or other white glass there is a continuous descending and ascending movement of the particles throughout the mass, as is proved by the wearing away of the bottoms of shallow tanks. The ad- vantage to be obtained from increasing the depth of these tanks will be the formation of a layer of chilled glass on the surface of the bottom, at which point the movement of the particles ceases, whereby the bottom blocks will be protected from wear, the presence of stones in the glass avoided, and a larger proportion of first- quality glass will be produced. It is also to be observed that by this construction the reduced surface of the tanks exposed to flame is accompanied with additional economy of fuel, owing to the diminished surface for loss of heat by conduction."

In reviewing this series of patents it is evident that the inventors have constantly striven to simplify and generalize the leading thought which led to the comprehensive basement-patent of 1872, and to guard this invention by auxiliary patents calculated to forestall and avoid interfering or competing rivalries, and at the same time to meet the requirements of the glass-maker's art. It is evident they never contemplated the remarkable advantages in the use of this glass furnace, now made available by the use of natural gas, flowing in unmeasured abundance in the very place, which, from its cheap coal, has already become the centre of the glass-industry of the United States. This bounty of nature simplifies the problem and does away with all the annoyances and expense of the gas-producer, leaving it to the ingenuity of the engineer only so far to modify his flues and gas- and air-ports as to meet the requirements of a gas free of nitrogen and carbonic acid, and enriched by ethane and its higher mutiples, and having of course a correspondingly greater calorific power, with the probability of a deposit of solid carbon in the flue and regenerator, unless the flow and temperature of air is properly adjusted to secure the complete combustion of the richer gas with which the engineer has to deal.*

* As we are going to press a notice reaches us in *Nature,* Nov. 6th, of a paper read by Mr. Frederick Siemens, at the Chester Meeting of the Iron and Steel Insti-

NATURAL GAS.

The flow of combustible gas from openings in the earth in various places, is a fact as old as Herodotus, and the Chinese are known to have used it, economically, from wells, said to be 3000 feet deep, bored, probably, before the days of Herodotus, and yet absurdly spoken of as "Artesian," as if the province of Artois, in France, could have instructed the wily Celestials in an art which was old in China before Gaul was known to the Romans, and, for that matter, before Romulus

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tute, "On a New Method of Heating in the Regenerative Gas-Furnace." Mr. Siemens has reached the important conclusion that combustion can be perfect, and can be maintained perfect only when the space in which it takes place is sufficiently large to allow the gases to combine out of contact with solid materials. Another important deduction from these investigations is that combustion should be considered in two stages or periods, which may be respectively called active and neutral. In the first, the purely chemical combination of the gases takes place, during which, as soon as the temperature of ignition has been reached, the whole of the heat of the highest possible intensity is produced, of which a large portion is given off by radiation, whilst in the second, the temperature having fallen in the proportion of the heat given off by radiation, the remainder of the heat, which is no longer of an active character, is best transmitted by conduction

"Mr. Siemens, in applying his investigations to practice, insists that flame must not be allowed to impinge on bodies to be heated, but must simply heat the bodies by radiation; and the furnace must be so constructed as to allow the flame to develop out of contact, not only with the substance on its bed, but with the walls and roof of the furnace itself. It thus follows that large furnaces must replace small ones; and to meet the objection that the loss of heat into the atmosphere must increase in proportion to the area of the furnace, Mr. Siemens explains that the heat developed in the furnace increases in a much larger ratio than its increase in area, because flame radiates in every direction from every portion of its entire volume, while a solid substance radiates from its external substance only.

The details of construction of metallurgical and glass-furnaces, and of steam-boilers, are given in this paper of Mr. Siemens, and will be awaited with interest by all here interested in this very important question of how best to burn the natural gas of our wonderful gas-wells.

It is stated, moreover, that " furnaces heated on the radiation principle have proved, both in Dresden and at Landore, to have been economical of fuel, whilst the saving from reduced oxidation and in the construction of the furnace has been found to be very great."

No allusion is made in the abstract of Mr. Siemens's paper to the use of natural gases in these furnaces, but we can scarcely doubt that so acute an observer as Mr. S. has long since discovered the necessity for important modification in the construction of the regenerators for using this gas as compared to those employing producer gas, and we shall not be surprised to find, either in the paper itself or in the text of the patents covering this new form of furnace, direct allusion to its, adaptation to the use of natural gas.

or Remus nursed the wolf.* The fire-worship of the Persians is believed to have had its origin in the escape of marsh-gas.

The earliest use to which this natural illuminant was put in this country, was in the village of Fredonia, in Southwestern New York, 'which was illuminated by the gas escaping from cracks in the rocks as early as 1827. This flow still continues, and has been increased by boring about 80 feet into the black shales of the Marcellus beds, which are everywhere charged with gas to a greater or less extent.

In the salt region of the Kanawha Valley, the existence of large quantities of marsh-gas was known to the earliest explorers of that interesting region. The "Burning Spring," mentioned by Mr. Jefferson, in his *Notes on Virginia,* was the accident of an early explorer going after nightfall, with a torch, to fetch water from the spring, when the flame of the torch ignited the gas escaping from its surface, to the great amazement of the explorer. When boring for salt water was, at a later day, commenced in that region, nearly every salt-well became also a gas-well, the gas, in many cases, jetting the water with force into the air, and this, taking fire, continuing to burn for a long time, even from wells of only 15 or 20 feet deep. It was about 1842 that Mr. William Tompkins first obtained a steady and permanent stream of gas of sufficient power, not only to throw the water up from the depth of a thousand feet to the surface, but to carry it into the reservoir elevated many feet above the bank of the river, thus avoiding the expense of a steam-pump. Mr. Tompkins appears to have been the first to think of using this gas as fuel. For this purpose he extemporized a gasometer, formed from a hogshead, placed over the reservoir, and into this vessel he carried the stream of water and gas. Providing an escape for the water, he soon had at command a steady flow of gas, which he conveyed by a pipe to the mouth of the furnace, a " salt block " of 100 feet long by 6 deep and 4 wide, producing a dense and intensely heating flow under the whole row of kettles.

Mr. James A. Lewis, of Kanawha C, EL, Va. (now West Virginia), from whom we cite these facts, mentions† the well of Messrs. Dickinson & Shrewsbury on the Kanawha, bored to the depth of one thousand feet, which presented an example of force and constancy at that time without example. The flow from this well was obstructed

* It is hardly- necessary to say, that in speaking of combustible natural gas, no reference is had to any other than the hydrocarbon gases,

† *Silliman's Journal,* [I.], xlix., 211. 1845.

by an iron sinker at the bottom of the well, a long piece of round iron, nearly filling the bore ; on this were 600 pounds of iron, and about 300 feet of auger-pole used in boring, united by heavy iron ferules; yet, notwithstanding all this obstruction, a stream of water and gas issued through a copper tube, 3 inches in diameter, inserted in the well to the depth of 500 feet, with the noise and force of steam from the largest steam-boiler. It was computed that a sufficient quantity of gas came from this well to fill a reservoir large enough to light the city of New York for twelve years.

These early examples of gas-wells are cited now only to show that the phenomenon is not new, and also as an interesting illustration of the fact that such remarkable phenomena should have been suffered to remain so long, practically without useful application. So slow is man to see the value of things requiring a departure from his daily experience. Thus it was with regard to the outcroppings of petroleum, familiarly known, since the days of Herodotus, on the Caspian, and from the earliest occupation by white men at Oil Creek and elsewhere in America.

The borings for oil and salt have been the means of opening many gas-wells, of which a familiar and rather exceptionally interesting example is that near West Bloomfield, New York, thirty miles south of Rochester. This well is said to be 500 feet deep; it was sunk in search of petroleum, and was túbed with a pipe of 5 inches diameter, descending into the Marcellus shales. The flow of gas was stated to be about 400,000 cubic feet in 24 hours, and its delivery had been constant for four years, when it was visited by Professor Henry Wurtz, in 1870.

A company, organized in Elmira, laid a line of wooden pipes, of 4-inch calibre, to Rochester, and introduced the gas as a source of heat, to the boiler of the chief hotel (Osborne House), for a time. A large quantity was introduced into the holder of the gas-works, on one occasion, but as no means were taken to remove the large quantity of carbonic acid the gas was known to contain, the result was disastrous, the next evening, to the brilliancy of the illumination. Meantime the pipes filled with mud, stones, and water, and the whole scheme was so wretchedly engineered, that it, of course, was disastrous to the promoters.

Professor Wurtz made a careful examination of the gas of this well, and the following is his analysis :*

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* *Silliman's Journal,* [II.], xlix., 336. 1870.

Marsh-gas,	82.41
Carbonic acid,	10.11
Nitrogen,	4.31
Oxygen,	0.23
Illuminating hydrocarbons,	2.94
	100.00
Density,	0.693

The carbonic acid in this gas is very much in excess of the amount; of CO_2 usually present in the natural gas-wells, which is often under 1 per cent. When Professor Wurtz visited this well, the jet of flame escaping from the open pipe rose into the air fully thirty feet. The temperature of the gas was judged to be about 50° F. The candle-power was about 6 candles, showing the effect of CO_2 in reducing the brilliancy of its illumination.

In a paper published in 1876, by Professor J. Lawrence Smith, on the gas-wells of Pennsylvania,* he speaks particularly of the Burns and Delamater wells of Butler County, then unique for the force and volume of gas delivered. In a quiet night, the roar of the escaping gas could be heard at 15 miles' distance, and at 4 miles it resembled the noise of a near approach of a train of railway cars; and when approached near at hand it was like the scream of a myriad of locomotives blowing off steam; at one-eighth of a mile it resembled the continued boom of cannon. The human voice was heard with difficulty, and the flame darted into the air to the height of 70 feet, like a burning church spire. In winter the surrounding hills were covered with snow, but for a couple of acres around the wells the herbage was green and in full vegetation quite near, where the earth resembled cooled lava. Troops of cattle were seen at a certain distance warming themselves, and browsing on the herbage which appeared as if coming out of a hot-house. The pressure at the wells, in the 5½-inch pipe, is stated at 100 pounds per square inch; in a 2-inch tube, conducting the gas 15 miles to Freeport, the pressure was reduced from 200 to 125 pounds.

Dr. Smith concludes his paper by citing the following analyses of the gas from four wells, by Professor Sadtler, of the Pennsylvania Geological Survey, which are also cited by the Engineers' Committee in their report on Natural Gas, of May last, more particularly mentioned beyond.

* *Puits de Gaz en Pennsylranie.* Par M. Lawrence Smith. *Annales de Chimie et de Physique* (5 sérìe), 8, 566,1876.

Analyses of Natural Gas, by Sadller.

CONSTITUENTS.	Burns's Well, near St. Joe, Butler County, Penn.	Harvey Well, Butler County, Penn.	Cherry Tree, Indiana County, Penn.	Leechburg, Westmoreland County, Penn.
Hydrogen, ...	6.10	13.50	22.50	4.79
Marsh Gas, ...	75.44	80.11	60.27	89.65
Ethane, ...	18.12	5.72	6.80	4.39
Propane, ...	trace.	. . . .	. . . .	. . . .
Carbonic Acid, . . .	0.34	0.66	2.28	0.35
Carbonic Oxide, . .	trace.	trace.	. . . .	0.26
Nitrogen, ...	. . . .	. . . .	7.32	. . . .
Oxygen, ...	. . . .	. . . .	0.83	. . . .
Illuminat'g Hydrogen,	. . . .	. . . .	. . . .	0.56
	100.00	99.99	100.00	100.00
Density, ...	0.6148	0.5119	. . . .	0.5580

The report of a committee of the Engineers' Society of Western Pennsylvania, made in May, 1884, at the meeting of this society and jointly of the American Society of Mechanical Engineers, then holding its semiannual convention in Pittsburgh, has since been published as a part of the volume of Memoirs, pp. 331-359, including the discussion called out by the report. From the physical and chemical side, this report is in many respects unsatisfactory, inasmuch as it leaves many interesting questions unsolved, and surrounded by conflicting statements, such, for example, as the initial pressure of the gas-flow, and its temperature. From the minute details given by the committee relating to gas-distribution, the emphatic testimony that only pipes of chain-metal, and never cast-iron, should be-used as the first essential of safety, that none but wrought-iron or bronze bends and unions can be admitted into dwellings with safety to those who use natural gas as a source of heat, it is evident that enormous pressures are to be provided for; and yet, we are left in doubt as to the initial pressure at the pipes of afflux. The temperature, of about 45° to 50° F., in the pipes of distribution appears in remarkable contrast with the accumulation of ice about the outlets of escaping gas, etc., evidently showing the necessity for multiplied observations and the more exact study of the conditions under which the natural gas exists in the deep-seated sources where the most obvious indications seem to point to its existence under a pressure equivalent to liquefaction. Of course, the intimate relation of the natural gas to the oil-outflow, is one of the conspicuous facts which all stand ready to admit, but for the full understanding of which facts are still wanting.

The one conspicuous fact remains, that in this great *Deodand, the* bounty of nature, we have a potential of a much higher value than can be furnished by any artificial gas-producer. Substantially free from carbonic acid, nitrogen, and other inert gases, when applied to glass-furnaces it offers to this industry a resource far surpassing any experience which the past can recall, especially when used in connection with the Siemens patents for glass-production.

SODA-ASH.

Until very recently, it has been considered a circumstance fatal to the production of cheap glass in the United States, that we failed to compete successfully with the cheap soda-ash of Europe by the Le Blanc process. But, thanks to chemistry, the steady march of improvement and discovery has, at length, brought the ammonia-soda process to a state of development which is not only *practical* in the best sense of that much-abused word, but which is to-day such as to enable the owners of the Solvay process at Geddes, near Syracuse, to furnish soda-ash in competition with Europe, but of a quality which sinks the Le Blanc process beyond competition. The new Solvay ammonia-soda product is 98 per cent to 98½ per cent pure carbonate, practically free from iron and other impurities, while the Le Blanc soda holds only at 78 per cent to 80 per cent of purity. The Solvay soda is free not only from iron, but also from the considerable contingent of sodium sulphate and chloride which give so much annoyance in the glass-pots from "gall," "scum," etc.

This new industry is now actually supplying about 5 per cent of all the soda-ash consumed in this country, and it is destined soon to develop to a very considerable importance; for, in western New York are ample beds of pure salt, and probably the same exist in Pennsylvania; while the beds of rock-salt lately penetrated in the Wyoming region, and the salt water which flows with the gas in some of the Pennsylvania wells, will provide very large quantities of the raw material for the manufacture of soda-ash by the ammonia process. Nor is there need to fear that an adequate supply of ammonia cannot be obtained, for it must be remembered that every day the coke-ovens of Western Pennsylvania are wasting far more ammonia than will be wanted, should all the soda-ash now used in this country be manufactured here.

The one waste product of the Solvay ammonia process which remains to be utilized, is the chlorine of the salt now thrown away as calcium chloride, and this may become an important factor in another direction if, as has been suggested by Dr. Drown, chloride of calcium should prove to be of moment in the washing of coal.

It appears, therefore, from this brief review of the facts connected with the glass industry, that we possess now all the material elements necessary to its prosperous prosecution. No mention has been made of the quartz-sand of the United States. But it is well known that this material exists in great abundance and of excellent quality, and is so distributed as to meet the wants of the glass-house at almost any point where the other elements of this industry are combined.

For cheap bottle-glass we must look to the supply of a natural source of silica and soda--feldspar, of which no use has been made in this country. But for hohl-glass, window-glass, and all other forms, we have every element in abundance.

The gas-wells of Western Pennsylvania certainly solve the fuel-question in a more satisfactory way than has been possible before in the history of this industry, either here or elsewhere; and the Siemens patents offer a solution of the utmost importance for the use of a part of this great natural bounty.

[NOTE BY THE SECRETARY.--The lamented death of Prof. Silliman, occurring January 14, 1885, while the foregoing paper was in press, prevented any revision of the proofs by him. Indeed, the manuscript itself was completed by him, with the aid of an amanuensis, during his illness. It was probably his last work; and the greater portion of it, which was in his own handwriting, gave touching evidence of his physical feebleness, and of his determined effort, notwithstanding, to complete what he had undertaken.]

QUICKSILVER-REDUCTION AT NEW ALMADEN.

BY SAMUEL B. CHRISTY, UNIYERSITY OF CALIFORNIA, BERKELEY, CAL,

THE mines of New Almaden were opened some years before 1850. The regular workings of which records have been kept extend from that date to the present time. During the 34 years ending with 1883, the quicksilver product of these mines has been exceeded by that of Almaden in Spain only.

During this period, the yield of New Almaden has been 79 per cent of that of its namesake in Spain, three times that of Idria in Austria, and greater than that of all the other mines in the world put together. Very little, however, has ever been published regarding either the mine or its works.

These facts, together with the energy with which improvements have been introduced and perfected at New Almaden, particularly during the last ten or twelve years, justify the length and detailed nature of the present paper.

This study of quicksilver reduction will consider:

1. The ores: their sorting and classification.
2. Methods of reduction: historical sketch.
3. Reduction-works: their situation and arrangement.
4. Furnaces : their construction, mode of operation and economic results.

a. Intermittent furnace.
b. Continuous coarse-ore furnaces.
c. Continuous medium-ore *(granzita)* furnaces.
d. Continuous fine-ore *(tierra)* furnaces.

In a subsequent paper will be considered the important subject of condensation, the production of the works, and the total cost of production.

I. ORES.

SORTING AND CLASSIFICATION-.

As is well known, the ore at New Almaden is cinnabar. Native quicksilver occurs also; but, as a rule, in small quantities only. Pyrite occasionally accompanies the ore. Bitumen is quite common, sometimes as a fragile black lustrous solid, resembling soft bituminous coal, but melting easity like tar; at other times it occurs in the vugs of the gangue, in a liquid state, like coal-tar. I have found lumps of apparently pure cinnabar from New Almaden, to give a voluminous residue of pulverulent charcoal, when subjected to sublimation out of contact with the air. This would seem to show that the bituminous substance is intimately associated with the cinnabar. The latter occurs associated with a gangue of serpentine, dolomite and a hard chalcedonic or soft chloritic "vein-matter." Very rarely the ore is found disseminated in sandstone.

The "vein-matter," just as it is broken in the *labores,* or stopes, of the mine, is run out in ore-cars on an elevated tramway above the *planilla,* or dressing-floor, belonging to each center of production. At the Randol *planilla,* for instance, this tramway is 14 feet 6 inches above the dressing-floor.

Beneath these tramways, at convenient intervals, are placed bar-screens inclined at 45°. The bars, slightly chamfered at the bottom to prevent choking, are placed an inch to an inch and a quarter apart. To prevent spreading, they are stayed with iron cross-bars at intervals of 4 feet. Their total outside width is 5 feet. Upon these screens the ore is dumped, and what passes through is known as *tierras.* The coarse fragments which fail to pass the screens are carefully examinee), and any lumps that show signs of cinnabar are broken by hand to a maximum diameter of 9 inches, and the waste is rejected. The picked ore is known as *granza.*

During 1882 and 1883 the totals from the mine were as follows:

		Tons of 2000 lbs. av.	
		1882.	1883.
Coarse material.	Waste rock from vein, rejected,	45,097.08	44,147.20
	Coarse ore (*granza*), ...	9,236.43	9,584.20
Screenings.	Fine ores (*tierras*), ...	14,705.81	20,289.24
Total product from ore-chambers, ...		69,039.32	74,020.64

This table shows that about one-sixth only of the coarse material stoped is sent to the works for treatment. All the fine ore is sent there.

Besides these ores which come from the present workings, there is another supply, coming from the old dumps, mostly situated at the mouth of Main Tunnel. These dumps are now being worked for a second time. In handling this material, all large lumps that are evidently waste, are immediately rejected; the rest is dumped upon screens similar to those just described. The screenings furnish "old dump *tierras."* The coarse fragments are broken and washed in a large tank on ore-forks, to remove the dust with which they are covered ; and any fragments which show even a color of cinnabar, are set aside as *terrcro.* This has a maximum diameter of 6 inches. The product of the old dumps for the last two years is as follows:

	Tons of 2000 lbs. av.	
	1882.	1883.
Terrero, ...	322	261.27
Tierras, ...	9,522	10,953.05
Total yield, ...	9,844	11,214.32

The old clumps being exposed to the weather are worked only during the dry season, while at the regular mine planillas, which are covered by sheds, the work goes on all the year round.

The cleaned ores are transported to the ore-chutes and bins at the *Hacienda* (the name given to the reduction-works). Here they are still further classified, partly by the screens in the ore-chutes, partly by screens on the top of the ore-cars. By this means, a new class of ore is introduced, intermediate in size between the *iierras* and the *granza.* This class is called *granzita.* The screens at the ore-chutes are mostly made of cast-iron plates, with 1¼-inch square holes arranged in diagonal rows across the plate. These separate from the mine-*tierras* and *granza* a certain quantity of coarser fragments *(granzita)* that has passed the bar-screens at the planilla, owing to the shape of the fragments or to the spreading of the bars.

The same ore-product is, therefore, classified somewhat differently at the mine and at the works. Thus :

At mine, . . .	New mine . .	*Granza*, coarse (rich), *Tierras*, fine (poor),
	Old dump . .	*Terrero*, coarse (poor).
At works, ...		*Granza*, 9 in.–3½ in. (rich), *Terrero*, 6 in.–3½ in. (poor), *Granzita*, 3½ in.–1¼ in. (poor), *Tierras*, 1¼ in.–dust (poor).

It will be observed that at the works, no distinction is made between new mine and old dump *granzita* and *tierra* ores.

The general effect of a heap of *granza-ore* with a light green background of serpentine and " vein-matter," lighted up by bright masses of cinnabar, is quite pleasing to the eye. This class of ore usually runs at present from 6 to 8 per cent. metallic quicksilver.

The *terrero* has much the same composition as the *granza;* only its exposure to the weather on the dump has given it a dull, rusty look, and its quicksilver content is not more than 1 to 2 per cent.

The *tierras* and *granzitas* vary, according as they come from one or the other of the above classes of ore, from a dull green to a rusty earthy appearance. Fragments of cinnabar are easily detected by the eye in some cases, and in others only by panning. Their quicksilver-content usually averages 1 to 3 per cent.

The total product of the mine for the last two years, classified as above explained, was:

	Tons of 2000 lbs. av.	
	1882.	1883.
Granza,	9,236.43	9,584.20
Terrero,	322.00	261.27
Tierras,	24,657.81	31,242.29
Totals,	34,216.24	41,087.76

The total amounts treated at the reduction works for the same periods were:

	Tons of 2000 lbs. av.	
	1882.	1883.
Granza,	9,569.85	10,428.40
Terrero,	297.60	185.35
Tierras and *Granzita*,	26,206.15	27,967.50
Totals,	36,073.60	38,581.25
Average percentage of quicksilver,	2.976	2.875

The differences between these sums total and the product of the mine is, of course, accounted for by the ore left over in the ore-bins.

The ore on hand at the reduction-works for the end of these periods was:

	Tons of 2000 lbs. av.	
	Dec. 31, 1882.	Dec. 31, 1883.
Granza,	1,265.99	421.79
Terrero,	195.375	271.295
Tierras and *Granzita*,	2.330.378	5,605.162
Totals,	3,791.743	6,298.247

The *granza* and the tierras are weighed on platform-scales as they leave the planilla; the *terrero* and *tierras from* the old dump are estimated by volume. At the works, the *granza* only is weighed; the *granza* screenings, *granzita* and *tierras* are estimated bv volume. The latter, by experiment, weigh about 85 pounds per cubic foot, or 23.5 cubic feet per ton.

It is evident that more than two-thirds of the total product of the mine is in the form of smalls. The method of treatment must, therefore, be adapted to this fact.

II. METHOD OF REDUCTION.

HISTORICAL SKETCH.

The above account of the nature of the ores in mind, the following sketch of the gradual development of the methods now in use will be more intelligible.*

The first attempt at quicksilver reduction was made by treating the ores in whalers' trying vats. These were made into retorts by luting on iron covers; but so much salivation of the men resulted from their use that they were soon abandoned, and regular iron retorts were introduced instead. The retort process necessitated crushing all the ores in order to mix them with lime, and was so expensive

* Most of the standard works on metallurgy state that quicksilver is reduced at New Almaden in retorts. This was once true; but, as nearly as can be now learned, has been abandoned since 1850. Retorts were used at the Enriquita Works later, till 1858 or 1860, for ore-reduction; at New Almaden proper (the *Hacienda),* they were used after 1850 only for making assays or tests. with rich ores. Since 1860, they have been entirely abandoned. The standard authorities are thus more than *20* years behind the times.

that only the rich ores would pay for treatment. As a consequence concentration by washing or a total rejection of the poorer ores was necessary, in either case giving rise to considerable loss. Hence, even before 1850, attempts *were* made to treat all the ores, as was then done at Idria, Austria, and at Almaden in Spain, by roasting them and condensing the quicksilver from the products of combustion.

The first furnaces built were badly constructed, with. poor materials, and gave rise to the loss of much metal in the foundations. But experience soon led to the type of intermittent furnace afterwards widely used in California. One of these furnaces, known as No. 6, is still in use at New Almaden, and with the other furnaces now used will be described in detail later on.

This furnace was a great improvement on the old retort-system. It was also an improvement on the intermittent furnaces then in use at Idria and Almaden ; for the ore was supported by a solid floor and not by arches attacked from below by the full force of the flames. It had, however, all the disadvantages common to discontinuous furnaces. In the treatment of quicksilver-ores, the dislocation of furnace and condenser-walls, resulting from sudden changes of temperature, was particularly injurious. The quicksilver escaping, both as liquid and as vapor, from these openings, caused both loss of metal and injury to the men. But the most serious disadvantage was the difficulty of treating the fine ores in these furnaces. The *tiaras,* forming, as we have seen, the greater part of the product of the mine, had to be mixed with clay and made into sun-dried bricks, locally called *adobes** before they could be roasted at all in the furnaces then used. As the *tierras* from which the adobes were made were poor ores, the expense of making them largely reduced the profit of treating these ores.

The next important improvement was the introduction of the continuous coarse-ore furnace. This furnace was first invented and built for burning lime near Berlin by the celebrated Count Rumford.† It was first introduced at Idria, Austria, by Bergrath Adolf Exeli in

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* The adobes were made in wooden frames by hand, just as bricks are made; the frames forming six at a time. The moulds were 4} inches by 5¼ inches by 10¼ inches inside measure; and the sun-dried adobe weighed about 12 pounds. In 1S75, the cost of making the adobes was 50 cents per ton, and that of handling them after-wards, drying, etc , 45 cents per ton Total additional cost of treating *tierras,* 93 cents per ton.

† Described in Karsten's *Archiv für Mineralogie, Geognosie, Bergbau und Hüttenkunde,* 1837, pp. 645 to 702.

1871, and proved so effective there that its introduction at New Almaden followed in 1874. The first furnace worked so well that a second was built in 1875. These furnaces, locally known as Nos. 7 and 9, are also called "monitors," in allusion to their shape, and to the fact that they are iron-clad. With the introduction of these furnaces, the economical treatment of the coarse ore was satisfactorily accomplished.

But the most serious problem yet remained. Two-thirds of all the ore had still to be worked into *adobes,* whether it went through the monitors or the intermittent furnaces. The fine ores of Almaden in Spain are even yet made into *adobes,* while at Idria, Austria, this class of ores is treated in continuous reverberatory furnaces *(Fortschaufclungsöfen).* At New Almaden, the problem has been solved in a much happier manner by the invention of the Hüttner and Scott furnace.

This must be regarded as the most important contribution to the art of quicksilver-reduction that has originated at New Almaden. The inventors of this furnace are Mr. H. J. Hüttner, the well-known mechanical engineer, who devised nearly all the details of the various furnaces of this type, and Mr. R. Scott, the furnace-mason at New Almaden. To the careful and patient experiments of its inventors and of Mr. J. B. Randol, the Manager of the Quicksilver Mining Company, who introduced several important improvements of his own, the practical success of this furnace is due.

The general idea of this furnace is similar to that of the Hasenclever-Helbig shelf furnace. In common with the latter, it utilizes a series of inclined shelves, placed in the opposite walls of a narrow vertical shaft to retard the descent of a column of fine ore. But it differs from the Hasenclever type in combining a number of ore-chambers in the same structure, and in the devices for regulating the passage of the products of combustion and for effecting the discharge.

The original experimental furnace, No. 5, contained two high, long and narrow ore-chambers, separated by pigeon-hole walls from the fire-place on one side and the vapor-chamber on the other. From either wall of the ore-chambers projected tile-shelves, placed alternately in the. opposite walls. These shelves were inclined at an angle of 45° to the walls, and each shelf was therefore perpendicular to the next lower one in the opposite wall. The distance from the edge of one shelf to the face of the next below it was three inches, thus forming an aperture through which the ore could pass. This aperture I shall call, for convenience, the *shelf-slit.*

When fine ore was fed into this ore-chamber through a hopper at the top, it ran from one shelf to the next, until the column found support upon the discharge-apparatus at the bottom, whereupon the whole column came to rest throughout the structure. Thus the shelves of the ore-chambers were kept covered by an irregular zigzag column of ore. The end-walls of the chamber were pierced with pigeon-holes, so that the flames might pass from the fire-place under each shelf and over the ore lying upon the shelf beneath, to a vapor-chamber on the opposite end of the ore-chamber. Thence they passed to the condensers. In the first experimental form, the flames made only one passage across the ore-chambers. The furnace, as thus constructed, roasted the ores well enough; but the escaping vapors were still quite hot, and the consumption of fuel was considerable.

To render the furnace more economical of fuel, to confine the greatest heat to the bottom of the furnace, so as to secure the thorough roasting of the ore, and to allow the vapors to escape to the condensers just above the boiling-point of quicksilver, was the next object. All the above improvements in the working of the furnace were effected by placing arches across the vapor-chambers and over the fire-box, so that the air and fumes were compelled to make four passages across the furnace on their way to the condensers. First, the air which entered the fire-place was drawn through the roasted ore, thus absorbing its heat and removing any quicksilver-vapor which it might contain. Next, the hot products of combustion passed through the nearly roasted ore, thus imparting to it a maximum temperature; and finally they were passed again back and forth through the colder ore in the upper half of the ore-chamber. In this way the excess of heat was imparted to the cold ore, and the fumes left the furnace for the condensers only moderately heated above the boiling-point of quicksilver. With these changes, the furnace was found to do uniformly good work at a small expenditure of fuel and labor; and in this form it was patented by Hüttner and Scott, October 31st, 1876.

The capacity of No. 5 was at first only 6 tons per 24 hours. It was afterwards increased to 12 tons, but it was evident that the full economy of the new furnace could only be attained when it was erected on a larger scale. Consequently, in the same year, 1876, a larger furnace, No. 8, was erected. This was a double furnace, two furnaces similar to No. 5, but larger, being united end to end in the same structure. It was originally supposed that one of these might be repaired while the other was in use. Experience has shown the heat to be too great to allow this; and they are now always used together without inconvenience.

In 1877 and 1878 a new furnace, No. 3,* was started. "While this furnace was of the same type as its predecessors, its capacity was still greater, and it differed in having three pairs of ore-chambers placed side by side, and all heated by the same fire-place. Another modification was introduced in the middle pair of ore-chambers. These were made with a 5-inch shelf-slit, and were to be used for roasting *granzita;* but it was found that the temperature best adapted for roasting *tierras* was not suited for *granzita;* and *tierras* only are now treated in all the chambers of this furnace.

Finally, in 1879, a new furnace, No. 2, with two ore-chambers, having an 8-inch shelf-slit, was introduced for treating the *granzita* ores, intermediate between *granza* and *tierras.* The *granzita,* it will be remembered, runs from 3½-inch down to 1¼-inch diameter. In 1880, a second *granzita* furnace, No. 1, was built with two pairs of ore-chambers. With the above improved furnace-plant, the economical treatment of fine and medium quicksilver ores may be said to be accomplished.

In the early history of the mine, according to most accounts, the condensation of quicksilver was very imperfectly effected. Professor W. P. Blake, in a letter to Professor J. D. Dana, † dated February 14th, 1853, speaks of the loss of mercurial fumes escaping from the chimneys, and of "the peculiar gray coating upon their tops." An article in the *American Cyclopœdia,* some ten years later, speaks of the salivation of men and animals about the works, and " the deposit of mercurial soot upon the roofs around."

During the last ten or twelve years, while improvements have been going on in furnace-construction, constant attention has been given to the subject of condensation. The various devices that have been found most successful will be considered under the head of condensers on another occasion.

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* Most of the furnaces at New Almaden are built on the sites of old intermittent furnaces, and retain their numbers as a survival. To avoid confusion, the designations used at the works are retained in this paper.

† American Journal of Science, vol. xvii., p. 438.

III. REDUCTION-WORKS.

SITUATION AND ARRANGEMENT.

The beautiful spot occupied by the *Hacienda,* or reduction-works, is familiar to many California travellers. It was chosen in the early history of New Almaden. The road leading to the mine leaves the San Jose Valley, and, turning to the south, enters the cañon of Los Alamitos creek. The handsome residence of the manager and the neat village of the officers and the workmen make a pleasing picture to the east of the well-shaded road. This latter is cooled by a running stream, a luxury all too rare in California summers. Just above the village, the narrow cañon widens out to an area of a dozen acres, giving barely room for the red notion-works.

The summit of Mine Hill is a mile to the west of the *Hacienda* in a direct line, and thirteen hundred feet above it. A fine wagon-road, three miles in length, and a shorter tramway with self-acting inclines, serve to bring the ore from the mine to the works.

A general idea of the arrangement of the latter is best given by the plan of the furnace yard, Plate I., from a survey made in]879 by Mr. Hennen Jennings, now superintendent of the mine.* Since that time considerable changes have been made in the condensation-systems These changes will be mentioned later.

The ore-tramway from the mine is seen entering the works at the top of Plate I. near the middle. It is situated at the foot of the tall bluffs behind the furnace, at a height of 60 feet above the furnace-floor. From thence, the ore is dumped into the ten chutes arranged along the sloping sides of the bluff at an angle of 40°. These are arranged with bar- or cast-iron screens, as before described, to separate the *tierras* from the *granzita,* and have in most eases aprons of hanging logs to retard the descent of ore and facilitate the removal of smalls.

The *granza* and *terrero* go directly from the chutes to the furnaces; but as there is not storage capacity enough in the chutes for the *tierras* and *granzitas,* the latter are distributed by elevated tramways to the ore-sheds arranged at convenient points in the furnace-yard. It is necessary to accumulate during the summer months a stock of these ores to last through the winter, as they would be too wet to

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* Plate I., and all those accompanying this paper except Nos. IV and V, were made from drawings of Mr. F. Von Leicht.

roast if exposed to the rains. Tin's is all the more necessary, since they already contain considerable moisture, and must usually be dried before roasting.

The situation of the furnaces we have mentioned is evident from the plan. Near the furnaces are seen the bottling and weighing rooms. These are kept under lock and key, and are in the charge of, the watchmen. The quicksilver is conducted from the entire system of condensers belonging to each furnace by iron pipes which lead to boxes, with goose-necks at the bottom, from which nearly constant slender streams of quicksilver flow during the regular working of the furnaces.

The metal is allowed to accumulate in large iron vats, whence it is weighed out into flasks, bottled and stowed ready for shipment. The product of each furnace is recorded separately.

After passing through the condensing system attached to the furnace in which it is produced, the smoke is conducted to brick towers. In these brick towers auxiliary fire-places are placed, to heat the side-hill flues in case of insufficient draft. The side-hill flues lead to tall brick chimneys on either side of the creek, which serve to dissipate the products of combustion. These chimneys are not shown in the plan.

The spent ore, or waste, locally termed "slag," is drawn from the cooling-pits of each furnace into cars, whence by tracks shown in the plan it is dumped into Alamitos creek which effectually disposes of it.

Owing to the lack of sufficient level space for stowing ore above the furnace-heads, three elevators are used to lift the *tierras* and *granzitas* from the floor of the works where they have been stored (or dried in the sun during the summer) to the top of the furnaces. Two of these are water-balance elevators, while the other is a water-pressure elevator with piston.

The furnaces, condensers and ore-floors are roofed over; but the sides of the structures are mostly left open to afford free ventilation for cooling the condensers and drying the ores.

Despite the necessity of making all improvements without any interruption to the regular production, the works are well and conveniently arranged, and are kept in excellent order.

In addition to the main plant above mentioned, the plan shows the situation of the soot-floors and kettles, the bath-rooms for the men, the offices of the company, the carpenter and the machine-shop. The latter is furnished with between 3 and 4 horse-power by an over-shot wheel, 6 feet wide and 20 feet in diameter. The New Almaden "Vichy" spring is also shown on the plan.

IV. FURNACES.

CONSTRUCTION, OPERATION AND RESULTS.

After this general view of the works a detailed study of the furnaces themselves comes next in order. No further mention will be made of devices now abandoned, and we shall consider only those furnaces now in actual use.

a. *Intermittent Furnaces.*

Furnace No. 6.—This, the last survival of the old intermittent furnace in its most perfect form, is shown in Plate II. The horizontal and vertical longitudinal sections show the furnace proper. In the left end of these figures (in the former), *A* to *B* is also shown the first condenser and combined ore-drier (not an essential part of the furnace, and to be mentioned in the next paper).

The ore-chamber which forms the main body of the furnace is also shown in cross-section G H. It is separated from the fire-place on the right and the vapor-chamber on the left by pigeon-hole walls. These walls have in plan the form of an arch with the convexity towards the ore-chamber, as they serve to keep the ore from the vapor- and fire-chambers.

The ore is charged into the ore-chamber through the top of the furnace, being lowered in a Mexican ore-basket by hand. A series of "channels" or flues is built along the bottom across the ore-chamber, in continuation of the apertures in the pigeon-hole wall, with lumps of coarse ore. In former times adobes were used for this purpose. "When the first series of channels has been built, a layer of coarse ore two or three feet thick, according to the size of the fragments, is charged into the furnace; then another series of channels is built, and so on to the top of the furnace. To counteract the natural tendency of hot air to roast the upper rather than the lower layers of ore, the channels are made smaller and farther apart in the upper layers of ore, and a certain amount of *tierras and* soot from the condensers is added to the coarse ore for the same reason. The ore-chamber is 12 feet long by 9 feet wide, and 17 feet 6 inches high, inside measures ; and the charge of ore is 80 to 100 tons. The discharge-ports or draw-holes are four in number, two on each side of the furnace. They are bricked up during the roasting of a charge, except a peep-hole, kept tight by a luted brick. It will be noticed that the final discharge-opening for the fumes has its bottom on a level with that of the ore-chamber, and its top at a height of 6 feet 9 inches above the floor. This is to counteract the upward tendency of the gases already mentioned.

The operation of these furnaces as now managed (without adobes) is as follows:

1. *Charging.*—This takes the labor of 8 men for one day. *As* already described, the coarse ores *(granza* and *terrera)* are used to build channels, the coarse ores are next piled in indiscriminately, then another series of channels, and so on, till a layer of soot and *tierras* fills the furnace to the top. The draw-ports are then bricked up; on top of the charge pieces of old sheet-iron are laid; on these is placed a two- or three-inch layer of straw manure, and on the latter, a layer of moist clay of about the same thickness. The furnace is then ready for the second period.

'2. *Roasting.*—This requires, in most cases, the labor of one man per shift of 12 hours for five days and four nights. Besides attending to the firing, the man in charge of the furnace lutes any cracks that may appear in the port-hole doors, and from time to time sifts ashes over any cracks that may form in the clay luting that covers the top of the furnace.

3. *Cooling.*—This, of course, requires no labor. When the firing , is stopped, the furnace is allowed to cool for three days and nights, the air passing through it into the condensers all the time, removing any quicksilver that may be still retained in it, and cooling the ore so that it may be handled by the men.

4. *Discharging.*—For this the labor of 4 men for one day is necessary. The top is removed to create an upward draft through the furnace; the discharge-ports are broken open; and the men draw the spent ore through the ports into the slag-cars.

In this manner a charge of ore is finished in just ten days; so that three such charges may be put through in one month. Formerly, when the intermittent furnaces only were used, Jess time was given to the roasting and cooling periods in order to increase the production. As a consequence, the ore was not always thoroughly roasted ; and the men who charged and discharged these furnaces suffered considerably from the heat and the fumes of the mercury. The time of roasting and cooling such a furnace should of course be greater with rich than with poor ores; and the fact brought out by the

No. 6.

Coarse-Ore Furnace (Intermittent).

Number of Runs.	1882. Month.	Number of days firing.	Granza, tons.	Terrero, tons.	Tierras, tons.	Total ore, tons.	Quicksilver (flasks).				Wood burned, cords.	Cost of fuel.	Cost of labor.	Total cost.
							Condensers.	Soot.	Total.	Per cent.				
One run, . . .	January.	4½	39.60	21.60	21.90	83.10	105	. .	105	. . .	11 00	$ 63.25	$ 57.50	$120.75
Two runs, . .	February.	8½	125.30	2.70	44.00	172.00	240	17	257	. . .	22.00	126.50	83.00	209.50
Two runs, . .	March.	11	149.60	1.80	31.50	182.90	262	7	269	. . .	27.87½	160.25	82.75	243 00
Two runs, . .	April.	9⅓	160.60	. . .	16.50	177.10	334	. .	334	. . .	26.75	153.81	103.50	257.31
Three runs, . .	May.	13½	201.30	36 00	25.50	262.80	498	. .	498	. . .	41.12½	236.47	120.00	356.47
Three runs, . .	June.	13½	191.40	64.80	12.00	268.20	502	. .	502	. . .	41.50	240.70	128.50	369.20
Three runs, . .	July.	12⅓	240.90	23.40	6.75	271.05	509	. .	509	. . .	38.50	223.30	120 00	343.30
Three runs, . .	August.	12½	168.30	83.70	6.75	258.75	409	. .	409	. . .	40.66⅔	236.84	126 50	363.34
Three runs, . .	Septem.	13⅓	212.30	37.50	6.75	256.55	465	. .	465	. . .	42.33⅓	254.00	124.00	378.00
Three runs, . .	October.	13⅓	237.60	22.50	6.75	266.85	556	. .	556	. . .	40.75	244.75	127.00	371.75
Three runs, . .	Nov.	12¾	264.00	2.70	5.25	271.95	581	. .	581	. . .	41.00	246.00	126.50	372.50
Three runs, . .	Dec.	13½	268.40	0.90	. .	269.30	647	. .	647	. . .	40.00	240.00	125.25	365.25
Thirty-one runs,	. . . .	138.08	2,259.30	297.60	183.65	2,740.55	5108	24	5132	7.16	413.50	$2,425.87	$1.324 50	$3,750.37
Per run, . . .	. . . .	4.45	72.881	9.600	5.924	88.405	. .	. .	165.548	7.16	13.339	78.254	42.720	120.98
Per ton of ore, .	. . . .	. . . .	. . . .	. . .	. . .	. . .	. .	. .	1.873	7.16	0.151	0.835	0.483	1.368

present management that sufficient time was not allowed *to* properly roast rich ores in these furnaces explains in large part the losses and evils formerly connected with their use.

In order to make a comparison of the merits of the different furnace-systems in use at New Almaden, I have given the actual working results of each of them for the year 1882. Thus, the actual results obtained from No. 6 are given in the foregoing table. This was made up from the admirable system of furnace-records kept at the *Hacienda.**

Thanks to the Hüttner and Scott furnace, it is no longer necessary to treat *tierras* in the intermittent furnace. If it were necessary to treat a full charge of adobes, this would, according to the results for 1875, add 95 cents per ton to the present cost of §1.37, or nearly 70 per cent, to the present cost of roasting in the intermittent furnace.

b. Continuous Coarse-Ore Furnaces.

Furnaces No. 7 and No. 9.—This pair of duplicate structures is with some slight improvements of detail the same as the continuous coarse-ore furnaces introduced at Idria, Austria, by Bergrath Exeli, from the model of the old Rumford lime-kiln. They are coarse-ore shaft roasting furnaces with exterior firing.

They are shown by the figures of Plate III. As will be seen from the horizontal sections and top view, the lower half of the furnace is a regular hexagon with abutments at the alternate sides. These abutments contain the fire-, ash- and draw-pits. Vertical section *AB* shows this still more clearly. Each abutment has on its face a fire-door and an ash-pit door, which latter also commands the discharge-door for the spent ore. The spent ore, after being drawn from the cooling-pit of the shaft into the ash-pits, is left there until its fumes are exhausted, and is then drawn into the slag-cars through discharge-doors. These discharge-doors are placed on the side of . each of the three abutments, lower down than the ash-pit doors. One of them is shown on the side of the abutment seen in the elevation.

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* In this connection it should be stated that the ruling prices at New Almaden during 1882 were as follows:

Furnace hands, ...	$1.25 to $2.50 per shift of 12 hours.
Coke (English), ...	15.00 per ton of 2000 pounds.
Charcoal, ...	12.00 per ton of 2000 pounds.
Coal (bituminous), . . .	8.94 per ton of 2000 pounds.
Wood (pine or oak), . . .	5.75 to $6.00 per cord.

The upper half of the furnace is cylindrical. It is closed at the top by a flat dome which contains the charging apparatus in the center. The fumes of the furnace are removed from the vapor-chamber at the top of the shaft above the surface of the ore, by means of iron pipes 12 inches in diameter. In No. 9, there are three of these discharge-pipes, one of which is placed at the top of the shaft on the side opposite each fire-place. In No. 7, there are, in addition, three others placed at the top of the shaft, one above each fire-place. By means of short cast-iron pipes, these holes are connected with a cast-iron down-take by means of a rectangular system of pipes which encircles the head of the furnace. These pipes, inclined downwards at an angle of 10°, lead into the condensers. To keep the pipes clear of soot, they contain small discs of iron. These discs are moved by iron rods, passing through stuffing-boxes at the angles of the pipe-system. They are only occasionally used, and the piston rods are luted with clay when not in use.

The shaft itself is a cylinder, 6 feet interior diameter, by 11 feet 3 inches high, joined to the frustum of a cone 8 feet deep, contracting to a diameter of 4 feet at the bottom. Along the sides of the cylindrical part of the shaft, opposite each of the fire-places, are placed a series of 4 peep-holes. These, ordinarily closed gas-tight, are used to determine the height of the ore-column and its temperature.

The fire-places and discharges have the details common to well-designed continuous shaft roasting-furnaces of this type. The shaft and fire-places are lined with fire-brick ; the rest of the furnace is of red brick, with the usual expansion-space between.

The entire structure rests on a slightly cone-shaped iron plate which crowns the foundation. This causes any quicksilver that might permeate the masonry to flow to the center of the furnace-bottom where provision is made for receiving it. Experience shows, however, that this precaution is hardly necessary, as no metal has ever reached it.

The lower half of the furnace is inclosed by cast-iron plates, bolted and cemented with rust joints. The cylindrical part has a jacket of 1/8-inch sheet iron; and a cast-iron top-plate crowns the whole, and makes the furnace vapor-tight.

The charging apparatus consists of a combination of devices used in iron-smelting, viz.: the hanging cylinder, and cup and cone. But, owing to the value and poisonous nature of quicksilver fumes, an additional cylinder and cover, with water- or sand-joint, is introduced above the other devices (section *A B).* The rod moving the cone passes gas-tight through a stuffing-box in the center of the cover, and is attached to a balance-weight. The cover itself is also attached to balance-weights by two chains passing over pulleys. The charging is thus easily effected without exposing the men to the fumes. The cover is lifted; a charge of ore and a little fuel is dumped from the ore-car into the hopper, and the cover is lowered into place. The charge is then allowed to warm in the hopper, till it has nearly assumed the temperature of the top. This is done to avoid chilling the fumes and condensing them in the furnace by contact with cold ore. At the proper time, an equal volume of spent ore having been meanwhile drawn below into the ash-pits, the cone is lowered and the charge dropped into the furnace. The small quantity of fumes that escapes into the space between the cup and cover is allowed to cool a few minutes, the cover is again lifted, and a new charge is added to the hopper.

These furnaces were erected under the immediate supervision of Mr. H. J. Hüttner. The details of construction are throughout excellent; they work admirably, and, although they have been in almost continuous operation for nearly ten years, they have required hardly any repairs.

The mode of operating these furnaces is as follows: when first started for a campaign, they are filled above the level of the fire-places with spent ore, and then with ore to just below the level of the uppermost peep-hole. This level is never exceeded ; so that there is always above the level of the ore a vapor-chamber, at least three feet high, containing 140 cubic feet, in which the fumes collect before passing out of the exit-flues. With the ore when charged there is mixed 1½ per cent. of coal, charcoal, or coke, to assist in raising the temperature at the top of the furnace and to keep the ore-column more open. A good fire of pine or oak is maintained in each of the three fire-places. The charge of 1600 pounds of ore and 24 pounds of coke or other fuel, previously weighed on the ore-scale, has been placed in the hopper. As soon as the lower peep-hole shows a dull cherry red, a quantity of spent ore is drawn into the ash-pits, the new charge is lowered into the furnace, and the hopper is refilled as before described.

The spent ore is allowed to remain in the ash-pits, discharging any fumes, that may be still retained, back again through the fire-place into the furnace. At the end of this period it is drawn through the side doors of the abutments into the "slag"-cars. Another

No. 7.

Granza Furnace (Continuous).

Remarks.	1882. Month.	Number of days run.	Granza, tons @ 2000 lbs.	Quicksilver (flasks). Condenser.	Soot.	Total.	Per cent.	Wood burned. Cords.	Coal, Coke, Charcoal, lbs.		Cost of fuel.	Cost of labor.	Total cost.
	January.	31	297.60	470	28	498	6.40	19.25	Coal, Coke,	2,400 8,928	$188.32	$140.00	$328.32
	February.	28	268.80	441	26	467	6.64	10.625	Coal, Coke,	8,400 8,054	146.92	105.00	251.92
	March.	31	297.60	527	34	561	7.21	17.25	Coal, Coke,	1,800 8,928	174.20	116.25	290.45
	April.	30	288.00	466	19	485	6.44	17.75	Coke,	8,640	166.86	112.50	279.36
	May.	31	297.60	505	24	529	6.79	19.25	Coke,	8,928	173.19	116.25	289.44
	June.	30	288.00	486	14	500	6.64	18.625	Charcoal,	8,640	168.50½	112.50	281.00½
	July.	31	297.60	560	30	590	7.58	19.00	Charcoal,	8,928	148.59½	114.37½	262.97
Stopped August 7 to 22. Cone fell in furnace. New one put in. Two water-backs put in condensers.	August.	16	148.80	340	2	342	8.79	10.25	Charcoal,	4,464	78.65	67.50	146.15
	September.	30	288.00	443	10	453	6.02	19.00	Charcoal,	8,640	152.88	112.50	265.38
	October.	31	291.20	516	0	516	6.77	18.75	Coal,	8,736	152.24	116.25	268.49
	Nov.	30	288.00	484	8	492	6.53	18.50	Coal,	8,640	149.88½	112.50	262.38½
	Dec.	31	297.60	672	0	672	8.63	19.75	Coal,	8,928	158.67	128.12½	286.79½
		350	3,348.80	5,910	195	6,105	6.97	208.00	Coal, 38,904 Coke, 43,488 Chcl., 30,672	113,064	$1,858.91½	$1,353.75	$3,212.66½
Per day, ...	. . . .	1	9.569	. . .	. . .	17.443	6.97	.594	Coal, Coke, Chcl.,	323.04	5.317	3.868	9.179
Per ton of ore, ...	. . . .	. . .	1	. . .	. . .	1.823	6.97	.062	Coal, Coke, Chcl.,	33.762	0.555	0.404	0.959

No. 9.

Granza Furnace (Continuous).

REMARKS.	1882. Month.	Number of days run.	Granza, tons, @ 2000 lbs.	Quicksilver (flasks). Condensers.	Soot.	Total.	Per cent.	Wood burned, cords.	Coal, Charcoal, Coke, lbs.		Cost of fuel.	Cost of labor.	Total cost.
Fired 2 P.M., Jan. 21, 1882. Seventy-eight flasks came from cleaning condensers before the run began.	January.	$10\frac{5}{12}$	89.60	74	78	152	...	6.25	Coke,	2,688	$56.10	$41.25	$97.35
	February.	28	268.80	425	44	469	6.67	17.62½	Coke,	8,064	149.72	105.00	254.72
	March.	31	297.60	524	21	545	7.00	18.37½	Coke,	8,928	172.58	116.25	288.83
	April.	30	288.00	480	26	506	6.72	17.75	Coke,	8,640	166.86	112.50	279.36
	May.	31	297.60	531	26	557	7.15	19.25	Coke,	8,928	173.19	116.25	289.44
	June.	30	288.00	468	16	484	6.42	18.62½	Charcoal,	8,640	168.50½	112.50	281.00½
	July.	31	297.60	549	32	581	7.46	19.00	Charcoal,	8,928	148.59½	114.37½	462.97
	August.	31	297.60	544	21	565	7.28	19.50	Charcoal,	8,928	151.51	130.00	281.51
	September	30	288.00	458	15	473	6.28	19.00	Charcoal,	8,640	152.88	112.50	265.38
	October.	31	297.60	558	13	571	7.33	18.75	Coal,	8,928	152.24	116.25	268.49
	Nov.	30	288.00	539	7	546	7.25	18.50	Coal,	8,640	149.88½	112.50	262.38½
	Dec.	31	297.60	615	0	615	7.90	19.75	Coal,	8,928	158.67	128.12½	286.79½
		344.42	3,296.00	5,765	299	6,064	7.037	212.37½	Coke, 37,248; Chcl., 35,136; Coal, 26,496	98,880	$1,800.73½	$1,317.50	$3,118.23½
Per day, ...	...	1	9.570	...	...	17.606	7.037	0.617	Coke, Charcoal, Coal,	287.091	5.228	3.825	9.053
Per ton of ore, . .	...	...	...	...	...	1.844	7.037	0.064	Coke, Charcoal, Coal,	30.000	0.5463	0.3997	0.946
SUMMARY OF GRANZA FURNACES.													
Furnace No. 7, .	...	350.00	3,348 80	5,910	195	6,105	6.97	208.00		113,064	$1,858.91½	$1,353.75	$3,212.66½
Furnace No. 9, .	...	344.42	3,296.00	5,765	299	6,064	7.037	212.37½		98,880	1,800.73½	1,317.50	3,118.23½
		694.42	6,644.80	11,765	494	12,169	7.000	420.37½		211,944	$3,659.65	$2,671.25	$6,330.90
Per ton of ore, . .	...	...	...	...	...	1.831	7.000	0.063		3.189	0.5507	0.4020	0.9527

charge, equal in volume to the new charge, is again drawn through the discharge-holes of the shaft into the ash-pit, and then the new charge is dropped from the hopper into the furnace. This series of operations goes on every two hours as long as the campaign lasts.

At this rate, these furnaces roast 93/5 tons per 24 hours, and, as by actual experiment they hold 21 tons, it takes 521/5 hours for a charge of ore to pass through the furnace. The capacity of those furnaces might easily be increased by drawing and charging more frequently or in greater quantities, and with poor ores this would be advisable ; but with the rich ores (6 to 8 per cent.) now treated in these furnaces, experience has led to the above practice.

The amount of labor required for these furnaces is very small. Two men per shift of 12 hours charge and discharge both of them.

The foregoing tables show the actual furnace records of furnaces 7 and 9 for the year 1882. The total amount of ore treated, of quicksilver produced, and the expenses, are given ; also, the expense per day and per ton for each furnace, and the average for both.

In comparing these furnaces with No. 6, it must be remembered that both the former are run with the same amount of labor that would be required for one of them if run singly. If two such furnaces as No. 6 were run together, while it would, of course, take double the labor to charge and discharge them, the same men could fire them both during the whole time of roasting. So, if we should compare two such furnaces as No. 6 with two such as No. 7 or No. 9, or if we compared No. 6 with either No. 7 or No. 9, working alone, we should have a more favorable showing for No. 6 than is here given. As it is, the cost of treating a ton of ore in No. 7 or No. 9, when both are run together, is only 70 per cent. of that of roasting in No. 6 when the latter is run by itself.

c. Continuous Fine-Ore Furnaces.

The great importance of finding some economical method of treating the large product of poor smalls produced by the mine has been already explained. Making this ore into adobes would add 70 per cent. to the cost of treatment in furnaces of the type of No. 6, and would double the expense of treatment of these ores in Nos. 7 and 9. The reverberatory furnaces *(Fortschaufelungsöfen)* used at Idria would equally be out of the question, at the high prices for labor and fuel that obtain in California.

We have already traced the gradual growth of the Hüttner and Scott furnace, and sketched the successive stages which the invention has reached. Now, for convenience in description, the furnaces will be taken up in the inverse order, the last-built being considered first,

Continuous Granzita Furnace, No. 1.--This is shown in Plates IV. and V., on a scale ¼" to 1'. In both plates the letters have the same significance. In the *horizontal sections,* Plate IV., are shown, in the upper half, the horizontal section through the first air- or vapor-chamber, and, in the lower half, the one through the fire-place.

The fire-place, *a a,* is arranged for burning wood, and is fed from both ends. An earthenware pipe, l l, 16 inches interior diameter, passes through the condensers, thus cooling them, and feeding the fire-place with warm air. From *11 run* also a series of air-ways, m m, built in the walls of the fire-place and of the ore-chambers, thus cooling them, and supplying air for the more perfect combustion of the flames.

In the upper section is the lower air- or vapor-chamber *d d,* and between this and the fire-place are the four vertical air-chambers into which the furnace is divided. The shelves are shown at s, ,, *s,,, s,,,,* as will be explained more clearly by Plate V.

The discharge- or draw-pits *j, k,* are fitted with counter-balanced doors, to retain the dust, and they feed upon an apron, and thence into the waste-car.

The horizontal dimensions of the furnace at this section, exclusive of the foundations, are 17 feet 6 inches by 25 feet 6 inches. The vertical height from the top of the furnace-masonry to the ground-line is 36 feet; the foundation goes down 7 feet 6 inches deeper.

The *horizontal views* in Plate IV. show the furnace-top with ore-tracks and turn-table t, and the two feed-hoppers *h h,* each arranged with four slide-valves moved by levers and pistons working in stuffing-boxes vapor-tight.

The two vapor-discharge pipes *i i,* provided with regulating valves, and leading from the last vapor-chamber of the furnace to the condensers, are also shown.

Plate V. shows on the left a half side-elevation and a half longitudinal vertical section ; on the right, vertical half-sections through the fire-places and ore-chambers.

The vertical section through the fire-place a, shows also the ash-pit *b,* and the second vapor-chamber *e e,* on that side of the furnace. All along the vertical wall between the fire-chamber *a,* and the vapor-chamber *e e,* and the sore-chambers beyond the plane of the section, are shown pigeon-holes *cc,* through which the flames and vapors from the ore pass into the ore-chamber and out of it again. The pigeon-holes in the fire-chamber walls are cut at the bottom so as to slant with the shelves, those in the vapor-chambers are cut across horizontally; but all are so bevelled that the ore from the ore-chamber and the dust from the gases do not accumulate so as to obstruct them. The former is shed back into the ore-chamber, and the latter falls to the bottom of the vapor-chambers, whence it is removed at the end of the campaign by the doors *g,* kept bricked during the run.

In case any obstruction should occur in the pigeon-holes, or on the shelves, peep-holes, *x x,* are placed in the end walls of the furnace, in the axis of the pigeon-holes. These latter are placed in the same line opposite each other, under the extreme ends of each shelf. The peep-holes are made of 3-inch gas-pipe, set in the masonry-wall, and are ordinarily closed by iron plugs luted with clay. When any obstruction occurs, it is thus easily removed by an iron bar introduced through these holes.

The air-pipe *I,* before mentioned, is shown below the grate-bars. Branching from it, and leading to the. pigeon-holes, are the hot-air flues *mm,* which cool the wall, and help to render combustion complete, thus diminishing the production of soot.

The vertical section through the two right-hand ore-chambers of this figure shows the arrangement of shelving and the descent of the ore, more clearly than words.

The horizontal length of the ore-chambers of this furnace is 11 feet 6 inches, the width of each 25½ inches, and their height 27 feet 3 inches from the roof of the ore-chamber to the point of discharge.

The tile-shelving of this furnace, as in others of this type, is placed at an angle of 45° with the side-walls of the chamber; the details, however, are simpler and cheaper than in the rest, and equally effective. It will be noticed that the shelves are placed 30 inches apart vertically, those on one wall being 15 inches above those on the other wall, and at right angles to them. The shelves are made of ordinary fire-clay tiles, 36 inches X 16 inches X 3 inches. Four of these make a length, and allow a 3-inch projection into either end-wall. These tiles are not let into the side-walls, but are supported at the top by slight abutments which project from the side-wall. At the bottom they rest at intervals of 18 inches on ordinary fire-bricks, which rest, end on, in depressions 1 inch deep, cut into the face of the next lower tile in the opposite wall. These bricks are placed so as to be edge on to the descending column of ore, and have their upper edges bevelled to oppose as little resistance as possible to it. As the bricks are 9 inches long, there results an 8-inch shelf slit for the furnace. The whole construction of the shelving is very simple, effective, and comparatively inexpensive.

The discharge of this furnace is arranged by supporting the end of the ore-columns of the interior ore-chambers directly on the bottom of the draw-pit, the ore-columns of the exterior ore-chambers are supported by cast-iron plates. The latter have in front, aprons which discharge the ore into the lower draw-pits, and thence the spent-ore from both chambers is raked into the waste-cars.

This simple arrangement works very well. The ore lies at its natural slope until it is raked out, when the whole ore-column gradually feeds down from bottom to top at the same rate. There are four double discharges on each side of the furnace. These are closed by sheet-iron doors to protect the workmen as much as possible from the hot dust.

Inclined iron plates are placed in the foundations of the furnace to prevent the waste of mercury. This precaution is now always taken.

On the left of Plate V. is shown a vertical longitudinal half-section and front or side elevation. Both fronts—the long sides—of the furnace are the same. From the fire-chamber *a,* the hot gases pass through the lower third of the ore-chambers to the vapor-chamber *d d,* shown on the left in dotted lines; thence they pass through the middle third of the ore-chambers to the vapor-chamber *e e,* on the right; thence they pass out through the top third of the ore-chamber again to the vapor-chamber f f, on the left, and thence out through the sheet-iron pipes *ii,* to the condensers.

This section shows alternately the right and left shelves *s1,* and *s,* of the inner ore-chamber. The bottom shelf, s3, is made of cast-iron to resist the abrasion that comes upon it; it is not as much exposed to heat as are the upper shelves.

Finally, are to be mentioned the ore-rakes. The New Almaden ore gives no difficulty from fusing or clotting, but occasionally in the winter, or when the ore is quite damp, it is found to bake together on the upper shelves so as to demand more or less barring through the peep-holes. To obviate this, Mr. Randol introduced the ore-rakes, marked *r* in the figures. One of these rakes extends through each of the ore-chambers just above the topmost shelves, where the ore enters the furnace from the hoppers. If any baking occurs, a few oscillations of the rake break up the clumps, and the ore descends regularly.

Furnace No. 1 has a capacity of 36 tons per 24 hours. Its capacity is greater than that of any other furnace at the works except *Tierra* furnace No. 3. When filled with ore, as in working, No. 1 holds 45 tons ; hence, at the rate of 36 tons per 24 hours, a single charge is in the furnace for 30 hours.

The routine of operations at this furnace is as follows:

The amount of 1 ton by volume* of the spent ore is drawn alternately from either side of the furnace every 40 minutes, or in all, 2 tons (by volume) are drawn from the furnace every 80 minutes. As a rule, 250 pounds are taken from each of the 8 draw-pits on each side of the furnace at the times of drawing; but, if the regular working of the furnace demands it, this quantity is reduced or adjusted, so that all shall be thoroughly roasted. The "slag-men" thus have to draw and wheel to the dump 2 tons of waste every 80 minutes.

Immediately after drawing from one side of the furnace, 2 carloads of *granzila,* of 1000 pounds each, and 20 pounds of coal are charged into the furnace from the hopper on the side from which the drawing took place. The hopper is then immediately filled for the next charge, both to warm the ore and to prevent the escape of fumes. Consequently, each of the two hoppers is charged alternately every 40 minutes, or in all 2 tons go into the furnace every 80 minutes.

The firing is done every hour; three four-feet lengths of oak or pine being ordinarily added to each side of the fire-place per hour. The amount varies with the state of the draft; the object being to keep the fire-place at a good cherry red. From 1½ to 1¼ cords of wood are burned per 24 hours, according to whether an auxiliary fire is made in the flue or not.

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* The *granzita* and *tierra* ores are not weighed at any of the furnaces, but are estimated by volume. This method, on account of the varying amount of moisture in the ore, probably gives better results than weighing without allowing for the moisture, and is sufficiently exact. The volume of the roasted ores is nearly the same as that of the raw ores in the case of *granzita* and *tierras*. With rich *granza* it is sometimes notably less. In any such case the amount drawn is diminished so as to keep the furnace full. It would not do in such cases to increase the amount or frequency of the charging, as that would lead to a loss of quicksilver. The roasted ores contain a larger proportion of smalls than the raw ores, are more brittle, and have a rusted earthy appearance.

No. 1.

Granzita Furnace (Continuous).

Remarks.	1882. Month.	Number of days run.	Granza,* tons.	Granzita, tons.	Total ore, tons.	Quicksilver (flasks). Condensers.	Soot.	Total.	Per cent.	Wood burned, cords.	Coal or Charcoal, lbs.	Cost of fuel.	Cost of labor.	Total cost.
Cleaning condenser.	Jan.	...	...	...	...	...	113	113	...	...	...	...	...	...
	Feb.	...	...	...	...	...	54	54	...	...	...	...	...	...
	March.	...	...	...	...	...	...	...	...	...	...	...	...	...
No Hg for ten days from condensers.	April.	26	43.50	661.00	704.50	157	...	157	0.85	34.50	‡18,600	$260.05	$218.90	$478.95
	May.	31	57.75	1,070.50	1,128.25	394	14	408	1.33	51.50	‡22,180	391.50	310.00	701.50
	June.	30	54.50	1,044.00	1,098.50	350	22	372	1.29	49	‡21,600	377.08	300.00	677.08
	July.	31	94.50	1,026.00	1,122.50	292	20	312	1.06	50.50	21,880	386.98	310.00	696.98
	August.	31	30.75	1,095.50	1,120.25	425	33	458	1.59	50.25	22,320	387.43	310.00	697.43
	Sept.	30	42.00	1,052.00	1,094.00	436	9	445	1.56	40.25	21,600	392.70	300.00	692.70
	Oct.	31	87.75	1,057.50	1,145.25	503	24	527	1.06	51.75	22,320	410.94	381.00	791.94
	Nov.	5	15.00	157.00	172.00	335	33	368	†8.134	8	8,340	63.03	56.58	119.61
Not running.	Dec.	...	...	...	...	...	...	...	...	...	...	...	...	...
		215	425.75	7,165.50	7,591.25	2952	322	3,274	1.664	344.75	149,040	$2,669.71	$2,186.78	$4,856.49
Per day, . .	...	1	1.98	33.328	35.308	13.73	1.50	15.23	1.664	1.603	693.209	12.417	10.171	22.588
Per ton of ore,	...	...	...	...	...	...	...	0.431	1.604	0.0455	19.633	0.352	0.288	0.640

* Really granzita proper, i.e., screenings of granza from *Hacienda* crushing. † Clean-up 257 flasks, 38 soot. Twenty-two days' work. ‡ Charcoal, rest coal.

When No. 1 furnace is worked alone, the labor required is as follows:

One charger, at $2.50 per 12-hour shift.

Two slag- or fire-men, at $1.25 each per 12-hour shift.

In addition, the labor of two men at $1.25 per day, who tram ore across from the ore-chutes to the furnace, is charged to it part of the time. Besides firing the furnace and discharging the ore, the fire- and slag-men pile the fuel, send the ore up the elevator to the charger, and assist the weigher in weighing the quicksilver and tightening the flask-stoppers.

The results of this furnace for 1882 are given in the foregoing table.

Continuous Granzila Furnace, No. 2.—This is shown in Plate VI. Its construction and mode of operation are similar to those of No. 1. But, having only two ore-chambers, its maximum capacity is only half that of the former; its discharging arrangement is simple also, owing to the small number of ore-chambers. The figures need no further remark, except that, while sections *A B* and *C D* show the pigeon-holes, section *E F* is so taken as not to show them.

The hoppers on top of this furnace are arranged in the same line, and feed into the same ore-chambers; but, as in No. 1, they are divided into compartments, so as to permit more control over the operation of the furnaces. These compartments are charged with 1000 pounds of ore (when in full operation) every forty minutes, alternating with each other. This would make the working capacity of the furnace 18 tons per 24 hours. As in No. 1, the drawing precedes the charging. In drawing, 250 pounds are taken from each of the two end draw-pits on each end of the furnace, or 1000 pounds (volume) at a time. The drawings, from either end of the furnace, alternate with each other every 40 minutes.

No fuel is charged with the ore of No. 2, but, instead, coal is used in the fire-place. The consumption of fuel is ¾ cord of wood and 500 pounds of coal per 24 hours.

When No. 2 furnace is run alone, there are employed: One charger and two fire-or slag-men per 12-hour shift, or six in all, per 24 hours. When No. 1 and No. 2 are both in operation at the same time, labor is economized by running them with the same force. For this purpose are assigned:

One charger, at $2.50 per 12-hour shift.

Four slag- or fire-men, at $1.25 per 12-hour shift.

No. 2.

Granzita Furnace (Continuous).

REMARKS.	1882. Month.	Number of days run.	Granza screenings, tons.	Granzita, tons.	Total ore, tons.	Quicksilver (flasks). Condensers.	Soot.	Total.	Per cent.	Wood burned, cords.	Coal or Charcoal, lbs.	Cost of fuel.	Cost of labor.	Total cost.
	Jan.	31	48.00	372.00	420.00	270	...	270	2.45	28.50	Coal, 14,000	$226.46	$232.50	$458.96
	Feb.	28	83.25	252.75	336.00	262	...	262	2.98	25.25	Coal, 14,000	207.76	210.00	417.76
ow percentage of	March.	31	48.75	363.25	412.00	316	...	316	2.93	23.87½	Coal, 15,500	206.56	232.50	439.06
Granza screenings	April.	30	35.25	378.50	413.75	261	8	269	2.48	21.37½	Coal, 15,000	189.96	151.10	341.06
absent,	May.	31	...	372.00	372.00	126	...	126	1.29	24.37½	Coal, 15,500	206.80	155.00	361.80
	June.	30	...	360.00	360.00	127	8	135	1.43	22.75	Coal, 15,000	196.45	150.00	346.45
	July.	31	7.50	360.50	368.00	98	6	104	1.08	23.37½	15,500	203.67	155.00	358.67
	August.	31	5.25	368.50	373.75	147	5	152	1.55	23.12½	15,500	200.78	155.00	355.78
topped. Seven flasks.	Sept.	30	7.50	355.00	362.50	143	18	161	1.70	23	15,000	205.50	150.00	355.50
Rest cleaned up,	Oct.	2	4.50	16.00	20.50	82	...	82	1.53	1.50	1,000	13.50	12.50	26.00
ot running,	Nov.	...	...	...	...	2	...	2	...	...	....	...	...	...
ot running,	Dec.	...	...	...	...	...	3	3	...	...	....	...	...	...
		275	240.00	3,198.50	3,438.50	1,834	48	1,882	2.09	217.12½	136,000	$1,857.44	$1,603.60	$3,461.04
er day,	...	1	0.873	11.631	12.504	6.669	0.175	6.844	2.09	0.789	494.546	6.754	5.831	12.586
er ton of ore,	...	...	...	...	1	...	...	0.547	2.09	0.0631	39.551	0.5401	0.466	1.006

In addition, two men are employed part of the time to bring the ore from the chutes to the furnace-bins.

Furnace No. 2 is not always run up to its full capacity, only enough ore being run through it to make up the desired monthly production.

The results for the year 1882 are given in the foregoing table.

d. Tierra Furnaces.

Furnace No. 3.—This is shown, in section and elevation, in Plate VII. It is arranged on the same general plan as Nos. 1 and 2, but is an earlier construction. It has three pairs of ore-chambers, placed side by side. This fact necessitates a different discharging arrangement from that used in Nos. 1 and 2. As previously stated the two outer pairs of ore-chambers for roasting *tierras* have 3-inch shelf-slits, while the inner pair, originally intended for granzita, have 5-inch shelf-slits. They are now all used, without alteration, for roasting *tierras.*

The feed-hoppers, fire-place, pigeon-hole walls, vapor-chambers, and ore-rakes, are entirely similar to those of furnace No. 1, and need no further remark.

The discharging arrangements, however, merit further description. Beneath each pair of ore-chambers a discharge-pit is arranged to contain the "slag"-cars, which are run in from a track on the floor of the works. The whole furnace rests on the usual inclined cast-iron plates, in which are discharge-slits for each pair of ore-chambers; the outside ones are three inches and the middle one is five inches wide, and they run the whole length of the ore-chambers. Immediately beneath each of these slits is its discharge-apron. This apron is a cast-iron girder, flat on top, and three times as wide as the slit above it. It rests at either end on rollers running on T rails, at right angles to its length. Each of these aprons is connected with a lever-arm outside of the furnace, by means of which a gentle oscillating motion may be given to it.

When the apron is in its central position the foot of the ore-column rests upon it, and runs out at its natural slope to each edge of the apron, and the whole ore-column in the chamber above is maintained in equilibrium. As soon, however, as an oscillating motion is given to the apron, the ore resting upon it is discharged in a shower from either edge of the apron into the car beneath, and the ore in both chambers, from bottom to top, descends.

It will be noticed that the partition-wall in each pair of ore-chambers rests upon a hollow cast-iron girder. As originally constructed, the space below this girder was entirely free to the passage of ore from either chamber. But, with this construction it was found that if, in discharging, the ore in either chamber of the pair got the start of that in the other, the velocity of the descending ore on that side would be great enough to impede the discharge from the other side. This difficulty was obviated by Mr. Randol, who introduced a vertical iron plate bolted on to the middle of the hollow girder. In the outside pairs of chambers these plates reach to within three inches, and in the middle pair to within five inches of the discharge-slits. This improvement entirely obviated the difficulty, and the discharge of this furnace is now effected with perfect ease and regularity.

The setting of the tile-shelving in this furnace and in No. 8 also differs somewhat from that of Nos. 1 and 2. The tiles are of peculiar shape, and were made to order for the furnace at Staten Island, N. Y. Those for the *tierra* chambers were made 207/6 inches wide on the upper face, while those for the *granzita* have a width of only 187/16 inches. Both are 3 inches thick. All of them were made with a square lug or shoulder, 5½ inches thick, and forming an angle of 45° with the face of the shelf. The width of the lugs on their upper face was made 4 9/16 inches, or 6¼ inches, according to the thickness of the partition-wall between the chambers. The wall between each two pairs of ore-chambers was made 13¾ inches thick, and between the two chambers of each pair only 9¼ inches. Two shelves, projecting into adjacent chambers, are set with their shoulders abutting against each other, allowing for ¼-inch to 1/8-inch joints. Consequently, the shelves form an integral part of the partition-walls. Beneath the shoulders of the two shelves is set another tile, also 5½ inches thick. This has the form of a frustum of a wedge, whose faces are at right angles to each other. This tile also forms an integral part of the partition-wall, and projects out into either chamber so as to support the shelves from beneath for half their width. Beneath the supporting tiles are four tiers of fire-brick, then the next pair of abutting shelf-lugs and their supporting tiles, and so on. The ore-chambers are 22 3/8 inches wide, and the shelves in each wall are 21 inches apart vertically. This method of setting has given good results, but the method now used in the later constructions is to be preferred on account of cheapness and simplicity.

In this furnace the fire-place is placed 5 feet above the discharge-s opening, and the air to supply the fire is drawn through the hot ore

No. 3.

Triple Tierra Furnace (Continuous).

REMARKS. Three pairs of ore-chambers.	1882. Month.	Number of days run.	Tierras, tons.	Quicksilver (flasks). Condensers.	Soot.	Total.	Per cent.	Wood burned, cords.	Coal and Charcoal, lbs.	Cost of fuel.	Cost of labor.	Total cost.
Started October 12, 1881, .	Jan.	31	1,116.00	425	..	425	1.46	57.00	23,000	$430.56	$387.50	$818.06
	Feb.	28	1,008.00	411	..	411	1.55	47.00	Coal, 28,000	395.41	350.00	745 41
	March.	31	1,116.00	387	..	387	1.32	49.25	Coal, 31,000	421.76	387.50	809.26
	April.	30	1,080.00	350	9	359	1.27	46.75	Coal, 30,000	402.91	375.00	777.91
	May.	31	1,116.00	309	7	316	1.08	46.625	Coal, 31,000	401.39	387.50	788.89
	June.	30	1,080.00	314	6	320	1.13	45.00	Coal, 30,000	390.00	375.00	765.00
	July.	31	1,116.00	351	26	377	1.29	47.50	31,000	408.80	387.50	796.30
	August.	31	1,116.00	301	13	314	1.08	47.00	31,000	405.90	387.50	793.40
	Sept.	30	1,080.00	461	24	485	1.71	45.583	30,000	408.50	375.00	783.50
	Oct.	31	1,116.00	392	11	403	1.38	47.00	31,000	421.50	387.50	809.00
	Nov.	30	1,078.00	372	12	384	1.36	45.25	30,000	406.50	375.00	781.50
Stopped December 1, 1882.	Dec.	..	...	165	33	198	...	...	....	...	...	...
		334	12,022.00	4,238	141	4,379	...	523.958	326,000	$4,493.23	$4,175.00	$8,668.23
Per day, ...	...	1	35.994	...	..	13.11	...	1.569	976.048	13.453	12.50	25.953
Per ton of ore, ...	...	..	1	...	..	0.459	...	0.044	27.117	0.374	0.347	0.721

below the level of the grates, so that the ore reaches the apron free of fumes, and cooled to such a temperature that it may be easily handled. In Nos. 1 and 2 the fire-place is nearly on a level with the discharge-openings, and the ore cools mainly in the draw-pits.

Furnace No. 3 is entirely inclosed by a sheathing of heavy iron plates, bolted and cemented, with rust-joints. The arrangement of this sheathing and the distribution of the peep-holes is shown in the elevation of Plate VII.

The normal capacity of this furnace is 36 tons, the same as that of No. 1. The furnace holds, when under working conditions, 51 tons of ore; a charge is, therefore, 34 hours in the furnace. The routine of operations at this furnace is as follows:

The aprons or shaking-tables under each of the three pairs of ore-chambers, are operated at intervals of 10 or 15 minutes, so as to discharge from each 1 ton (by volume) every 2 hours. After the ore has descended in the various chambers, subsequent to discharging below, one ton of ore is added to each of the three ore-hoppers at intervals of forty minutes, *i.e.,* each hopper receives 1 ton every 2 hours. The firing and tramming of the spent ore goes on meanwhile as at the other furnaces.

The fuel required at this furnace is 2½ cords of wood per 24 hours, if that alone is used; but, if coal is used, the amount of wood is reduced in proportion. The working force is:

Two men, at §2.50 per 12-hour shift.

One man, at §1.25 per 12-hour shift.

The campaign for 1882 is shown in the accompanying table.

Furnaces No. 4 *and No.* 5. —Furnace No. 4, one of the old intermittent furnaces, is now torn down. No. 5, the first experimental form of the Hüttner and Scott, stiil exists. As already stated, this furnace at first had a capacity of only 6 tons. It was afterwards enlarged so as to handle 12 tons. In this shape it gave excellent results, as far as good roasting was concerned, but on account of its smaller size it was not so economical of labor and fuel as the larger ones, and is now seldom used.

Furnace No. 8.—This *tierra* furnace completes the list of the fine-ore furnaces. A drawing of this furnace has been already published by M. G. Holland, * so that it need not be repeated here. This furnace is really two separate furnaces, like No, 5, on a larger scale, united in one structure. Each furnace contains a pair of ore-

* *La Métallurgie du Mercure en Culifornie, par M. G. Rolland. Société d'encouragement, etc.,* 1878, \>. 85, Figs. 7 and 8.

chambers, its own fire-place and vapor-chambers and exit-flues entirely distinct from that of the other. These two structures stand united, end to end; the fire-places at the outside, and the exit-flues and vapor-chambers opposite the fire-places, side by side, in the middle. As a consequence, there results a long, high, and narrow-structure, 37 feet by 9 feet 5 inches on the ground plan, by 41 feet total height above the ground-line.

The setting of the tiles is like that of No. 3. The ore-chambers are a little narrower, being 18 inches wide by 8 feet 8 inches long, and 30 feet 9 inches high, from the discharge-slit at the bottom to where the ore enters at the top. The fire-places are 3 feet above the discharge, so that the lower part of the furnace acts as a cooling-chamber. The last discharge-tile is made of cast-iron. This furnace is iron-clad, and, like No. 3, is a beautiful piece of work.

The location of the furnace in the works and its shape necessitate an arrangement for discharging different from that of No. 3, although it operates on the same principle.*

The normal capacity of No. 8 is 24 tons per 24 hours. When full it holds 32 tons; consequently, a charge stays in the furnace 32 hours.

The hoppers of each pair of chambers receive each a charge of 1000 pounds per hour, or the double furnace receives 1 ton per hour. The hoppers are charged alternately. The discharge is effected by the shaking-table, as in No. 3, by working it every 10 or 15 minutes.

Two cords of wood are burned per 24 hours, and the working force of the furnace is :

One man at $2.50 per 12-hour shift.

One man at .$1.25 per 12-hour shift.

The campaign for 1882 appears in the following table:

* The two ore-chambers are in the same plane, that of the horizontal and vertical axes of the furnace, and discharge through three-inch ore-slits, as in No. 3 furnace. Beneath each of them is placed an apron, or shaking table, like those of Xo.3. But instead of resting on rollers, as in the latter, they are carried by a heavy frame of cast iron shaped like the letter H. The feet of this frame rest in bearings, which allow the same oscillating motion that would be given by the rollers. The connecting bar of the H-piece is below the level of the floor of the works, and carries a platform with rails, on which is borne a low truck, with rails upon it, at light angles to those on which it runs. By means of this device a long "slag"-car (7 feet long) may be run sidewise from the floor of the works on to the platform of the H-piece directly under the discharge-apron. By means of levers, a slight oscillating motion may now be given to the H-piece, and to the apron, platform, and ore-car which it carries. As a consequence, the ore is discharged in a shower from either edge of the apron into the car, just as in No. 3 furnace. While drawing either of these furnaces the draw-pits are closed, to keep in the dust.

No. 8.

Double Tierra Furnace (Continuous).

REMARKS.	1882. Month.	Number of days run.	Tierras, tons.	Quicksilver (flasks). Condensers.	Soot.	Total.	Per cent.	Wood burned, cords.	Coal burned.	Cost of fuel.	Cost of labor.	Total cost.
Closed for repairs and cleaning up. Afterwards not started till needed.	Jan.	..	...	...	69	69	...	...	...	...	...	...
	Feb.	..	...	...	4	4	...	...	...	...	...	...
	March.	..	...	...	..	...	...	...	...	...	...	...
	April.	..	...	...	..	...	...	...	...	...	...	...
	May.	..	...	...	12	12	...	...	...	...	...	...
Fired July 11, 1882. No Hg	June.	..	...	...	5	5	...	...	...	...	...	...
for seven days, ...	July.	20¼	425.00	49	..	49	0.44	41.00	...	$237.80	$140.00	$377.80
Stopped September 25, 1882.	August.	31	744.00	192	..	192	0.99	62.333	...	361.54	232.50	594.04
Eighty-nine flasks cleaned up.	Sept.	24¾	585 00	284	..	284	1.86	50.583	...	303.50	185.00	488.50
Fired 6 P.M., October 12, 1882.	Oct.	18¼	420.00	129	..	129	1.17	38.25	...	229.25	138.75	368.00
Ten flasks cleaned previous	Nov.	30	718.50	243	3	246	1.31	60.25	...	361.50	225.00	586.50
to firing.	Dec.	31	744.00	244	..	244	1.25	62.50	...	375.00	256.25	631.25
		155¼	3,636.50	1,141	93	1,234	1.298	314.916	...	$1,868.59	$1,177.50	$3,046.09
Per day, ...	...	1	23.424	...	..	7.949	1.298	2.028	...	12.036	7.584	19.620
Per ton of ore, ...	...	..	...	...	..	0.339	1.298	0.086	...	0.514	0.323	0.837

Resumé of Granzita and Tierra Furnaces (Production and Cost).

Furnaces.	No. of months run in 1882.	Number of days run.	Granza screenings, tons.	Tierras and Granzita, tons.	Total ore, tons.	Quicksilver (flasks). Condenser.	Soot.	Total.	Per cent.	Wood burned, cords.	Coal, etc., lbs.	Cost of fuel.	Cost of labor.	Total cost.
No. 1,	7	215	425.75	Gr. 7,165.50	7,591.25	2,952	322	3,274	1.664	344.75	149,040	$2,669.71	$2,186.78	$4,856.49
No. 2,	9	275	240.00	Gr. 3,198.50	3,438.50	1,834	48	1,882	2.09	217.125	136.000	1,857.44	1,603.60	3,461.04
No. 3,	11	334	...	Tr. 12,022.00	12,022.00	4.238	141	4,379	1.39	523.958	326,000	4,493.23	4,175.00	8,668.23
No. 8,	6	155.14	...	Tr. 3,636.50	3,636.50	1,141	93	1,234	1.298	314.916	.....	1,868.59	1,177.50	3,046.09
Totals,	...	979.25	665.75	26,022.50	26,688.25	10,165	604	10,769	1.543	1,400.749	611,040	$10,888.97	$9,142.88	$20,031.85
Average per ton of granzita and tierras,	...	...	...	......	....	...	...	0.4035	1.543	0.052	22.895	0.408	0.343	0.751

Resumé of Costs per Ton, Granzita and Tierra Furnaces.

	Quicksilver (flasks). Total.	Per cent.	Wood burned, cords.	Coal, etc., lbs.	Cost of fuel.	Cost of labor.	Total cost.
Furnace No. 1,* capacity 36 tons per 24 hours,	0.431	1 664	0.0455	19.633	$0 352	$0.238	$0.640
Furnace No. 2,* capacity 12 tons per 24 hours,	0.547	2.09	0.0631	39.551	0.5401	0.466	1.006
Furnace No. 3, capacity 36 tons per 24 hours,	0.459	..	0.0440	27.117	0.374	0.347	0.721
Furnace No. 8, capacity 24 tons per 24 hours,	0.339	1.298	0.086	.....	0.514	0.323	0.837

* In working Nos. 1 and 2 the labor of tramming the ore from the chutes to the furnaces has been included. The low cost of working No. 1 is partly due to the fact that Nos. 1 and 2 are usually worked together. No. 2 was not worked to its full capacity. The advantage of increasing the capacity of these furnaces is evident from the table.

The saving effected by the Hüttner and Scott furnaces may now be readily calculated. If they were not in use, the old intermittent furnaces being used in their stead, and the ore being made into *adobes,* we should have, per ton : .

Cost of roasting in intermittent furnace,	$ 1.368
Cost of making tierras and *granzila* into *adobes,* .	0.500
Cost of handling *adobes,*	0.450
Total cost per ton,	$2.318
26,688.25 tons at $2.318,	$61,863.364
Present actual cost in Hüttner and Scott furnaces,	20,031.850
Annual saving,	$41,831,514

If, instead of treating these ores in the intermittent furnaces, the *adobes* were roasted in the Monitors, we should have, per ton:

Cost of roasting in 7 and 9 furnaces, ...	$0,953
Making and handling adobes,	0,950
Total cost per ton,.	$1,903
26,688.25 tons at $1903,	$50,787.74
Present actual cost in Hüttner and Scott furnaces,	20,031.85
Annual saving,	$30,755.89

Instead of making the *granzita* into *adobes,* this might be in part roasted directly in the coarse-ore furnaces, and the latter might be made to work faster than with rich *granza.* These modifications might slightly reduce the above saving; but the difference would be slight. In making this comparison, the interest on the furnace-plant has not been mentioned.

In concluding this account of the Hüttner and Scott furnaces, it may be said that they fulfill every requirement of a good roasting furnace. They utilize the principle of opposed currents; they allow the ore to cool in the furnace itself before it is drawn, thus utilizing the heat and removing the last traces of quicksilver. The stirring of the ore is entirely automatic and very thorough; for each time the ore passes from one shelf to the next opposite one the ore, which lay at the bottom of the layer, next to the surface of the upper shelf, and out of contact with the air, is on the next lower shelf brought to the surface, where it is directly exposed to oxidation. This operation is repeated from 20 to 30 times, according to the number of shelves in the chamber. The feeding and discharge of ore and waste is effected with a minimum of labor and without the

Summary of all the Furnace Records.

1882. FURNACES.	Number of days run.	Granza, tons.	Terrero, tons.	Tierra and granzita, tons.	Total ore, tons.	Quicksilver (flasks), Condensers.	Quicksilver (flasks), Soot.	Quicksilver (flasks), Total.	Quicksilver (flasks), Per cent.	Wood, cords.	Coal and Charcoal, lbs.	Cost of fuel.	Cost of labor.	Total cost.
Granzita and tierra, .	979.25	†665.75	...	26,022.50	26,688.25	10,165	604	10,769	1.543	1,400.749	611,040.00	$10,888.97	$9,142.88	$20,031.85
Granza, ...	694.42	6,644.80	...	...	6,644.80	11,675	494	12,169	7.000	420.375	211,944.00	3,659.65	2,671.25	6,330.90
Intermittent, . . .	*138.08	2,259.30	297.60	183.65	2,740.55	5,108	24	5,132	7.160	413.500	....	2,425.87	1,324.50	3,750.37
	1,811.75	9,569.85	297.60	26,206.15	36,073.60	26,948	1,122	28,070	2.976	2,234.624	822,984.00	$16,974.49	$13,138.63	$30,113.12
Per ton of ore, . .	...	...	...	...	1	...	..	0.980	2.976	0.619	22.814	0.4705	0.3642	0.8347

The total cost of cleaning condensers and working soot from all furnaces was $2,509.85, or per ton of ore, ... 0.0664
Total direct cost of working one ton of ore, ... 0.9011

* Firing time only.

† Granza screenings, *i.e.*, rich granzita.

use of power. Add to this that the whole operation is under perfect control, and may be modified at any time, according to the nature of the ore, without stopping the regular operation of the furnace; and also, that the repairs are mostly slight and inexpensive,* and we have a very good showing for the furnace.

The ores of New Almaden cannot be regarded as difficult to roast, and the results obtained with this furnace might be thought not to apply to other ores. The fine ores at the Sulphur Banks Quicksilver Mine, however, present many difficulties. Thus at times they contain alkaline borates, and so frit to a pasty mass; at other times the lumps decrepitate in the furnace to a dust as fine as ashes; this, when red-hot, runs almost like water. After much difficulty with other furnaces, the Hüttner and Scott furnace was introduced there by Mr. Ferdinand Fiedler, and gave excellent results. It is not improbable that this furnace could be used with advantage in roasting fine ores of other metals. Those which are not too fusible could probably be treated in it with success.

The preceding summary gives the results of the year's run of all the furnaces for 1882.

During the year 1883 the furnaces were in operation as follows:

No. 6 made 27 runs.

Nos.' 7 and 9 worked continuously 365 days.

No. 1 ran 286 days.

No,. 2 ran 253 days.

No. 3 ran 188 days.

No. 8 worked 352, and was stopped only for lack of dumping-room.

The production was even greater than for 1882, the total amount treated for 1883 being:

Granza,	10,428.40	tons of 2000 lbs.		
Torero,	185.35	"	"	"
Granzita and tiaras,	27,967.50	"	"	"
Total,	38,581.25	tons of 2000 lbs.		

* The wear and tear on the tile-shelving would, at first sight, be thought considerable ; bat Mr. Scott, who has himself built and repaired the mason-work of these furnaces, assured me that with good tiles there is very little wear, except in the lower part of the furnace, where they are directly exposed to the full heat of the flames. These tiles gradually become brittle and crumble, so that they have to be replaced. The others suffer very little; in fact, some of them plainly show the stamp of the maker on the upper face after several years, of constant use. The tiles . in the granzita furnaces wear out sooner than those in the *tiara* furnaces.

It should be stated in this connection, that these furnaces and all the devices pe- . collar to them are protected by letters patent

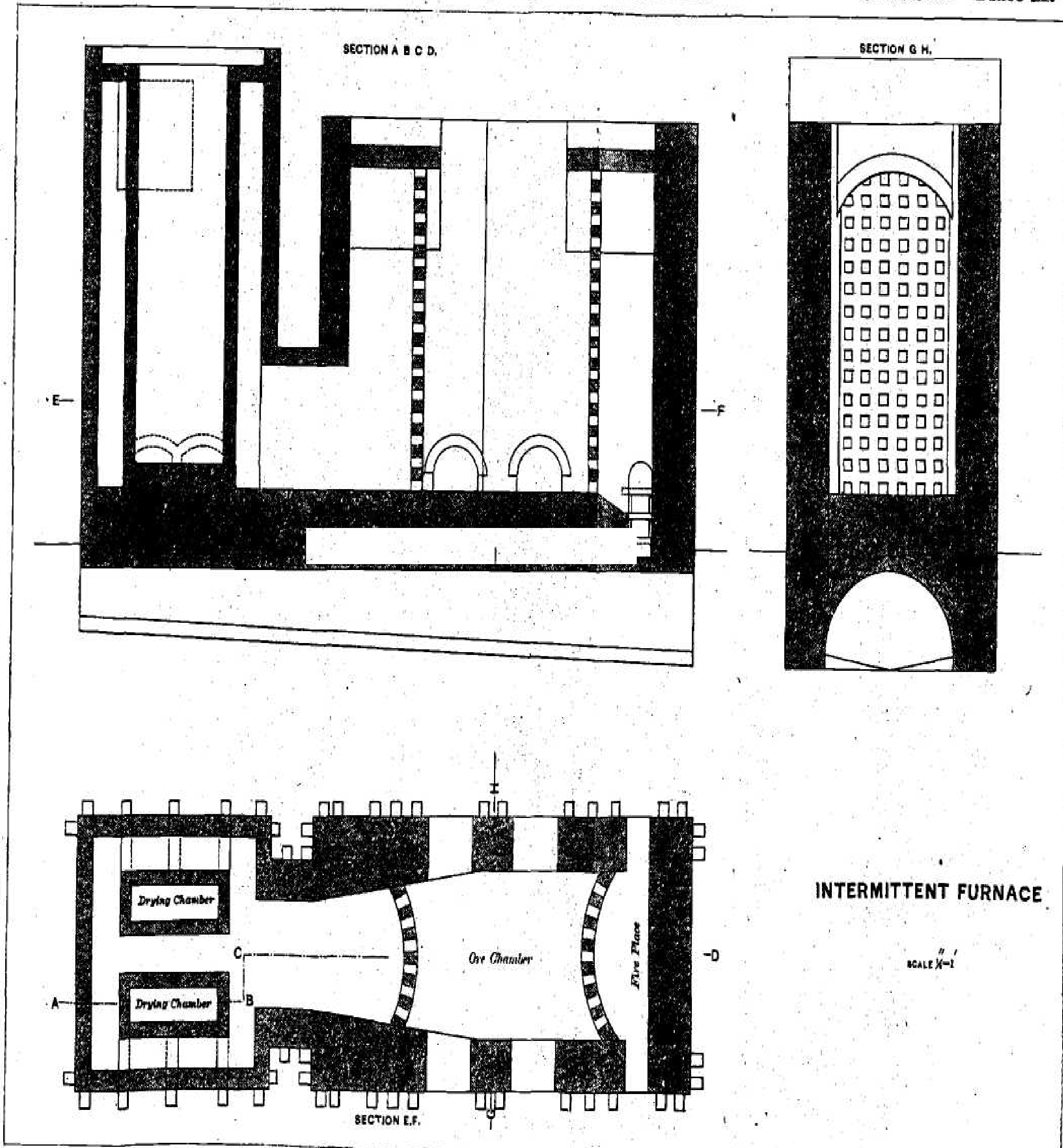
The product of quicksilver for the year was 29,000 flasks at 76½ pounds, or a yield of 2.875 per cent.

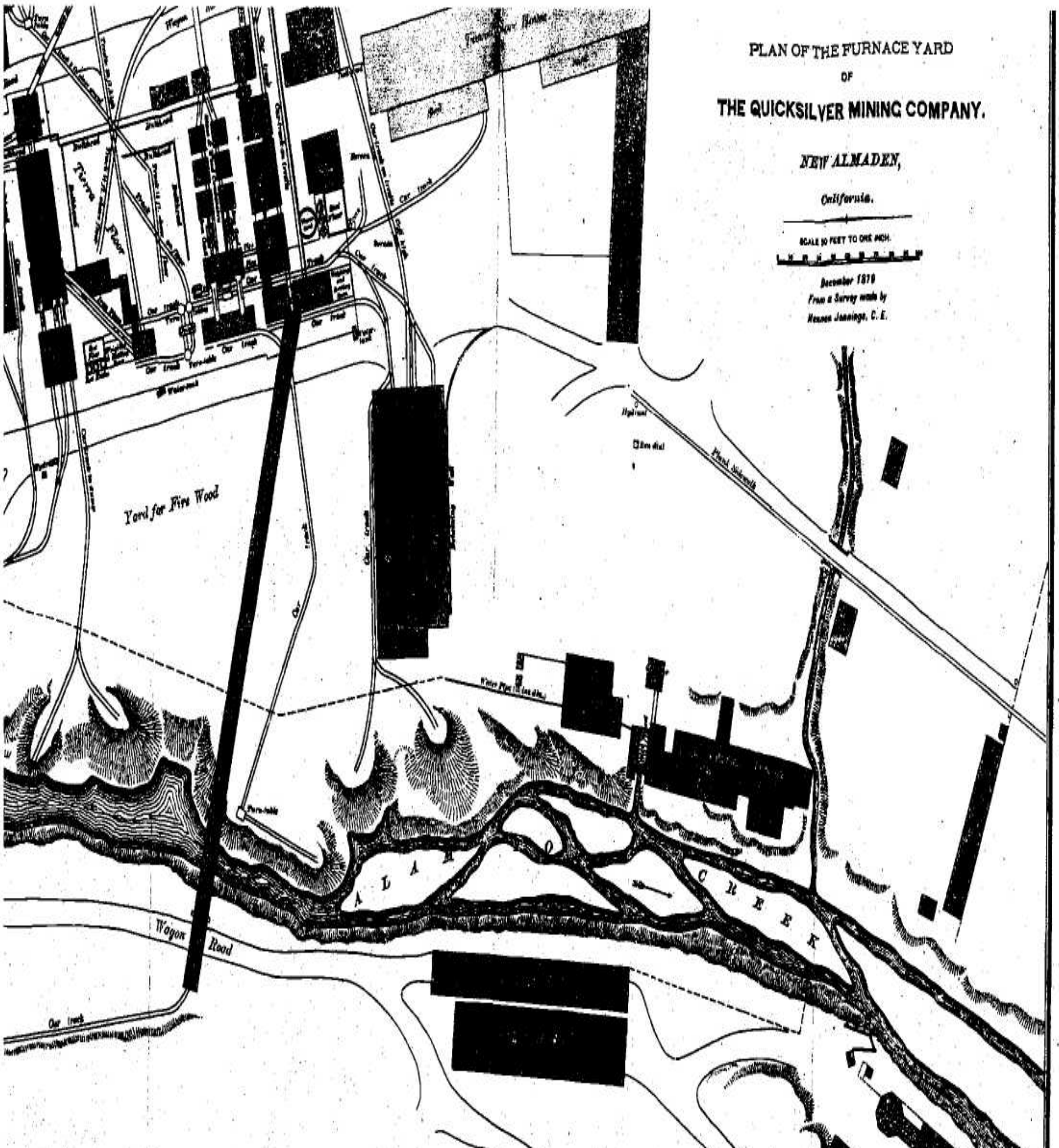
Finally, in concluding the present paper, the best idea of the increased efficiency of the new furnace-plant may be gathered from the recent great increase in the amount of ore annually reduced. Thus, in the year from July, 1850, to July, 1851, there was reduced less than 2500 tons of ore, an amount less than one-fifteenth that of 1883. From 1850 on, the quantity annually reduced increased, with some interruptions, until in 1876 it rose to nearly 17,000 tons. Since then, that is during the seven years ending with 1883, this amount has been more than doubled. This great increase has been, of course, mainly due to the introduction of the Hüttner and Scott furnaces, which allowed the treatment of large quantities of low-grade ores that formerly could not be handled at a profit.

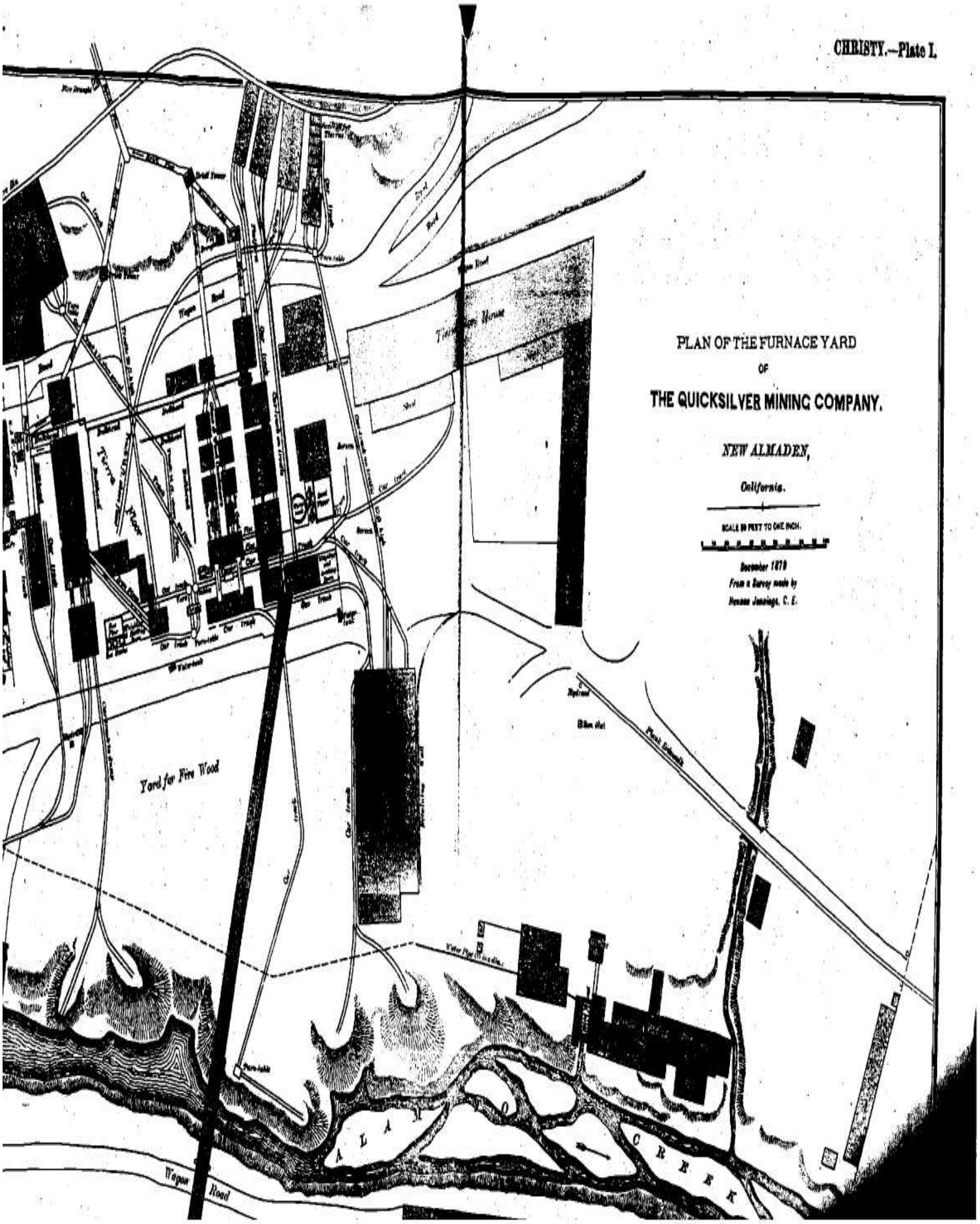
The percentage yield of the ores treated has gradually decreased from 36.74 per cent. in 1850-51, to 2.875 per cent. in 1883. This| reduction in the content of the ore is, however, partly due to the great increase in the amount of low-grade ores now treated, although the richest ores now run only as high as 6 or 8 per cent., as against an average of 36.74 per cent. in 1850.

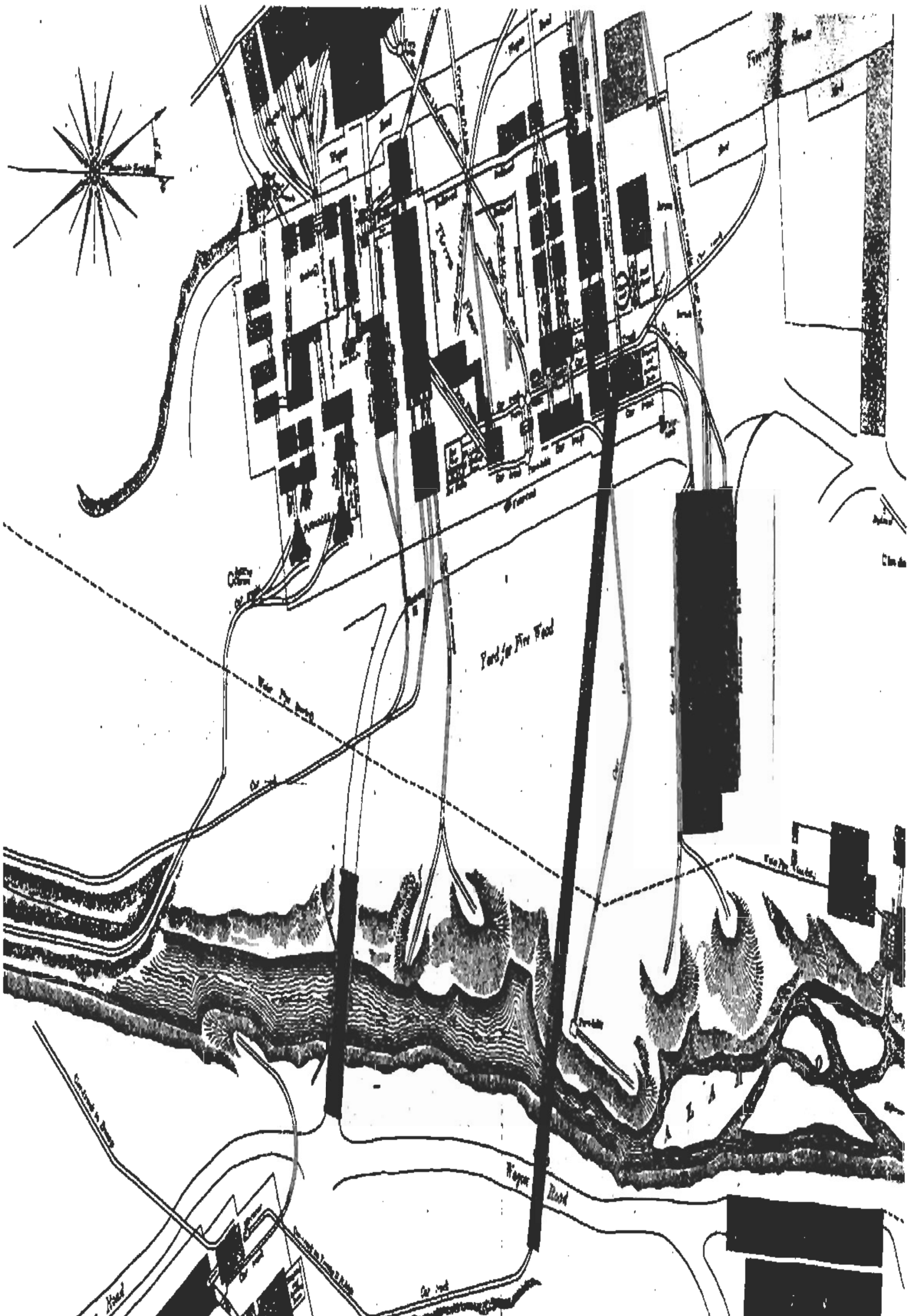
The greatest annual yield of quicksilver since records have been kept,* occurred from 1861 to 1866, when the rich Ardilla and Santa Rita *labores* were being worked. The highest annual yield of the mine now on record was in 1865, when it produced 47,194 flasks The quicksilver product then declined till, in 1874, it had sunk the 9084 flasks, an annual yield, however, that has been exceeded by only three other mines in California. From 1874 to the present time, owing to constant improvements in the furnace-plant, the annual yield has steadily increased, almost without interruption, till in 1883, it reached 29,000 flasks, the highest product since 1866.

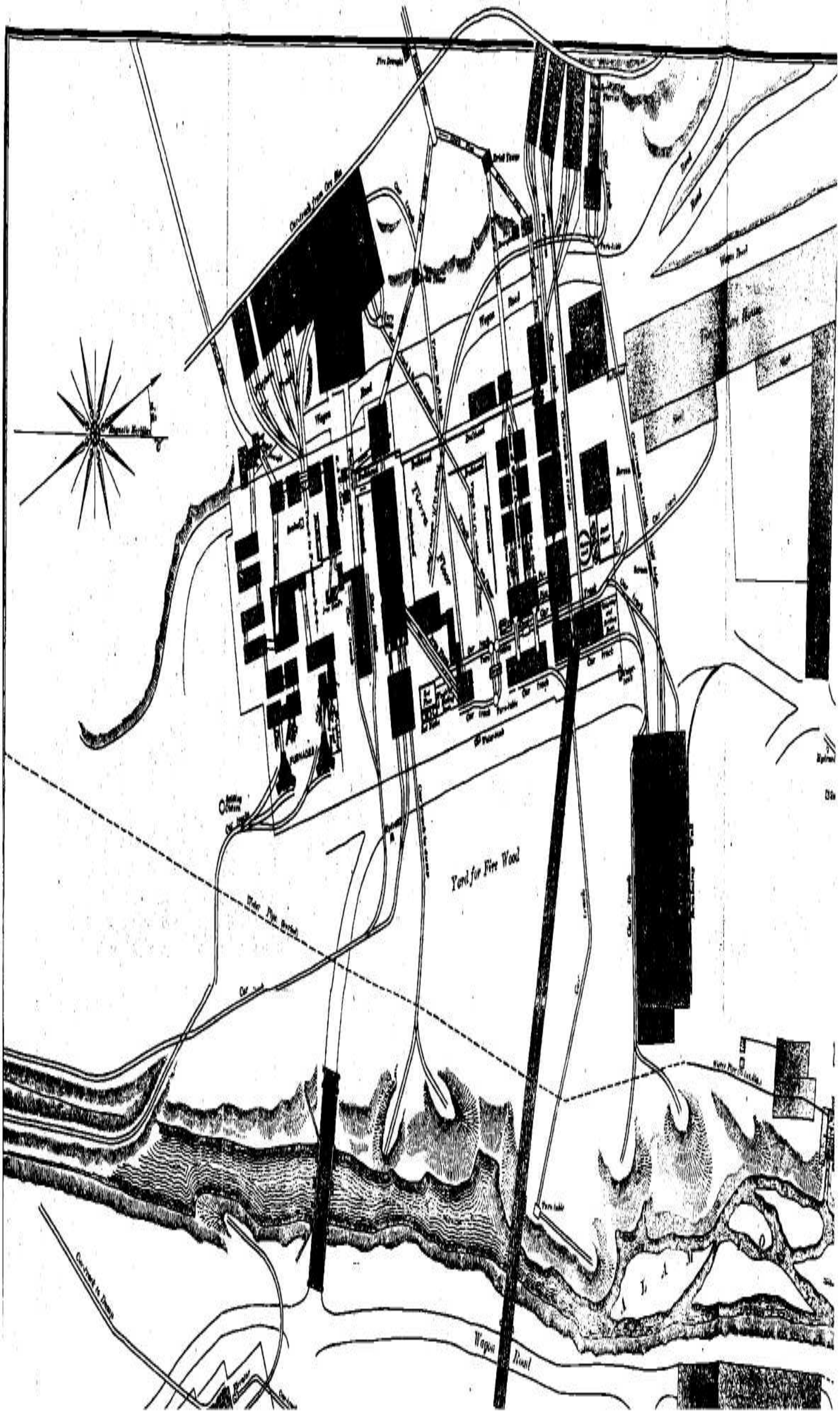
* That is, since 1850.


SECTION A B C D.
SECTION G H.
E
F
Drying Chamber
Drying Chamber
Ore Chamber
Fire Place
A
B
C
D
SECTION E.F.
INTERMITTENT FURNACE


PLAN OF THE FURNACE YARD
OF
THE QUICKSILVER MINING COMPANY.
NEW ALMADEN,
California.
SCALE 30 FEET TO ONE INCH.
December 1879
From a Survey made by
Hennen Jennings, C. E.
Yard for Fire Wood
ALAMO CREEK
Wagon Road
Car track


PLAN OF THE FURNACE YARD
OF
THE QUICKSILVER MINING COMPANY.
NEW ALMADEN,
California.
Wagon Road
Yard for Fire Wood
A L A M O
C R E E K
Wagon Road


Yard for Fire Wood
Wagon Road
Wagon Road


Yard for Fire Wood
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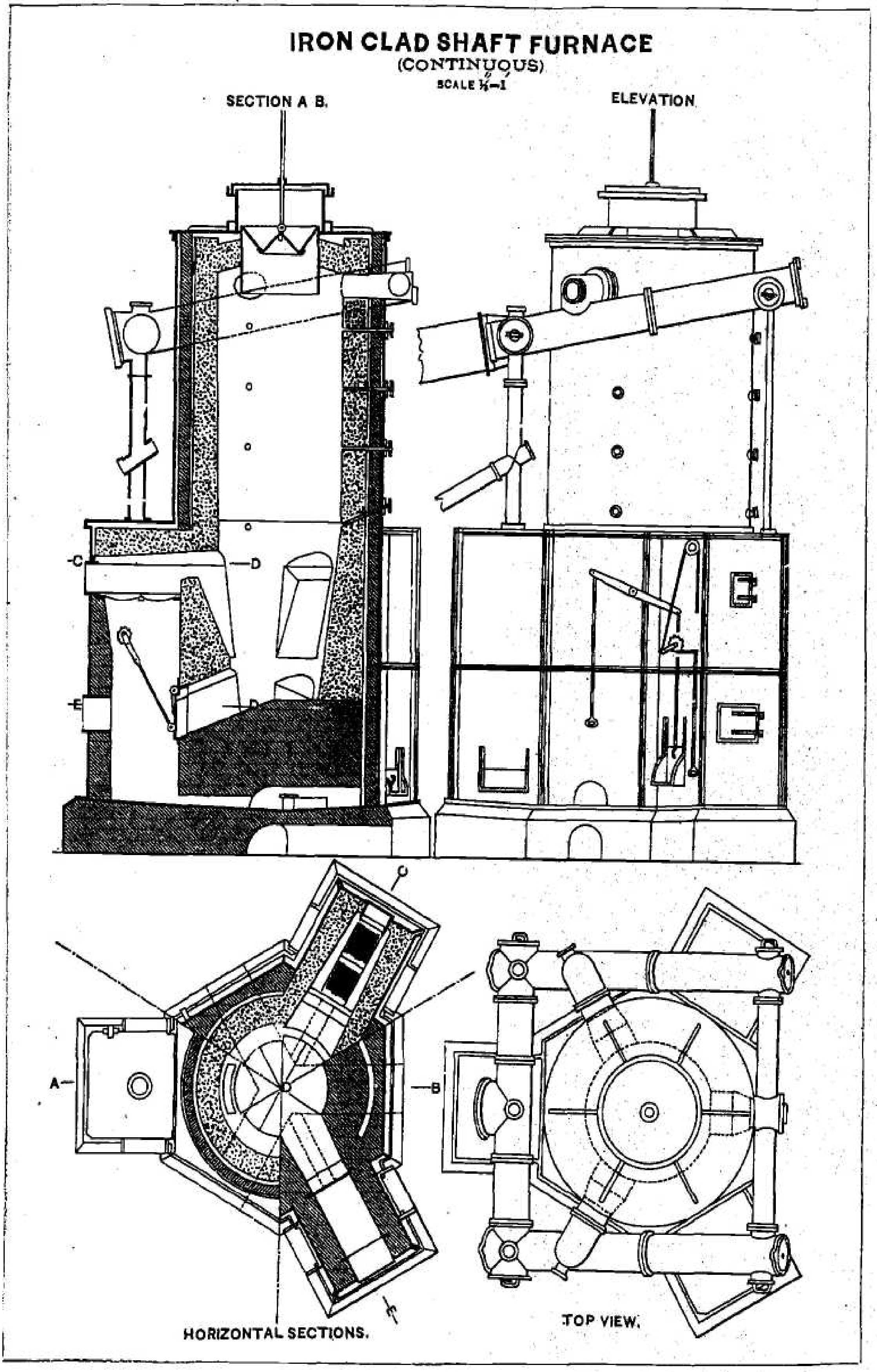
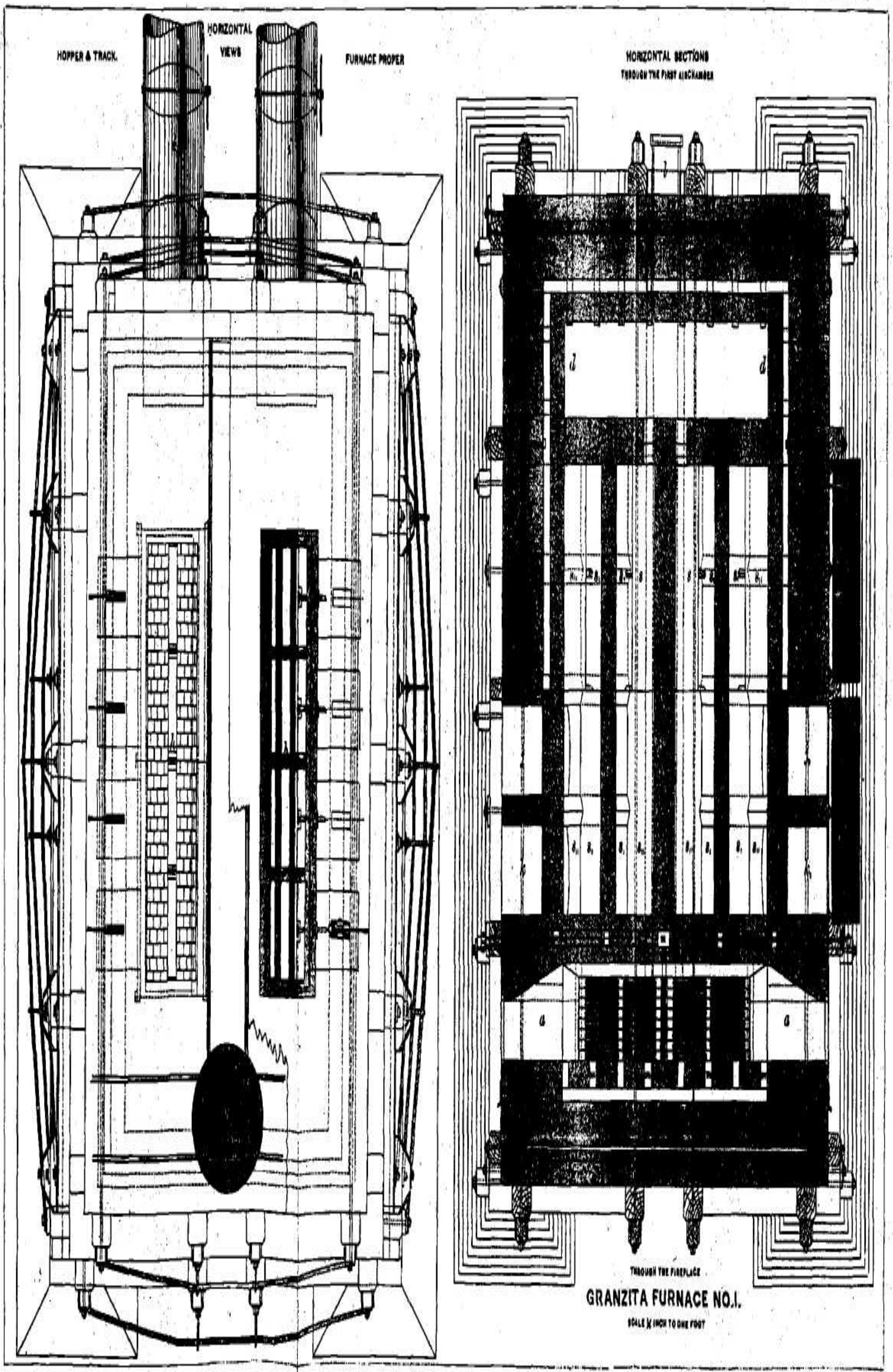
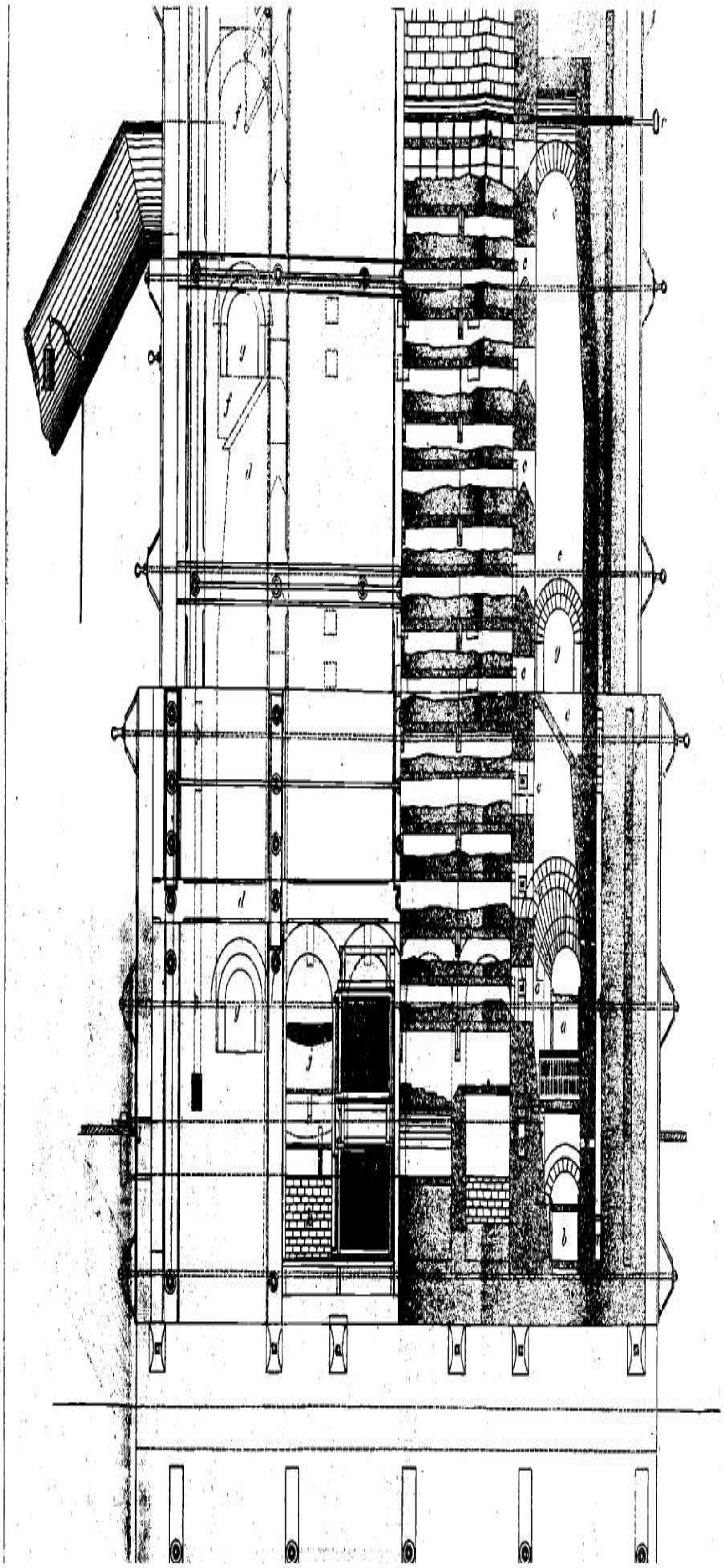

IRON CLAD SHAFT FURNACE
(CONTINUOUS)
SCALE ½"=1'
SECTION A B.
ELEVATION.
C
D
E
A
B
HORIZONTAL SECTIONS.
TOP VIEW.



GRANZITA FURNACE NO. I.

SCALE ¼ INCH TO ONE FOOT

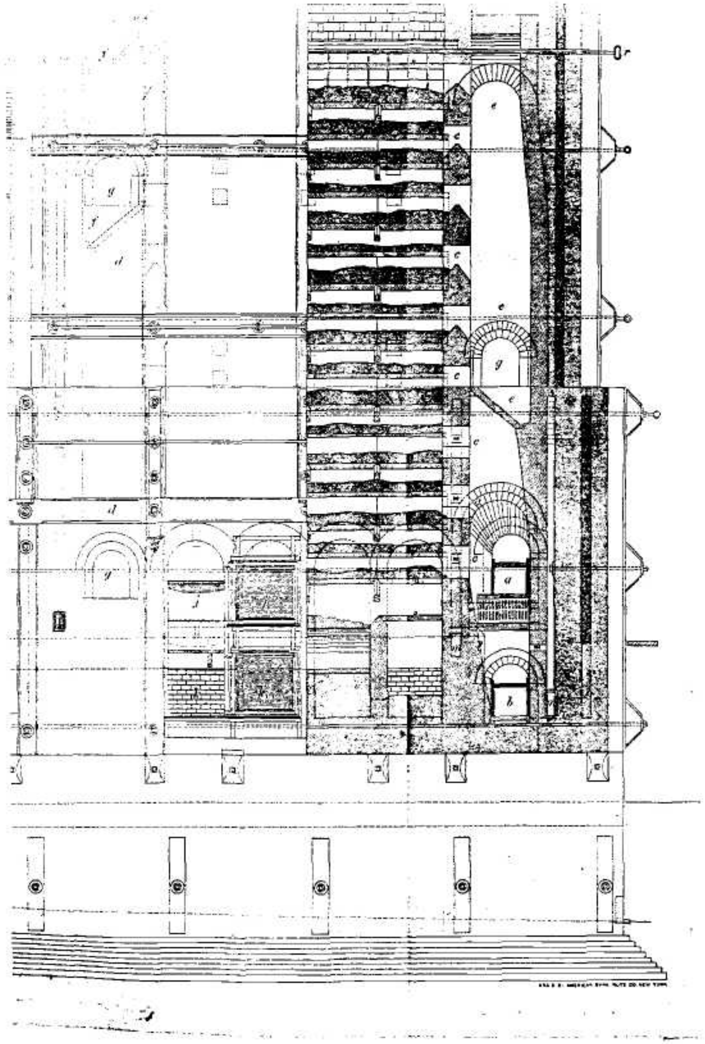


GRANZITA

FURNACE,

No. 1.

Scale ¼'' = 1'

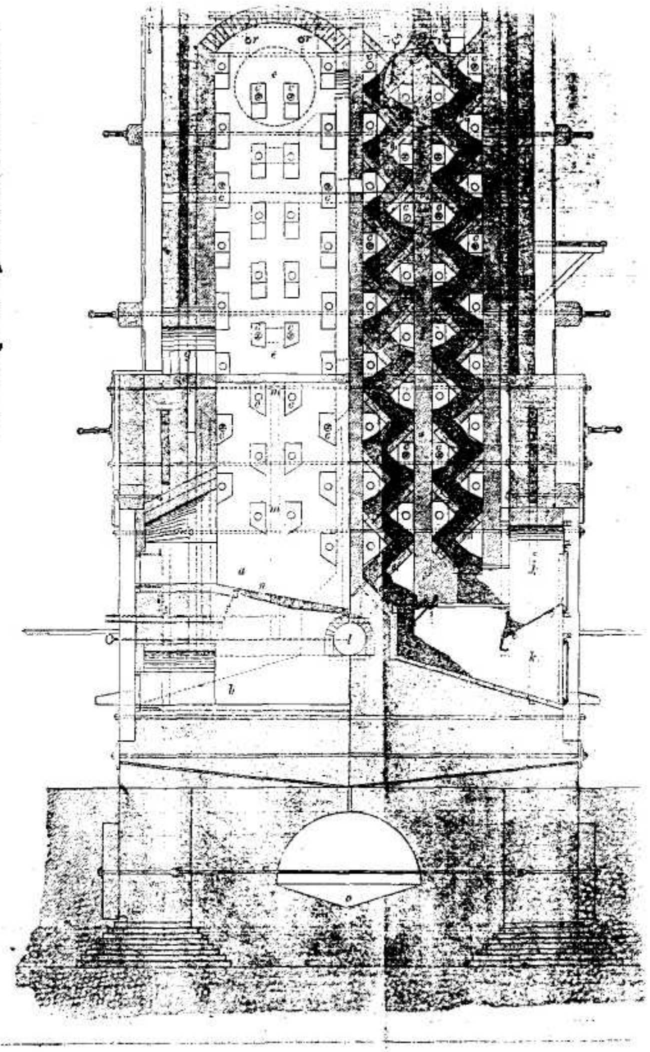


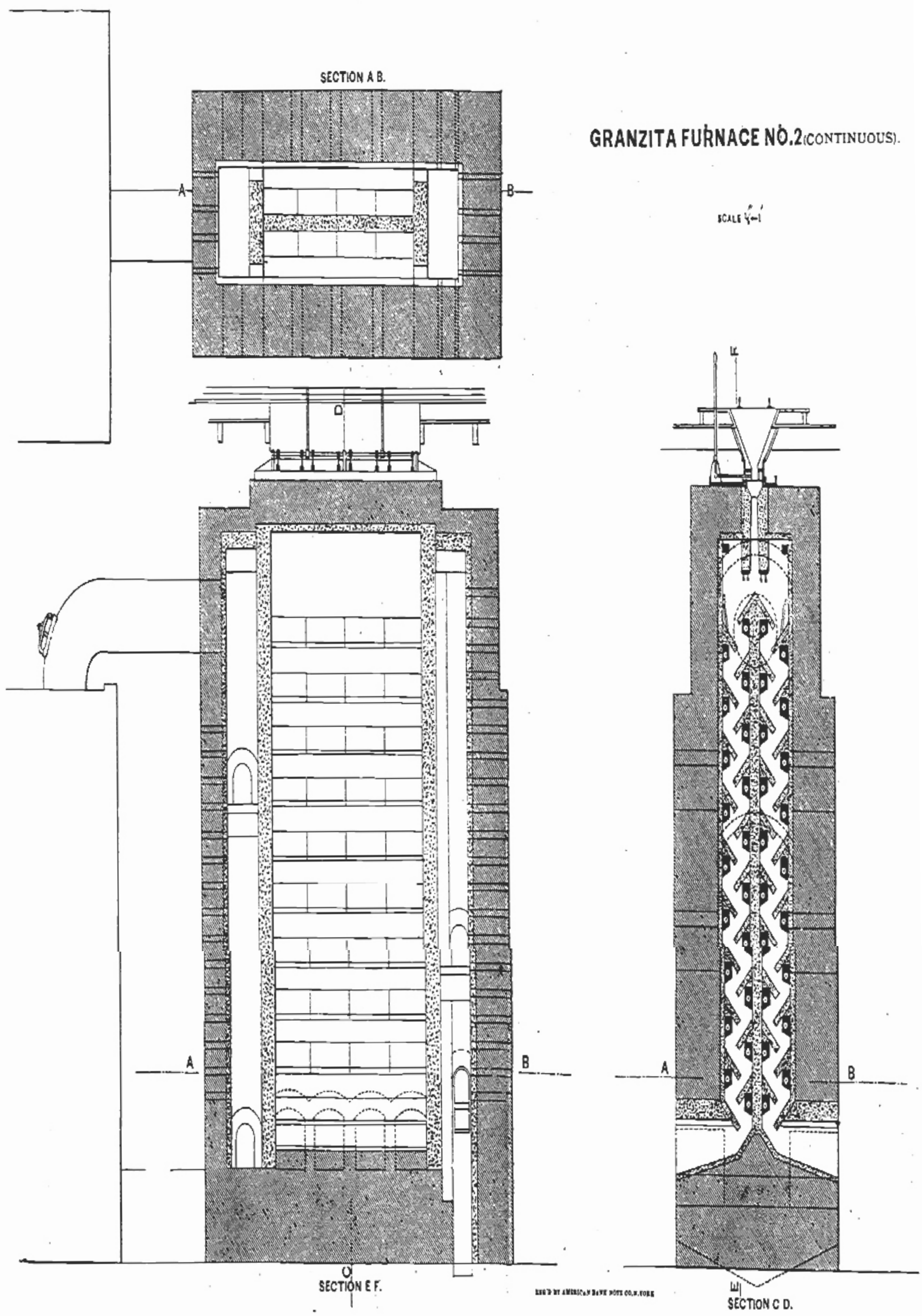
CRANZITA

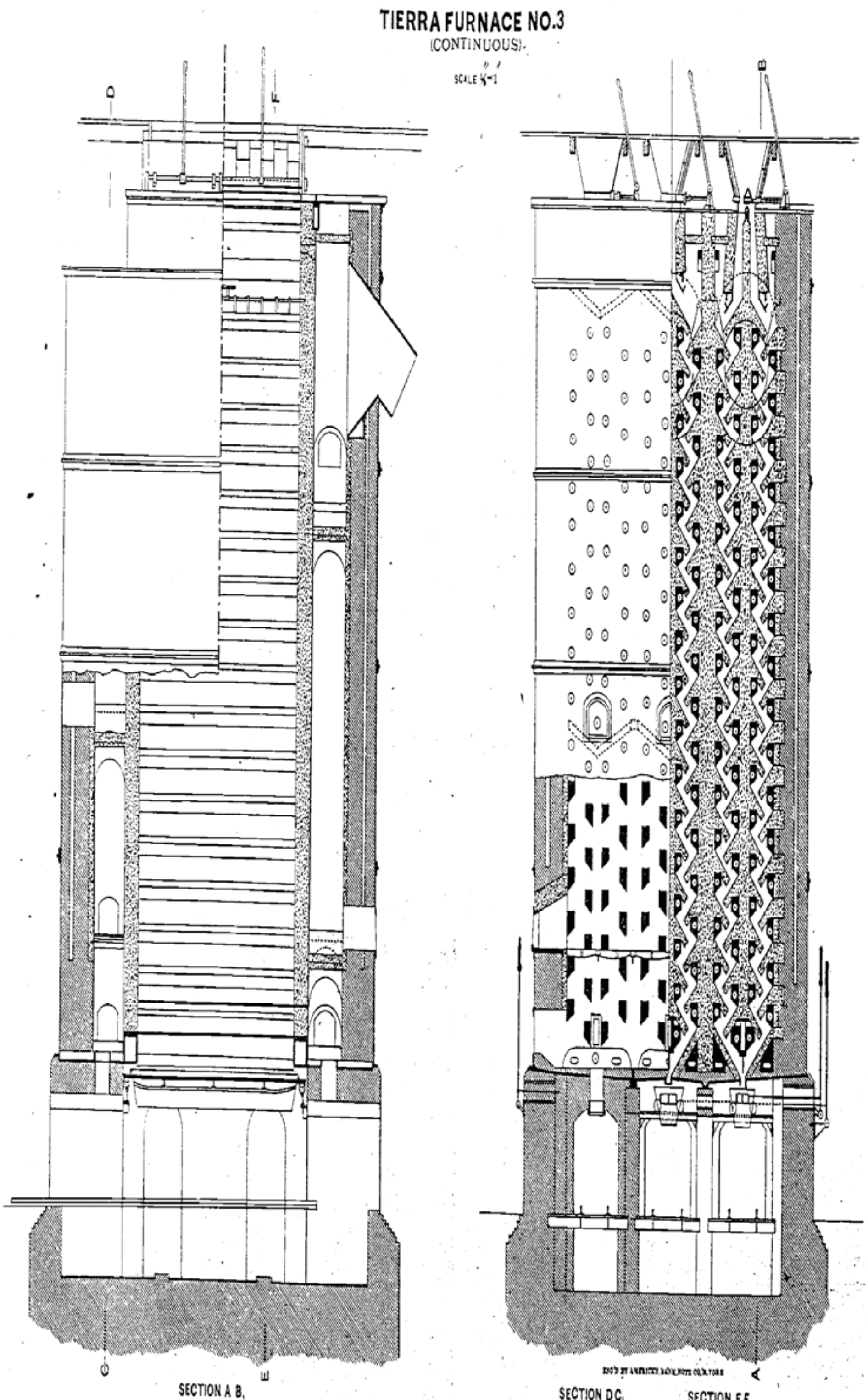
FURNACE,

No. 1.

Scale ¼'' = 1'



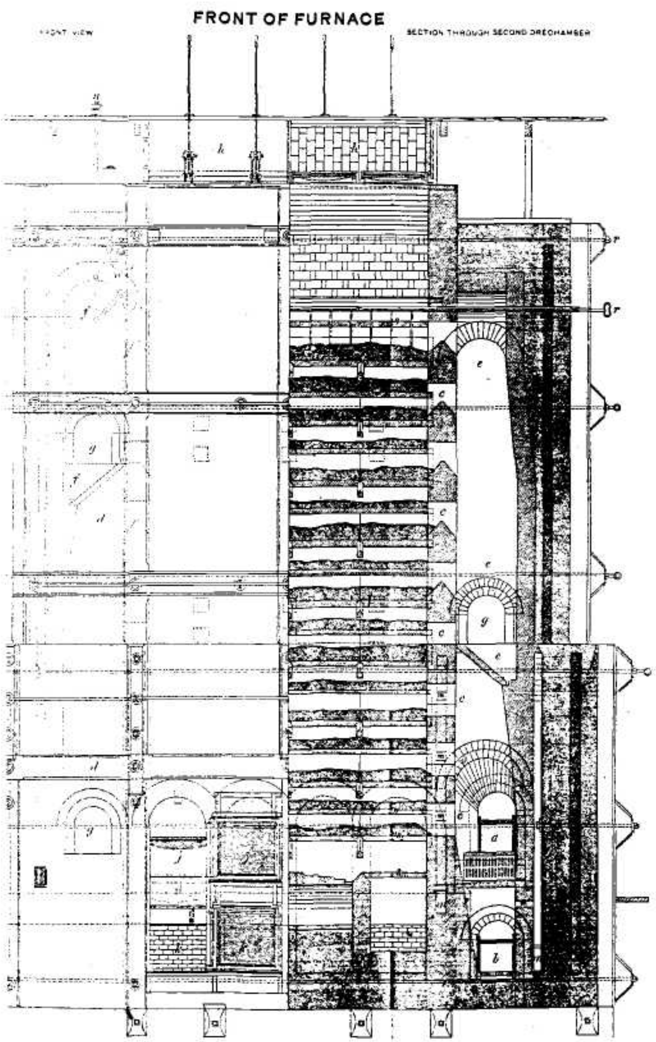

SECTION A B.
A
B
GRANZITA FURNACE NO.2 (CONTINUOUS).
D
A
B
SECTION E F.
A
B
SECTION C D.



SECTION A B, and part of Side Elevation.

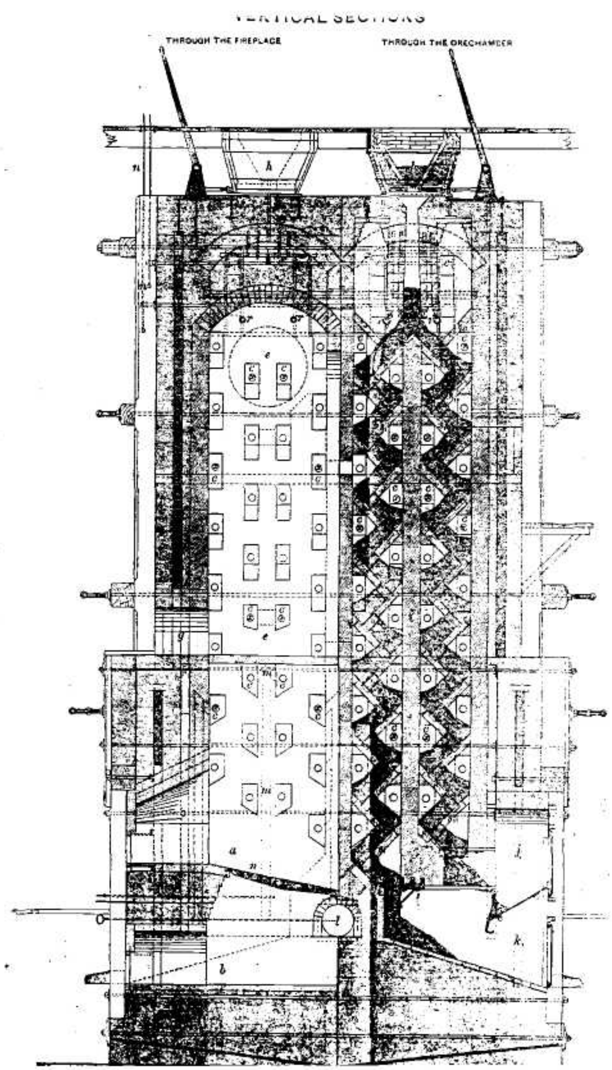
SECTION D C, and part of Front Elevation.

SECTION E F.



CRANZITA FURNACE, No. 1.

Scale ¼″ = 1′



PROCEEDINGS

OF THE

ANNUAL (XLIst.) MEETING IN NEW YORK.

FEBRUARY, 1885.

PROCEEDINGS OF THE FORTY-FIRST(ANNUAL) MEETING, NEW YORK, FEBRUARY), 1885.

LOCAL COMMITTEE.

David Williams, *Chairman;* William H. Wiley, *Secretary;* William P. Shinn, Charles Macdonald, James F. Lewis, Thomas C. Clarke, Austin G. Gorham, Charles Kirchhoff, Jr. *Headquarters:* Park Avenue Hotel, Fourth Avenue and Thirty-second Street.

The opening session was held on Tuesday evening, February 17th, in the hall of the Academy of Medicine, No. 12 West Thirty-first Street. Mr. David Williams, Chairman of the Local Committee, called the meeting to order, and, after briefly welcoming the members, introduced Hon. William R. Grace, Mayor of New York, who extended to the Institute the welcome of the city.

President J. C. Bayles, after acknowledging the courtesy of the Mayor, proceeded to address the Institute as follows:

GENTLEMEN OF THE AMERICAN INSTITUTE OF MINING ENGINEERS ; LADIES AND GENTLEMEN : In opening the annual meeting of a society which subjects all papers brought before it to the analysis of discussion, the President should not presume too much upon the privilege of his office by presenting, as an address from the chair, a technical essay labeled *hors de concours,* and expect you to accept it as part of your transactions. Contributions of real value to scientific literature are seldom created like Minerva in the myth. More often, they are like new houses in which, however well planned or well built, there is almost always a settling and shrinkage somewhere; and their publication, *"Subject to Revision,"* is very much like the agreements of owners with their first tenants to point up the cracks and cover the patches with paper within two years. The extensive repairs at the author's expense, which are sometimes necessitated by the wear and tear of discussion, usually add a great deal to the value. of papers; and since custom has given exemption from discussion to addresses from the chair, they should, I think, deal with safe statis-.tical and economic truths, rather than with subjects which, if brought forward in papers, would at least serve the purpose of precipitating some of the wisdom held in solution in our meetings, and needing an original observation or a new conclusion to build on in shining crystals.

The subject I shall have pleasure in considering this evening is, briefly, whether the conditions of success in manufacturing are so arbitrary and difficult of attainment as to discourage young men from engaging in competition with the vast aggregations of capital which are popularly supposed to be fast acquiring a monopoly of profitable production.

A thoughtful writer in a recent issue of a leading English rnagazine, in an article discussing the increasing concentration of industry, presents some statistics intended to show that steam has extinguished the handicrafts, and that as steam-power is most economically employed on the largest possible scale, it is rapidly and inevitably leading to a monopoly of manufacturing by large establishments, and the extinction, one by one, of those which are small. The situation in Great Britain is represented to be as follows : Trade after trade is monopolized, not necessarily by large capitalists, but by great capitals. In every trade, the standard of necessary size, the minimum establishment that can hold its own in competition, is constantly and rapidly raised. The little men are ground out, and the littleness that dooms men to destruction waxes year by year. Of the cotton-mills of the last century, a few here and there are standing, saved by local or other accidents, while their rivals have either grown to gigantic size or fallen into ruin. The survivors, with steam substituted for water-power, with machinery twice or thrice renewed, arc worked while they pay one-half or one-fourth percent, on their cost. The case of other textile manufactures is as bad, or perhaps wose. Steel and iron are yet more completely the monopoly of gigantic plants. The chemical trade was for a long time open to men of very moderate means; but recent inventions threaten to turn the plant that has cost millions to waste brick and old lead. Already nothing but a trade-agreement, temporary in its nature, has prevented the closing of half the factories of St. Helen's and Widnes, and the utter ruin of all the smaller owners. Every year the same thing happens in one or another of the minor industries. Retail trade was, until lately, the recourse of men whose character, skill, thrift, and ambition won credit and enabled them to dispense with large capital. The larger branches of retail trade are already superseded by co-operation or monopolized more and more generally by vast, skilfully organized establishments, with which the small capitalist, however diligent, honest, and capable, cannot possibly compete. They can sell at little over wholesale prices, while giving their customers all and more than all the conveniences proffered by the ordinary tradesman. A gloomy picture, certainly, but possibly somewhat overdrawn.

In this country, it is not unusual to hear similar statements from those who study great social and industrial problems from their surface-indications only. We hear them frequently as furnishing an excuse for the lack of success which attends so many industrial ventures; but its insufficiency as an explanation of failure is found in the fact that here, as elsewhere, industrial greatness is usually, if not always, the result of development from small beginnings. The investment of capital in manufacturing enterprises which are to be great from the outset is always perilous and often disastrous to the investors. Among those which start small, the law of the " survival of the fittest" operates in a perfectly natural and proper way. We can see the reason for what happens, whether the happening be success or failure. With conspicuous justice, "the many fail, the one succeeds." To those enterprises which succeed, capital is naturally attracted, while from those which do not succeed it as naturally withdraws in search of safer and more profitable investment. The successful establishments are extended and enlarged, and become corporations of overshadowing importance; those less successful barely hold their own, or gradually fall hack, changing hands from time to time, and finally relapsing into permanent idleness. This process is constantly going on, for the reason that, with the ever-changing conditions of business success, the establishments which become great under one management may decline or collapse under another.

Industrial greatness would, perhaps, be a function of capital alone if capital were something outside of business, always available for use and self-renewing. But capital represented by land, buildings, machinery, patterns, etc., may and often does become like a millstone around the neck of a corporation. The management which made a manufacturing establishment great rarely suffices to keep it at the head, even during the life of the generation which saw it begun. Ordinarily, the longer it lives the more dead weight it has to carry, and the instances are comparatively few in the world's industrial history in which a plant adapted to supply the wants of one generation is suited to meet the wants of the next. For this reason, the field is always open to skill, enterprise, and courage.

I have been led to these reflections by a careful and more or less thorough study of the conditions of success in the manufacture of iron and steel. The history of the iron-industry of this country shows most strikingly upon how many conditions, other than the extent and temporary importance of iron-making plants, success is dependent. It is unnecessary to examine its statistics in detail or in general, further than to note that they show a gradual and fairly steady Westward progress of the wave of iron-production. It is not long since the conditions of success in iron-making were found in small furnaces planted in the woods of New England and the Middle States, and dependent for an outlet upon the haulage of their product over corduroy or country roads; and in rolling-mills located on streams affording ample water-power to drive their rolls. The census-tabulations for 1880 place the geographical center of iron-production in western Pennsylvania beyond the Alleghenies; and the development in the South since the census was compiled would probably move the point as far West and South as Pittsburgh. This shifting of the geographical center of production means a gradual but irresistible change in the conditions of success in iron-making; and as offsets to such changes, the *prestige* of former greatness and controlling industrial importance counts for very little. That the Northeast is not keeping up its proportion of the pig-iron production of the country is clearly shown by the statistics of the trade. The natural territorial sources of pig-iron supply for the Northeast are the New England States, New York, New Jersey, and the Lehigh Valley of Pennsylvania. That these sources have not made much progress in production in the past ten years is indicated by the fact, that within that time their proportion of the total pig-iron production of the country has declined from 30 to about 20 per cent. Southern and Western irons have come in to supply the increased consumption of the Northeast, and they are to-day crowding our markets, while so many of our local furnaces stand idle, unable to produce at present prices. These facts are significant as showing that the large capitals of the old, established iron-work of the northeastern States do not give them any conspicuous advan tage in competition, as against better natural advantages elsewhere offered. In fact, their large capitals are the heaviest burdens they are staggering under.

The steel-industry is still comparatively a new one in this country, and we have, as yet, witnessed no great change in its geographical center of production. Even the youngest in our membership can remember, not its beginning, perhaps, but its initial triumphs in the production of grades of steel that could safely challenge comparison with foreign makes. But during this brief period we have seen some surprising happenings. Small capitals have grown, and large capitals have, in some instances, shrunk to nothing. Great establishments have been organized which, because of their greatness, have fallen to pieces almost before they began production; and small beginnings, judiciously planned and managed, have been the foundations of brilliant industrial and financial success. The changes of the next twenty years, though impossible of prediction, are likely to be quite as important as those of the past twenty years. In the Bessemer industry we have witnessed a marked change which is probably but the prelude to one still more marked. Its beginnings are easily recalled and its history is familiar. Certainly it shows that courage and enterprise often count for more than large capital and the prestige of past success. No industry has seemed to be so completely a monopoly of large capitals as pneumatic steel-making. The bigger the converters and the more of them, the better seemed the chances of success. Everything else needed to be big in proportion, and the more tons of rails a mill could turn out in a year the greater the apparent security of the investment. It looks now as if the small plant were more desirable than the large one and four-ton converters seem to be more convenient and desirable property than fifteen-ton converters. During the next few years we are likely to see Bessemer mills built and run as departments of works of medium size, as rolling mills might have blast-furnaces connected with them; and there are doubtless some large Bessemer plants, representing an enormous investment, which could be bought for a very small part of their original cost, but which few shrewd business men would care to take as a gift on the condition of keeping them in operation for a term of years.

But if no one need be deterred from entering iron- and steel-making by the apparent impregnability of the great capitals which stand like fortifications along the highways of industrial enterprise, still less need he fear those gigantic organizations effected by combination and consolidation. More often than otherwise, these consolidations are brought about in the hope of shoring up enterprises which cannot Stand alone. They are very formidable on paper, but they are apt to fall to pieces suddenly through the weakness of their component parts. We have watched the formation of several such consolidations in the iron-trade, but in every case they have failed to accomplish the object for which they were formed, and sooner or later they have gone the way of all bubbles which owe their expansion to the elas-ticity of an extremely tenuous film.

In other and allied industries, we find reason to doubt that, in this country at least, manufacturing is, in any sense, the monopoly of large capitals. Those who own or control vast establishments are likely to insist that, through the advantages of larger capital and the control of plant in which every appliance for economizing the cost of making and handling has been provided, they can make and Roll cheaper than their small competitors, for the reason that, while their cost per ton or per piece is less than it would be with less perfect appliances, they have an important advantage in the fact that their incidental expenses, being divided into a larger product, show a less percentage per ton or per piece than in the case of the small factory. Those who lead the trade consequently affect to believe that the tendency is to make the great concerns greater and the small con-cerus smaller and less numerous; that within a few years production and distribution will be controlled by a *few* immense corporations, and that the smaller manufacturer, unable to compete, will give up the unequal contest. On the other hand, the small manufacturers are by no means ready to be convinced, by argument or statistics, that their position is hopeless. Primarily, they do not admit that the great establishments are, by reason of their greatness, able to produce on a large scale cheaper than is possible on a small scale. They claim that there always exist in large establishments conditions involving costs which cannot be taken into account in an estimate. but which appear in the annual balance-sheets. There is too much subdivision of responsibility, a less close and intelligent supervision of details, a larger number of small leaks and a greater proportion of waste. The small manufacturer who wanders about the establish-ment of his great competitor usually thinks he recognizes a disregard of that which, in his case, would make all the difference between profit and loss; and while he cannot fail to notice that there are advantages in a large plant which a small one does not posses, he also sees disadvantages in a business which has so far outgrown the supervision of the proprietor that he is at all times dependent on the skill and fidelity of subordinates, who, even if skillful and faithful. do not always work together so harmoniously as to insure the be?? results.

It is unnecessary to take sides in this discussion; but without doing so, I may say that in assuming that only the great capital can safely meet the increasingly sharp competition of trade, we are in danger of mistaking the effect for the cause, and of hopelessly confusing our argument. It is sufficient for our present purpose, however, to accept the fact that the greatness of the now great industrial establishments does not necessarily bar the way to progress for those which are now small. The chances of twenty years are in favor rather of what are now small beginnings, provided they are headed in the right directions, than of the great enterprises which BOW seem to overshadow their modest competitors. There is a reason for this. A successful manufacturing business is likely, in a quarter of a century, to outgrow the conditions which made it successful. When there died in this city, some years ago, a merchant whose name had become almost a synonym for business success and uncounted wealth, a great many surprising facts came to light. In the complex structure of his vast business, there were hundreds of rotten timbers. Carried from year to year by the sheer force of an enormous capital, it might have gone on for years longer; but it was in no sense profitable as a business. It had millions of dollars' worth of mill-property which had not turned a wheel for years ; and competition had tapped it at so many points that it was honeycombed through and through. Those who are old in business experience can recall a score of instances in which the great establishments of the last generation have disappeared in this.

The facts I have presented are significant merely as so many emphatic contradictions of the popular impression that the tendency is toward a monopoly of manufacturing by great corporations. It is toward a monopoly in the hands of those who can manufacture the best products at least cost; but this is not always true of the largest i. concerns. There is always room enough in the forest for young trees to grow. Those which have already grown may lock their branches overhead; but somehow the saplings manage to get their share of light and heat and nutriment from the soil. So it is in the manufacturing industries. Those which take root and begin to grow, adapt themselves to the conditions that surround them. As their plant increases, it constantly gains in productiveness. Its development is along the lines of natural progress. Each generation has its own development, and its legacy to the future coming generations will necessarily in great part discard. There is just as good a chance to-day for skill, courage and enterprise as there ever was. Machinery has destroyed the handicrafts to a great extent, but it has given each man muscles of iron and fingers of steel with which to work. Conditions have changed, but opportunities have been broadened and diversified.

Within a few years we have had a great development in this country of facilities for technical education. Large classes are anunally graduated; and every year a considerable number of young men, peculiarly well equipped for industrial success, are called upon to decide what they will do in life. That only a small proportion engage in pursuits in which their education gives them an important advantage over young men who have spent in business the years they have passed in college, is unfortunately true. Having been brought a great deal in contact with graduates of our technical schools, I know that they are all more or less impressed with the idea that the time is past when a young man without capital or influence has any chance of success in applying his knowledge practically in manufacturing. They seek employment in the service of the great concerns, and generally fail to get it, for the reason that very few capitalists care to provide these boys facilities for a post-graduate course. They seek employment as assistants to the management of smaller works, but their qualifications arc not usually of a kind much in demand, and they are not, as the rule, willing to accept what they can get. At last, discouraged and disheartened, they make up their minds that no way of utilizing their knowledge is open to them, and they are very apt to go into trade, with regrets that they had not spent in gaining business experience the time they feel they haw wasted in college. Their decision is, in most cases, based upon an entirely erroneous conception of the opportunities open to clever and ambitious young men in the manufacturing industries. In these, better and easier than in any other fields of usefulness, can a young man who has the elements of success in him, afford to be indifferent to his lack of capital and influence. It devolves upon the young engineer who has such education as the schools can give him, to select the line of work most congenial to his taste. If he has no prefer ences, he need consider only his opportunity, for one line is as good as anotsher in the average of years. How he begins is a matter of no consequence; but the less he depends upon his acaden?? degree, and the more he relies upon his industry and capacity to learn. the better his chances of starting right and making a steady upward progress. There is always a demand for competent foremen, and young man who, at the bench or in any subordinate position among the wage-earners, gives evidence of fitness and capacity beyond fellows, can have promotion without asking for it in ninety-nine car??

out of every one hundred. What he has learned in college, combined with what he has learned in practical work, should make him so much more competent than foremen usually are, that one responsibility after another will devolve upon him. From that point his fortune is pretty much what he may choose to make it. Capital is . constantly on the lookout for men who are distinguished for capacity and skill, and there never has been, and probably never will be, a time when there is not room for new undertakings to succeed in competition with old ones. These may seem to be mere commonplaces --bits of good advice of the kind ladled out to long-suffering and much-patronized graduates on commencement day--but they are something more. I speak for our manufacturing industries. They .need every one of the young men who are graduated from our technical and engineering schools, not as superintendents or consulting engineers, but as material out of which to make the great captains of industry who must organize and lead our manufacturing progress ten or fifteen years hence. Trade offers them no such inducements; the professions hold out no such opportunities. No country of the world has such a promise of extensive industrial development as this. The iron-and steel-industries offer to any young man of good habits, good courage, fixed purpose and a technical education, all the chances of success which the most ambitious could desire. They turn their backs upon these opportunities, less because they are afraid of work than because they are deceived as to the conditions of success in manufacturing, and fail to discover that, notwithstanding the apparent tendency to a monopoly by large capitals, there was never a time in the history of the world when equal opportunities were offered , for those prepared to lead industrial progress.

If the distinguished honor of having been chosen to the presidency of this great Institute, which includes in its membership so many " eminent in science and industry, shall seem to the young men of our technical schools to entitle what I have said to more consideration . than attaches to words of truth and soberness spoken unofficially, I shall find cause for satisfaction in the thought that I have used this dignified opportunity for a good and worthy purpose.

The first paper read was a biographical notice of Professor Benjamin Silliman, by Dr. T. Sterry Hunt, of Montreal, Canada.

A paper on the Fahnehjelm Water-gas Incandescent Light, was then read by Dr. R. W. Raymond, of New York city, who exjg'bited and explained the light, and, in conclusion, introduced to the meeting the inventor, Mr. Otto Fahnehjelm, of Sweden. Mr. Fahnehjelm spoke briefly, giving additional particulars as to the light.

Professor Thomas Egleston, from the Committee on Uniform Tests,* reported progress.

Dr. R. W. Raymond, from the Holley Memorial Committee,† reported progress, and exhibited a plaster model of a proposed memorial to be erected in Central Park, New York city. This design though favorably considered by the sub-committee having charge of the subject, had not been definitely adopted.

President Bayles appointed as scrutineers Messrs. J. F. Holloway and Martin Coryell.

The second session was held on Wednesday morning, February 18th, at the Stevens's Institute of Technology, Hoboken, N. J., when the following papers were read and discussed :

The Cost of Gold Mining and Milling in Nova Scotia, by Willard Ide Pierce, New York city.

Fuel Economy in Engines and Boilers, by P. Barnes, New York city.

Source and Behavior of Fire-Gas in the Johnstown Mines, by John Fulton, Johnstown, Pa.

Use of High Explosives in the Blast-furnace, and of Water.

Spray for Cooling in Blowing-Down, by W. J. Taylor, Chester, N.J.

A New Regenerative Hot-Blast Oven, by J. C. Long, Mechanicsburg, Pa.

The third session was held on Wednesday evening, February 18th, at the Hall of the Academy of Medicine, when the following papers were read and discussed :

The Clapp & Griffith Process, by J. P. Witherow, Pittsburgh. Pa.

The Clapp & Griffith Process, by Robert W. Hunt, Troy, N. Y.

Tin-Ore-Deposits of the Black Hills of Dakota, by W. P. Blake. New Haven, Conn.

Note on Tantalite and Columbite in the Black Hills of Dako?? by W. P. Blake, New Haven, Conn. (These two papers were read by title in the absence of the author.)

E. N. Riotte, New York city, gave a verbal account of the Eas tin-mine of Dakota, illustrating it upon the blackboard, and cxhit-

* *Transactions,* vol. xii., p 460. † Ibid., vol. x., p. 239.

iting large and numerous samples of rock and ore, etc., and photographs. An interesting discussion followed, in which Mr. Gilbert E. Bailey, manager of the mine, took part.

. The fourth and concluding session was held on Friday morning, February 20th, at the Columbia College School of Mines.

The following gentlemen, proposed for election as members and associates and recommended by the Council, were elected:

MEMBERS.

Bacon, C. A.,............................Care H. T. King & Co., Cornbill, London.
Bell, Dr. Robert, ... Ottawa, Canada.
Bunning, Charles Z., ... Warora. Central Provinces, India,
. Clark, E. A. S., ...Sharpsburg, Pa.
Cone, John J.,.... ....618½ *Jersey* Avenue, Jersey City, N. J.
De Camp, Edward F.,.............. 43 Exchange Place, N, Y. City.
Elliott, M. P.,............................Crystal City, Mo.
Eyre, Thomas T., ...Carlisle, Grant County, New Mexico.
Fouear, Edouard L.,..................El Paso, Texas.
Freeland, Francis T. ....Denver, Col,
Frink, George S., ... Irondale, Duchess County, N. Y.
Gay, Harry S. ....Wilkesbarre, Pa.
Gross, Louis N., ...Deadwood, Dak.
Hahn, Albert G.C., ... 64 Perry Street, N. Y. City.
Hotchkiss, John,..............................30 Platt Street, N. Y. City.
Humphreys Alexander C, ...Bergen Point, X. J.
Humphreys, Charles,................Carlisle, Grant County, New Mexico.
Janin, Alexis....................................610 Hyde Street, San Francisco, Cal.
Kebler, Julian A.,.................... Ottumwa, Iowa.
Krom, Stephen R,,....................93 Washington Street, N. Y. City.
Lütseher, Gandenz,- ....Cleveland, O.
Luttgen, Eberhard,...................Catasauqua, Pa.
McCay, Dr. L. W.,....................Princeton, N. J.
McGenniss, I. W., Jr.,...............Chicago, III.
MacTeague, J. J.,.......................Socorro, New Mexico.
Neale, George F.,.................... Crystal City, Mo.
Newberry, W. E., ...Copperopolis, Arizona.
Nye, Harold B.,..........................Bellaire, O.
Peters, Edward D., Jr., ... Butte City, Montana.
Price, E. A. ....Casa Granda, Arizona.
Price, Thomas ....624 Sacramento Street, San Francisco, Cal.
Reuleaux, Jules, ...1411 Thompson Street, Philadelphia, Pa.
Robertson, David, ...Dagus Mines, Pa.
Sheaffer, S. Taylor, ...Fairmount City, Pa.
Small, George W., ...Oconomowoc, Wis.
Steyern, Baltzar von,.................Falun, Sweden.
Stillman, Thomas B., ...Stevens' Institute, Hoboken, N. J.
Wagner, E. C,..................................Girardville, Pa.

Webb, H. H.	405 Front Street, San Francisco, Cal.
Weitzel, Richard S.,	Logan, O.
Whiting, Henry A.,	1425 Pacific Street, Brooklyn, X. Y.
Woliston, R. T	Deadwood, Dakota.
Worthington, Charles C,	145 Broadway, N. Y. City.
Wurgler, A.,	7 Rue Viète, Paris, France..

ASSOCIATES.

, N. Y. Amy, Ernest J. H	18 W. Twenty-seventh Street, N. Y. City.
Bemis, Frederick P.,	138 E. Fiftieth Street, X. Y. City.
Delahaye, Fernand H.,	3 Avenue de PObservatoire, Paris, France.
Dwiglit, Arthur S.,	1S3 Prospect Place, Brooklyn, N. Y.
Enunons, Arthur B.,	Newport, R. I.
Hildreth, Russel W.,	25 Madison Avenue, N. Y. City.
Huntington, F. W	School of MinesCity.
Lacombe, Charles F.,	81 Cliuton Place, X. Y City.
Lee, George B	2039 Seventh Avenue, N Y. City.
Marie". Leon	48 W. Nineteenth Street, N. Y. City.
Merrill, Frederick J. H,	26 E. Sixtieth Street, N. Y. City.
Nave. Felix	Éeole des Mines, Paris, France.
Norris, Robert Van A.,	School of Mines, N. Y. City.
Robinson, Neil,	Coalburg, \V. Va.
Sanders, Wilbur E	Helena, Montana.
Smythe, A. E.,	7 Nassau Street, N. Y. City.

The status of **the** following associates was changed to membership :

C. H. Gibson.	Philip S. Morse.
Charles W. Miller.	John I. Northrop.

The following papers were then read and discussed :

The Removal of Obstructions from Blast-Furnace-Heartlis ami Boshes, by T. F. Witherbee, Port Henry, N. Y.

A Water-Gas Open-Hearth Furnace, by N. Lilienberg, New York City.

A Bessemer Converter-House without a Casting-Pit, by L. G. Laureau, New York City.

Prof. Thomas Egleston announced the tidings, just reccived, of the death at Paris, on the first day of February, of Mr. Sidney Gilchrist Thomas, of London, a distinguished member of the I use tute, not only professionally known to all as the inventor of the basic Bessemer process, but also personally endeared to many of American fellow-members.

George W. Maynard, New York City, formerly associated with Mr. Thomas, followed, with appropriate remarks, and was requested by the President to prepare a biographical notice for the *Transactions* of the Institute, to be published with the papers of the present meeting.

The following papers were then read by title:

A New System of Ore-Sampling, by D. W. Brunton, Denver, Col.

The Iron-Ore Range of the Santiago District of Cuba, by J. P. Kimball, Bethlehem, Pa.

Notes on the Treatment of Nickel- and Cobalt-Mattes at Mine la Motte, by James M. Neill, Mine la Motte, Mo.

The Patience of Copper and Silver, as Affected by Annealing, by H. M. Howe, Boston, Mass.

Hematite of Franklin County, Vt., by Alfred F. Brainerd, St. Alban's, Vt.

Combined Concentration and Amalgamation of Silver-Ores, by Walter, McDermott, New York City.

Note on the Occurrence of Nickel and Cobalt in Nevada, by A. D. Hodges, Jr., Roxbury, Mass.

A Theory to Explain the Cause of Hard Centers in Steel Ingots, by R. Gatewood, Washington, D. C.

Certain Interesting Crystalline Alloys, by Richard Pearce, Denver, Col.

The La Plata Mountains, Col., by H. C. Freeman, Alto Pass, III.

The Secretary read the following:

REPORT OF THE COUNCIL.

In accordance with the rules, the Council makes the following Report to the Institute.

The financial statement of the Secretary and Treasurer, duly audited, shows receipts for the year from all sources of $19,052.36, and expenditures of $17,384.47, leaving a surplus of $1667.89. In addition to this, the Treasurer holds U. S. bonds belonging to the Institute as follows: 4 per cent. bonds, $900 par value; 4½ per cent. bonds, $4400 par value, total $5300; present market value, say, $6026.

Since the balance from the last annualstatement was $3711.96, the actual receipts of the year were §2044.07 less than the expenditures.

The detailed statement is as follows :

Statement of the Secretary and Treasurer, of Receipts and Disbursements, from February 1st, 1884, to *January* 31st, 18S5.

DR.

Balance from last statement,	$3,711 96	
Received for dues from members and associates,	12,223 55	
Received for life-membership,	1,200 00	
" sale of publications,	740 67	
" binding *Transactions* and Index,	427 25	
" authors' pamphlets,	304 58	
" electrotypes,	61 80	
" portraits of Holley,	39 00	
" desk and chairs sold,	20 00	
" copying-press sold,	6 00	
" engraving, etc.,	25 05	
" postage and exchange,	1 06	
" intereston U.S. bonds, $234 00		
" interest on deposit, 57 44		
	291 44	
		$19,052 36

CR.

Paid for printing vol. xii. *Transactions,*	52,063 09
" binding vol. xii. *Transactions,*	656 05
" printing Index,	538 63
" binding Index,	263 20
" printing Holly Memorial volume,.	463 00
" binding Holly Memorial volume,.	292 26
" printing pamphlet editions of papers,.	2 442 09
" printing anthors' editions of papers,	328 00
" " list of members,	30 00
" " mailing-list,	19 50
" " circulars, ballots, etc.,	118 93
" binding miscellaneous volumes,	110 10
" " exchanges,	138 08
" engraving and electrotyping,,	1,936 70
" stationery (including post-paid envelopes),	371 58
" postage,	1,553 35
" travelling expenses, mailing books and pamphlets,	80 35
" advertising,	2 75
" moving furniture, etc., to new office,	30 45
" fitting up new office,	218 14

Paid for small expenditures in office (unclassified),	$33 37
" janitor's fees	38 50
" rent of office,	150 00
" freight, express-charges and duty,	168 05
" telegraphing,	18 25
" purchase of *Transactions*,	9 00
" storage of *Transactions* (1884),	154 79
" artotypes of Holley,	10S 50
" bank-note plate-paper,	625 00
" storage for *Transactions* (adv. for 1885)	113 40
" salaries of Secretaries and three assistants	3,794 50
" extra clerical labor in preparing Index to vol. xii.,	25 00
" expenses of Secretary and assistant at meetings,	491 86
	$17,384 47
Balance,	$1,667 89

The expenditures stated above include the cost of two extra publications, the Index to Vols. I.-X. and the Holley Memorial. The cost of the former was: for printing, §538.63, for binding §263.20, for distribution, about §100*, making a total of, say, §900. The cost of the latter was: for printing, §463.00, for binding, §292.26, for frontispiece portrait, $92.50, for distribution, about §150.00; total, say §997. These two volumes, therefore, distributed to members free of charge, in addition to the regular publications, represent an expenditure of $1897. It should be added that a considerable number of copies of each is still on hand, and that sales are frequently made. Moreover, the Index-volume, by rendering the first en volumes of the *Transactions* readily available for reference, stimulates the demand for back volumes, and thus increases the income of the Institute. Both of these books have been received by the members and associates with unanimous satisfaction.

Attention is also called to two items, which properly relate to the next year's expenses, namely, the payment of $113.40 storage for 1885 in advance, and the purchase at the cost of §625 of a lot of bank-note paper, specially manufactured for the Institute, and intended for the plates of the next volume. The large and increas-

* A rough calculation of the postage on the book and the accompanying letters of notification. The item of binding is chiefly the binding in paper covers and the topping for the mail, for which no charge was made to members.

ing stock of back-volumes of the *Transactions,* formerly kept in two parts (for greater safety) in private houses in Easton, is now stored in the fire-proof building of the Manhattan Warehouse Co., Lexington Avenue, between 41st and 42d St., New York City, and by payment for a year in advance, a favorable rate has been obtained. The substitution in the annual volume of a superior quality of paper for plates is an experiment, the success of which must be determined when that volume (now more than half printed) makes its appearance. It is believed that the result will justify the increased cost. To obtain the quality and size required, it was necessary to order from the makers the amount purchased, which is considerably more than the next volume will require. This paper has been used in some cases on authors' special editions, but not on tie regular pamphlet editions of papers. The two items here mentioned as belonging properly to the future, amount to §738.40.

The expenses of moving the books, etc., of the Institute from Easton to New York, and of fitting up the New York office amount directly to $211.89, besides a large number of small items, indirectly occasioned by that removal, but not charged to that account.

The postage-account, which was, year before last, $765.60, fell last year to §572.G0, and is this year §1553.35. The explanation is in part, that the postage on Volume XI. of the *Transactions,* amounting to about §300, was paid this year (the volume having been distributed in January and February, 1884) as well as the postage on Volume XII., distributed in November and December, l881. Moreover, there have been distributed to members during this year eight packages of pamphlets as against four in the preceding year, the increased postage due to this item being about $360.

The same engravers and printers having been employed, and at the same rates this year as last, the large increase in the items of printing and engraving is due to a corresponding increase in the quantity of work done. An examination of Vol. XII., which contains 182 more pages and many more illustrations than Vol. XI., will account for a part of this difference. But another important cause is the advance which has been effected in the time of publication of the annual volume. By extraordinary exertions Vol. XII, was brought out some three months earlier than its predecc???, and the work of engraving and printing on Vol. XIII. is now for in advance of that on Vol. XII. at the corresponding period of lsst It is hoped that through the cordial co-operation of the authors of papers, Vol. XIII. may be issued some time next summer. Evidently the great gain thus effected has thrown an unusual amount of printing and engraving into the accounts of this year. Without discussing details at wearisome length, it may be roughly estimated that the extra expenditure of the present year due to acceleration of publication has been §1200.

Recapitulating the items of extraordinary outlay in the foregoing accounts, not connected with the natural increase of the expenses through the growth of the Institute and consequent increase of editions, postage, clerical labor, storage, etc., we have:

Extra publications presented to members,	$1897.00
Purchases and payments for next year,	738.40
Cost of moving office to New York,	211.89
Postage properly belonging to last year,	300.00
Extra printing and engraving due to acceleration of publication,	1200.00
Extra postage due to the same cause,	360.00
Giving a total of	$4707.29

or $2663.22 more than the apparent excess of expenditures over receipts as stated above.

Three meetings have been held during the year: the annual (xxxviiith) meeting in Cincinnati, a May meeting in Chicago, and a September meeting in Philadelphia. They were, as usual, professionally successful and socially delightful.

The changes in membership since the last annual report have been as follows:

Two honorary members, 146 members, and 33 associates have been elected and have accepted their election; 7 members and 1 associate elected before the last report, have accepted since that time; 7 associates have been made members ; 23 members and 9 associates have resigned ; 49 members and 13 associates have been dropped; the list of "foreign members " has been diminished by the election of Prof. Richter to honorary membership; and the list of members has been likewise diminished by the similar transfer of the name of Dr. Drown.

The list of deaths comprises one foreign member, Mr. J. R. Priest (whose death, which occurred in 1880, was not reported to the Secretary until 1884), 13 members, D. R. Davidson, Thomas Dickson, Anton Fernekes, C. C. Hussey, E. K. Hyndman, S. W. Ingersoll, John Leisenring, William Lorenz, Isaac Newton, R. H. Rickard, H. S. Stirling, T. E. Sickles, Benjamin Silliman, J. M. Stinson, and Sidney Gilchrist Thomas; 4 associates, David McKee, W. S. Mackintosh, P. E. Phillips, and L. E. Warner. Of these, the death of Mr. Stirling occurred in 1882 but was not reported.

These changes are tabulated as follows :

	Hon. M	For. M.	M	A	TOTALS.	
At date of last report,	3	50	1134	154	1341	
GAINS--By election during year,	2		146	33	1S1	
By acceptance of previous elect'n,			7	1		
By change of status of associates,			7		7	
LOSSES--By resignation,			23	9		32
By dropping from roll,			49	13		62
By change of status,		1	1	7		9
By deaths reported,		1	14	5		20
Total gains,	2		160	34	196	
Total losses		2	87	34		123
Present membership	5	48	1207	154	414	

The comparatively large number of resignations and of names dropped by the Council is the result of a strict revision of the list, and a personal correspondence on the part of the Secretary with members and associates in arrears, when their addresses could be obtained. When this was not possible, the names were dropped without further notice. In the exercise of the discretion authorized by Rule iii., it has always been the practice of the Council to show great leniency to worthy members and associates who signified their desire to continue and their intention to pay their dues. Novolome is ever sent to those in arrears for the year in which the volume was published; but the pamphlet edition of papers and the circulars from the Secretary's office are sent for one year at least, and have often been sent for two years, to members and associates in arrears. The wisdom of such liberality has been amply proved by the frequent receipt of arrears in full from members and associates, who, by reason of long absence in foreign countries, or by oversight, or through temporary financial embarrassment, had omitted their regular payment. But a careful scrutiny of the whole list led to the belief that in some cases this liberality was abused, and persons who did seriously expect to pay their dues were continuing to receive phlets and circulars without protest. Personal correspondence accom. plished in most instances what printed circulars had failed to do; and the result is shown in the resignations and names dropped, shown in the above table. It is believed that no injustice has committed; but the way is open for any who desire to return by payment of arrears and upon satisfactory explanation to the Council. The Institute is so large and strong that it needs no support from mere names which do not represent members caring enough for their connection with it to pay with reasonable promptness their proportion of its expenses, and to keep the Secretary advised of their addresses. Moreover, the increasing labor and expense involved in distributing publications to so large a membership should be more strictly confined to those who show that they appreciate the benefits conferred by the Institute upon its members and associates.

The Scrutincers appointed at the first session of the meeting reported the following officers as elected:

PRESIDENT.

JAMES C. BAYLES,	New York City.

VICE-PRESIDENTS.

(To serve for two years.)

JOHN FULTON ..	Johnstown, Pa.
RICHARD PEARCE,	Denver, Col.
C. A STETEFELDT,	New York City.

MANAGERS.

(To serve for three years.)

C. A. ASHBURNER,	Hiladelphia, Pa.
W. E. C. CONE,	Heading, Pa.
E. GYBBOX SPILSBURY,	Haile Mine, S. C.

TREASURER.

THEODORE D. RAND,	Philadelphia, Pa.

SECRETARY.

R. W. RAYMOND,	New York City.

On motion of J. D. Weeks, of Pittsburgh, Pa., duly seconded, **the** following resolution was adopted :

Resolved, That the Secretary be and is hereby directed to express the thanks of the Institute to the resident members, and to all persons, firms, societies, and corporations to whom such acknowledgment is due, for the courtesies extended to visiting members and guests, and particularly to the Local Committee for its faithfol and successful labors in the arrangement of this meeting.

The President then declared the meeting adjourned.

EXCURSIONS AND ENTERTAINMENTS.

Cordial invitations were received as follows, and were accepted by such of the members as were desirous of visiting the different places named :

From the American Society of Civil Engineers, to visit and make use of its rooms in the city.

From the New York Steam Company, to visit its "Station B," in Greenwich Street, near Cortlandt. This station is designed to contain 16,000 horse-power of boilers in four stories, with a loft above for the storage of coal. The building has been roofed in temporarily below the final elevation, and now contains boilers of 8750 horse-power, arranged principally in the second and third stories. Specimens of the special apparatus of the company were on exhibition on the first floor of the building; also some of the maps, showing the extent of the work and the obstructions encountered during its progress. Mr. Charles E. Emery, engineer and superintendent of the company, accompanied parties of visitors during Wednesday and Friday afternoons.

From Messrs. McDermott & Duffield, to visit their New York ore-milling and testing; works, No. 528 West Sixteenth Street. The machinery at these works is managed with a view to accurate working on a small scale for experimental purposes.

From Messrs. Poulson & Eger, to visit the warerooms in Twenty-third Street, of their Hecla iron works, and also the works themselves, at North Third and Eleventh Streets, Brooklyn, E. D. At these works the Bower-Barff rustless process is applied to east-iron, and very interesting and beautiful architectural and decorative iron work is done. Visitors were conducted by Professor George W • Maynard.

From the Joseph Dixon Crucible Company, to visit its works at Jersey City, N. J. At these works crucibles, lead-pencils, and other products of plumbago are manufactured on an extensive scale. Mr. John A. Walker took charge of visiting parties.

From Mr. T. C. Clarke, to inspect the New York and Brooklyn bridge, including the machinery of traction, etc.

From Mr. E. W. Bliss, to visit his extensive establishment, Adams Street, Brooklyn, for the manufacture of special machinery.

From Messrs. Ledoux & Ricketts, to visit their chemical and metallurgical laboratory, No. 10 Cedar Street.

From Messrs. Tiffany & Co., to visit their establishment in Union Square, and particularly to inspect the large and unique collection of rough diamonds on exhibition there.

From Mr. George S. Dwight, agent of Mr. Otto Fahnehjclm, to inspect the Fahnehjclm water-gas incandescent light, at the works of the Municipal Gas Company.

From Mr. P. H. Dudley, to inspect his track-inspection car, at the Grand Central Depot.

From Lieutenant G. McC. Derby, to visit and examine the difficult, interesting, and important work under his charge, the excavations at Flood Rock, under the East River, carried on by the United States Government, preparatory to blowing up the last great obstruction to the navigation of Hell-Gate. Large excursion parties were conducted to this point on Wednesday and Friday afternoons by Mr. James F. Lewis.

In addition to the foregoing, a general excursion was made to the Tilly Foster iron-mine of the Lackawanna Iron and Coal Company, near Brewster's station on the New York and Northern Railroad. A special train, provided by the Local Committee, left the depot of this road, in One Hundred and Fifty-fifth Street, at 10 o'clock on Thursday morning. At the mine the large party was entertained at luncheon by the Lackawanna Iron and Coal Company, and as many as desired were conducted into the mine, where Mr. Andrew Cosgriff, the superintendent, exhibited and explained the novel method here employed, of using concrete pillars to support the walls of the large deposit where the ore has been removed. The excursion returned barely in time to permit members and ladies to attend the subscription dinner, which took place at Delmonico's on Thursday evening, and at which the company numbered about 175, more than 70 being ladies.

At the close of the session at the Stevens Institute, on Friday morning, the numerous members present were entertained at luncheon by President and Mrs. Morton ; and, on Friday evening, the crowning social enjoyment of the week was provided in a reception by Hon. and Mrs. Edward Cooper, at their residence, No. 12 Washington Square, North, where a company was gathered which would have crowded a less spacious mansion, and which comprised the leading civil and military engineers, professors and scientific and literary men of New York, as well as many ladies of the city, invited to meet the visiting members and ladies of the Institute.

MEMBERS AND ASSOCIATES PRESENT.

The following members, associates, and guests registered their names at the headquarters of the Local Committee:

A. V. Abbott.
Charles A. Ashburner.
W. S Ayres.
G. E. Bailey.
S. W. Baldwin.
P. Barnes.
A. 8. Bartolet.
J. C. Bayles.
Alfred L. Beebe.
Frederick P. Bemis.
John Birkinbine.
Charles P. Bleecker.
John Bogart.
Jerome L. Boyer.
V. M. Braschi.
H. W. Buckley.
Robert Bunsen.
William Burnham.
Charles Butters.
I. P. Carson.
J. Clemente Castro.
H. M. Chance.
A. H. Childs.
A. D. Churchill.
F. Collingwood.
C. Constable.
Martin Coryell.
J. L. Cunningham.
Gram Curtis.
Floyd Davis.
E. V. D'Invilliers.
W. F. Downe.
T. M. Drown.
P. H. Dudley.
W. F. Durfee.
A. S. Dwight.
E. H. Earnshaw.
Thomas Egleston.
A. Eilers.
B. F. Emerson.
Charles E. Emery.
John D. Evans.
R. Forsyth.
H. Van F. Furman.
Albin Garrett.
William Garrett.
F. L. Garrison.
Richard George.
J. L.Gill, Jr.
Austin G. Gorham. *
A. G. C. Halm.
C. H. Henderson.
G. C. Hewett.
H. D. Hibbard.
L. Holbrook.
I. F. Holloway.
W. A. Hooker.
H. M. Howe.
Robert W. Hunt.
T. Sterry Hunt.
A. D. Ihlseng.
E. P. Jennings.
W. H. Jennings.
B. F. Jones.
C. H. Jouet.
Hugh Kennedy.
J. Kennedy.
William Kent.
Max Kinkead.
C. Kirchhoff, Jr.
J. M. Knap.
W. B. Kunhardt.
L. G. Laurean.
B. B. Lawrence.
George B. Lee.
A. E. Lehmann.
James F. Lewis.
N. Lilienberg.
Stuart Lindsley.
E. F. Loisean.
John C. Long.
E. V. McCandless.
Walter McDermott.
S. W. McKeown.
Charles Macdonald.
J. B. Mackintosh.
C. A. Marshall.
J. A. Mathieu.

George W. Maynard.
E. Mickley.
Charles W. Miller.
George F. Milliken.
Philip W. Moen.
H. S. Munroe.
George S. Morison.
S. F. Morris.
A. J. Moses.
Knight Neftel.
R. Van .A. Norris.
George Ormrod.
I. P. Pardee.
W. I. Pierce.
J. C. Platt, Jr.
R. W. Raymond.
J. M. Rich.
Ellen H. Richards.
.R. H. Richards.
J. H. Ricketson.
George W. Riggs.
E. X. Riotte.
Kenneth Robertson.
R. P. Rothwell.
William S. Saunders.
E. J. Schmitz.
William B. Shinn.
A. T. Shoemaker.
Oberlin Smith.
John C. Smock.
A. E. Smyth.
A. Spies.
\V. F. Staunton.
C. A. Stelefeldt.
Edward G. Stoiber.
George C. Stone.
Victor O. Strobel.
W. J. Taylor.
George E. Thackray.
Edwin Thomas.
Herbert G. Torrey.
W. W. Van Voorhes.
J. A. Walker.
Joseph D. Weeks.
R. S. Weitzel.
John Wilkes.
David Williams.
Frederick H. Williams.
S. T. Williams.
T. F. Witherbee.
J. P. Witherow.

PAPERS

OF THE

XLIst (NEW YORK) MEETING.

FEBRUARY, 1885.

TEE IRON-ORE RANGE OF THE SANTIAGO DISTRICT OF CUBA.

BY JAMES P. KIMBALL, LEHIGH UNIVERSITY, BETHLEHEM, PA.

THE south slope of the Sierra Maestra, which, east of the Bay of Santiago, forms the coast range of the Island of Cuba, is for a distance at least of some thirty miles east of the bay, made up of eruptive syenite, covered with a massive overflow of trap (epidotic diorite). This has reached the surface through innumerable dykes.

The serrated crest of the range, within these limits, appears at a distance to be uniformly denuded of diorite, as are also the foot-hills at the coast directly in front. Farther east the range, as viewed from the sea, exhibits a topography characteristic of a trappean surface from summit to base.

Within the same limits the immediate coast is emerged coral-reef, reposing directly on the syenite.

The Bay of Santiago corresponds to an original indentation of the coast. It is excavated from coralline, of which three terraces are preserved. These mark successive elevations of the coast range. Their combined thickness is over 300 feet above tide. The third terrace, forming the present or immediate shore, like the two elevated terraces from which the shore-line has advanced, is precipitous and practically vertical, from the undermining action of the waves.

As will presently be shown, geological traces are afforded of the former existence of corallines still further back from the coast. These were in remote but direct succession with the subsequent uplifts as marked by the still existing terraces. Intervening corallines may have disappeared from the intermediate belt of syenite hills by erosion, to which the minor topography of the range is wholly due.

The trappean belt reaches a thickness which I estimate to be not less than 2000 feet on the slope of the Sierra, and a height of some 3500 feet. As it declines from this elevation toward the sea it likewise thins off. Thus the upper part of the south slope is an enormous mantle of diorite resting on the syenitic body and base of the range.

The Juragna Hills, so-called, are the culmination of the foot-hills of the Sierra between the bays of Santiago on the west and of Guantanamo on the east. They constitute an alpine body of hills, distinguished from the massive body of the Sierra Maestra by their isolation as four distinct parallel ranges, successively declining in elevation with the general slope toward the sea.

The summits of the first or upper isolated range of the Juragna Hills, reaching an elevation of some 2000 feet above the sea, are mainly eroded from the dioritic mantle down to the syenite, which first makes its appearance at their lower or southern base.

The hills of the second distinct range of the same body are covered with a reduced thickness of the same trappean rock, but these are eroded well into the syenite.

It will be shown that this range, as compared with the only other iron-ore bearing range, namely, *the first,* presents the more favorable conditions both for the original development of iron-ore bodies and for their preservation.

A further east and west extension of the iron-ore bodies of the Juragua Hills is seen to have once been a pronounced feature--es pecially of the second range. Toward the west these have survived the general erosion only as remnants. This is also the case with the hills
hills themselves which they flanked. These fall off very rapidly in size from the culmination of the Juragua Hills. Thus increase tie-destructive effects of erosion in both directions along this range, until stayed by structural changes in the Sierra Maestra, which it is needless here to describe. The Lola and Berraco bills to the eastward, both containing undeveloped ore-bodies, are an extension' the second range under the changed structural conditions referred to. So too, still farther east, with the ore-hills of Sigua, which I have observed only from a distance.

The third and fourth ranges of low hills of the Juragua group and completely denuded of diorite, if indeed, as seems doubtful, they were ever covered with it. These form the syenitic coast-margin conspicuous features of which are the very numerous dykes of highly epidotic diorite.

This trappean rock, so largely developed upon the flunk of the Sierra, may be supposed to be the present form of an originally more basic material from which large volumes of ferric oxide. have been separated by metasomatism (weathering). The large mass?? specular ore found along the first and second ranges of foot-hill can correspond only to a small proportion of the ferric oxide which. together with other mineral matter, has been eliminated by chemi?? forces from the original igneous magma.

The unequal development of the iron-ores of these two ranges of foot-hills points to unequally favorable conditions for the separation, concentration and preservation of the ferric oxide.

The second range of hills, as above remarked, affords altogether the best type of ore-bodies. This, type is well exhibited in the so-called East Mine and West Mine hills of the Juragua Iron Company, Limited.. The diorite of these hills, reduced in thickness as it falls away toward the coast, is in contact along this range with the syenite. This contact, therefore, seems to have become the seat of great chemical activity--especially through the action of alkaline carbonates from the feldspar of both rocks in process of weathering.

Second or Lower Iron-Ore Belt.

The large bodies of hematite or specular oxide, together with associated ferruginous aggregates--in part of magnetic oxide, are secondary products from the decomposition of basic eruptive rocks, now represented by the epidotic diorite which has penetrated and overflowed the syenitic base of this part of the Sierra Maestra. They are the result of the alteration or epigenesis of highly basic, and therefore unstable, roek-aggregates, and of their resolution into new aggregates with the aid of surface-agencies, in subordination to the new conditions met with at and near the surface. Thus the presence of oxygen in atmospheric air, and of alkaline and earthy bicarbonates from decomposing silicates, has rendered unstable the highly ferriferous material from deep-seated sources. These aggregates were basic from excess of protoxide bases, and especially protoxide of iron. Such eruptive material cannot long resist further oxidation at the surface, with the result of more or less complete disintegration of the original aggregate, and its recomposition into new compounds. This process of permutation is known as weathering* (metasomatism). Many of the commonest phenomena of mineral veins are of this nature, and all rock-masses exhibit the same on a greater or less scale. The phenomena of mineral pseudomorphism and rock-metamorphism are of the same general class.

To be more specific, the eruptive material which gave origin to the iron-ore consisted of proto-silicates, or silica combined with the protoxide bases, iron, lime and magnesia, and with alumina. Under its new conditions at the surface, with access to oxygen in the atmos-

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Weathering is here used in the broad sense of the term *Verwitterung,* as defined Roth *(Chcmische Geologic,* I., 2).

phere and in circulating waters, and in contact with bicarbonates of the alkalies and of alkaline earths (also circulating in meteoric waters and derived in part from itself, but especially furnished in large proportion by still more feldspathic material like syenite in the process of weathering) the protoxide of iron became rapidly further oxidized into ferric or sesqui-oxide, which is a comparatively stable product under conditions prevailing at the surface. The oxidation of the ferrous to ferric oxide is attended with more or less complete dismemberment of the eruptive rock little by little. Silica originally combined with the ferrous oxide is isolated as silica. Silicates of lime, magnesia and alumina, being more stable, form new aggregates among themselves, in part according to atomic proportions. Soluble material as fast as isolated enters into solution in circulating waters, and is thus at hand to assist in the work of weathering. This work of alteration has gone on till a complete change has been wrought not only in the composition but also in the arrangement of the original eruptive rock. By the law of molecular attraction a process of concentration has gone on simultancously with the process of weathering decay. Homogeneous material, such as ferric oxide, has collected by itself to a degree far greater than the other earthy residues, because in the process of conversion from ferrous to ferric oxide it has been in solution, and so in circulation, and hence becomes finally deposited under long prevailing conditions of uniform circulation. The process here briefly followed out has gone on, not *on* the surface but *below,* within the range of circulating waters. The same action at the surface is followed l>y waste or diffusion of the products of alteration. This is the partial explanation of the occurrence of the ferric oxide in defined positions so as to finally constitute ore-bodies. This explanation will be completed by the following very important observation :

The best of the iron-ore bodies, including those of the East Minc, and the developed ore-bodies of West Mine, hills, are mainly, if not indeed wholly, replacements of coralline limestone.

A second and different class of ore-bodies will remain presently to be described.

The eruptive overflow, which probably took place in part below the sea level, involved masses of littoral coralline limestone and of coral reef. The final elevation of the Sierra Maestra was a subsequent event. It is these masses of coralline limestone which, in several instances of the better class of iron-ore bodies, including those of the Estancia location, as well as of East Mine and West Mine hills, have become replaced by a highly concentrated ferric or specular oxide. Thus the outlines of such ore-bodies, as well as their dimensions, correspond in the main to those of the original limestone masses. Hence the great difference in size and attitude, and many of the irregularities of all the ore-bodies appertaining to this class.

The replacement of limestone by ferric oxide is well understood as a not uncommon mode of origin of several familiar types of iron-ore deposits.

The process of replacement referred to may be briefly explained as follows:

Meteoric water circulating within the superficial or weathering zone of rock, takes up enough carbonic acid from the atmosphere, and under other favorable circumstances also sulphuric acid from the oxidation of pyrite, to impart to it solvent effects, especially in its action upon limestone. Coralline limestone, before consolidation and induration from crystallization, yields most readily to such solvents. As particle by particle enters into solution, its place is taken by any available substance in the process of precipitation from the same water, or from intermittent sources of water. In the case in hand, lime becomes dissolved in the same water that has taken up ferrous oxide as a bicarbonate, and that is precipitating ferric oxide. In other words, water dissolving lime as a bicarbonate has from a neighboring source taken up protoxide of iron, likewise as a bicarbonate, but which is rapidly precipitated as ferric oxide (by peroxidation), this oxide being an insoluble one. Or again, through the mediation of sulphuric acid, ferrous carbonate results from the reaction of ferrous sulphate upon limestone, and by exchanging acids and bases with other alkaline carbonates also upon dioritic and syenitic rocks which supply these carbonates, including carbonate of magnesia. Or, still farther, carbonic acid along with ferrous sulphide may follow from the reduction of ferrous sulphate by decaying organic matter. And so on through a round of permutations according to the adventitious composition of passing mineral waters.* Hence the process of replacement is a gradual one.

Proof of the replacement of coralline limestone is afforded by fragments of ore still retaining the structure of coral. Several such specimens are in my possession. These are sufficient to establish the truth of the mode of replacement referred to. Still better proof is afforded on the ground, as something of the radial structure charac-

., * See a paper by the present writer, these *Transactions,* viii., 213. Index to vols. i.-x. *{Errata),* 2.

teristic of coral is necessarily sacrificed to the trimming down of hand specimens to a convenient size.

Collateral proof of the truth of the general proposition, namely, that littoral coralline limestone and coral-reef have been involved in the vulcanisin of the iron-ore bearing range, is to be found in the presence, exclusively within the limits of the range, of highly crystalline limestones, or white marble, in isolated bodies correspouding in size and general attitude to certain ore-bodies already instanced.

It must be borne in mind that almost all limestones have their origin in coralline material, derived directly from the consolidation or induration of coral-reefs; or, to a far greater degree, from the accumulations on sea-bottoms of coralline sediments after comminution by the waves.

Why in some instances the coralline masses have become bodily indurated and crystallized into marble, while in others they have disappeared by dissolution and their place has been taken by specular oxide of iron, is to be explained by a difference in local circumstauces, of which at least the following are easily conceived.

1. A mass of coralline limestone situated at an elevation so that drainage would be away from it, would not be subject to the solvent effect of carbonated or other acidulated waters, except upon its surfaces. Such is the topographical situation of all the marble deposits known to me in the region.

2. The period of the crystallization of the calcareous or coralline material has doubtless in some eases governed the matter in question. If originally crystallized as one of the immediate effects of igneous contact, it would be in a state to resist solvent action of circulating waters except at its surfaces. The alteration of limestone into the crystalline form of marble is a common effect of vulcanism, whether of trap-dykes or other larger injections.

3. The condition of the coralline limestone when overflowed, whether emerged and therefore to some degree consolidated, or whether still of the nature of coral-reef, is a question of some moment in its bearing upon the differences to be observed among the several developments of limestone, and of the iron-ores. In other words, some of the points of difference suggest the probability that in some cases the coralline masses involved, were at least under water and parts of them still of the character of reef, when iuvolved in the igneous flood. The presence of orgauic life is indicated by the pyritous ore possessing the structure of corallum at the "north

shaft" (pit) of East mine, which is near the contact of one of the great ore-bodies with the syenite.

The limestone so far as at present known is completely obliterated in the case of the development of large ore-bodies..

Nor have I met with it in the same hills with large bodies of iron-ore. Small exhibitions of float, usually of good quality, are generally found in their vicinity, but no ledges of ore nor heavy float indicative of outcrops. The presence of limestone seems to be incompatible with the presence of considerable bodies of iron-ore. At Berraeo only, have I observed any crystalline limestone in the same hill along with considerable bodies of iron-ore. In this instance the limestone was found simply as a fragment, probably from a concealed ledge high up the hill; or, what seems to me still more probable, from a former ledge so situated, and now obliterated by the degradation of the hill. This probability follows from the fact of the situation near the summit of the. higher hills of all such bodies of limestone that I have met with.

The iron-ore bodies of the alpine district east of Santiago, are exceptional, from the fact that they are attributable to the *immediate* alteration of eruptive rocks, and that resulting residues, including an important portion of their original ferriferous contents, have been preserved almost *in situ.*

The other great bodies of ferric oxide in North America, like the Huronian deposits of Michigan and Wisconsin, are similarly derived from the decomposition of highly but less basic rocks of *metamorphic,* and not of direct eruptive origin. Such stratified specular iron-ore bodies are believed to owe their existence to the accumulation by precipitation of ferric oxide from basins of water receiving the drainage from such basic rocks. In the bottoms of hydrographical basins the ferric oxide is preserved in laminae and beds, along with the mechanical sediments (clay, sand and marl) corresponding to the insoluble parts of the same decomposing basic rocks. The source therefore of the Archean crystalline, or so-called primary, iron-ores, including most deposits of magnetite, was basic rocks comparatively poor in ferrous exide and rich in earthy silicates.

The Sierra Maestra ores, on the other hand, are derived without intermediate stages of development from basic silicated aggregates, particularly rich in ferrous oxide, an important proportion of which has been preserved as ferric oxide in places below the surface near its source, without ever reaching hydrographical channels of drainage. Under ordinary circumstances in past geological times, the same as universally observed at present, all but a comparatively minute proportion of ferrous oxide dissolved in circulating waters, or of sedimentary ferric oxide, must have been lost in the general drainage.

But for the presence of considerable bodies of soluble coralline limestone implicated in the littoral igneous flow, no such preservation of the ferric oxide as has taken place could under the past or present topographical conditions of the Sierra Maestra range have occurred. The related hydrographical conditions must always have been against the local accumulation or preservation of fine detritus of any kind in its water-channels, while no basins upon its slope can ever have existed. The southern slope conies down to the sea, the coralline coast-line having become advanced as successive elevations of the range have taken place.

The epigenesis of the iron-ore bodies of the Sierra Maestra, as above briefly sketched, is not without precedents in all but special features.

Perhaps the nearest familiar analogue to the phenomena above described, considered from a geological point of view, is the disintegration of the porphyries of Leadville, Colorado, and the local preservation of their insoluble residues, including ferric oxide of a high degree of concentration.

Parts of the well-known deposits of Pilot Knob and Iron Mountain in Missouri must, it seems to me, be referred to a similar origin.

The Huronian specular iron-ore bodies of the James River, Virginia, resemble the Sierra Maestra ore-bodies in point of derivation from neighboring rocks, but differ in their occurrence as a concentration of the ferric oxide, so derived, between divisional planes of stratification, as space has thus been provided by the shrinkage of the parent rook through loss of this and other soluble material.

A familiar example of the replacement of limestone by ferric oxide is afforded by the Clinton fossil-ore beds of the Upper Silurian of the United States as developed in the Middle and Southern States.

Still more numerous examples might be furnished of the segregation of ferric oxide as limonite and red hematite from rooks, in the gossans of mineral veins and in other classes of iron-ore deposits, all of which indeed, it may be said in general, are at least of secondary origin as products of decomposition from some less concentrated form of complex rock.

The irregularities which are thus far revealed by the few actual workings in the Sierra Maestra deposits are such as are not inconsistent with the explanation here given of their origin. The same may be said of their little regularity, so far as presented.

Of the nature of regularity may be considered the generally prevailing approximately east-and-west direction of the longer axe? of the separate ore-bodies. This, it seems to me, follows from the advance of the flow of the lava-sheet from the north in a line parallel to the coast, and the consequent overflow of the surface of corallines, between *playas* or mouths of streams. With the subsequent elevation of the chain, the inner edge of the coralline would naturally correspond to its upper edge in elevated positions.

Irregularities on the other hand are numerous. These are differences of size; of degree of erosion (or, *vice versa,* of preservation); of-topographical relations; and of quality. On all these points ranch remains to be proved by excavations, as explorations are continued, and as the workings of the Juragua Iron Company, Limited, are advanced.

The workings of this company alone are the only ones at present worthy of mention. Of the whole number of "mines" thus far discovered and denounced between Santiago and Berraco, some 18 miles in longitude to the east of that port, those alone of the Juragua Iron Company, Limited, have yet proved of immediate economic value or importance, especially when considered with reference to transportation within reasonable limits of practicability. The limits of the ore-range, as far as known, are Sigua at the east and Sevilla at the west, the longitudinal distance between these two points being some eighteen miles.

GENERAL QUALITY OF THE ORE.

The type of ore thus far described is physically characterized by a high degree of polarity and by the absence of cleavage. It occurs in all forms of red hematite, including micaceous, amorphous, granular, and sub-crystalline varieties. The last-named variety is commonly studded with minute crystals of magnetite and martite. Variations in the color of drillings, from red to black, imply unequal distribution of altered hematite or of unaltered magnetite, of water of hydration, and of manganic oxide. The dense and amorphous character of the ore precludes the recognition of pseudomorphic effects. As the earthy admixtures are mainly chloritic and epidotic, these ores are essentially basic, especially in comparison with other types of well-known speculars, like those of Lake Superior, whose jaspery intercalations render them more or less acid; or those of the James River, whose acid property springs from segregated quartz. Their proximate chemical constitution is partially shown by the following percentages:

Moisture,	0.24	0.81
Silica,	5.00	10.50
Iron,	61.00	68.5
Phosphorus,	0.009	0065
Sulphur,	0.045	0.248

Many grades of ore occur within the iron-range, including, besides those already described as complete replacements of limestone, other ferriferous combinations in great variety, but which fall below the grade of shipping ores. These are notably quartz aggregates contain. ing large proportions of iron in the form of magnetite, and garnet rock similarly charged with anhydrous ferric and magnetic oxides These ferruginous compounds are the metasomatic association which oxide of iron has formed when bodies of dissolving corallines. have not been at hand to receive ferric oxide from passing chalybeates. and to preserve them free from other extraneous mineral substances.

Such earthy impurities as were present in the coralline material when overflowed remain, in part, as impurities in the ore. Wide differences in quality of the ore are to be thus explained. difference in the quality of the original corallines is to be explained by the numerous sources of detritus from mountain streams discharging into the sea at intervals of every few miles as at present.

It will be proper to note here a point having an important ??? logical bearing, namely, that, in this part of the Sierra Macstra at least, the denudation has probably kept pace with its successive elevations. Feldspathic rocks, like diorite and syenite, which enter principally into its structure, especially yield to weathering action The effects of this are very pronounced on the whole southern slope as seen from the sea, the same as back of Santiago. The successive elevations, as above stated, are shown by successive terraces of emerged coralline, and by the occurrence so far inland, of remnants or fossils of coral, and of isolated bodies of crystalline limestone marble.

It is by the complete replacement of very pure coralline that from oxide of extraordinary purity is afforded by at least parts of every ore-body in the region whose relations may be traced to coralline It seems probable, too, that the best ore is through the replacement of masses of coral-reef as distinguished from coralline limestone; and that, on the other hand, some of the large deposits of impure ore correspond to the replacement of coralline of the latter class. This explanation seems the more probable from the fact that there proves to be in association with ore-bodies of this description a type of rock 'nowhere else seen in the region, which I take to be the altered form of sedimentary deposits locally associated with littoral corallines. These are especially seen at the Lola (west) and Berraco mines. They are soft quartzose but somewhat basic rocks, weathering rough, and with a ferruginous surface of brown oxide at the Lola, and of red oxide at Berraco.

. Another circumstance already referred to as supporting the above view, is the presence of sulphur in some of the ore freest from earthy impurities. This suggests the effect of organic, and especially of animal, matter. So far as has been observed within the present stage of development, there seems to be a decrease of pyrite, and also of copper salts (from copper pyrite), as the interior of ore-bodies is reached. This might be supposed to arise from the circumstances that the reducing power of organic matter would not survive its ultimate destruction, and that therefore this power would be exerted early in point of time and near the exterior 'of any coralline body.

SHAPE AND SIZE OF ORE-BODIES,

What is simply known as the weathering of rocks, embraces the phenomena above described. This process is the same whether in a rock upon the surface, or in a body of rocks in place. The process goes on from the surface in the measure of its exposure to weathering agencies. Surfaces are presented to weathering action underground in rock-masses by the various divisional planes which traverse them, and which practically separate a mass into blocks. In dense eruptive rocks joints and cleavage present even more dicisional surfaces of this kind than stratified rocks, in which they are likewise developed.

Weathering of a prismatic block, whether on the surface, or *in situ* goes on from the outside inward. The tendency of this action, then attended by loss of cohesion, as in the weathering of crystalthe rocks, is to produce a scale on the outside with perhaps little cohesion Hence the rounding of such blocks upon the surface. Thus boulders are produced. These may often be seen *in situ* in southern latitudes where the weathered zone of rock near the surface has not been swept off by glacial erosion. Nowhere in greater perfection can be seen such phenomena of weathering action than on that part of the coast of Cuba under description. The highly feldspathic syenite of the Sierra Maestra foot-hills is visibly weathered to a depth of nearly 100 feet, its composition within this zone being mostly of rounded masses, or cores of blocks which have thus for resisted complete dissolution, the wide interstices being filled out with disintegrated syenite. The numerous railroad cuts of the Juragua Iron Company, Limited, through such material required but little blasting, except to break up the larger of such boulders.

The tendency to concentric sealing or weathering is seen to perfection in such boulders, many being found with the scale- still adhering; while with others the scale develops very rapidly on exposure to the atmosphere.

These phenomena are recalled to illustrate the formation of the iron-ore bodies, or such at least in the region as have given it importance as a source of shipping ore. I allude to those ore-bodies which I have referred to as essentially replacements of coralline masses.

It is not supposed that such an ore-body is a cast of the original coralline. On the other hand, it is almost certain that the coralline was but a nucleus, the rapid dissolution of which gave space and freedom for the circulation of subterranean waters, and for the play and localization of chemical or metamorphic forces. With the loss of material and change of form, shrinkage of the weathering crape tive mass took place, so that every ore-body referred to probably conforms in size and outline approximately only to the original coralline.

But every ore-body showing an actual terminal surface, likewise shows the concentric structure referred to as characteristic of weath ering masses of rock.

The result of this structure is to constitute what is known ass boss of ore, resembling an onion, with divisional surfaces very sags gestive of bedding, and easily mistaken for stratification. This is well shown by the northeast ore-body at the East Mine, and is the two openings at the West Mine less perfectly, but at the more northerly quarry very clearly.

The result of this configuration is to produce a lenticular outline All sections of ore-bodies, therefore, whether longitudinal, transverse or oblique, if projected to terminal outlines, result in approximately elliptical figures. Assuming the surface of the underlying syenite to retain its original undulating topography as left by erosion, this surface regarded as the base of ore-bodies would tend to complete their lenticular outlines—however it may be as to the prevalence of the concentric mode of deposition within their deeper, as well as in their more superficial, parts.

In projections of outlines of the several ore-bodies,* I have represented them as symmetrical. Although somewhat forced at certain points, no other plan seems to fulfil the purpose of diagrams. This, in the present state of development, must be limited to what alone is practicable, namely—to indicate the kind of outline rather than the outline itself. In thus representing the geological and topographical relations of the several ore-bodies, a wide margin must be allowed in each case for their actual limits.

Still- another result of concentric structure is outer foliation of impure ferric oxide beyond the limits of the original coralline, within the territory of the weathering rocks, and occupying some divisional plane of least resistance near the boundary of the *locus* of deposition.

This, at least, is my reasoning from analogy to account for such outer divisions of ferric oxide of 1 to 5 feet thick, as may be seen at the north drift of East Mine, and which I have good grounds to believe to be likewise presented at the Northeast working of West Mine. The analogy is drawn from the weathering of smaller masses. This may be illustrated by the concentric alteration of clay iron-stone into spherosiderite, and of this into limonite.

The practical result of such a structure would be to invest the ore bodies with a. sort of shell.

Pair passu, it would follow that the interior of such ore-bodies would be the best. This I venture to believe, on the scanty evidence yet afforded, and by the reasoning above followed in brief. Yet this remark refers especially to the ends rather than to other parts of ore-bodies, and to such ends only as are strictly terminal, that is, inclosed or surrounded by rock. For the tops of most of the known ore-bodies have been more or less eroded, so that really their upper surfaces correspond to what originally were interior parts. Reference therefore is made only to still buried portions of ore-bodies, but not less perhaps to the sides or walls parallel to their longer axes than to the ends.

The general term chlorite has been locally applied to the rocks

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* Geological report to the Juragua Iron Company, Limited, August 1884.

encasing the ore-bodies, and perhaps is as descriptive as any. They are of a pronounced magnesian type, bleached free from notable proportions of iron oxides, comparatively soft, and exceedingly Shelly from a high degree of cleavage. As residues of decomposition, their true classification would refer them to their unaltered form which they no longer resemble.

The shape and size of none of the bosses of specular iron-ore have yet been fully revealed. They appear to be elongated masses, the longer axes of which take approximately an east-and-west course throughout the region. Reference to this fact has already been made, and an explanation attempted. The deeper drainage-channels, or streams, having a general southerly course from their sources high up the slope of the Sierra Maestra, the ore-bosses generally lie transverse to the ridges of the several summits in which they are found; or, what is the same, transverse to the general course of the streams. Thus they seem to rib the slopes on which they occur, the ore being so hard and compact, compared with the encasing chlorite, as to form subordinate divides between the watercourses of the hillsides, which, as usual, have eroded their way in the softer material.

The smaller ore-bodies of the East Mine correspond to fragmental bodies of corallines. These seem to be actual casts of such frog mentary corallines, as shown by the peculiar warped surfaces characteristic of their fracture in considerable bodies. This peculiar fracture may be observed to good advantage along the coast, where large masses have become detached from the escarpment of the middle terrace.

All the large bodies of ferric oxide, the origin of which may be traced as above, are encased in such portions of the chloritic or iron bearing formation as are immediately in contact with the under lying syenitc. The Juragua River, on which is West Mine of the Juragua Iron Company, Limited, and its branch, the Benvolenc?? on which is the company's East Mine, follow the same contact where they pass these localities. This is a significant fact in its bearing on the theory of the relation of the main ore-bodies to coralline, as above sketched.

Aggregates of magnetic oxide with magnesian silicates, and with granular quartzite, also occur in the immediate vicinity of the ??? and ribs of ferric oxide, together constituting the East Mine. There seem to occupy divisions of jointing or cleavage of the altered ??? rite, and are thus found in plates of limited extent, and have ??? proved of no economic importance.

At least the lower ends of the bosses and ribs of ferric oxide of East Mine are, at several points already uncovered, variously traversed by irregular courses of chlorite a few feet in thickness, and characterized as "horses" by the miners. A similar occurrence is seen at the south opening of West Mine hill. If, as there seems some reason as above stated to conclude, these intrusions of rock within the body of the ore are limited to the outer portions, which thus would form a sort of shell to the inner portions, trouble from this source will become less as workings advance. This is borne out by the fact that as far as the quarry has advanced, these intrusions have become less and less.

The practical question arises as to the conditions in depth of the iron-ore bodies corresponding to replacements of corallines.

While the phenomena which they exhibit are such as have been produced by essentially superficial agencies, comparatively understood, it seems to me, if the reasoning here followed out be sound, that the ore-bodies of this class will be found to rest upon the underlying syenite, or at least to extend to an horizon not far from this contact. The intervention between the ore-bodies and the syenite of a zone of decomposed silicates representing a lower belt or residuum of earthy silicates, such as circumscribe other surfaces, may be argued from analogy—general as well as special.

In the case of East Mine and West Mine hills, the lower syenite contact is at their bases, or near the beds of the streams. ' The inclination of the plane of this contact doubtless follows the original slope of the syenite, more or less modified by erosion according to the topography of the syenite when overflowed.

A good part of the small ore-float, of excellent quality, found toward the head of the ravines on the divides between streams, and near the summits of hills covered with the iron-bearing rocks, may be believed to proceed from small ore-deposits of the nature of plates or of scale, on the contact of bodies of crystalline limestone with the encasing iron-bearing rocks. Bodies of such limestone, with marked cleavage, but without stratification, occur near the summit of West Mine hill; and on the opposite culmination of the East Mine hill, to the north of the comparatively low hill on which are the several workings of this mine. Together with these ledges of crystalline limestone, or marble, and likewise inclosed within the iron-bearing formation, occur ferriferous aggregates, already described as quartzite and garnetiferous rock, highly charged with magnetic and specular oxides. These have already been referred to as the forms assumed by the alteration in such elevated localities, or remote from the syenite contact, of the original basic rocks from which all the ferriferous compounds have been derived.

ORE-FLOAT.

I now come to one of the most striking features in the region namely, the great profusion of so-called ore-float on the hillsides, and in the ravines.

Probably more iron-ore, and this generally of the best description, is thus found as float than has yet been exhibited *in situ* in the form of ledges or bosses.

This phenomenon is one of the wide series of phenomena, so richly afforded by the whole range, of deep weathering of surface-rocks, and of their erosion under circumstances of steep slopes and a high rainfall.

It cannot but be believed that in more instances than are clear, excellent bodies of ore have practically undergone complete destruetion, while all that come to the surface have suffered heavy loss by the gradual falling away of their outcrops. Fragments up to many tons in weight lie scattered upon and below the outcrops, often obscuring the ledge, and gradually working down hill into the ravines. Slopes and ravines so richly strewn with blocks and boalders of first-class ore would, under circumstances of less difficult transportation, become productive sources of supply.

Instances have come to my notice, as at the Lola east mine (not of the Juragua group), where the erosion of the hillsides has taken place in the best of ore. At this locality, the ore is exceptionally soft and porous, and hence has yielded to erosion more readily than the encasing rock. Thus, only the remnants of a once fine body of ore still exist, and these only as float upon the sides and bottom of a deep ravine, which occupies the place of the former ore-body none of which is left above drainage level. It must have conformed to the type above described. The float from this body of ore, which-is abundant, is characterized by a weathered. surface highly suggestive, in the case of large blocks, of coralline structure..

At Sevilla, what was once an elevation containing a boss of ieon ore, is seen in the last stages of dissolution, iron-ore float being all that is left, and this lying directly on the disintegrating syenite

Like the occurrence at Sevilla, many of the lower syenitie ??? hills, in line with the second range, in which are developed all the ore-bodies known to be extensive, although eroded of dioritie overflow, still bear upon, or just below, their surface, remnants of ore. The nearly vertical dykes of epidotic diorite exposed in such hills, stripped of their former mantle of the same rock, are very numerous.

SILICIOUS PRISMATIC ORES.

A second prominent type of ore-body remains to be described, especially noticed on the first range of foot-hills.

On West Mine hill, following the 1 per cent. gradient from the explorations in North or Dry Arroyo upon an ore-body of this type, a number of ribs of iron-ore come to the surface, including at least two which physically differ from the developed ore of East and West mines.

The specular oxide of these mines is quite free from cleavage, and in weathering assumes a rounded outline.

The second type of ore referred to, weathers in prismatic blocks, and possesses the structure of dense trappean rocks, such as abound in the form of dykes both within the syenite and the altered overlying iron-bearing rocks. Ledges of this description are uniformly rich at exposed surfaces, and so is their detritus or float.

Such occurrences are the result of the decomposition *in situ* of basic eruptives by the dismemberment of silicates, followed by the concentration of ferric and magnetic oxides. This action is essentially superficial,

I therefore argue on general grounds that such deposits even under exceptional circumstances are not likely to be permanent in depth, while the majority of them must be expected to prove of a very shallow character. The fact that most of the deposits of this type are simply veneered with the anhydrous oxides of iron although of extraordinary richness, has been made clear to me in a number of instances both within and beyond the territory of the Juragua Iron Company, Limited.

The genesis of ore-deposits of this type is to be explained, with reference to what has already been said, as follows: The concentration of ferric oxide *in situ* from basic traps differs from the process of replacement of limestone, from external sources, chiefly in point of time required in the two cases. The circulation of chalybeate waters through dense trappean rocks would necessarily be so much retarded as to induce the peroxidation of the ferrous oxide in *situ,* or at least soon after entering into solution. It’s greater insolubility as compared with the proto-silicates when liberated from their original bond, and especially with quartz under certain conditions of temperature and pressure, ultimately leads to the elimination of all but difficultly solublesilicates. These still remain as earthy impurities of this imperfectly concentrated mixture of ferric and magnetic oxides. Magnetic oxide, as a stable or difficultly soluble mineral originally present as such in basic eruptives, has likewise been left as a residuum. This occurs in admixture with ferric oxide. Such changes are the inevitable result of metasomatism of unstable rocks, such as highly basic eruptives, which must have been the source of all the concentrated forms of iron oxides above noticed.

The occurrence of iron oxide in both types of deposits mainly as ferric oxide, and not as ferric hydrate, is the result of gradual dehydration more or less complete.

It will be perceived that, unlike the great Archean deposits of specular oxide, both classes of ore deposits above described have undergone a process of concentration without going through the intermediate stage of sedimentation. In other words, they are products in the one case of the segregation of ferric oxide, in part from immediate sources ; and, in the other, of alteration *in situ* of protoxide basic rocks by peroxidation of their most unstable base, namely, ferrous oxide. Hence while in the case of the ferric replacement of corallines the phenomenon of segregation is presented on a large scale in common with all mineral veins, all further resemblance to mineral veins fails from the absence of the phenomena of fissures, like brecciation, intermittent or successive deposition of miscellaneous minerals, and friction surfaces.

The superficial effects of the weathering of all the rocks which have come under ray observation on the Sierra Maestra slope are of the same general kind characteristic of all southern latitudes.

Yet the decay and bleaching of the rocks above hydrographical drainage must be greatly promoted by such an absorbent as the superficial zone of detritus *in situ.* That it possesses a high capacity for absorption is shown by the total absence within its limits of visible sources of water, like springs, notwithstanding periods of excessive rainfall. The marked saline property of water in flowing streams of the range is another proof of still active decay of its covering.

It should be distinctly noted that the ores above described as replacements of corallines in close proximity to the outcrop of, or contact with, decomposed syenite, including those of the Juragua Iron

Company's East and West mines, and of its Estancia and Juragnacito tracts, occupy the *second* distinct range of foot-hills from the main body of the Sierra Maestra range.

These deposits of soft high-grade ore occupy in fact the thinning edge of the great body of eruptive rocks which overspreads the syenitic flank of the Sierra, From the next or third lower range to the south, the trappean rocks, if ever developed as an overflow, have entirely disappeared by erosion, and in part by thinning. It is under such circumstances that much of the work performed in the metasomatism of the rocks of the second range of foot-hills, resulting in the formation of the best class of iron-ore, is here ascribed to the influence of weathering syenite and the action of alkaline bicarbonates from this additional source.

FIRST RANGE OF IRON-ORE DEPOSITS.

Still another or third group of iron-ore deposits remains to be described. These have much in common with the second class already described as occurring on West Mine hill. '

I refer to those which occur within the first range of foot-hills next below the summit of the Sierra Maestra, and distinct from its immediate south flank. This flank, which has a breadth of some three or four miles, together with the first range of hills referred to, is distinctly covered by one expanse of epidotic and dioritic trap, the topography of which has been produced by erosion. This assumption rests on the belief that the summit of the Sierra is syenite, and on the fact that it appears again at the base of the first range of foot-hills referred to, whence southward towards the coast, the surface is sculptured out of the same formation.

This great formation of epidotic diorite appears to be in close relation to the very numerous injections of the same kind of rock, throughout all exposed parts of the syenite. This overlying formation, it may be believed, had its origin in the overflow of just such dykes in great number, if not indeed of great size.

In the first range of hills referred to, and within the development of the mantle of epidotic trap, occur bodies of ferric oxide more or Jess magnetic from admixture with magnetic oxide. Such are the ore-bodies of La Folie tract of the Juragna Iron Company, and of tracts not belonging to this company.

Nothing has been done to explore any of the ore-bodies referred to. While all afford hand-specimens of first-class ore, especially from the immediate surface, the bulk of so much of their product as can be seen falls as a rule below the standard of even the second-class ore of East and West mines.

I am not indeed prepared to say that inclosed masses of coralline have not likewise determined the *loci* of even these masses of ore found within the first range of trappean foot-hills. Garnetiferous, rather than distinctly ferriferous aggregates occur at the Yuca ore-body, resembling corallum structure, while the base of the ore-body itself is distinctly of trappean structure and origin. Hence the possibility arises that while corallines have given place to secondary deposits, concentration of ferric oxide has taken place only imperfectly and tardily beyond the compass of such calcareous centres, after the-e, perhaps, have been replaced by available mineral matter of which ferric oxide was but a minor part. Yet the presence of coralline in process of replacement, it may be imagined, would be sufficient to determine the *locus* of metasomatic activity—involving even adjoining parts of the dioritic mass. Or again, the condition of excessive-impurity
impurity from admixture of silicious with coralline sediments in such cases, may be sufficient to account for the rocky character of the fragments found at the Yuca suggestive of corallum casts.

From the above description it follows that the most favorable conditions for the development of large bodies of highly concentrated specular oxide in the iron-region of the Sierra Maestra, are to be found toward the edge of the expanse of trappean rocks, where reduced in thickness by erosion, near their contact with the underlying syenite. Apparently only under the influence of alkaline carbonates from-the syenite, has the trappean mass been submitted to that kind and degree of alteration and epigenesis, which have resulted in the. formation of iron-ores through the intervention of involved coralline ??? larly situated.

The location of such ore-bodies thus determined, is comparatively low in the hills. The higher hills often bear toward their summits less concentrated forms of ferric and magnetic oxides, and occa-i?? ally also bodies of crystalline limestone. These elevated positions, it has already been observed, are beyond the reach of alkaline ca?? ates, while lower positions have received the benefit of their drainage and of mineral matter, thereby transmitted.

This general proposition is borne out on the one hand by the ??? bodies of East Mine and of West Mine hills, and by those of the Estancia tract as far as determined, and by that of Juragua cito. All of these are found near the base of the Juragua Hills. To this class of ore-bodies belongs also the Lola east ore-body, of which traces only remain. On the other hand, the circumstances governing the conditions of higher altitudes and positions remote from the syenite contact, are illustrated by the higher parts of West Mine hill deposit and by the Yuea, and by some of the ore-bodies at Berraco.

The blenched dioritic, or so-called chloritic, rocks, found in association with the better class of ore-bodies near the decomposed, and in places kaolinized, syenite, are distinctly recognized, wherever they occur, as in a far more highly weathered condition than the general mass of dioritic rock, forming the first range of hills, as well as the immediate southern flank of the Sierra, where, overspreading the syenite as a mantle, it has protected the latter rock from weathering, while all drainage of the syenite at the base of the first range of diorite hills is directly to the watercourses. Hence the lack of alka-j line carbonates, except from the diorite itself, back of the second [range of foot-hills to assist in the disintegration of the mantle of diorite, and in its alteration under the conditions of a thin development as witnessed at the base of the Juragua range of hills.

| As bearing upon the observation of the depth to which exposed parts of the syenite are weathered, and thus rendered soft and porous so as not to admit of the presence of springs, may be mentioned the fact that, on the other hand, springs are a feature of the first range of diorite foot-hills, as seen in La Grande and the Yuca hills. This [fact is important in its relation to the supply of alkaline carbonates from decomposing syenite, as these are believed to have been one of the most powerful agencies in determining the *loci* of metasomatic activity such as has resulted in the concentration of ferric oxide from basic rocks.

While the massive epidotic diorite of the Sierra is to be regarded as the altered product of the original still more basic material, under the less favorable conditions, the more thoroughly altered forms of the same material found in association with the iron-ore bodies cor-Bfespbnd to the more favorable conditions. The lithological identity of both forms is clear. Only in close proximity to ore-bodies developed within the massive diorite of the first range of foot-hills, at the sothern base of which alone the syenite is visible, is the great expanse of epidotic diorite seen to be unequally altered. In such proxitnity, the diorite is seen to be bleached and weathered, but in a way different from its weathered appearance under conditions of reduced thickness near its contact with the syenite.*

This is another auxiliary fact going to justify the importance here given to **the** effect of **the** alkaline carbonates. In determining the range of their influence, we determine the limits of at least one of the most favorable conditions under which the best bodies of specular oxide occur. This, I think, has practically been done. The results of other favorable conditions have, in a general way, likewise been assigned. If such conditions have, in the main, been correctly recognized, the propositions here brought forward will go far to render practicable a discrimination between the different classes of iron-ore deposits in the region, with direct reference to their practical value.

NOTES ON THE TREATMENT OF NICKEL-COBALT MATTES AT MINE LA MO TTE.

BY JAMES W. NEILL, E. M., MINE LA 3I0TTE, MO.

THE occurrence of minerals of nickel and cobalt at Mine La Motte is probably known to every mineralogist. I will not attempt to describe these minerals, but, before entering on my subject will briefly mention the ores, etc., which call for metallurgical treatment and enter into the composition of our mattes. Our staple lead-ore, the dressed galena, is the chief source of nickel and cobalt. It carries but a small percentage of these metals, viz.: 0.2 to 0.3 per cent. usually, though when much copper pyrites is contained in the gangae?, the amount of nickel and cobalt may be as great as 1.0 to 1.5 per cent. Next in importance is the "middle product" of the dressing, consisting of the sulphides of iron (and copper) with and galena. This usually carries 20 to 23 per cent, of lead, 1.0 per cent, of copper and 2.5 to 3.5 per cent, of nickel and ???. A larger percentage of copper always carries with it an ???nickel and cobalt. In some few cases 12 to 15 per cent, of ??? gives 6.5 to 8.0 per cent of these metals. Besides these ??? the dressing-works, there is a small quantity of true nickel-???

* For further lithological references, see Geological Relations and ??? Specular Iron Ores of Santiago de Cuba, by the present writer, in the ??? Journal of Science, xxviii., 1884.

produced, which, averaging only 1.0 to 2.5 per cent., has, until lately, been of small importance. Through recent developments in the deeper workings, where the nickel, cobalt and copper sulphides occur disseminated (but separate from one another) in a porous sandstone, the amount of this ore has been largely increased.

The dressed galena we roast in reverberatory furnaces *(Forlschaufelungsöfen),* treating from 6 to 8 tons per 24 hours, and leaving from 5 to 7 per cent, of sulphur in the charge. This is then treated in the shaft-furnace with fluxes, producing lead, "first matte" and slag. The "middle product" is also roasted in the same furnaces (leaving from 8 to 10 per cent. of sulphur), and is then used in part as iron-flux in the lead-smelting, where it can only be employed in small quantities, lest it should raise too much the percentage of sulphur in the charge, and also give mechanical trouble from tits fineness. Where these sulphides are rich in copper and nickel-cobalt, they are roasted and smelted separately, producing a rich matte.

The first matte formed, as above remarked, from lead-ore with sulphides as flux, etc., carries usually from 3 to 3.5 per cent. of nickel rand cobalt (about 2 nickel to 1 cobalt), 0.5 to 1 per cent. of copper, and 20 to 25 per cent. of lead. After a period of exposure to the weather, which slacks it more or less thoroughly, it is broken with hammers to fist-size and roasted in a reverberatory having a 45-foot by 12-foot hearth. This furnace produces from 4½ to 6 tons of roasted material in 24 hours, leaving about 5 per cent. of sulphur in the [charge. It burns from 4 to 6 cords of wood, and is served by 6 to 8 men, according to the amount produced, etc.

This roasted first matte, when accumulated sufficiently, is used as iron-flux in smelting the lead-ore, producing lead, "second matte" and slag. The second matte should carry, if no losses occurred, at least double the quantity of nickel and cobalt contained in the first; but experience has proved that the more thorough the roasting of the first matte, the greater the loss of nickel and cobalt in the slag; *i. e., the* better the matte is as an iron-flux, the worse the concentration. I have found from 5 to 6 per cent. of sulphur in the first matte to be the best limit. This does not make a very good flux, but the losses are smaller.

Slags from this matte-lead-smelting having shown as much as 0.7 ber? cent. of nickel and cobalt, I made one campaign, as an experi- ??? on this roasted first matte alone, using acid fluxes, and ex- ??? to produce a matte rich enough' to warrant shipment. But the resulting matte, carrying 12 to 15 per cent. of nickel and cobalt and 25 to 30 per cent, of lead, was made at such expense for labor and fuel, that we returned to the old method.

The second mattes, carrying from 3.5 to 6.5 (usually 5 to 6) per cent, of nickel and cobalt, 25 to 30 per cent, of lead and 1.0 to 2.0 per cent. of copper, are roasted in the same manner as the first mattes, but not so sharply, the roasted charge retaining from 7 to 9 per cent, of sulphur. This high percentage is necessary to protect the nickel and cobalt, which, if entirely deprived of sulphur, will largely cnter the slag, even though the sulphur-contents of the charge be sufficient to "cover" them. Of course, in the subsequent smelting, the matte produced is high in lead. It will thus be seen that in this process the lead works against the concentration of the nickel and cobalt.

Until recently, the roasted second matte was smelted with acid fluxes (such as sandstone, old acid slags, etc.) and limestone. The resulting " third matte," after crushing and packing in barrels, was shipped to Europe. This smelting was done in the lead-ore furnace, which is circular, 45 inches in diameter at tuyeres, 6 feet at charger, door and 12 feet high. It proved too large for the purpose. The-charge being very low in lead, and, of the lead present, very little being reduced, the lead always froze in the basin and "well," thes increasing the percentage of lead in the matte by imperfect ??? cal separation in the slag-pots. Four per cent. of lead was the ??? we produced from the second matte by this process. The resulting third matte usually carried from 35 to 40 per cent, of lead, 12 to 15 to 17 per cent, of nickel and cobalt, and 3 to 5 per cent, of copper The slags would average 1.25, and often 1.75 per cent, of nickel and cobalt, and 2 to 2.5 per cent, of lead. The losses in the slags were large; and, moreover, by shipping this matte, the lead-content 135 to *o* 40 per cent.) were lost, since the buyers do not pay for lead.

An attempt to concentrate this matte further by melting it in ? reverberatory furnace, was made some years ago, but was not a ??? cess, the resulting (granulated) matte being higher in lead in ??? proportion to the amount of iron which had been slagged off, wher the slag carried 5 per cent. of nickel and cobalt, and 5 per ??? lead. I am told that formerly some lead was regained from the matte, by an addition of metallic iron to the molten matte in thas furnace; but I found this to be impracticable, the expense of ??? labor and fuel being far above the value of any lead regained. separating nickel and cobalt from the lead by making speiss;

after much discussion of arsenic-ores, speiss, etc., we bought 13 tons of mispickel-ore (carrying 23 per cent. of arsenic) from the Canada Consolidated Gold Mine of Marmora, Out. With this we smelted in the large furnace some 35 tons of a roasted matte, carrying 12.5 per cent, of nickel and cobalt; the furnace basin, as usual, chilled; and the resulting speiss and matte did not separate perfectly in the pots. The clean speiss regained, carried 36 per cent. of nickel and cobalt and only 6 per cent. of lead. The matte was still high in lead (35 per cent.); but it carried 19 per cent, of nickel and cobalt. The slag was unsatisfactory, carrying many shots of matte, and was all returned to the furnace. No analysis was made of it. The lead produced carried some 3 oz. gold and 3 oz. silver per ton. There was a large loss of arsenic in the fumes, probably carried off by the sulphur, as the gases at times looked yellowish, at times red.

• This experiment, though financially not successful, proved satisfactorily that arsenic would separate the nickel and cobalt from the lead, and would prevent large losses in the slags. It showed, also, that the lead-furnace was too large. Before making further experiments, we built a smaller and more suitable furnace, 30 inches Square at the tuyere-line, 48 inches at the charge-door, and 6 feet, 6 Inches between these points, with 18 inches depth of basin, lead-well behind, fore-hearth (or sump), three tuyeres, no jackets, sides of 9-inch fire-brick, cooled by irrigation.

For our next experiment, we bought some low-grade lead-speiss, hand-sample of which had the following composition : silver 3 ounces per ton ; gold, 0.04 ounce per ton ; lead, 5 per cent.; copper, 3 per cent.; arsenic, 12.5 per cent, (antimony not determined) ; iron, 55 per cent. With this speiss, I smelted a second matte, carrying in percentage 23 of lead, 1 of copper, 6 of sulphur, 5.28 of nickel and cobalt, and 35 of iron. As an acid flux, some of the nickel-cobalt-ore previously mentioned, was employed. This carried 77 silca, 2 nickel and cobalt, 2 copper and 2 lime, per cent. The furnace worked well on this combination. After the first few shifts, the pines of arsenic, which at first were strong, almost disappeared ; the ead (or rather bullion) ran freely and remained hot throughout; the ??? was much higher in silica than calculated (owing probably in art to corrosive action on the fire-brick walls), but was fair in apearance and separated nicely from matte and speiss; and these also parated well in the pots. The slag carried 1 per cent, of lead yet assay) and 0.78 per cent, of nickel and cobalt. The amount of ??? made was much larger than calculated (owing to the larger percentage of antimony in the purchased speiss), and, of course the percentage of nickel and cobalt was lower than expected, viz., 14.5 per cent., while the lead amounted to 12 and the copper to 5.8 per cent. The matte produced carried only 5.14 per cent, of nickel and cobalt, 5 per cent, of copper and 13 of lead, was thus too poor to ship (as was desired), and will be treated with the next lot. The lead produced amounted to 2G per cent. of the matte used, showing that the speiss-sample did not justly represent the pile. This lead carried per ton, 9 ounces silver and 0.1 ounce gold, and netted us enough to pay all expenses of smelting and leave a decent margin. After running 10 days, the brick walls of the furnace were nearly eaten through, in spite of the water; and, as other work was pressing, I blew down ; but we have now ordered a set of water-jackets, and expect to blow in again on their arrival.

This last experiment has conclusively proved that the old method must be abandoned, certainly, for the treatment of the second matte; whether it will not be more economical to treat the first matte also with speiss, remains for future experiment to determine. The same may be said of the "middle-product" sulphides.

Whether the nickel-cobalt-speiss produced, can be advantagcously re-treated here, either by using it again as arsenic-surrogate in the blast-furnace with further first or second matte, or by concentrating in the reverberatory-furnace, is also a question for future solution.

POSTSCRIPT.

Since the foregoing was written, we have made a second campaign under more favorable circumstances, and with even better results. The furnace was of the same dimensions as before, viz., 30 by 30 inches at tuyeres, 48 by 48 inches at top, 7 feet between these ??? but with cast-iron water-jackets, 30 inches high, with 6 inches ??? The speiss used was from different sources; one lot, from a ??? carried 33 oz. *Ag* and 0.9 oz. Au, with 12 Pb and 10 Cu, only 55 As and 21 Sb; the other, a clean arsenic-speiss from Leadville, with 12 oz. Ag, and about 25 per cent. As (not determined). These two lots were used in equal amounts. ,

The charge consisted of roasted matte, 150 pounds; rousted ??? phides, 50 pounds; nickel-ore, 65 pounds; speiss, 40 pounds; ??? stone, 35 pounds; slag, 50 pounds; with occasional slight ??? as the slag, etc., called for change.

The amount of fuel (coke) used was large, owing to the materials being frozen and full of snow; it varied between 20 and 25 percent.

The furnace worked very well ; during the run of 23 days we did not slacken the blast, or take out a tuyere. Only once was it necessary to drive a bar. "We put through about 25 tons of charge daily, and made, in all, 64 tons of bullion, 37.5 tons of speiss, and about 100 tons of matte.

The bullion assayed about 17 oz. *Ag,* and 0.4 oz. *Au,* its value more than covering all expenses. The speiss carries 22.53 per cent. Ni-Co (about 1/3 Co), 6.4 Pb (of which 2.6 was contained in shots), and 4.25 Cu. The matte, of which we have not yet a general sample, carried, according to a "grab-sample," 8 per cent. Pb, 7 Cu, and 3.25 Ni-Co. This will, of course, be re-treated. The slags I caused to be analyzed several times; the highest in Ni-Co was 0.32 per cent.,.the lowest, 0.16; highest Pb 0.8, lowest 0.6—all wet analyses. These results are so much in advance of those first achieved, that I have communicated them before the final and complete analyses have been made.

The commercial result, viz., the obtaining of products which in value are at least treble the expenses, is fully as gratifying as the metallurgical.

A NEW SYSTEM OF ORE-SAMPLING.

BY D. TV. BRUNTON, DENVER, COLORADO.

THE erection of large metallurgical establishments for the treatment of gold, silver, copper, and lead-ores, at railroad and topographical centers, where fuel and fluxes, together with proper ore-mixtures, can be cheaply and constantly obtained at all seasons of the year, has led to the very general introduction of a system of ore-handling known as "public sampling." By this system the ore, instead of being shipped direct to the mill or smelter, is sent to a public sampler, where it is crushed and sampled. Guaranteed samples are sent to the different metallurgical establishments, a|nd the ore is then sold to the highest bidder.

Though differing in many respects from the English system of "ticketing," the underlying principle is nearly the same, while the greater rapidity with which a lot of ore can be disposed of renders the American system infinitely better adapted to the requirements of the West,

The steadily increasing practice of leasing mines to working miners has also given a great impetus to the system of public sampling. Where mining is carried on by large companies who can afford to keep at the metallurgical establishments where the ores are treated an agent to watch the sampling and make settlements, the advantages of public sampling are not so marked; but where mince are leased to small parties of working miners, who will never combine together or employ a common agent, the public sampler meets their requirements fully, and renders the presence of the owner at the valuation and sale of the ore wholly unnecessary. Upon the whole, the system is a decided benefit even to the buyer. When the sampling and assaying are performed by a third party, the former endless disputes between the miner and the smelter are no longer possible. Again, metallurgical establishments have heretoffore ??? almost compelled to receive all the ore sent them, whether ??? or otherwise; but under the new system they need only bid ??? such ores as are required in their mixtures; the larger variety of ??? from which they have to select more than compensating for the increased cost.

Before the introduction of public sampling, the ore, after being crushed, was generally sampled by hand, either by taking every fifth or tenth shovelful, by "quartering," or by the "split shovel"

Since large quantities of ore have now to be handled, and ??? competition has made cheaper methods of work an absolute ??? mechanical sampling, in some form or other, has become almost ???-versal. While the devices employed for this purpose exhibit as almost infinite variety of type, yet they all work upon the same general principle, viz.: by dividing or cutting out from a falling ??? of ore, by means of narrow spouts, dividing flanges or travell?? buckets, a certain percentage, which is taken to represent an average sample of the whole.

Many of the samplers exhibit a vast amount of ingenuity, and ??? dry ore, crushed and screened to a uniform size, and perfectly ??? from strings, chips, rags, etc., some of them will yield accu?? suits.

Unfortunately, however, these conditions are rarely realized ??? practice; and the result has been that both sellers and buyer ??? very often insisted on checking the work by means of hand-sampler Even if the above objections did not occur, many of the samplers ??

still give inaccurate results; since a stream of falling ore, either in a vertical or in an inclined spout, is never entirely homogeneous in all its parts, there being a constant tendency to a greater proportion of coarse, rapidly-travelling particles in the centre of the stream, and an excess of finer, slower-moving particles on the edges. Consequently no part of the stream would exactly represent the average of the whole.

Again, where intercepting buckets are used, the coarse, heavy particles often rebound from the buckets and fall into the rejected ore, thereby rendering the sample inaccurate. . Even the fine crushing and accurate sizing required by the best of these devices is a decided objection, if the ore is to be afterwards treated in a shaft-furnace, where an undue proportion of fine stuff not only increases the loss in dust, but materially reduces the daily capacity of the furnace.

About a year ago the writer's attention was directed to these facts by one of the largest ore-dealers in the West, with a request that he would investigate the matter and devise some method which would yield accurate results, satisfactory to both miner and smelter, and at the same time permit the sampling of ore with extreme rapidity and at the lowest possible expense for power, labor, and repairs.

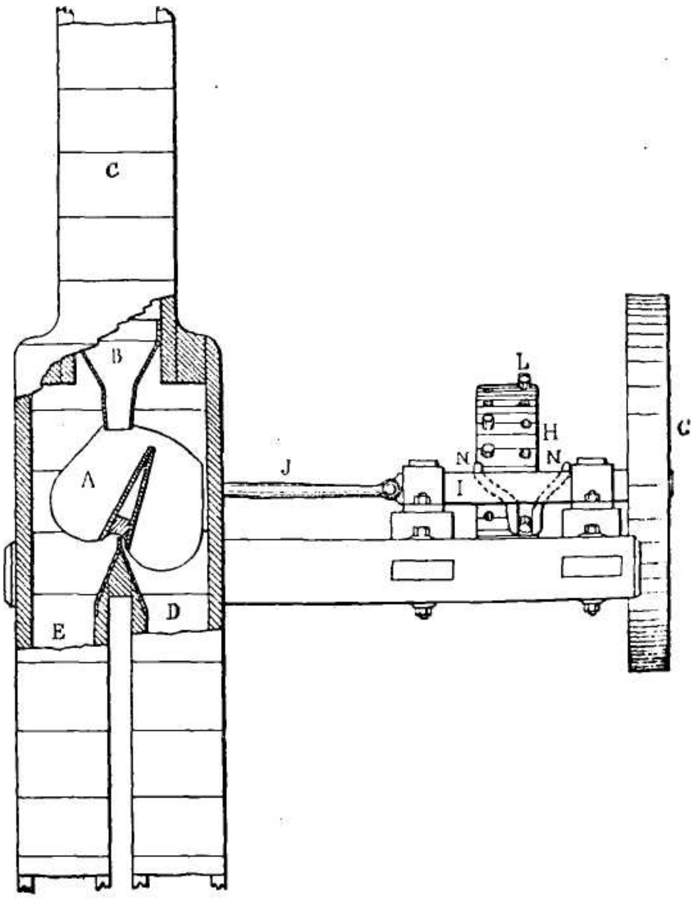
After examining into the matter for some time, and taking into consideration the marked preference of the principal ore-buyers for coarse ore, the writer decided that it would be necessary, on account of the objections already mentioned, to avoid splitting or dividing the falling stream, and, instead of dividing the ore. to make the division one of time—something which could be divided with exactitude and to infinity. With the new machine the sample is obtained by *deflecting* the *entire stream,* alternately to the right and to the left, the relative proportions of these two divisions to each other being determined by the difference *in time* between the deflections to the right and the deflections to the left.

The construction and operation of the machine will be readily understood from the accompanying drawings, in which C is a vertical or inclined spout, containing a falling stream of ore; B is a funnel for narrowing the width of the falling stream, so as to reduce to a minimum the necessary travel of the deflecting-chute, A. This chute, A, is pivoted upon the rock-shaft, K. When it is deflected to the right the entire stream of ore is thrown into E; and when it is deflected to the left the entire stream is thrown into D.

The deflection is caused by the movement of the crank, O, receiving motion from the driving-bar, I, and connected with it by the pitman, J.

The driving-bar, I, receives its motion from the pins, L, in the face of the revolving-wheel, H, which is driven by the pullcy, G, receiving motion from a line-shaft through the belt, M. The face

FIG. 1.

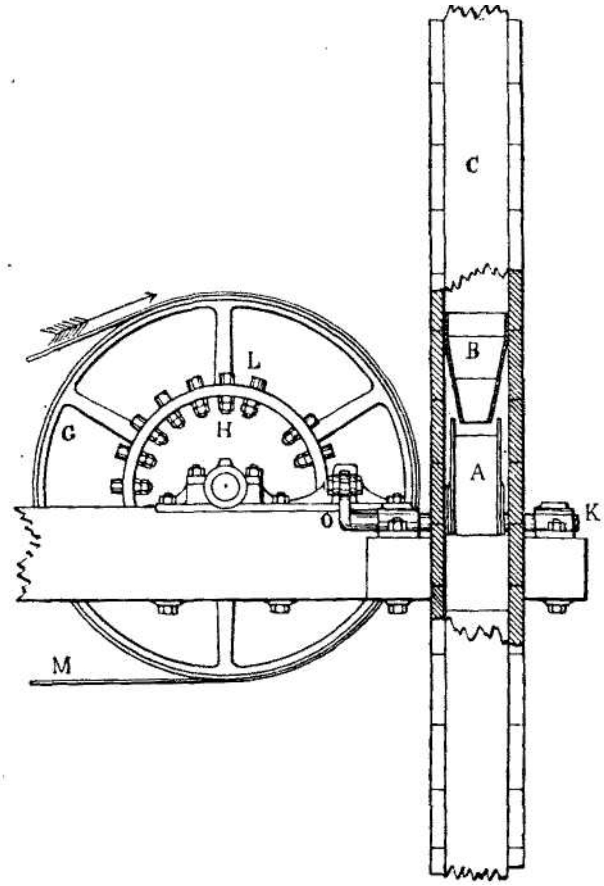


of the wheel, H, is perforated with two rows of holes, the dis?? between the two rows being the same as the necessary movement of the crank, O. Into these holes are inserted a number of pi??? held in place by jam-nuts on the interior of the wheel-face. ??? ferably, twenty holes are bored in each row, each hole or pin ???

seuting five per cent of the time necessary for a complete revolution of the wheel.

Now if fifty per cent, of the pins are placed in the right-hand row of holes, and fifty per cent, in the left, then the revolution of the wheel, II, carrying the pins, L, through the guides, N *N,* on the

FIG. 2.



driving-bar, I, will hold the deflecting chute, A, on the right during one-half of the revolution, and on the left during the other half, thus dividing the stream into two equal portions,

If twenty per cent, of the pins are placed in the right-hand row, and eighty per cent in the left, then the deflecting chute, A, will be held on' the right during one-fifth of a revolution and on the left during four-fifths, thus throwing twenty per cent, of the ore into the spout E, and eighty per cent, into the spout D, etc.

In practice the wheel, H, is driven with considerable velocity, so as to make the divisions of time as minute as is practicable without injuring the machine by excessive vibration.

In improved machines now being built, although the principle is identical with the above, the construction is somewhat different. Sliding motion, always objectionable in dusty situations, is wholly avoided, and the pin-wheel, II, is inclosed in a tight iron ease; filled with oil. This arrangement, while far from complicated, is exceed ingly compact, the journals, wheel, case, and frame being in one casting; but, owing to the position of the different parts, it is very difficult to explain by cuts; hence the employment of the oilier drawings in the foregoing description.

When in use the machine runs noiselessly, without either jar or vibration, and never clogs, no matter how wet or how full of chips, rags, and strings the ore may be.

Two of these machines have been running steadily for the past six months, during which time they have given complete satisfaction to seller, sampler, and buyer. No errors in sampling have ever occurred, even upon the richest ores. Not a cent has been spent upon either alterations or repairs, and the attention bestowed upon the machine has been restricted to a daily oiling.

As the stream of ore is neither split nor divided, fine crushing on large samples is entirely unnecessary. After the ore has been broken in a Blake or Dodge crusher, it falls into an elevator, and is raised a few feet above the level of the storage-bins. The sampler is placed between the elevator-discharge and the top of the bin, so that the ore falls through the divider which throws out, for a sample any amount per cent, to which the machine may be set.

In practice this amount varies from ten to fifty per cent- ??? cording to the value of the ore; the richer and more "spotted" the mineral, the larger sample should be taken.

The rejected ore drops directly into the storage-bins, while ??? sample falls through a spout into a pair of rolls placed on the same level as the breaker.

With most ores, from ten to twenty per cent, has been found amply sufficient for a coarse sample; and, as at least eighty per cent. of the entire lot is generally sent to the smelter as it comes from the breaker, there is no objection to setting the rolls close, especially as they only crush from one-tenth to one-third of the amount of ore handled.

After being crushed fine by the rolls, the sample is raised by a smaller elevator to the same level as at first, and drops through a second divider, set to take any desired amount per cent.

The rejected ore falls into the bin with the ore from which it was at first separated, and the final sample drops into a closed and locked bin on the working-floor below.

On ordinary ores, 10 per cent, of 20 per cent, or 2 per cent, of the original quantity, is an all-sufficient sample; while on richer rock 15 per cent, of 30 per cent., or 4½ per cent, of the original quan- tity is perfectly safe. By this plan only a small proportion of the ore is crushed fine,—a very decided advantage for smelting purposes over all of the other systems, which require that the ore must be rolled before a sample can be taken.

The two machines are driven at different speeds, to prevent any possible error which might arise from isochronal motion. In testing these machines by re-sampling various lots of ore, it has been found that the limit of error is less than one-fourth of one per cent., while even the best "hand-quartering" often varies two per cent.

The weight of the sample actually taken, even on the largest lots, never varies more than a few pounds from the percentage to which the machines are set. As the division is one of *time,* not of *ore,* it follows that the machines will take the percentage to which they are set, whether the ore passing through them be wet or dry, light or heavy, coarse or fine. This fact is of the utmost importance to the sampler, as it enables him to obtain a correct sample of intended mixtures, by simply passing the different lots through the crushing machinery in succession. Not only will the ore delivered in the sample-bin represent an exact average of each lot, but the amounts taken will bear the same relative proportion to each other as did the original Jots, and the entire sample will consequently be an exact average of the whole.

Under this system the cost of sampling is reduced to the lowest possible limit, the principal and almost only items of expense being power and the cost of wheeling ore into the rock-breakers; and since the accuracy of the samples is in no way dependent upon the skill of the workman, the very cheapest labor may be profitably employed. Many other advantages might be enumerated; but the writer hopes enough has been said to explain clearly the system and enable anyone interested to judge fully its adaptability and value.

THE PATIENCE OF COPPER AND SILVER AS AFFECTED BY ANNEALING.

BY HENRY M. HOWE, BOSTON, MASS.

SOME interesting experiments* by Professor R. H. Thurston on the resistance of iron to prolonged stress, have brought to light the fact that unannealed iron (which was already known to have a much greater tensile strength than the same iron has after annealing) has much greater *patience* than annealed iron. That is to say, if we call the tensile stress which is just able to tear the metal apart instantly the "immediate breaking load," then not only has unannealed iron a much greater immediate breaking load than the same iron has after annealing, but it is capable of resisting without fracture, a given proportion (say 80 per cent.) of its own high immediate breaking load for a much longer time than that during which annealed iron is able to resist 80 per cent, of its own much smaller immediate breaking load.

I suggest the name "patience"† to express this power of resisting prolonged stress, which evidently bears no fixed relation to what is ordinarily spoken of as tensile strength, or the power of resisting tensile stress for a very brief period.

Professor Thurston's interesting results led me to apply similar investigations to copper and silver, the results of which form the subject of the present paper.

THE EXPERIMENTS.

Preparing the Metals. —Ordinary silver wire was hard-drawn to No. 23 Brown and Sharp gauge; it was cut in two, and one pier was carefully annealed in the ordinary way. The wire was p?? pared by Messrs. Guild and Delano, jewelers, Boston.

The Ansonia Brass and Copper Co., Ansonia, Conn., kindly far ?nished me with some hard-drawn copper wire No. 31, A. W. G. and some of the same wire after annealing in the ordinary way.

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* *Science,* vol. i., p. 418.

† Possibly "endurance" would be a better word.

Immediate Breaking Load.—This was determined for both unannealed and annealed copper and silver wire in the following way: A piece of the wire whose immediate breaking load was to be determined, was suspended vertically from a fixed support, and to its lower end was attached a flask loaded nearly to the breaking weight of the wire. Immediately after effecting the suspension, that is to say, as soon as the tensile stress was imparted to the wire, a fine stream of dry sand was run into the flask until the combined weight of the flask plus the sand just sufficed to break the wire. The stream of sand was so arranged that the moment the wire broke, allowing the flask to fall, the stream was diverted from it. The combined weight of sand and flask was then noted.

The time occupied by the sand in running into the flask after the latter had been suspended was so short that the results thus obtained were very near to the immediate breaking load, though, of course, always slightly below it, since an appreciable length of time elapsed between the suspension of the flask and the instant of fracture, and during this time the heavy load rapidly weakened the wire. The results thus obtained arc not, accurately speaking, the immediate breaking loads, although I shall so call them; it would be more accurate to speak of them as the loads sufficing to break the wire in an exceedingly brief time, or the " almost immediate breaking loads." They probably differ very slightly from the immediate breaking load proper, and are certainly much nearer to it than those obtained with ordinary testing machines, where the metal is exposed for a much greater length of time than in my experiments, to a stress approaching that at which it finally yields.

The mean of at least three observations was taken in each case.

Patience of the 31elals.—Loads equivalent to 90, 80, and 60 per cent, of the immediate breaking loads of both annealed and unannealed silver, and to 90, 80, 70, and 60 per cent. of the immediate breaking loads of both annealed and unannealed copper, were then prepared. These loads were suspended by pieces of the appropriate classes of wire from comparatively yielding and springy pieces of woodwork, in a substantial brick house resting on piles. The woodwork was attached to the side walls of the house and not connected with the ceiling, so that jarring from people walking overhead was avoided. It was thought that these precautions sufficed to reduce the effect of the vibrations of the building to an amount so small as to be safely neglected.

The wires were exposed to the loads thus prepared for nearly nine months, during which time many of them broke; I was then unfortunately compelled to bring the experiments to a close. No two of the wires broke at or about the same time, so that the jar caused by the breaking of one wire appears to have had no traceable effect on the patience of the neighboring wires. Indeed, from the position of the wires I think little effect can have been thus caused.

The Stretch.—In order to determine the rate of stretch of the annealed copper wire, pieces of from three to five feet in length were employed in determining its patience, and the amounts which they stretched under their respective loads were noted from time to time.

In the case of the copper wire, both annealed and unannealcd, all the observations were made in duplicate.

THE RESULTS.

Patience.—The results thus obtained are given in the following table, and are also represented graphically in Fig. 1.

Patience of Copper, Silver, and Iron.

Percentage of immediate breaking load, .	90	80	70	60
Metal.	Number of days load was sustained before wire broke.			
Silver, annealed, . .	3.	156.		Unbroken A
Silver, unannealed, .	3.	114.		Unbroken A
Copper, annealed, . .	0.07	Unbroken A.	Unbroken A.	Unbroken A
Copper, unannealed, .	0.5	Unbroken A.	Unbroken A.	Unbroken A
Iron, annealed, . } Prof. Thurston.	35.	91.	Unbroken B.	Unbroken B
Iron, unannealed, } Prof. Thurston.	0.003	266.	455.	Unbroken B

A. Unbroken after nine months.
B. Unbroken after seventeen months.

In Fig. 1* each curve represents the results obtained with one of the four classes of wire experimented on, the unbroken lines giving

* This diagram represents the results obtained during the first 75 day???The directions of the curves for the remainder of the time remain substantially changed. To represent the whole period covered by the experiments would require an inconveniently large diagram.

the patience of unannealed and annealed silver, the broken lines that of copper, and the broken and dotted lines that of iron as de-

FIG. 1.

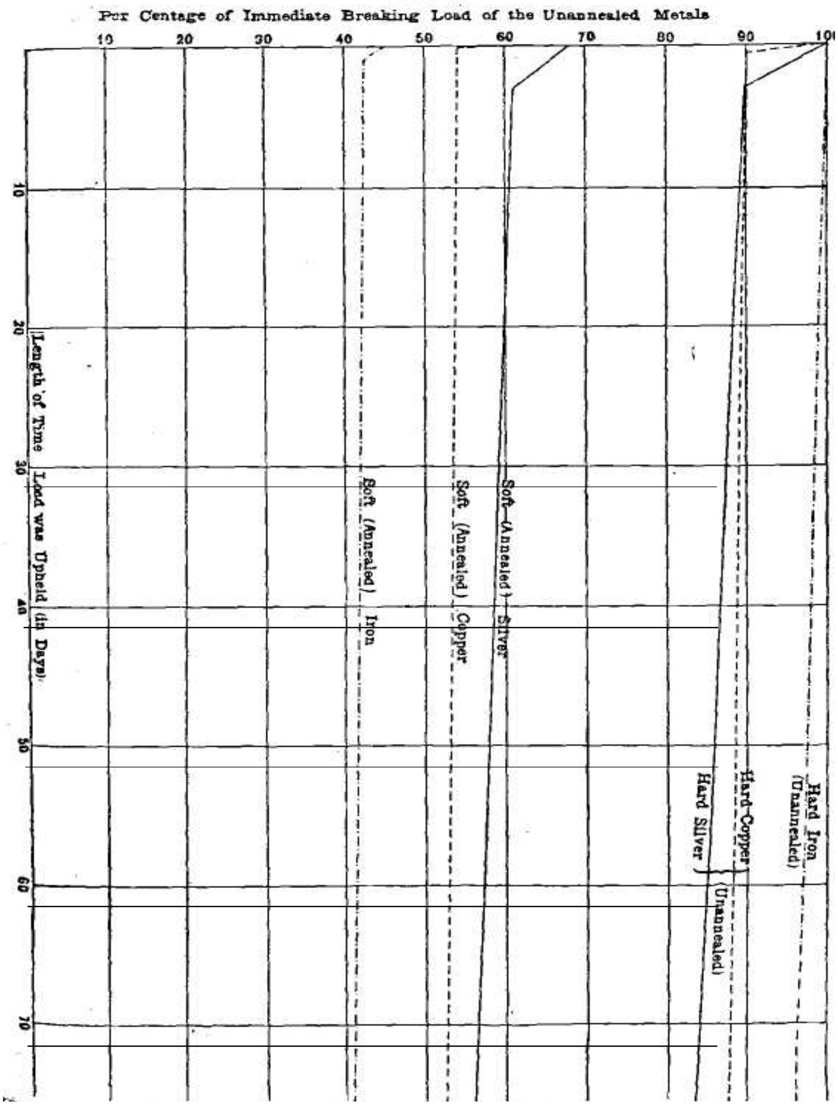


Diagram showing the patience of copper, iron, and silver, as affected by annealing.

termined by Prof. Thurston. With his results I have taken certain liberties which will be explained (and, I hope, justified) beyond.

The vertical distance from the horizontal axis (ordinate) of any point in each of these curves, indicates the percentage of the immediate breaking load of the unannealed metal corresponding to that point; and the horizontal distance of the point from the vertical axis (abscissa) indicates the length of time which this load was sustained before the wire finally broke under it. The ordinates of the curves of each metal, both when annealed and when unannealed, are measured in percentages of the immediate breaking load of that metal when *unannealed* so as to indicate to the eye the proportion between the loads which the metal is capable of carrying for a given number of days in the annealed and in the unannealed condition.

From the points at which the curves of the annealed metals have the vertical axis, we see that the immediate breaking loads of annealed silver, copper, and iron are respectively about 68, 61, and 50 per cent. of the immediate breaking loads of these metals when unannealed. The fact that annealing diminishes the immediate breaking load of silver less than it does that of copper and much less than that of iron agrees well with the further results that the patience of silver is somewhat less affected by annealing than that of copper, at least for heavy loads, and much less than that of iron. Thus, when we pass to the right side of the diagram we notice that among the curves of the nnannealed metals, iron stands uppermost, and silver lowest; while with the curves of the annealed metals this order is exactly reversed. That is, while unanuealed iron has greater patience than unannealed copper and much greater than ?? annealed silver, yet annealed iron has much less patience than these other metals when annealed.

The curves of annealed and of unannealed silver are almost parallel, showing that, although annealing lowers the immediate breaking load, the patience of the annealed silver remains practically the same as that of the unannealed metal, measuring the patict?? each, of course, in percentages *of its own* immediate breaking ???

With iron, however, the case is very different. While unannealed iron sustained for seventeen months without breaking ??? cent. of its immediate breaking load, annealed iron gave way in ??? day under 85 per cent. of the much smaller immediate breaking load of the annealed metal. Though this perhaps rather over-?? the case (for Prof. Thurston apparently got an exceptionally ??? piece of unannealed iron for his 85 per cent. load, since. With ?? lighter load, only 80 per cent., the unannealed wire broke after ??

days), it must still be admitted that the difference in the behavior of the three metals is very striking.

A surprising difference between the patience of copper and that of silver is brought out by these experiments, a difference which exists in both the annealed and the unannealed condition. While copper, whether annealed or not, fails much more rapidly than silver under 90 per cent, of its immediate breaking load, yet the former metal upholds 80 per cent, of its immediate breaking load much longer than silver docs. Thus annealed and unannealed copper broke under 90 per cent, of their respective immediate breaking loads after 1.75 and 12.67 hours respectively (the determinations were made in duplicate and triplicate), while both annealed and unannealed silver sustained 90 per cent, of their respective immediate breaking loads for 3 days. But when we come to the 80 per cent, loads we find these results exactly reversed; for while annealed and unannealcd silver broke under SO per cent, of their respective immediate breaking loads after 156 and 114 days respectively, annealed and unannealed copper, in duplicated tests, sustained 80 per cent, of their respective immediate breaking loads till the conclusions of the experiments, or about nine months, without breaking.

The Patience-Curves of Iron.—Professor Thurston's results are given in the following table:

Effect of Prolonged Stress.—Swedish Iron Wire.

Per cent. of Maximum Static Load.	Time Under Stress.	
	Hard Wire (Unannealed).	Soft (Annealed).
95	80 days.	3 minutes.
90	35 days.	5 minutes.
85	17 months, unbroken.	1 day.
80	91 days.	266 days.
75	Unbroken.	17 days.
70	Unbroken.	455 days.
65	Unbroken.	455 days.
60	Unbroken.	Unbroken.
55	Unbroken.	Unbroken.

It will be noticed that there are serious discrepancies in this table In some cases, both with the unannealed and the annealed iron, the wire broke under a light load much sooner than under a heavier one This I take to be due to local variations in the strength of the iron, perhaps to actual though invisible flaws. If the above results were plotted just as they are, they would give very irregular lines, which it would be exceedingly difficult to compare with those of the patience of copper and of silver. In order to get simple lines readily comparable with those of the other metals, I have interpolated figures midway between Professor Thurston's results. Thus I have assumed that the patience under 92.5 per cent, of the immediate breaking load would be midway between the patience under 90 and 95 per cent. of that load, etc. I have plotted the curves of iron from these interpolated figures, instead of from his original results. While

FIG. 2.

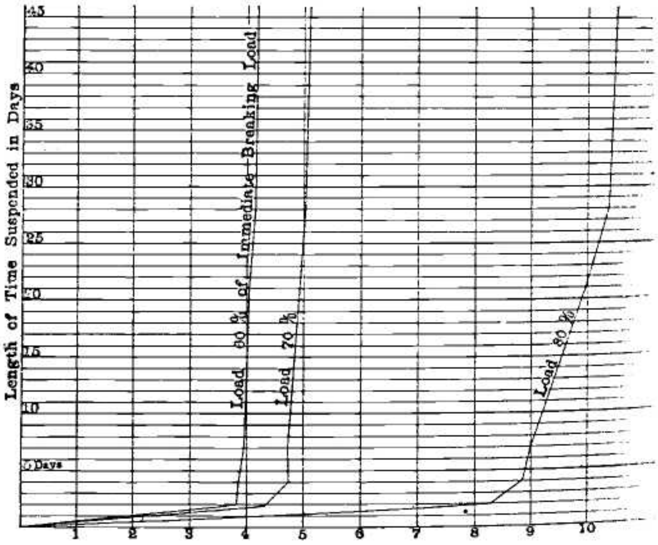


Diagram showing stretch of annealed copper wire, loaded with 60, 70, and 80 per cent, respectively of its immediate breaking load.

the figures thus obtained can have no claim to accuracy, they are probably near enough to the truth to afford a fair comparison between the patience of iron and that of the two other metals experimental on. The very much greater harmony between the results of my experiments on copper and silver seems to point to the fact fact that th?? metals are less liable than iron to local variations in strength.

Stretch of the Wire.—As already stated, in determining the patience of annealed copper wire, pieces sufficiently long were employed to admit of their stretch being readily observed. The amount of stretch was noted from time to time, and the results obtained are given in the following table, and are also graphically represented in Fig. 2. Here horizontal distances (abscissæ) represent the amount of stretch, in percentages of the original length of the wire, while vertical distances (ordinates) indicate the length of time during which this stretching took place.

The results given in the diagram are the mean of two sets of experiments, carried on simultaneously.

Extreme accuracy is not claimed for these figures, since changes in the temperature of the wire have not been allowed for.

We see that, even when subjected to a stress equivalent to only 60 per cent, of their immediate breaking load, these wires appear to go on stretching indefinitely, though, of course, at a constantly diminishing rate; and, even after being subjected to this comparatively light stress for over five months, a further continuation of the same load caused them to stretch a considerable amount—in one case, 0.3 per cent, of their initial length.

With a load equal to 80 per cent. of the immediate breaking load the results arc much more marked. After sustaining this stress for upwards of five months, further continuation of the same stress caused a further stretch of 1.4 per cent. of the initial length of the wire.

If the curves of stretch for the 60 and 70 per cent. loads continued in their present shape, it would probably take some centuries For the amount of stretch under these loads to equal that which had been produced by the 90 per cent. load at the moment when the wire parted under it, Now, if we assume that these curves would continue in their present shape, and further that the wires would break under these loads when the stretch had become equal to that which had taken place at the instant of rupture under the 90 per cent. load, we may infer that these wires would eventually break after upholding their loads for centuries.

In view of the extraordinary length of time during which copper ?tretches under such a small fraction of its immediate breaking load, the interesting question presents itself to our speculation, whether it and similar metals would *forever* resist any tensile strain, no matter ?ow small; whether even under a very light stress the metal would not keep on stretching and stretching, very slowly to be sure, but still always stretching, until, after a sufficient number of æons had rolled by, it would suddenly break.

Stretch of Annealed Copper Wire under Prolonged Stress.

Stress to which Wire was Subjected, in Percentages of its immediate Breaking Load.	Times under Stress.	Amount of Stretch in Percentages of the Initial Length of the Wire.		
		First Case.	Second Case.	Mean.
80 per cent.	2 days.	8.12	8.50	8.31
	4 days.	8.75	9.00	8.87
	7 days.	9.06	9.30	9.18
	21 days.	10.00	10.00	10.00
	28 days.	10.00	10.70	10.35
	167 days.	10.62	12.9	11.76
	222 days.	11.25	14.3	12.77
70 per cent.	2 days.	2.73	...	...
	4 days.	2.98	6.55	4.76
	7 days.	2.98	6.55	4.76
	21 days.	2.98	7.00	4.99
	28 days.	2.98	7.14	5.06
	167 days.	3.26	7.74	5.50
	222 days.	3.43	8.02	5.72
60 per cent.	2 days.	2.73	4.94	3.83
	4 days.	2.73	4.94	3.83
	7 days.	2.92	4.94	3.93
	21 days.	3.13	4.94	4.03
	28 days.	3.22	5.07	4.14
	167 days.	3.31	5.51	4.41
	222 days.	3.52	5.81	4.66

That the effects of rupture by static stresses, such as form the subject of this paper, are not local, but extend throughout the pie??

which is subjected to the stress, whether the stress equals the Immediate breaking load, or is smaller than it, is well illustrated by the following observations.

Portions of the silver wires which had broken under prolonged stress were re-suspended with the loads which had originally broken them. They now broke in a very small fraction of the time which had been originally required to break them.

Kind of Wire.	Stress in Percentage of Immediate Breaking Load.	Time under Stress before Fracture Occurred.	
		Under Original Stress.	When Reloaded, with the Original Stress, after being Once Broken by it.
Hard silver, . . .	90 per cent.	3 days.	8 hours.
Hard silver, . . .	80 per cent.	114 days.	Less than 2 days.
Annealed silver, . .	90 per cent.	3 days.	About 1 minute.

As these second fractures did not occur near where the first fractures had taken place, it is evident that the wires had been gradually weakening during their original suspension, not only in the immediate neighborhood of the point where they finally broke, but over their whole length.

In the case of the immediate breaking load, similar results were obtained. When the load on a wire is rapidly increased till it breaks, fracture, of course, occurs at the weakest point, and it would at first be supposed that, if we now re-suspended one of the fragments of this wire, a slightly greater stress would be required to break it, since we now have to break it at some point where the wire was strong enough to resist the original load when it was applied. But, in a great number of observations which were made, exactly the opposite generally resulted. When fragments of a broken wire were re-suspended and the load on them was rapidly increased, they generally broke undera lighter load than that which had been required to break the wire the preceding time, and generally at aconsiderable distance from the preceding points of fracture. In one case annealed copper wire had its immediate breaking load lowered in this way 8 percent, while steel wire (so-called) lost 10 per cent of its immediate breaking load by being five times broken in this manner. This clearly illustrates the fact that even a very brief application of a tensile stress just sufficient to break a piece of metal at its weakest point weakens the metal over its entire length.

Practically, the subject of the gradual yielding of metals, when subjected for indefinite periods to comparatively light stress, may be of especial importance in the case of cables, whether for haulage, for bridges, or for telegraphy.

A more important question still is the gradual yielding of metals under very light but indefinitely repeated shocks, and on this subject the writer has commenced a series of investigations, the results of which he hopes to lay before the Institute on another occasion.

A practical inference from the curves of patience is that, while it is probably unsafe to subject annealed wrought iron to a prolonged static stress greater than about 40 percent. of that which unannealed iron of the same kind can safely carry, annealed copper can safely sustain about 60, and annealed silver about 67 per cent., of the prolonged stresses which these two metals can safely carry when unanncaled. Further experiments are required, however, before this inference can be regarded as an established fact.

TEE ESTIMATION OF PHOSPHORUS IN IRON AND STEEL

(SUPPLEMENTARY NOTE.)

BY BYRON TV. CHEEVER, UNIVERSITY OF MICHIGAN, ANN ARBOR, M??

IN working up the process which I described at the Chicago Meeting, May, 1884 (p. 163 of the present volume), for the estimation of phosphorus in iron and steel, I employed sampb? of steel obtained from one works only, and of a given bracd. Since then I have had frequent occasion to test the process on other steels, and find that it works equally well. But some steels present certain colors which may mislead the operator; and I therefore po?? pose a slight change in the directions formerly given. On the second page of my paper, in the second paragraph, I would substitute the following modified directions:

Place the flask under the hydrant, till the solution is perfectly cold ; then add, gradually, strong ammonia, with constant stirring till the solution is changed into a pasty mass and the ammonia in slight excess; then add cautiously HNO_3 (1.40 specific gravity till this mass is dissolved ; cool the solution to 60° C. It should then have a straw color. If the solution has a decided red tinge, iron will be thrown down with the phospho-molybdate precipitate, which can only be removed by a re-precipitation and with a loss of phosphorus. To remove this red tinge, add some strong HNO_3, shake well and then add about 25 cc. of water. The solution should now not exceed 200 cc. Heat the solution to 60° C. and add 60 ee. of molybdate solution; place the flask on an iron plate heated to 60° C (not more) and let it stand one hour.

NOTE ON AN OCCURRENCE OF NICKEL AND COBALT IN NEVADA.

BY A. D. HODGES, JR,, MINING ENGINEER, ROXBURY, MASS.

IN 1874 my attention was called to what seemed to me an interesting and new nickel and cobalt combination found in Ludwig and Carter's copper mine, near Mason Valley, Esmeralda County, Nevada. With the assistance of Mr. A. Hebberling I made several partial analyses of the mineral or minerals. I also communicated with my friend, Professor H. B. Cornwall, of the John C. Green School of Science, College of New Jersey, who analyzed a couple of specimens which I forwarded to him.

The copper ore occurs in the mine principally as carbonate and to a certain extent as silicate, the latter generally in connection with clay seams or bands,

In some places, together with the copper silicate and clay, generally interstratified with them, there occurred a compact shining black mineral (a) containing nickel and cobalt.

Occasionally, in cavities, in connection with *(a)* was found a black substance (b), either massive and in this case very similar to (a) out with duller lustre, or forming an incrustation with rough and botryoidal surface and radial-fibrous structure, or granular and earthy. A few specimens were found having on the surface very. agile black needles (c) sometimes ½-inch long, interspersed with needles of malachite.

The mineral (a) seemed, according to the analyses, to be of nearly constant composition, and was considered by Professor Cornwall to be a chrysocolla containing nickel and cobalt--a new occurrence to me. It was nearly infusible before the blowpipe (or fusible only with difficulty on the edges), was completely decomposed by HCI, and had a specific gravity (Cornwall) of 2.57. It is the No. 15 of the analyses given below.

The substance (6) gave varying results. Professor Cornwall thought it to be a mixture. Perhaps the brittle incrustation was entirely different from what appeared to be a massive occurrence of the same substance, and the variations in the analyses were due possibly to imperfect separation of the two. Various partial analyses were made, several of which (Nos. 2, 6, 8 and 10) are appended.

The needles (c) were of very rare occurrence, and were so fragile that only those specimens carried in the hand survived the perils of transportation. I possessed only two specimens, I think, which, on account of their beauty and remarkable character, I reserved for the examination of some mineralogical expert. They met, however, with the usual fate of delicate specimens kept in rough mining camps. I cannot now describe them any better than by saying that at first sight I thought them to be malachite crystals colored black by some oxide. But Mr. Hebberling and I both tested separate crystals, and found a large amount of cobalt and nickel but no siya of copper.'

The following table gives the results of some of the analyses made Those marked C are by Professor Cornwall. The others, II, are partial analyses made by me at Dayton, Nevada:

	No. 2.		No. 6.	No. 8.	No. 10.	No. 15.	
	C	H	H	H	H	C	C
H_2O, . . .	15.98	16.0	Undet.	Undet.	Undet.	20.86	20.86
SiO_2, . . .	39.33	39.4	27.8	34.6	44.4	38.96	38.82
$Al_2O_3+Fe_2O_3$*	25.79	30.2	30.4	17.0	12.0	4.29	4.15
CuO, . . .	3.92	6.25	13.7	5.95	2.0	30.61	30.61
Mn_2O_3, . .	3.93	2.7	10.4	10.0	9.9	Trace.	0.68
CoO, . . .	9.46†	8.6	4.3	16.8	8.8	0.49	0.43
NiO, . . .						3.59	3.47
CaO, . . .	1.02	Undet.	Undet.	Undet.	Undet.	Undet.	1.06
MgO, . . .	0.57	Undet.	Undet.	Undet.	Undet.	Undet.	0.04
	100.00	103.15	86.6	84.35	77.1	98.80	100.12

* Only a very little Fe2O3.

† By loss. Lost by breakage. Evidently contained much CoO.

THE COST OF 3IINING AND MILLING GOLD-OSES IN NOVA SCOTIA.

BY WILLARD IDE PIERCE, NEW YORK CITY.

CONSIDERING the extent of the gold-fields of Nova Scotia, which occupy an area of 6000 to 7000 square miles, a few words as to the cost of extracting and reducing the ores may prove of interest.

The veins are for the most part narrow, 4 to 12 inches being the usual width, while a 2-foot vein is considered a large one; but they offer many advantages, inasmuch as the ore is easily treated wages are low, and machinery and supplies can be transported by water to within from 1 to 15 miles of the different mining districts. The Salmon River vein is a notable exception to the above rule as to width. It ranges from 4 to 20 feet in width. The Hall-Anderson of Fifteen-Mile Stream (where there are several veins) is another, which has proved to be from 3 to 4 feet in width.

The ownership of all mining claims is retained by the Crown, but persons wishing to work them can lease as many unoccupied areas as they please for twenty-one years, with option of renewal, on the payment of two dollars for each area, and a royalty of 2 per cent. on all gold extracted. Each area consists of 150 feet along the lode and 250 feet across, upon which a certain amount of work must be done, which by recent law is reduced from one hundred to forty days' work for each area every year. Any person erecting in a district the first mill, having at least 8 stamps, and being at least 10 miles prom any other mill, is entitled to a lease of 10 areas, free from advance-payment and from royalty, for twenty-one years. A record must be kept, and filed every quarter at the office of the Commissioner of Mines, of the total number of days' work done on the areas, and a monthly statement of the number of tons crushed, and theactualyieldofgold.

Gold-mining in Nova Scotia may be said to have commenced with the finding of a nugget of gold in a brook at Tangier in 1858. The following table, taken from the official report,* gives the total yield

* Report of the Department of Mines, Nova Scotia, 1884.

with the number of tons of ore crushed since 1862, in which year statistics were first collected :

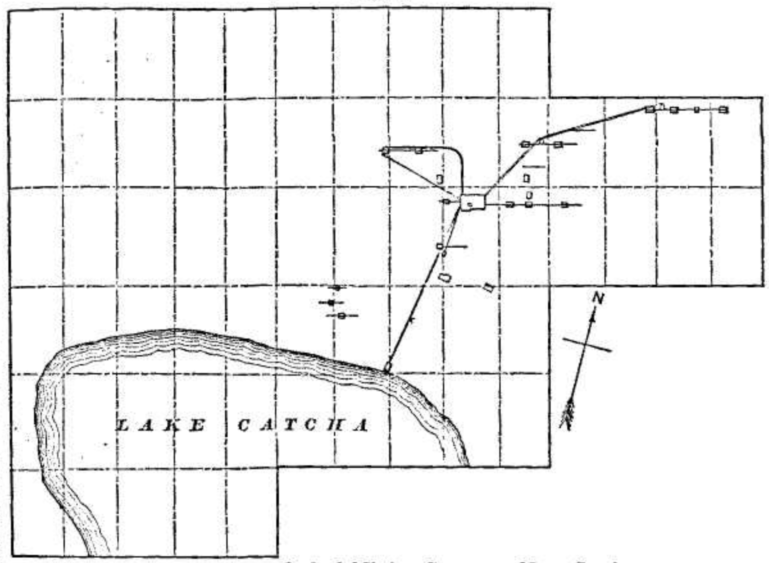
Year.	Total amount of Gold Extracted.			Ore Crushed.	Yield per Ton.		
	Oz.	Dwt.	Gr.	Tons.	Oz.	Dwt.	Gr.
1862	7,275	0	0	6,473	1	2	11
1863	14,001	14	17	17,002	0	16	11
1864	20,022	18	13	21,434	0	18	16
1865	25,454	4	8	24,423	1	0	20
1866	25,204	13	2	32,161	0	15	2
1867	27.314	11	11	31,386	0	17	9
1868	20,541	6	10	32,262	0	12	17
1869	17,868	0	19	35,147	0	10	4
1870	19,866	5	5	30,829	0	12	21
1871	19,227	7	4	30,791	0	12	11
1872	13,094	17	6	17,093	0	15	7
1873	11,852	7	19	17,708	0	13	9
1874	9,140	13	9	13,844	0	13	5
1875	11.208	14	19	14,810	0	15	4
1876	12,038	13	18	15,490	0	15	13
1877	16,882	6	1	17,369	0	19	10
1878	12.577	1	22	17,990	0	13	23
1879	13,801	8	10	15,936	0	17	8
1880	13,234	0	4	14,037	0	18	20
1881	10,756	13	2	15,556	0	12	20
1882	14,107	3	20	22,081	0	12	18
1883	15.446	9	23	25,954	0	10	21
Total,	350,916	13	2	470,776			

This is an average yield, per ton of ore crushed for the whole period, of 14 dwt. 22 gr. of gold.

As there is great similarity amongst the gold-ores of Nova Scoth, and as the work of extracting and treating the ore in the different districts presents the same general features, one typical example may be given as representing the conditions of all. I select for this purpose the Oxford property, which has no special natural advantage tending to reduce the cost of working, but at which, on the other hand, all circumstances are utilized which favor more economy working, and as a result, perhaps, some distinct features are page sented.

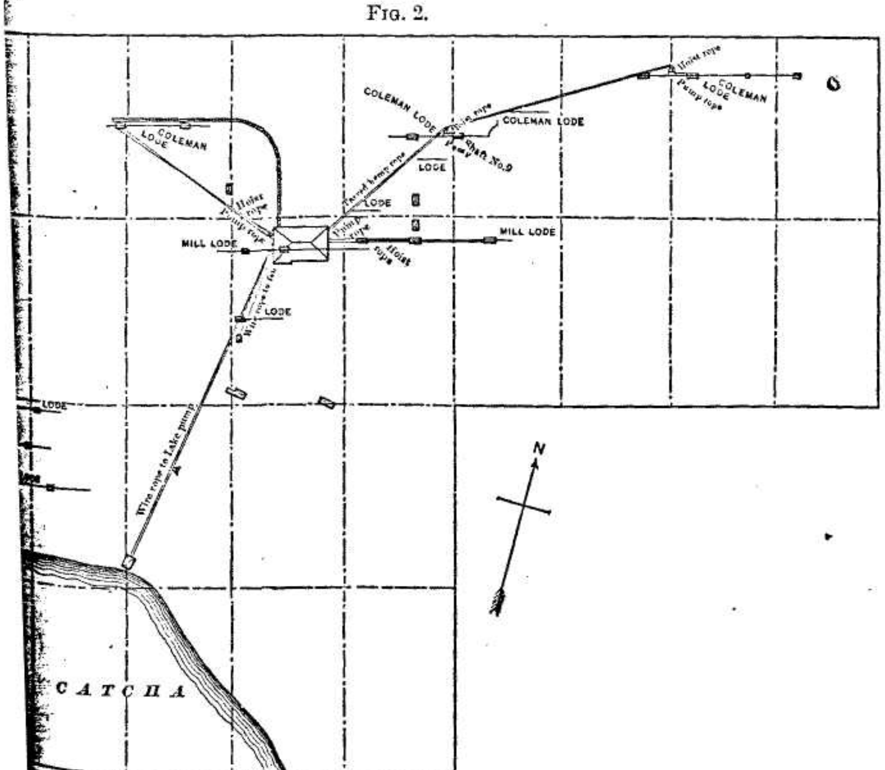
This property, on which work was begun in March, 18?-, CCA sists of 63 areas of 150 by 250 feet, situated in Lake Catcha trict, 30 miles northeast from Halifax. Fig. 1 shows the whole property divided into its areas; and Fig. 2 shows a part on a scare twice as large. On these areas have been found a number of gosle bearing veins; but beyond ascertaining their comparative vah little active mining work has been done on any except the M?? and Coleinan lodes. All the veins strike about E.N.E. and W-S. W.,

Fig. 1.



Property of the Oxford Mining Company, Nova Scotia.

Fig. 2.



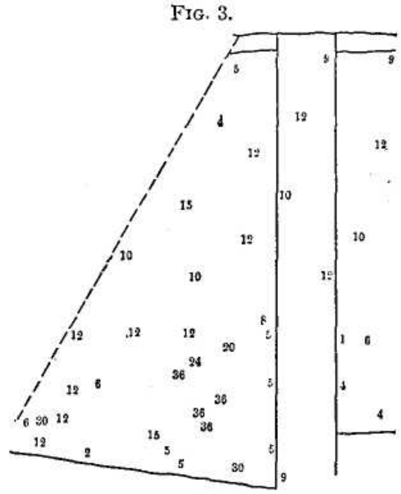
Part of the Property of the Oxford Mining Company, Nova Scotia.

and dip northward about 85°. They are dislocated by a series of faults, the faulting fissures running N. and S. The vein-matter is a hard white quartz, inclosed in slate with walls of quartzite.

A peculiar break is found in the Coleman lode where the ends of the walls are broken as usual in faulting, but are not immediately discontinued. On the contrary, the walls and vein-matter continue around a curve for some little distance, and then suddenly end, the vein being found further north, lying in its proper course.

The quartz carries, besides the gold, from 3 to 5 per cent, of iron pyrites ; but as the latter contains but little gold, no attempt is made to save it. The gold is found varying from coarse to very fine; but a great deal is in coarse grains or " sights " (from pieces weighing 1/2 oz. each, down to shot-sized), so that it is impossible to obtain from the ore direct a correct assay of it. The only way to determine the

FIG. 3.



6CALE 1 3O

Varying Thickness of Vein at Shaft No. 9, Coleman Lode.

real average value of the ore is to add to the value of the bullion. produced from a given number of tons, the value of the tailing-which are run off. The distribution of the gold in the veins is very irregular, a uniform yield being seldom continued for more than feet in the vein. There are usually one or more zones of quartz richer than that surrounding it; and these zones do not seem to follow any general law, but lie at every angle, and are of varies length and width. The veins of quartz vary greatly in width, running from 2 inches to 4 feet. The sketch of the vein at shaft No.

9, Coleman lode (Fig. 3), illustrates the variations in width of the quartz-seam. The figures show the width in inches of the quartz at the points marked.

The width of the quartz seems to have little effect on the walls as they retain their same relative positions, from 3 to 6 feet apart, whether the quartz-seam is narrow or wide; only the slate, in the latter case, is very much pinched.

The cost of extracting a ton of ore varies greatly, according to the width of the quartz-seam, as all matter is removed between the walls, the whin-rock and part of the slate being thrown on scaffolds which are formed about every 18 feet in depth.

The walls being solid, no other timbering is required, and the average cost for scaffolds set up, on walls 3 feet apart, is 32 cents per running foot.

Underground work is done by contract or days' work, wages for underground men being $1.25 to §1.40 and for deckmen to attend to hoisting, emptying buckets, etc., $1.25 per day, while the wages for laborers are $1.00 to $1.20 per day.

The average cost of mining a ton of ore on a 12-inch quartz-seam, walls 3 feet apart, is §4.95, which includes raising the ore to the surface and pumping. On a 6-inch seam, the cost will be a little more .' than double, and on a 2-foot seam a little less than half of the cost on a 12-inch seam, the distance between the walls being the same.

The power for hoisting and pumping in the different shafts is all transmitted from the mill by means of wire or tarred hemp rope, and the cost, per ton of ore raised, for pumping and hoisting is:

Labor in hoisting—deckman,	$0.40
Extra fuel used in mill	0.12
Wear and tear, etc.,	0.05
Total,	50.57

The mill of the Oxford Company is a 10-stamp steam-mill, and has been in operation since July, 1882. It is built over the Mill lode, one shaft of which opens within the mill, so that all ore placed in the bucket at the bottom of that shaft is hoisted direct to the |breaker floor of the mill without other handling. The property and the immediate neighboring country are slightly undulating and in places swampy, and well wooded with soft wood [(spruce and fir), and hard wood (beech, birch and maple). The [price per cord delivered at mill is, for soft wood, $1.40, hard wood, $210.

The ore from the different shafts is brought to the mill by car or cart, and, if by the latter, is dumped direct into a car at the foot of an incline to the mill. Thence the ore-car is hauled up by wire rope to the breaker-floor, where it dumps automatically. From here the ore is passed through the breaker to the ore-bin, thence by chutes to self-feeders, where it is fed into the batteries.

The stamps are run at GO drops per minute and have a fall of 0 inches, crushing 1 1/5 tons of hard rock, or 2 tons rock and slate per head every 24 hours. The stamps weigh 661 pounds, the weight being divided as follows:

Stem	280 lbs.
Shoe	145 "
Head	148 "
Tappet	88 "
Total,	661 lbs.

The stem is 13 feet long and 2 7/8 inches in diameter. The shoes are of chrome steel and have given great satisfaction, the last set crushing 3.300 tons. The dies are of the same material and weigh 94 pounds each. From the mortars the ore as crushed passes through iron wire screens of 40 meshes per inch, and all gold not caught by the plate inside of the mortar passes over copper plates, silver-plated, which are arranged in a series of steps, the first three of 3 inches each in length, the next 5 1/2 feet, and the last 2 1/2 feet long, with a fall of 1 1/2 in 12. From here the tailings run through launders out of the mill and to waste.

The greater part of the gold is caught inside of the mortars, the proportion ranging, according to the coarseness of the gold, from 1/2 to 9/10 of the whole amount. From 94 to 98 per cent. of the gold in the ore is saved, the loss including the value of the sulphurets. In the 2 1/2 years that the mill has been in operation it has crushed 4 7 5 1 tons of the average value of $22.70 per ton. The gold is of a high degree of fineness, ranging from .945 to .966 1/2, with an average of .953.

The cost of milling a ton of ore is as follows:

Labor—crushing and amalgamating,	$0.76>
Fuel	0.32
Hauling to mill,	0.05
Supplies—wear and tear,	0.15
Total,	$1.28

The motive power is furnished by two engines of 35 and 12 normal horse-power, which furnish all power for the mill, hoisting and pumping at the different shafts, hoisting ore-ear from foot of incline to breaker-floor, pumping water from the lake for use in the mill, and running blacksmith's fan.

Power is transmitted from the mill by different methods, as is found most convenient, for the different workings. For hoisting and pumping on the eastern workings of the Coleman lode the following method is employed :

On the main counter-shaft (in the mill), which revolves at the rate of CO revolutions per minute, is placed a 2-foot bevel-gear-wheel. Leading from this and attached by a 1-foot bevel-wheel is an upright-shaft 2 3/4 inches in diameter, which extends about 2 1/2 feet above the upper floor of the mill. This shaft is geared to make 120 revolutions per minute and turns in guides placed in the middle and at the upper end. Just below the top guide is keyed a 7-foot wooden sheave, which revolves horizontally, and is grooved to take a 1/2-inch tarred hemp rope. Hemp rope is used here instead of wire rope, on account of its greater lightness and durability as here employed. By the use of sheaves, placed horizontally, the rope may be carried in any direction around the circle, and by increasing the width of the sheave additional grooves may be made so that power can be transmitted in different directions at the same time. The rope leads on and off the sheaves over small guide wheels, 1 foot in diameter, and is carried off to the point where it is desired to transfer the power for hoisting and pumping.

If it is desired to carry the power on beyond this point for additional working, the sheave around which the rope is passed has a second groove, around which a rope is passed and it is carried to the second shaft where it is to be utilized. Near the shaft where the power is to be used a suitable frame of heavy timber, set. on bed-rock, and reaching 18 to 20 feet above the surface, supports hoisting-gear, etc. The hoisting-gear, which is placed from 5 to 6 feet above the surface, consists of a drum 10 feet in circumference journaled to a 3 5/16-inch shaft, but not attached thereto.

The shaft is horizontal, one end projecting sufficiently from bear-jtog to take a pump-disk ; the arrangement of the shaft from one end to the other being pump-disk, bearing, collar, hoisting-drum, friction-wheel (which slides back and forth on shaft on feathered key), 50-inch bevel-wheel, bearing. The end of the drum next to the friction-wheel has a beveled flange of cast-iron 6 inches deep, into which the friction-wheel is beveled to fit. To hoist, the friction-wheel is thrown into the flange of the drum by means of a lever extending into the shaft-house, and. worked by the deckman at the shaft, and the means of checking or holding a load is furnished by a brake that fits the outside of the flange, hung underneath,—the lever which works it also extending to shaft-house within reach of the deekman. In the 50-inch bevel-wheel is matched a 10-inch pinion, attached to an upright shaft. At the upper end of this shaft is keyed a 7-foot sheave which receives the rope from the mill. The speed of the 7-foot sheave and upright shaft is 120 revolutions per minute, while that of the horizontal shaft, which supports the hosting drum and pump-disk, is reduced by gearing to 24 revolutions per minute. The winding speed on the 10-foot drum, of 240 feet per minute, is not found to be too great, as it is all under the complete and easy control of one man. *

The sheaves arc made of seasoned oak, and are of great weight and strength for the work they are called upon to do. On the hoisting drum, iron-wire rope is used, 5/8 inches diameter, which passes over a sheave in the shaft-house 14 feet above the top of the shaft.

Pumping on the Mill lode and on the western workings of the Coleman is done by means of a pump-disk geared to a second counter-shaft C feet above the main counter in the mill.

On the pin of the pump-disk, is a suitable box having two hooks placed in opposite directions. On each hook is slipped a wire rope furnished with an eye for that purpose, and run out of the mill, one to the eastern workings on the Mill, the other to the western workings of the Coleman lode.

The ropes pass all the way from pump-crank to pump-rod, being led over 3-foot sheaves at deck-head. The pump-rod is held in its proper plane of movement by a guide moving on a slide just above the pump. This pump-rod is long enough to permit the attachment of a weight—about 100 lbs.—to carry the pump-rod down, and as the down-stroke at one shaft is the up-stroke at the other, the weights serve to counter-balance each other.

The rope from the pump-crank to the shaft is supported at inter vals either on roller-wheels or by proper hangings.

Either pump can be put at rest in an instant at the mill, without stopping any other machinery, by catching and holding the ropeal the end of the up-stroke, and as the disk revolves, the rope is slipped' off and placed on the stationary hook.

Hoisting at these workings is done by drums placed on the first and second floors of the mill and suitably connected with the engine. One end of a wire rope is wound around the drum, the other end reaching to the shaft, having the bucket attached to it. The load is under the control of the deckman at the shaft, who, by pulling one of two cords attached to different levers on the second countershaft in the mill lowers, hoists, or holds the bucket under his charge.

Water is pumped from the lake to the mill by means of a 1/2-inch wire rope leading from the mill to the brow of the hill, where it passes around a 4-foot vertical sheave having two grooves, the other groove taking a 3/8-inch rope to a similar sheave on the shaft to which the pump-disk is attached. A 4-inch pipe placed underground carries the water from the lake to the mill.

With horizontal transmission-wheels, in a stretch of 250 feet, a difference of level of 20 feet would not affect the run of the rope; and a greater difference of level, for instance 50 feet or even more, could be compensated for by putting the rope on somewhat slack, or by putting guide wheels above the rope where it enters and leaves the lower wheel, thereby bringing the rope down to the groove. With vertical sheaves, the difference of level between driver and driven is immaterial, the only considerations being that the stretch or distance between the two must not be too great (not over 400 feet), as the strain on the ropes caused by their own weight, would be a serious cause of wear ; and the ropes must not touch the ground or other object. Hence, if the distance is too great, or the rope is carried to the other side of a hill, as is the ease with the lake pump, an intermediate vertical wheel is necessary.

I am indebted for much of my data to Mr. A. H. De Camp, a member of this Institute, Superintendent of the Oxford property, under whose supervision the arrangement for the transmission of power by means of wire rope was erected.

Since the above was written, a question has been asked as to the percentage allowed for "stealage," owing to the coarseness of a great deal of the gold. I would say, in reply, that the amount to be allowed under this head is very small. This is, perhaps, due as much to the comparatively isolated position of the property, as to the laws of the Province. The nearest town is 4 miles from the mines, and is reached in winter by road across the frozen lake, and in summer by means of a row-boat, or by walking across 2 miles of swamp to the wagon-road. All the miners change their clothes in a "dry-house," and live in an adjacent boarding-house, or in cottages on the property. There are no convenient saloons, since by the law of the Province no liquor is allowed to be sold within 3 miles of a mining district.

The laws are severe on all persons found with gold in their possession (in the shape of nuggets or bars) unless they can prove their right to it, and from what leased claims it was obtained, as all such gold is considered as belonging to the Crown until the royalty has been paid.

DISCUSSION.

H. M. HOWE, Boston, Mass. (communicated by letter to the Secretary) : It may be appropriate to place on record, in connection with Mr. Pierce's interesting paper, the results of some observations on gold mining and milling made during a recent professional visit to the Sherbrooke, Nova Scotia, gold-field.

The conditions and practice in this field agree pretty closely with those described by Mr. Pierce, the chief difference being in the cost of milliner, which is very much lower at Sherbrooke than as given by Mr. Pierce. While the figures given me by the superintendent of a Sherbrooke mill, $0.32 per ton of ore milled, may be somewhat below the mark, on account of not allowing enough for wear and tear, yet, making all due allowances, it is manifest that the cost of milling at Sherbrooke is vastly lower than at the Oxford mill. Labor, the chief item, is only $0.27, against §0.76 at the Oxford mill ; and at Sherbrooke the mill is run by water-power, eliminating the cost of fuel. The *custom-charge* for milling at Sherbrooke, $1.15, is considerably less than the *actual cost* at the Oxford mill. §1.28.

The Sherbrooke mills treat the free gold-bearing quartz from the neighboring town of Goldsborongh. The ore consists of hard glassy quartz, mixed with a little slate. There were at the time of my visit about 100 men employed in these mines. The cost of mining was put down at about §1.25 per ton of material broken In the chief group of mines which I visited, there are two very small veins of quartz, from 0.5 to 3 inches thick, inclosed in hard tough slate, without gouge. Consequently but a very small proportion of rock was hoisted, the greater part being piled on stulls.

The system of mining is very rude, all the rock being broken from a straight continuous breast, by underhand stoping, with absolutely no development-work. The low cost of mining appears to. be mainly due to the low price of labor, which is only about $1.25 per ten-hour day, on the average, and to the fact that the workings are ex tremely shallow and dry. It was surprising to find that, in this old mining town, the meanings of such words as "winze" and "stull" were unknown to the miners.

The details of milling at Frazer's mill, which is reported to be one of the best, were as follows. They were obtained as far as practicable by actual observation, but, of course, for most of them I was obliged to take the statements of the superintendent. There are three batteries of five stamps each, stems 3 inches in diameter, and set 10 inches apart from center to center:

Weight of stamp, including 250 pounds for stem,	COO pounds.
Fall (order of falling, 1-4-2-5-3),	10 inches.
Drops per minute,	50 to CO.
Quartz crushed per stamp per 24 hours, approximately,	1 ton,
Labor, 3 men per 24 hours, or, per ton crushed,	0.2 day.
Mercury consumed per ton crushed,	0.038 pound.
Order of falling,	1-4-2-5-3.

This enables us to calculate the cost approximately as follows :

Lahor, crushing and amalgamating 0.2 day at, say, $1-37,	$0 27
Mercury, 0.033 pound at, say, 40 cents,	0 02
Wear of shoes and dies, at $55 per annum,	0 03
Total cost per ton of ore,	$0 32
Mai-gin for profit, amortization, interest, repairs, supplies, etc.,	$0 83
Custom-rate for milling,	1 15
Custom-rate for hauling from Goldsborough, say, 3 miles,	0 45
Charge for milling and hauling,	$1 60

The carts which haul the quartz from the mines dump it just behind the batteries. Most of it is small enough to be fed at once [into the battery, as it is cobbed down quite small at the mines to avoid hauling waste rock to the mill. What further breaking is necessary is done by hand, and the quartz is fed by hand into the batteries.

In front of each battery are three silver-plated copper plates The first is stationary, and 4 feet by 4 feet 6 inches. The other two arc about 2 feet 6 inches square, and have a slow reciprocating motion parallel with the length of the battery, with a travel of about 10 inches.

At the time of my visit, there were said to be in the district 92 stamps standing, and 99 dismantled. The total cost of erecting a 15-stamp mill, including buildings, flumes for water, etc., is currently estimated at §8000.

THE USE OF HIGH EXPLOSIVES IN THE BLAST FURNACE AND OF A WATER-SPRAY FOR COOLING IN BLOWING DOWN.

BY W. J. TAYLOR, CHESTER, N. J.

FURNACE-MEX who have not taken advantage of the use of dyna mite in certain blast-furnace troubles, as explained by Mr.William bee in his valuable papers read before the Institute some years since, cannot appreciate the quick relief and great advantage that may bed derived at times from its judicious employment.

Before giving my experience in the use of high explosives in blast furnace troubles of certain kinds, I will record a method I have used with marked success in "blowing clown." Had I not under stood, however, the use of powder, I would have " salamamdered" effectually the first time I tried it. Early in my straight-furnace periments, last summer, at the Chester, N. J., Furnace, I wanted to blow down to within 3 or 4 feet of the tuyeres. To do this with a down-comer not lined, and without putting in any limestone to keep the gases cool enough to do no harm, was not an easy task. Weoald keep the bell and hopper cool by filling them with water, say 12 inches deep ; but before we got the stock down 15 or 20 feet the pyrometer in the gas-flue on top was up to 1300°, and the down comer was red-hot, with the heat still rising.

In this emergency my assistant, Mr. N. M. Langdon, urged the trial of a plan he had often advocated, viz., the introduction of water in some way under the bell in the proper quantity, in order that i? evaporation might absorb and reduce the heat of the escaping gave to a point where it would not do any harm. He thought the last and hopper might be " cracked," that is, the bell eased from the hopper sufficiently to admit the necessary amount of water without getting in too much. I was afraid of this measure, as there was no proper control of it. But it was necessary to do something quickly, or put something in the furnace.

I then happened to think of the three 1/2|-inch pipes inserted through the plates and hopper for measuring the height of the stock in the furnace. These, of course, were quite near the walls and about equal distances apart. We immediately put a small stream of water in each of these pipes. The result was a reduction of temperature in a short time to about 700°, and we were masters of the situation. We then kept on water enough to hold the temperature at about that point and no more, until we got down to within 4 or 5 feet of the tuyeres, when we put in a larger amount of water, in order to have things comparatively cool on top when we stopped and swung the bell, to. examine the condition of the interior of the furnace. But the old saying, " Too much of a good thing is good for nothing;," proved true when we took off the blast, for the water immediately ran out of all the belly-pipes and the tuyeres all got black at once.

After lowering the bell and ascertaining that the walls were entirely clean, we made a few blank charges of coke as quickly as possible and put the blast on again. After driving in bars and working for some time at the tuyeres, they began to brighten up and also to melt a little; but we soon found that none of the tuyeres would clear themselves of cinder, and in the course of an hour the pressure was getting so high (14 or 15 pounds) that the engine would just turn Over. Poor gas, poor steam, and the belly-pipes filled with cinder; in short, we were stuck. ft

After stopping and taking down the belly-pipes, I ordered a hole drilled in at the cinder-notch, large enough to take a 3-inch boiler- tube, on an angle of about 45°, so that when it reached the center of the furnace it would be at the bottom of the hearth as near as might be. This took about three hours, and when it was down everything was black, clear to the bottom. We then plugged up one end of a 3-inch boiler-tube with wood and loaded it with about pounds of dynamite (No. 2 giant powder),.putting in two fuses with two caps. After lighting both fuses, we slid it. into the hole ill it reached the bottom. Probably, nearly one minute elapsed before it exploded, giving us plenty of time to get away from it. The explosion was only a heavy thud in sound, and did no harm in by way, but it broke up all the cemented stock in the furnace, so that when we got the belly-pipes up and the blast on, **the** pressure was only about two pounds. The tuyeres soon brightened up, and in the course of three hours all the tuyeres would clear themselves when cinder was tapped at the notch ; and we had a normal hearth again. To have recovered from this trouble without the use of powder would have been a serious and difficult matter, and might have taken a week.

Every furnace-man knows the great difficulty of bringing out a furnace that is chilled solid in the hearth—not with iron in the bottom, for this seldom occurs; but when the cinder sets as far up as there is any melting, encasing all the fuel, so that air cannot In-driven in, or if it could, would not give any useful result, since there is no escape or vent for the gases of combustion. Under such circumstances, there is no relief until a clearance can be made through or up to the loose stock. This is sometimes done by opening the furnace and barring out the stock till an opening or connection with the loose, stock is made, when, after a good deal of coaxing and the exercise of much patience and good judgment, a hearth can be brought into normal condition. But a few pounds of dynamite will break up this salamander of cinder and coal in an instant, suffieicatly to allow the blast to enter and the gases of combustion to escape. thus accomplishing at once what might otherwise take days.

Another case in which I found great benefit in the use of dynamite, was when the stock "bridged" on the boshes in blowing in. I have had this occur twice at the Chester Furnace, and on both occasions the relief was complete. The first time it occurred, thestock stopped settling entirely about six hours after putting on the' blast. The furnace got tighter and tighter till the pressure was about 15 pounds, with the engine just turning over. The tuyetes were all bright and dry, but there was no escape for the gas excep where it was breaking through the walls about the tuyeres. The was the condition of things after blowing about twelve hours. The stock had not settled any for six hours. I was well satisfied by the time that the coal had bridged or arched on the boshes, and that the ore above it was reduced and disintegrated, it had worked does into the interstices till they were all closed, leaving no vent for ?? gases. Hence the high pressure; and nothing could be done ?? the arch was broken.

We then stopped the engine and drilled a hole into the furnace about 13 feet above the tuyeres, where we found, as I expectest cavity nearly of the full diameter of the furnace and about " height from the top of the lower or loose coal to the under side of the circular arch. We then charged a 2-ineh gas-pipe with about 7 lbs. of dynamite, in the same way as before explained, and exploded it as near the center of the cavity as we could, so that the concussion would break the arch. No harm was done except to drive the clay packing out from one of the tuyeres and raise a little dust on top; and the result was a complete success. The arch was broken, and the stock settled immediately. We then closed up the hole and put on the blast, and the furnace traveled right oft' as though nothing had happened.

My second experiment was just the same, only the stock did not settle 6 inches from the time the blast went on, till in about six hours we were stuck by the high pressure and break-outs at and above the tuyeres. On opening the same hole we found the bridging and all conditions practically the same as in the first case; but the explosion did not seem to break the arch as thoroughly, and, as near as we could tell, only about two-thirds of it came down. Consequently the furnace settled faster on one side than on the other. Next day we drilled in on the high side about 15 feet above the tuyeres and found the stock, for about three feet in, was not traveling. We then exploded in this stock, quite close to the wall, two 1 1/4-inch cartridges, in a smaller pipe but in the same way, after which the stock settled the same on that side as on the other, and the condition of the furnace became normal.

I have also tried the effect of powder on dirty walls or partial scaffolds, after the furnace had been in blast for some time, by exploding a moderate quantity of powder, say one or two cartridges, just inside of the walls where the stock was not moving; but I never got any permanent benefit from this. It would seem that in that case, the stock was too pasty, confining the effect to a very small space; while in the case of the bridging the blast had been on such a short June that the stock at that point was only red-hot, and dry instead of pasty, and hence in good condition for the action of the powder. In the case of the explosion in the hearth, the cinder was all cold and set, which also made the conditions right for breaking up the whole mass with an explosion. A bad ring-scaffold might, I think, be removed in this way if it was pretty well up in the furuace and the furnace was blown down below the bottom of the scaffold and a lew cartridges (capped) dropped in from the top. Or a hole could drilled in from the side where the thickness of the stack would admit of it, at a point below the scaffold and over the loose stock, and the powder put in with a pipe. Or a hole might be drilled from the outside directly into the thickest and strongest part of the scaffold and near the bottom of it. In this way the powder might break the ring, thus bringing down the whole scaffold. If not, one or two more holes might be put into the scaffold where it was not broken. I have had no experience in this, as I have had no ring scaffolds to contend with since I learned the use of powder; hut I think now I could break down with powder ring-scaffolds which would formerly have forced me to blow out.

Whenever powder is to be exploded, where there is sufficient heat to ignite the exploders in a short time, no fuse need be used; but I always put more than one exploder in with the powder—two at least, and three would be better. When the heat is not sufficient, I put in two fuses to make sure of one, light the fuses first, and then slide the pipe into the hole to the point where the explosion is wanted. In either case the pipe should be tamped with sand on top of the powder, the same as in an ordinary rock-blast, but I never did any tamping around the pipe after it was inserted for exploding. A boiler-tube, with a wooden plug driven in one end, is better for loading than gas-pipe, as it is not so thick and strong.

Returning to the use of the water-spray for blowing down, I would say I blew down the straight furnace once after the time previously mentioned, and also blew out both times, using water-spray with complete success, and without chilling the hearth or getting any water in the belly pipes—one experience of that kind being quite sufficient. I am satisfied this is the simplest and easiest way of either blowing down or blowing out a furnace, as the evaporation of a-small amount of water absorbs a large amount of heat. If there is a hole near the center of the bell large enough to admit, say, a 3/4-inch pi?? perforated at and near the end with small holes equal to, say, one-hall the area of the pipe, and then a good pressure of water is put on, commencing soon after blowing down is commenced, and before the bell and down-comer get hot, it is not difficult to hold the temporary ture of the escaping gases at, say, 800° or 900° all the way down. by regulating the quantity of water to suit, particularly if plenty of water is kept in the bell and hopper. Of course, the more the water is split, up into spray, the better the gases can act on it and vaporize it before it reaches the coal or stock, and the less water is requiret. Little or no more water should be put in than vaporizes before reaching the stock; but we found no chilling below when we only per in water enough to hold the pyrometer at about 900°. When we produced a chill, as described above, by the use of too much water, we were reducing the gas-temperature at the last to 600°, which was, as the result showed, further than we could go with safety.

REMOVING OBSTRUCTIONS FROM BLAST-FURNACE HEARTHS AND BOSHES.

BY T. F. WITHERBEE, PORT HENRY, N. Y.

SUCCESS in this operation is much promoted by adhering to a definite plan. Random work is of little account. In general, anything done that will enable the blast to pass through the obstruction, providing the melted products can be got away from the tuyeres, is all that is necessary. Hence the utility of high explosives in breaking up the chilled mass in the hearth. (This, by the way, should be done with the wind on, so as to prevent the filling of the tuyeres with the usual rush of cinder following the explosion.)

If from any cause it is not expedient to use explosives, the simple but very effective instrument known as the kerosene or hydro-carbon blow-pipe can be depended upon to perforate the contents of a blastfurnace hearth to any extent required. It consists, as used in the Champlain district (first by Mr. Charles H. Foote), of several pieces of gas-pipe, liberally supplied with elbows (five in number) so as to be flexible; one end being connected to a tuyere-stock and the other brought to bear upon the place to be melted out. A 1/4-inch pipe leads from the last length, or blow-pipe proper, to a reservoir of Kerosene or crude oil, set high enough to overcome the blast-pressure. This 1/4-inch pipe should have a valve conveniently located to regulate the flow of oil, and also another next to the reservoir.

With a good hot blast and a surprisingly small quantity of oil, this apparatus will melt, burn or mechanically dislodge anything around a blast-furnace hearth excepting firebrick and water-cooled castings or plates.

It may be helped by vigorous prodding with a suitable steel bar, to detach the fused but sometimes sticky material. A very good way to operate on a chilled hearth with it, is to open up a hole from a cinder- or iron-notch to the nose of the most con-Bient tuyere and then make a blow-pipe of the tuyere by turning the oil into its belly-pipe. The hole will soon become a cavern and generally make work for all hands in taking care of the cinder flow ing from it. As soon as good fuel comes down to the tuyere, the use of oil in that place is of no benefit and is not required. In all cases the oil should be admitted far enough from the outlet of the blow pipe to insure its complete vaporization, since any oil *as such* leaving the pipe has a cooling effect. Besides the use of the blow-pipe as described it may be used in many minor operations around a furnace, such as opening tuyeres, melting out tuyeres and water-blocks that cannot be otherwise handily removed, and, last but not least, it will sometimes save much labor in tapping an iron- or cinder-notch not possible to drill. Sometimes the use of high explosives is impractical ble, owing to the difficulty of making a proper hole for the cartridge That, the blow-pipe will do.

When the mass to be operated on is cold, or projecting, a good plan is to cause the gas to pass through a fire-brick arch, or tunnel, and so get a reverberatory effect, igniting at first with hot cinder or coal until the breast or bricks become hot enough to keep the- gas burning.

In case a furnace is so tightly scaffolded as to have stopped " gas sing" at the top, it is a question whether continued blowing is not worse than useless; instances being known where a 24 hours' rot of furnace and men has sufficed to cure the trouble. If the hearth i« solidly chilled, the healthy part above will get no worse by delay: there is no occasion for haste or worry; and all preparations may be deliberately and thoroughly made, in the faith that, with high ex plosives and the blow-pipe, the obstruction must go.

I think this blow-pipe, or a similar one, was first used at Pitter burgh ; but having seen no published account of it or its work, thought best to advertise it, and so possibly find its owner.

The only drawback to its use is its deafening racket—not quite as loud as thunder but much more disagreeable. The sizes 1 have used are from one inch up to four inches in diameter.

Occasionally "getting a hole up through " is overdone, as was the case at Cedar Point about three years ago, after a stoppage of four teen days, caused by breaking the blowing-engine cross-heat and incidentally, two guides and housings, eight gibs and the cap abase the guides, and finally putting a reverse curve in the steam-piston rod and breaking it partly off in the clamp.

At the time of the accident the furnace was on all anthra??. making something over 60 tons No. 1 and No. 2 iron, with a heavy burthen, 15 turns of the engine, 12 pounds pressure, and, luckily, in good condition for holding its breath for an unknown period.

The two weeks were used up in sending piston- and connecting-rods to the Delamater Iron Works for repairs, making patterns and castings, and finishing and erecting the same at home.

The bronze tuyeres were removed; everything was made as tight as possible below; all water was shut off, and 40 barrows of coal-dust were charged on top. Immediately after the smash, seven beds of iron were cast, and the crucible was drained of cinder as far as practicable without the blast.

The cross-head showed an old flaw about two inches in diameter on the top corner. An examination showed that it had broken on the up-stroke, and experts said it had been cracked about 8 inches down for some time. It was of Bessemer steel, 5 inches by 23 inches at the fracture, and a tough piece of metal.

In thirteen days the engine was repaired, but one day more was taken to get things fully ready to tackle the furnace. Upon opening the iron-notch, the hearth was found full of coal alone, at a dull red heat; the air immediately drew in and lightened it up, gas showing at the same time on top.

A large hole was made in the hearth by raking out coal to make room for cinder and iron as soon as melted : the intention being to hold cinder in as long as possible, and then, by exploding a cartridge of Atlas powder, to let it down and out at the iron-notch. The wind was put on in clue time, and everything looked promising; the blast from the different stoves showing 480°, 390°, 420° and 510°, cooled down from an average of 1200° in fourteen days.

When cinder showed strongly at the tuyeres, cartridges were exploded below, the third of which brought a mushy lot of stuff to the iron-notch, where it chilled.

The next attempt was made at a cinder-notch ; and one good run of cinder and white iron got out—the first and last for several days, as all tuyeres soon closed up.

Here, I wish to say, a great mistake was made in not putting oil into all tuyeres from the time wind went on. All the furnace seemed to want was heat, which the oil would have probably sup-f'ied.

Both Atlas powder and the blow-pipe were used in getting holes into the center of the crucible, and in time loose stock was heaved out in great quantities; but the mass adhering to the sides refused to let go, and that which did come away was noticed to fall from an unknown height.

The **third** day (Thursday) the stock was reported 24 feet from the top, and the top-man was directed to keep it at about that point. Charging with a light burthen of ore was kept up, and also "heaving" out" at the bottom, as required.

By Friday the bell got very hot—above a cherry-red—and continued so until Sunday, the seventh day after the wind was put on, when the actual condition of the furnace was discovered. When a charge was dumped from the bell, it was heard rattling down through the stack, seemingly clear to the tuyeres; and upon measuring on top *through the central bell,* a hole was found 45 feet deep, while upon the sides the same old 24 feet was shown. Then for the first lime the remarkable regularity of that report for several days past was noticed, and the mysterious appearance, that morning, at the bottom, of coke put in the night before at the top, was accounted for.

All that remained to be done was to fill up the hole with fuel. It took 67 tons of coal and coke to bring the middle even with the sides, when regular charging was resumed and the trouble soon came to an end.

I am led to think that such cases *of burning up through the center* are of not very rare occurrence, and are indicated to a greater or less degree by an abnormally hot top. Under such conditions I know of no better way than to fill up with fuel, drive in the wind and melt out the ring.

DISCUSSION.

J. D. WEEKS, Pittsburgh, Pa.: I believe the first use of what is here called the kerosene blow-pipe was made by Captain .lones in connection with the chilling of one of the Edgar Thomson furnace

JULIAN KENNEDY, Pittsburgh, Pa.: At the Edgar Thomson furnaces, at the time spoken of by Mr. Weeks, the blow pipe was used with coke and worked very well. The arrangement for using oil was devised shortly afterward, and is better suited for working. where there is very little room ; the coke, however, works well where there is space enough to apply it. I have been informed that the blow-pipe with coke was used at the Himrod furnaces for burning. through hard tapping-holes as far back as 1870. After melting hole into the nose of a tuyere, it is not necessary to use any more or coke, as the blast can then be turned on at the tuyere, where combustion of the reduced iron in the hearth will give all the heat necessary. In one furnace that was tightened, we melted in with the blow-pipe to the nose of the tuyere nearest to the cinder-notch, and then .by blowing through the tuyere we burned the hearth out clean for 10 or 12 feet above the tuyeres before the stock dropped from above. As soon as the loose stock came down, the trouble was all over. In regard to the point, mentioned by Mr. Witherbee, of letting the furnace rest, I have noticed that a furnace which is working cold, and for some reason has to be stopped for a day or two, will often start up hotter and in better shape than before the stoppage, the process of reduction seeming to go on during the stop with a very small expenditure of heat.

COMBINED AMALGAMATION AND CONCENTRATION OF SILVER ORES.

BY TV. M'DERMOTT, NEW YORK CITY.

IT is well known that many so-called free-milling silver ores are so classed more from their value necessitating a cheap process than from a real adaptability to raw amalgamation. Such low-grade ores, carrying more or less sulphurets, are more profitably treated by a cheap rapid process than by the more effective but costly process of roasting and amalgamation. The tailings are sometimes crudely concentrated, or, after lying and becoming partially oxidized, are again worked in pans. Of late years, by the use of improved methods of concentration, many old low-grade tailings-piles have been reworked to a good profit; and in some improved mills arrangements are made to concentrate before or after amalgamation, thus making a single treatment in mill-suffiee.

• It is self-evident that on a low-grade ore a small increase in percentage saved is of no commercial advantage if accompanied by a material increase in cost, and therefore a cheap and continuous system of work is the real necessity, if a fair saving be effected. As an illustration of the possibilities of combined concentration and amalgamation on some ores, the following results of a working test at the New York Ore-Milling and Testing Works will be of some interest.

The ore treated was a hard white quartz from Mexico, carrying very small percentage of finely divided sulphurets, chiefly iron pyrites. The original average assay was 35.5 oz. silver and 0.125 oz. gold per ton. The ore was stamped wet through a 40-mesh screen and passed direct to the Frue vanner. The concentrates produced were about one per cent. of the original ore, *i.e.,* 100 tons into one. The concentrates assayed 1397 oz. silver per ton, and 5.2 oz. gold per ton. The tailings from the vanner assayed 16.4 oz. silver per ton and 0.05 oz. gold. The tailings were run into a settling tank and afterwards worked by regular pan-amalgamation, yielding bullion .858 fine, and thesettler-tailings assayed 4.1 oz. silver per ton with a trace of gold. The combined process yielded, therefore, about 89 per cent. of the assay value. In this test about one-third of a ton only was operated on and a certain quantity of ore remained in the battery, which was weighed and assayed and proved to be concentrated to a value of about §100 per ton in gold and silver. It may safely be assumed that the precious metals which concentrated in the battery would in regular running be found in the concentrations and bullion to the same percentage as those in the discharge of the battery. But should this method of calculation be objected to, the following figures based on actual yield of test are reliable :

Bullion value in original ore by assay,		$14.51
" " of ore left in battery,		3.41
" " " " discharged and treated,		$11.10
" " concentrations by assay,	$5 77	
" " bullion from pan,	3.81	
" " total yield,		$ 9.58
Loss by difference,		$ 1.52
Bullion value of settler-tailings by assay,		1.42

Of course it is not possible to clean up accurately in a small test either the few pounds of rich concentrates, or the small quantity of bullion from the pan ; but a substantial agreement of yield with the differences between assay of original ore and tailings justifies con-fidence in the result of the test. The samples of tailings from both concentrator and settler were taken by automatic sampling machine and the settler-sample was further checked by a sample taken from the pan just before discharge. These points are mentioned a- an excuse for basing calculations as to working processes on so small test, in which, however, it is to be noted that the actual operation was exactly the same as it would be on a large scale. The stamp battery was fed by automatic feeder; the concentration was automatic and similar to that in any good gold-mill; the pan-charge was run but six hours with a small quantity of blue-stone and salt.

In speaking of the percentage of value saved as 89, two assumptions are made, viz.; first, that the residue in battery was from the fact of its concentration as susceptible to treatment as the discharge of the battery ; second, that the contents of the rich concentrates constitute a final product. These assumptions are correct enough for the general purposes of this paper. The percentage of loss in subsequent reduction is of course very small per ton of original ore crushed. The additional cost of concentration in a properly arranged mill for amalgamation is extremely small, as it necessitates even in a 40-stamp mill not more than two extra men in 21 hours, with a consumption of but trifling power. If continuous amalgamation be employed, the whole process is of course cheapened still more. The process is adapted to low grades of ore, carrying sulphurets, which it is not advisable to roast; and even some higher grades, under certain local conditions, will yield better commercial results than by any process involving a preliminary roasting. The disposition of the small quantity of rich concentrates is determined by local conditions; the product can either be roasted and put through the pans, smelted with other ores, or shipped to reduction works. The roasting of a small, rich product is of course a very different matter to roasting the whole of the crude ore, and can be done in a small, cheaply built reverberatory furnace. Where the ores and local conditions favor, raw leaching by the Russell process can take the place of amalgamation, leaving the same work of utilizing the sulphurets to the concentrators.

THE LA PLATA MOUNTAINS, COLORADO.

BY HENRY C. FREEMAN, C. E., E. M., ALTO PASS, ILLINOIS.

THE writer spent the month of November last in the La Plata mountains, Colorado, and the material portion of his observations, so far as they may be of general interest, is here recorded.

The La Plata mountains lie northwest of the town of Durango. The California mining district is co-extensive with the mountains. They appear on the map as an isolated group; but an examination on the ground shows that they are the continuation of the great mineral-bearing range of San Juan county, although the Hermosa valley, cutting nearly across the range, and being very deep, with much erosion of the slopes, gives them an isolated appearance.

The mountains are as bold and broken as those of San Juan county with this distinctive feature, that they have an abrupt termination at the southern end of the range, and, seen from the south, appear to rise boldly out of the plain which extends two-thirds of the distance around them.

The whole group is an uplift of Carboniferous strata, with some indications of a central axis. The main valley is the La Plata, a narrow gorge with side-gulches, narrow where they enter the main stream, but most of them expanded into basins towards their heads, and all formed by erosion and giving shape to the separate mountains. Mt. Hesperus, the highest on the west side, and near the head of La Plata river, rears its summit to 13,316 fect, and several other peaks are not much below it.

Approached from the south by the only road (which enters them at Parrott by the La Plata gorge), the mountains rise abruptly from the plain, with a clip of the strata of 25° to 30° to the south. On the peaks near the head of the river, nearly horizontal strata may be seen, dipping easterly on the east side and westerly on the west side of the La Plata, and indicating that the group as a whole is an anticlinal uplift.

Coal is found at the base for about two-thirds the circuit; and it is evident that the coal-area, given in the U. S. reports as Cretaccons, once covered the space occupied by these mountains, and has disappeared by erosion during or since the uplift.

All the strata of the mountains are metamorphosed, the sandstones being changed to quartzites and the clays to aluminous silicates. But a single bed of limestone was noted, namely, a bed at the southern entrance, said to be 14 feet thick, and producing good lime. It appears to run out towards the north long before reaching the higher peaks.

Throughout the mountains, fissures filled with porphyry, and sometimes quartzite, which form great dykes, cut through the strata to the summits. In these chiefly are found the veins of gold- and silver-ores. The porphyry dykes are large—from 15 to 100 ft and over in width.

The distinguishing features of the ores of gold and silver are their silicious character and the general absence of galena. They may divided into two general classes : pyritous quartz-ores carrying good with little silver; and those of silver carrying little gold. The latter appear to be chiefly antimonial and arsenical, with some tellurides. Besides these two classes there are some lodes carrying a fair proportion of both gold and silver.

There are some very rich tellurides; and that singular ore "Amalgam," containing quicksilver in a free state in such excess that it can be shaken out of the ore in drops, has also been found.

The veins are very numerous and of good size--3 to 5 feet generally, with good pay-streaks of 10 to 30 inches, and often mineral in the whole width. They dip mostly, so far as observed, at a high angle, a large number being vertical or very near it, and few dipping less than 75°.

The claims are mostly in the hands of prospectors yet, and consequently there is not much development. The veins generally cross the gulches, so that they can be opened by drifting on the vein ; and the-slopes of the mountains are so steep (about 45°, sometimes steeper in high altitudes) that the gain of "backs" overhead in driving adits is very rapid.

Durango, which is 20 miles from Parrott--the entrance into the mountains--as one smelting establishment. Beyond Durango, Pueblo and Denver are the markets for the ores. The rates of freighting prohibit shipping out any but high-grade ores; and the silicious character of these ores increases the charge for smelting.

At the expense of the county, the wagon-road was extended during the past summer to the head of the La Plata; and this will make a material reduction in the cost of getting ores to market. The claim-owners can now build branch-roads to their property, greatly reducing the number of mines from which ore will have to be packed, as heretofore, for several miles on *burros* (donkeys).

From Parrott, the road up the La Plata to its head is 9 1/2 or 10 miles long.

There have been two attempts at milling in the vicinity of the mines, but both establishments were shut down after a brief trial. One was arranged for a gold-mill with arrastres without stamps; the other was a 5-stamp gold-mill, with silver ores only accessible for working.

There is a fair prospect that' this coming spring the arrastre-mill will be refitted and put in good condition with additional machinery for profitable work under proper management.

There is abundance of good quartz-gold-ore accessible to this mill. The successful establishment of one mill in this district would lead to many others, and the present depressed condition of this camp would change to that of permanent activity.

The coal of this region is of excellent quality, and is furnished at the mines for §2.00 per ton. It makes a tine coke, which is used at the smelting works of Durango.

When the Denver and Rio Grande R.R. shall extend westward from Durango, it will skirt the southern base of these mountains, passing through or near Parrott to reach the waters of the Mancos. A railroad connection at Parrott would place this mining-camp in as favorable position as any other in the mountains of the west.

A THEORY TO EXPLAIN THE CAUSE OF HARD CENTERS IN STEEL INGOTS.

BY E. GATEWOOD, ASSISTANT NAVAL CONSTRUCTOR, U. S. N., WASHINGTON, D. C.

THE solution here offered is at once simple and important in its direct and indirect bearings.

According to the principles *of surface-tension,* which will be found sufficiently enlarged upon for present purposes in Clerk Maxwell's excellent little treatise on *The Theory of Heat,* a mechanical mixture of liquids will frequently of itself divide into groups, consisting of liquids mixing among themselves but withdrawing from the other liquids. The following simple and familiar illustration will suffice:

" If we mix water with alcohol, the liquids diffuse into each other. If we now attempt to mix oil with the alcohol and water, the two liquids separate from each other of themselves, and in the act of separation sufficient force is brought into play to set in motion considerable masses of the fluids."

Maxwell goes on to show that this relative energy is one of arrangement, depending on the nature of the fluids and the area of the surface of contact, the act of separation tending to reduce this surface to a minimum consistent with equilibrium; that this surface-tension exists between a solid and touching fluid, either liquid or gaseou- being of one sign or the other, in the case of a liquid, according as it tends to draw itself up into a drop on its surface or to spread and wet the solid. After considering various cases, he states that which particularly interests us, thus:

" When a solid body is in contact with two fluids, then, if the tension of the surface separating the solid from the first fluid exceeds the sum of the tensions of the other two surfaces, the first fluid will gather itself up into a drop, and the second will spread over the surface." *A fortiori* the two, if liquid, stirred together and poured into the solid containing vessel, will separate out throughout the mass, and tend to assume that relative arrangement which permits the least surface of contact consistent with equilibrium--spherical, if the difference in specific gravity be small.

In all the liquids experimented on--all, of course, liquid at ordinary temperatures--the value of the coefficient of surface-tension increases as the temperature diminishes, being a maximum at the point of solidification, and vanishing at the critical point between the liquid and gaseous states. In fact it would seem to have an important influence on the phenomena of solidification and evaporation.

If the mixture of the liquids, therefore, be at a higher temperature, than the walls of the vessels, separation should take place near the sides before it occurs in the mass of the liquids, and at a greater rate. In separating out under these conditions, very fine drops will be formed at the sides, which may or may not coalesce, but collectively seek the center at top or bottom according to the relative specific gravities of the liquids.

Eirst Case.--Let us take as a particular case, *a,* the same material as the containing solid c, but in the liquid state; *b,* a liquid, or mixture of liquids soluble in one another, of small mass compared with a, than which it has a less specific gravity and somewhat lower point of fusion. Let *b* be stirred with *a* and the mixture poured into *c,* which is maintained at a temperature such that a gradually solidifies to form part of c. We inquire what will be the action and what the nature of the resultant solid at different points.

As we have seen, *b* will tend to draw to the center and top of a, but, since this action will generally extend over some time, *a,* as it solidifies, will retain a certain amount of *b,* in increasing proportion as we pass towards the center and top of the resulting solid. Plainly, the slower the rate of cooling and the higher the initial temperature of the liquid mixture, the greater will be the segregation of *b,* which may be almost entirely removed from the bottom portion of a in the extreme case. It is probable that *b* will be more uniformly disposed and in a finer state throughout the bottom and near the sides than towards the top and center.

Second Case.--The relative specific gravities remaining the same, let the surface tensions of a and *b* be reversed, so that *a* does not wet c, while b does so completely. Then *a* will separate in drops which seek the bottom, and a somewhat similar condition of segregation as in the previous case will obtain, except that, if the segregation be rapid, the distribution of *b* will vary much from ton to bottom, and but little across the section of the mass at a given level. If, however, the separation be slow and the length of the resultant solid large as compared with its lateral dimensions, while solidification goes on more or less uniformly over the whole shell, the center portions of the upper layers, remaining fluid a longer time than the outer portions, will receive a greater proportion of 6, rising through *a* from its less specific gravity. The distribution of *b* will then he found very similar to that in the first case, but the physical structure of the resulting solid will be very different.

It is this last condition which is believed to obtain in the particular application to be considered.

The condition in which the so-called impurities are contained in iron and steel has long been a matter of inquiry. One thing seems agreed upon, that it is impossible to conceive of the great effect of comparatively very small changes in the amounts of these impurities on the assumption that they are contained in a state of extreme dilution throughout the whole mass. At present there is a good deal of theorizing on the subject, especially as to the condition of the carbon, the opinion being fairly well supported that it exists in the mass as two, or possibly more, definite carbides. It is, of course, a well known fact that the greater the proportion of carbon, the lower is the point of fusion of the metal.

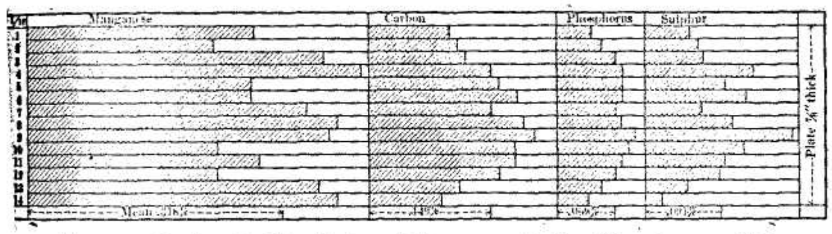
It was long ago observed that phosphorus, or its compound with iron, was liberated from pig in the puddling furnace while the mass of the metal was as yet only in a plastic or semifluid condition High phosphorus seriously affects fluidity and is essential to the very high fluidity or sharpness required in delicate castings.

Silicon affects the fluidity and, within certain limits, the physical structure on sudden cooling.

Without enumerating the more complex effects of other impurities with regard to temperature, let us resume our direct subject.

Consider the mass of molten steel in the ladle as a mechanical mixture of the following substances in liquid condition: (1) pure iron; (2) one or more definite carbides of iron ; (3) a phosphide of iron; (4) a sulphide of iron ; (5) a silicide of iron ; (6) an oxide of iron. Possibly each of the elements may, under different circumstances, combine in different proportions, but for our present purpose it is sufficient that we suppose them present in molecular conditions distinct from one another and from the mass of pure iron. The condition of the manganese will be referred to later.

Let us further suppose that of the above constituents some mix freely with each other but not with the pure iron, while others seek the pure iron and tend to separate from the first mixture. We then have essentially two liquids as regards quality of surface-tension. It is not necessary to consider the specific gravities of each constituent, but only those of the essential liquids. Now if these two essential liquids bear the same relation to each other and to the sur-



Diagram, showing the Distribution of Manganese, Carbon, Phosphorus and Sulphur in a Portion of the "Livadia's" Boiler-Plate.

face of the solid shell in cooling as the liquids *a* and *b* in the cases considered, we shall have a corresponding segregation and distribution of the constituents throughout the resulting ingot, and the distribution of each of the elements contained in either of the essential liquids ought to be similar, except, perhaps, in the very uppermost portions of the ingot, where slight differences in the point of fusion may affect the result.

Now, so far as we know, this is just the condition of an ingot with a *hard center*. As illustrative, and particularly striking to the eye, the accompanying diagram is given of what is believed to be the first hard center thoroughly investigated, being that of a portion of the steel shell-plate of a boiler built for the Russian Imperial Yacht "Livadia," and described by Mr. *W.* Parker, Chief Engineer Surveyor to Lloyds' Register, in the *Transactions of the Institution of Naval Architects,* for 1881.

It will be noticed that the carbon, phosphorus and sulphur are arranged through the thickness of the plate with perfect similarity, the hard center being towards the bottom of the diagram. The manganese is disposed with less order. I am, indeed, rather of the opinion that manganese ordinarily exists in steel in two distinct conditions, the one an oxide in a finely divided state and therefore rising slowly through the bath in the furnace and not allowed time to escape, and the other in the metallic state or alloyed with the pure iron. The two have different surface-energies, and the resultant distribution of the element is determined by difference.*

TABLE.--*Analysis of a Sample of the Livadia's Boiler-Plate.*

NOTE.--Shavings about 1/16th inch thick were taken off in successive layers through the thickness of the plate and carefully analyzed for manganese, carbon. phosphorus, and sulphur, with the following results:

	Manganese.	Carbon.	Phosphorus.	Sulphur.
1st 1/16th inch cut	.280 per cent.	.100 per cent.	.040 per cent.	.054 per cent.
2d " "	.230 "	.110 "	.054 "	.065 "
3d " "	.367 "	.120 "	.069 "	.080 "
4th " "	.410 "	.150 "	.076 "	.131 "
5th " "	.283 "	.160 "	.077 "	.097 "
6th " "	.283 "	.180 "	.079 "	.123 "
7th " "	.348 "	.160 "	.072 "	.066 "
8th " "	.381 "	.190 "	.074 "	.105 "
9th " "	.371 "	.200 "	.095 "	.177 "
10th " "	.237 "	.180 "	.086 "	.118 "
11th " "	.288 "	.180 "	.079 "	.098 "
12th " "	.237 "	.160 "	.076 "	.090 "
13th " "	.360 "	.110 "	.050 "	.052 "
14th " "	.381 "	.090 "	.039 "	.018 "

This solution explains why rapid cooling and low temperature of cast tend to prevent segregation. The proper use of soaking-pits is

* The known rapidity of escape into the slag of manganese added to ?? blown steel forms no argument against this conception, as the oxide of iron in case blown metal is in a much more agglomerated condition than is possible in n?? metal. The relative rapidity of escape may be well illustrated by the analysis the rapid fall of rain in drops as compared with the gradual settling water held in suspension in a very finely divided state, under the action of ?? in a calm atmosphere.

also seen to be a very delicate matter of temperature. In order to obtain the greatest chemical homogeneity of metal in hollow or annular forms, notably for parts of a gun, the largest possible cores should be used and the mass cooled from within, subsequent forging being around a mandrel. Fluid compression would appear not to influence the result materially, except that, as ordinarily carried out, it affects the rate and conditions of cooling.

HEMATITE OF FRANKLIN COUNTY, VT.

BY ALFRED F. BRAINERD, ST. ALBANS, VT.

SOME fifty years ago, iron-ore was discovered near the town of Sheldon, Franklin County, Vermont, in a vein out-cropping on a knoll near Black Creek, which empties into the Missisquoi River a ; couple of miles away. A short time after this discovery, the owners, Mr. W. O. Gadcomb and Hon. Lawrence Brainerd, both of St. Albans, commenced mining (mostly by open cut); and also erected a Catalan forge, from which iron blooms were produced, most of which were worked into bar-iron and used in the neighborhood of the forge, while some were shipped by Lake Champlain to Troy, Albany and New York. But by reason of the lack of any railroad connections, and an insufficient demand for the blooms, this forge [was subsequently abandoned, and the material used in its construction removed to other places.

Mr. Keith, of Sheldon, used for many years a mixture of this ore with bog-ore from Swanton, in a charcoal blast-furnace, the product of which he consumed partly in his own foundry, shipping, however, a considerable amount to Troy and New York. Accurate data as to this enterprise are not at hand.

The same vein has since been traced for some 20 miles, and some prospecting has been done on its outcrops at Berkshire, Enosburg and a few miles east of St. Albans; but the vein being small, only few ear-loads of ore were taken out from these places. The commencement of the St. Albans Iron and Steel Works in 1872, and the erection in 1877 of a ten-ton Siemens open-hearth furnace for the manufacture of steel rails, opened a new use for this ore. The furnace-charge consisted of pig-iron, old rails, steel scrap, and magnetic iron ore, added towards the close of the heat. The ore and pig-iron were at first principally from Port Henry and Crown Point, N. Y. It was, however, ascertained by experiment that the hematite from Sheldon could be successfully substituted for the magnetite; and this was therefore used exclusively. The owner of the Sheldon ore-mines, Mr. Aldis O. Brainerd, commenced active mining operations in consequence, and has since mined and shipped several thousand tons of the ore, which has been carried by teams three miles to the Missisquoi R. R., and from that point to St. Albans.

As an experiment with the ore at the works referred to, several charges were made in the Siemens furnace, consisting of 50 per cent, of pig-iron and 50 per cent. of the hematite (averaging 62 1/2 per cent. iron). The ingots produced were rolled into rails as usaul and the crop-ends subjected to the following physical tests: they were placed on supports 3 feet apart and a ton-weight was dropped on them from the height of 20 feet, without producing the slighted crack, although the tests were bent nearly double. Iron rails sub jected to the same test were cracked, in some instances, nearly through the rail. As another test, the flange of one of these steel rails was struck sixty-four times with a large sledge-hammer before it was broken. This broken end, hammered down cold to a piece about half an inch square and eight inches in length, was beated, and a perfect "sand weld" was made without the use of bora. This steel had a chemical composition of 0.18 carbon, 0.15 phorns phorns, 0.01 sulphur, 0.015 silicon and 0.25 manganese.

The mine is situated in the southeastern part of the town of Sheldon, about one mile west from the St. Johnsbnry and Lake Champlain R.R., and half a mile west of Black Creek. It is that the county road ; and the distance to various other points is as for lows: to the Sheldon depot of St. J. & L. C. R.R., 1 1/8 miles; to the junction of that R.R. with the Missisquoi R.R., 2 1/2 miles to the Sheldon depot of the latter road, 3 miles; to St. Albans by rail, via the two roads, about 13 miles ; and about the same distance via the St. Johnsbury road to Lake Champlain, where it can by shipped to Troy, Albany and New York. Other connections, to Rutland, Bennington, etc., need not be here detailed, as they was be plain to any one who consults a railway-map of the region.

At the mine there are two distinct parallel veins out-eropping the surface and about two rods apart, the out-crop of each l?? nearly three feet wide. The most westerly vein is the one on what most work has been done. It shows several small open cuts ??

two shafts over GO feet deep. The ore is three feet wide at the surface and ten at the bottom.

The vein strikes N. 35° E. and dips easterly. The mouth of the shaft is about one hundred feet above the bed of Black Creek. No water has been struck to interfere with mining operations. No timber has been found necessary in sinking the shafts, as the walls are well defined.

The ore resembles Pilot Knob Specular in appearance, has a dark gray color, sub-metallic lustre, a red streak, and a laminar fracture; occasionally it is massive. Upon exposure to the weather for a long time it becomes lighter in color and does not look like iron-ore.

According to a series of analyses the average composition is about as follows:

Ferric oxide,	89.285
Lime,	0.200
Phosphoric acid,	0.239
Silicious residue, undetermined elements, water and loss,	10.276
	100.000
Metallic iron,	62.5
Phosphorus,	0.105

The above figures for phosphorus are the highest obtained by the writer in many analyses, and represent about the average shown by these analyses taken together with those of Mr. A. A. Blair, chemist of the St. Albans works. The lowest phosphorus was 0.005, in 'samples of " weathered " ore.

TIN-ORE VEINS IN THE BLACK HILLS OF DAKOTA.

BY WILLIAM *V.* BLAKE, NEW HAVEN, CONN.

, THE discovery of tin-ore in the Black Hills of Dakota dates from June, 1883, and short preliminary notices were published in Sept ember of that year.* The discovery-point is known as the Etta Mine, in the central portion of the Hills, about six miles east of

* *Amer. Journ. Sci.,* Sept., 1883; also, *Eng. and Min. Journ.,* Sept. 8,1883. .

Harney Peak, and twenty from Rapid City. The Etta was located for mica. It is a granitic mass, rising in the midst of fine-grained. micaceous and arenaceous slates, which resemble the Coos group of the White Mountain formations of New Hampshire. Some portions of these slates are highly garnetiferous; other portions contain staurotide ; and in some places there is a large development of sandstones of regular stratification, in thick beds, which form prominent ridges. These sandstones are compact and solid, and possess a bluish-gray color, due to protoxide of iron. They are in the condition of quartzites, and they indicate shallow seas on the borders of some continental or extensive shores in that remote period of the world's history.

There is a singular absence of limestone strata and of maguesian rocks in these old formations. Hornblendic slates and syenitic rocks are also rare. Granite, in the form of bosses, and (nearer to the Harney Peak range) in long dikes is common. But at the Etta, and in its vicinity, the granitic masses are columnar, rather than tabular, in form. The Etta outcrop is nearly circular, in horizontal section, measuring about 200 feet in its longest diameter, and 100 to 150 feet in its transverse diameter across the outcrop.

The line of demarcation between this granite mass and the slates is sharp and distinct; and where the contact is opened to view by the lower tunnel, there is a clay selvage making a distinct wall, as in regular veins. This mass, like most of the similarly-formed granitic masses of the region, is characterized by extremely coarse, massive crystallization of the constituent minerals. Slabs of pure feldspar, from twelve to twenty inches in length, may be frequently seen, and masses of white quartz, several feet thick and nearly pure, are abundant.

Structure of the Etta Vein.—The outcrop and the whole columnar mass have a rudely concentric structure; the outer portions, next to the country rock, being characterized by a band or belt of dark colored mica, alternating in places with muscovite in large plates This is succeeded by massive quartz, with irregular bunches of massive albite and of orthoclase feldspar, together with enormous crystals of spodumene and irregular bunches of a dense aggregation of small crystals of mica and albite, forming a kind of greisen-rock, an albitic greisen, in which cassiterite is abundantly disseminated to small grains and partly-formed crystals.

Percentage of Black Tin in the Ore.—The mineralization i??? markably even. The masses of greisen are rarely without the grains of eassiterite sprinkled through the mass. The percentage of black tin is not yet ascertained by working in a mill in the large way ; but average samples show that it is about 2| per cent. Hand-samples of selected rock will yield as high as 6 per cent. The result originally obtained by sampling the outcrops was 3 per cent. A sample lot of two tons of greisen-rock ore sent to New York, and there worked, yielded between 3 and 4 per cent. of concentrate black tin of high grade—some of which, smelted by Mr. Riotte, at the New York Metallurgical Works, gave a number of 25-pound bars of excellent tin.

These percentages are, of course, independent of the massive cas siterite, of which some hundredweights have been found outside the greisen-rock. This occurrence is exceptional; but more may, at any time, be brought to light by the excavations.

The percentage of black tin in the ore compares favorably with that found in the ore of other tin-regions.

The general average percentage of black tin of six large mines , upon the great flat lode of Redruth, Cornwall, in 1870, was *2 22/100;* and less than this has been worked with profit in some places.

Minerals Associated with the Tin-Ore—The mineralogieal association of the tin-ores at the Etta and other places in the Black Hills, appears to be very similar to that observed in other tin-regions. As a general rule, mica is the most common associate. This is the mineral with which the cassiterite is most directly and closely connected. Albite may be mentioned as next in intimate relationship, while in some of the veins—notably in the Hill City district—quartz is the pervading gangue or veinstone. At the Etta, also, spodumene, rich in lithia, is a close associate, and occasionally cassiterite is found in the midst of the massive crystals. This association of spodumene with tin-stone is common in several of the granitic masses in Maine, and was brought to my attention by Mrs. Ellen Richards, of the Massachusetts Institute of Technology (oue of our members). I am not aware that this paragenesis has been observed abroad.

The absence of topaz, so far as yet known, is a little peculiar. Beryl, which is common in the Black Hills in other granitic masses, has not yet been recognized as present with the tin-ore. The same may be said of tourmaline, which is very abundant in some of the granitic dikes, and especially in the great cliffs of Harney Peak and its vicinity, yet does not occur to any noticeable degree in the Etta; and where it does occur, so far as yet ascertained, tin is absent. An exception may be noted in the Bob Ingersoll dike, where indicolite a beautiful blue tourmaline, is abundantly entangled with muscovite mica in large plates; but it is not in direct association with the tin ore, which is inclosed in albite. This species, tourmaline, is gene rally enumerated as one of the associates of tin-stone ; but my observations in the Black Hills lead to the belief that it is not so, thus confirming the observations of Lodin upon the tin-bearing veins of Villeder and Morbihan, France, described in his paper recently presented to the Geological Society of France,* which notes the fact that tourmaline, though abundant in the region, is not found in close relationship with the cassiterite.

In addition to the minerals already mentioned as found with the tin-stone at the Etta mine, the following should be mentioned:

Apatite, triphy line, heterosite, lencopyrite (or rather a stanniferous arsenical iron, requiring further examination), tantalite, or colum bite, a small quantity of vitreous copper (the only sulphide seen), and a few secondary oxidized species, due to the surface-decomposition of the arsenical compound and the copper sulphide.

The associates of cassiterite in New South Wales, according to Professor Liversidge, † are quartz, mica, orthoclase feldspar, fluorspar, molybdenite, garnet, beryl, and topaz; also, mispickel and tourma line. Wolfram does not occur in the same veins with the tin, but is in other veins almost in juxtaposition. This association is not unlike that found in Dakota, with the exception of fluorspar, topaz, and molybdenite, which have not yet been recognized. Wolfram has not yet been found with the tin-ore, though it occurs in the region.

Extent of the Tin-Region.—There are now three well-defined dis - tricts of tin-bearing lodes in the Dakota portion of the Black Hills:

1. On the east side of the Harney range, at the Etta, Ingersoll, Monarch, Peerless, and other claims.

2. Near the summit, at Bismarck's rancho, where cassiterite occurs in several narrow veins of quartz.

3. At Hill City, on the western side of the Harney range, where there are both granitic veins and quartz veins bearing tin-ore.

To these we may add mention of a tin-district in the Wyoming portion of the Black Hills, about twenty miles west of Deadwood. where a considerable amount of stream-tin has been washed out of the bed of Sand Creek, and the discovery of the ore in place-to granitic veins is reported.

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* *Bulletin de la Societe Geologique de France,* 1884.

The Minerals of New South Wales, by Archibald Liversidge, F.R.S., 1883, P

In the Hill City district, the cassiterite is generally in crystalline bunches or masses in the midst of quartz, together with a bordering mass of mica in close compact crystals, frequently forming sheets of mica crystals in the midst of the quartz, parallel with the walls. It is rare that any other minerals are found in these veins. In the granitic veins the grains of cassiterite are smaller, blacker, and more crystalline than in the quartz veins.

Contemporaneous Origin of the Ore and Rock.—In the numerous tin-veins and tin-ore-bearing granitic dikes of the Black Hills tin-region, the phenomena of occurrence and association indicate that all of the minerals of the dikes—the quartz, feldspar, spodumene, mica, beryl, columbite, tantalite, phosphates, and other associates of the cassiterite, were contemporaneous in origin. The tin-stone is apparently as much a part of the mass as the mica or quartz. It was, to all appearance, present when the whole mass assumed its crystallization. All the constituents of the dike appear to have crystallized from a semi-fluid or pasty magma, in which the elements were free to arrange themselves from one side of the dike to the other and to crystallize out slowly. This is indicated in several ways, but strikingly by the gigantic crystals of spodumene stretching across the mass at the Etta, in straight lines, for twenty to forty feet, in the midst of quartz, feldspar, and tin-ore.

The aggregation is totally unlike that seen in narrow fissures, filled gradually by the flow of solutions depositing layer after layer on each side, until the fissures were gradually filled up. In the granitic dike, or intrusion, or segregation, of the Etta, and other places where tin occurs, the rude concentric or parallel structure seems rather to be clue entirely to the different conditions of pressure or temperature next to the walls while the fissure was full of the unsolidified constituents of the lode or the dike. There are no signs of infiltration 'or of alteration or of replacement, in a secondary way, of the minerals by the tin-stone, which, in all cases, would appear to have been one of the original constituents of the granite, as much so as any of the other earthy minerals. So far, also, as yet seen, there is nothing to sustain the views expressed by Dr. Le Neve Foster, that the tin-stone of Cornwall, at least, is the result of the infiltration of solutions depositing it in the granite adjacent to fissures, and partly replacing and altering the minerals of the granite.

. It is also difficult to find in the conditions observed in Dakota a full confirmation of the theory of Daubrée,* which supposes that

* *Annales des Mines,* t. xx., 1841.

cassiterite results from the decomposition of volatile fluorides or chlorides of tin. The usual association of cassiterite with minerals of which fluorine is a constituent, is considered an evidence of this. But in Dakota such conditions are not prominent.

TANTAL1TE AND COLUMBITE IN THE BLACK HILLS OF DAKOTA.

BY WILLIAM P. BLAKE, NEW HAVEN, CONN.

IN September I contributed an article upon Columbite in the Black Hills of Dakota to the *American Journal of Science*. I had not at that time seen the paper by Professor Charles A. Schaefffer, of Cornell University, upon the occurrence of tantalite in the same region,* or I would have gladly made reference to it. His analysis, proving the entire absence of columbic acid, shows that the specimen he analyzed, at least, should be called tantalite, and not columbite, if the distinction between those two closely related species is to be maintained. It is hard to say where the line is l<> be drawn, in such cases, between two minerals, when the specific characters and the composition are so nearly the same. If the name is to be determined by the relative amounts *of* tantalic and columbic acids, what shall we call the mineral when these acids are present in nearly equal quantities? Preference was given in this case to the name columbite, for the reason that the specific gravity, as ascertained by the ordinary scales at command, was nearer 6 than 7. As Professor Schaeffer had only one fragment by post, while I had an abundance from many places, it may yet be found that columbic acid predominates in some of the specimen?. I therefore use the name columbite or tantalite indifferently. With this explanation I proceed to give a few observations upon the occurrence of the mineral with the tin-ore of the Black Hills.

There are two localities, especially, where the mineral is *found in* the same dike or vein as the cassiterite: 1. at the Etta mine;2 at the Bob Ingersoll claim. At the Etta it occurs in close association with albite aud feldspar in crystals from one to four or five inches broad, and from one-quarter of an inch to three inches thick. It is not in contact with or mingled with the cassiterite, and each can be

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* *Proc. Am. Inst. Min. Eng.,* Chicago Meeting 1884, vol. xiii., p. 231.

separately taken out. It is easily distinguished from tin-stone by its color and dark streak or powder, which is very different from the streak of cassiterite. It has never been mistaken for tin-ore by any one connected with the Etta development, and the fragment sent by mail to Professor Schaeffer by the superintendent of the mine was not supposed to be tin-ore. It is rarely found in the greisen rock with the tin-ore, but a few small crystals have been seen near the outer margin of one of the irregular masses of the latter. It does not replace the tin-ore, or interfere with its abundance to any appreciable extent, and it has not been looked upon as an impurity to be avoided. Even if it were present to a considerable amount it would not injure the tin in smelting. It does not alloy with tin, but carries a small percentage of tin which would probably be liberated in smelting. These remarks are rendered important and necessary by the fact that the announcement of the discovery of tantalite has 'been in some quarters abroad considered as showing that a mistake had been made respecting the occurrence of tin-stone, and that the supposed tin-stone had proved to be merely tantalite.

I found at the Ingersoll claim a very remarkable mass of colum-bite or tantalite, which must weigh over two thousand pounds. It is the only body of the mineral seen in that part of the vien, and is not in close association with the cassiterite. One charge of giant powder broke it into several fragments, three or four of which were each too heavy for a man to lift. The mineral is found also in a greisen-like aggregation of mica, which at this locality is not tin-bearing.

It has not yet been found in the tin-ore veins of the Hill City district, except, perhaps, in one instance, and then not in contact with tin-ore.

A BESSEMER CONVERTING-HOUSE WITHOUT A CASTING-PIT.

BY L. G. LAUREAU, NEW YORK CITY.

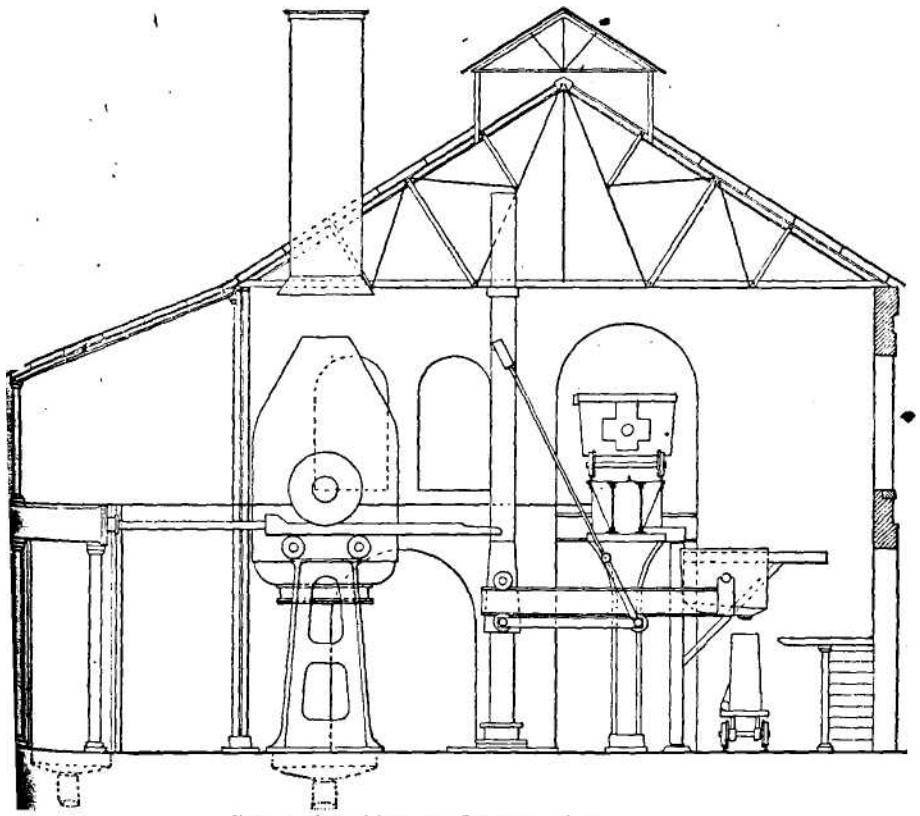
THIS paper is presented to call the attention of steel-manufacturers to the need of further reform in the manner of casting and handling ingots. The problem of making the work usually performed in and around the casting-pit less dangerous to the men and less costly to the management is one which has occupied the minds of all Bessemer engineers since the first days of the discovery. Holley's unerring judgment led him at once to condemn the 9-feet deep, two-story high, English well-hole, and his American plant maybe said to have had the shallow pit for a starting point; it necessitated the raising of the vessels, and brought about all the attending advantages.

European engineers have also endeavored to improve the original casting-pit, and the later English plants have no depression at all, the ingots being cast in a ring on the general level. On the Continent, especially in Sweden and in connection with small converters or the Casperson converter-ladle, the moulds are sometimes placed on turn-tables, revolving so as to bring the mould-tops within reach of the casting-nozzle. Some important establishments, both in England and on the Continent, have adopted the movable ladle, which, after receiving the charge, is hauled to a distant building, where the moulds stand either in a trench or upon the ground. Ingots are also cast from a ladle into moulds placed on cars. The two last-mentioned methods give the possibility of separating casting from stripping, thus affording relief from the excessive heat of a pit in which both operations take place at a time. A long practice has proved that the dangers from spilling or the bursting of a ladle, and the subsequent fouling of the running-gear of the ladle or mould-car, have been exaggerated. Hundreds of thousand of tons haw been east in that way, and I have been assured by engineers who have used these means extensively, that no serious trouble had ever been experienced.

While movable ladles and the movable mould-cars have proved fairly successful in rendering the work less arduous, it cannot be said that any economy in labor or apparatus is realized by their use ; the ingot-cranes must do their work, as in any other case, by first remov-ing the mould and then the ingot. This is necessarily wasteful of steam by reason of the false maneuvers it implies, the crane making several motions to perform one act only. Any system aiming at the greatest economy in this respect must be automatic or nearly so, or use steam- and water-pressure in such a way as to waste the least power possible, and at the same time suppress all, or nearly all, the hand-labor. I believe the solution of the problem lies in casting the ingots into moulds placed on cars so constructed that all subse- quent operations, such as stripping and putting back into place, may be done automatically or by easily-handled machinery. One of the first advantages to be derived from the use of mould-cars is the extreme simplicity to which the converting-house can be reduced. The pit and the ingot-cranes can be entirely suppressed, and all the operations of casting, cleaning, ladle-changing, etc., can take place on the general level.

Fig. 1 is a cross-section and Fig. 2 a plan of a converting-house, specially adapted to casting on cars. There are two 10-ton vessels

FIG. 1.

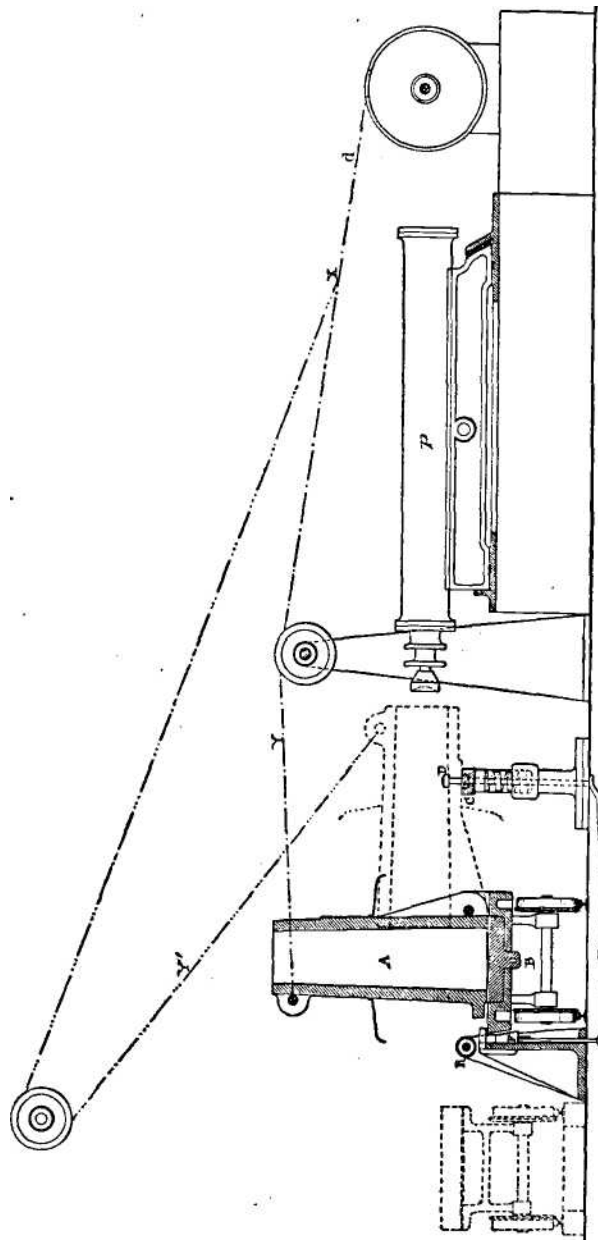


Cross-section of Laureau Bessemer Plant.

receiving the metal in front. The only crane of importance is the ladle-crane, which is raised by hydraulic pressure, and has a radial motion. The only other crane in the house is a small one, the jib of which swings under the platform. It is used mainly in turning over the ladles after a cast and raising the materials for stopping moulds to the casting-platform. The platforms around the converters are ample—in fact more roomy than in the usual plant-and all the operations usually carried on in the casting-house can be performed without hindrance or lack of space, and yet the whole building is only 62x43 feet in the clear, with a total height of 32 feet. The repair-shop and cupola-house can be placed at any convenient point, the location depending entirely upon the configuration of the ground.

The arrangement to change ladles on the crane is as follows: They are brought from the repair shop on a low car which runs on a track T. The track T', which crosses the track T almost at right-angles, is raised from the ground, so that when a ladle-car is upon it the ladle-trunnions are a few inches above the trunnion-bearings on the large ladle crane. The ladle-car is raised to the level of this track T' (about two feet above the ground) by means of lift 2, which is then turned around so as to brine the tracks in a straight line. The ladle-crane is swung so that its jib straddles the track T'. The ladle is then pushed between the jib, and when the trunnions are in position just above the bearings, the crane is made to lift the ladle off the car. The exchange of ladles is made in a similar manner. An empty car is placed in the proper position on the track T', and the crane, being swung around, deposits its old ladle upon it; it is then ready to pick up a repaired ladle in the way above described. The operation of casting is carried on by one man at the ladle and two men to stop the moulds; this is all the pit-force necessary. The number of men on the pulpit may also be reduced by reason of the suppression of the ingot-cranes. Having cast the ingots upon a car, the next step is to handle them as speedily and as economically as possible, reducing both apparatus and labor to the simplest expression.

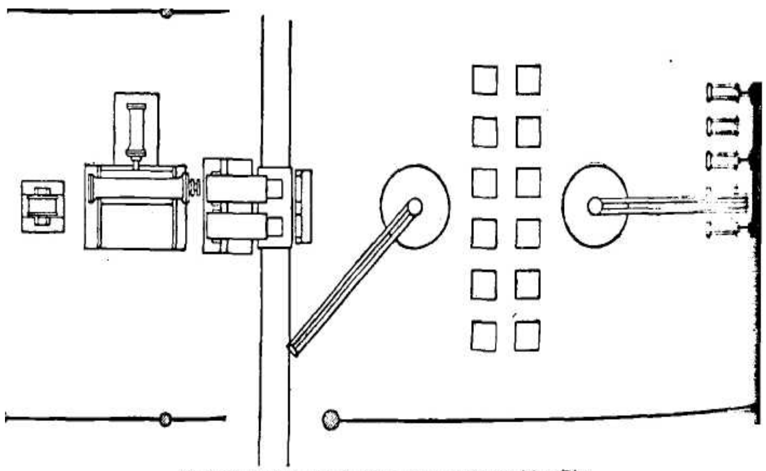
The apparatus shown in Fig. 3 consists, first, of a hydranlic cylinder P, moved horizontally upon ways by a small auxiliary cylinder. The moulds A are hinged to the car B in the manner shown. A wire rope or chain *d,* bifurcating at X into two branche Y and Y', winds around a drum actuated by a quick-working steam cylinder and passes over pulleys, as shown. The car having beca brought to its position, the hook at the end of chain Y is attached to a bar which binds the two moulds together near the top. The dram is made to revolve, and the moulds are pulled over toward the carry ing-bar C, fixed upon strong buffer-springs. While the moulds are descending, the slack of the rope is taken up by a quick working of the drum, so that the fall may be eased up by applying a brake at the



Apparatus for Stripping Ingots.

right moment. The moulds, before falling upon the carrying-bar C touch the pin D, which, through the underground lever E, causes the face-plates F to rise against the sides of the car B. The cylinder P is then made to push out the ingots, which pass over the roller R on to an ingot car if the ingots are to be reheated in furnaces, or to the floor if they are to be placed in soaking-pits. The hook at the end of chain Y' is afterward attached to the bar and the ingot-moulds are straightened back into place by working the drum. This system might be modified so as to push ingots straight from the moulds into the heating-furnace, thus combining the charging and stripping apparatus into one, and realizing further economy.

FIG. 4.



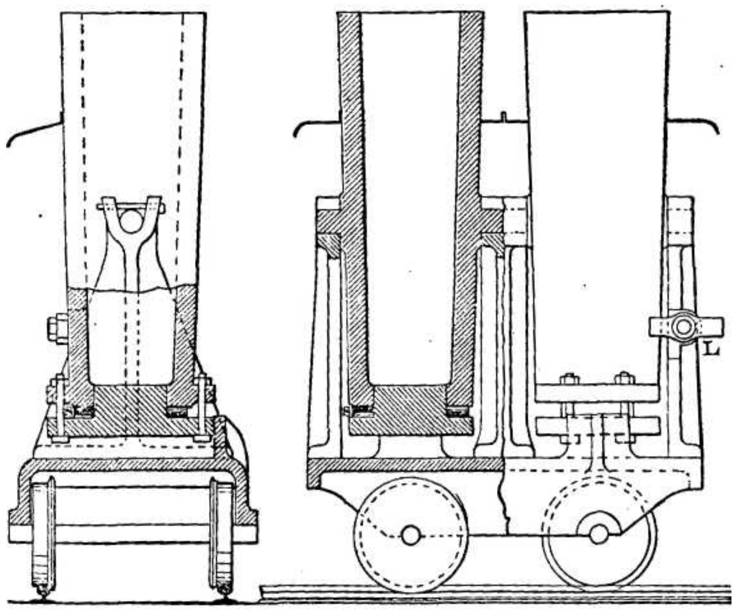
Stripping Apparatus in Connection with Soaking Pits.

Fig. 4 shows the apparatus in connection with soaking-pits. A crane picks up the ingot on the floor and places it in the pit, while another crane on the other side takes out the regenerated ingot and puts it on driven rollers to the blooming train. The apparatus could easily be handled by two men—one at the valves and the other at the hooks. If used at the heating-furnace, no extra men need be put on the work, the usual rolling staff being sufficient.

The arrangements shown on Figs. 5 and 6 were devised with a view to make the work of stripping almost entirely automatic, and represent the result of an exchange of ideas between Mr. E. L. Ford and myself.

Fig. 5 will be easily understood. The ingots are cast butt-end up in a mould provided with trunnions. The bearings are on a ear. The moulds are hung so that they are slightly top-heavy when filled. The only necessary labor is the removal of the latch L ; the moulds will then turn over and drop their ingots on the floor or on a table. The bottom-plug may be separated from the body of the mould by a heavy corrugated spring, S, so that in case of a " sticker " a blow from

FIG. 5.



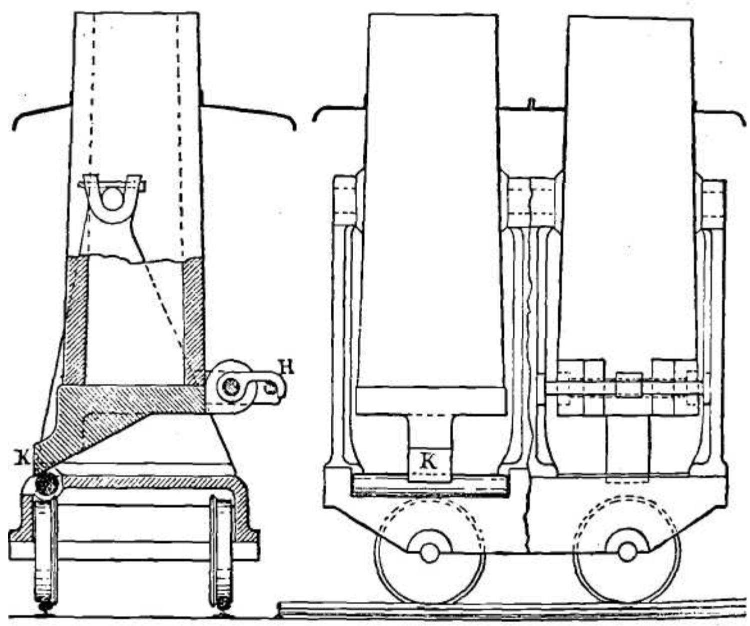
Mould Car.

a heavy sledge would be more effective in dislodging the ingot. A slight impulse will bring the moulds back into their original position.

Fig. 6 shows a mould on trunnions, as in Fig. 5, but in this case the butt-end is down, and the stool is hinged to the bottom of the mould. It is provided with a projection or lip K, bearing upon a roller placed on the side of the car. A hook II works on the hinge pin and closes upon a fixed bar running between the trunnion bearings. Upon removal of this hook the stool slides forward on the roller, and, the bottom of the mould being free, the ingot falls tout. The forward motion of the mould is assisted by placing the trunnions out of center. When the mould is empty, the stool is pushed back into place and the hook secured. It will be seen that the two last-mentioned arrangements are practically automatic, using no crane, no pushing-cylinder or machinery of any kind.

In order to complete the system, it would be necessary to establish a repair-shed at some convenient point between the rolling-mill and the converting-house, where the moulds could be cooled and the cars

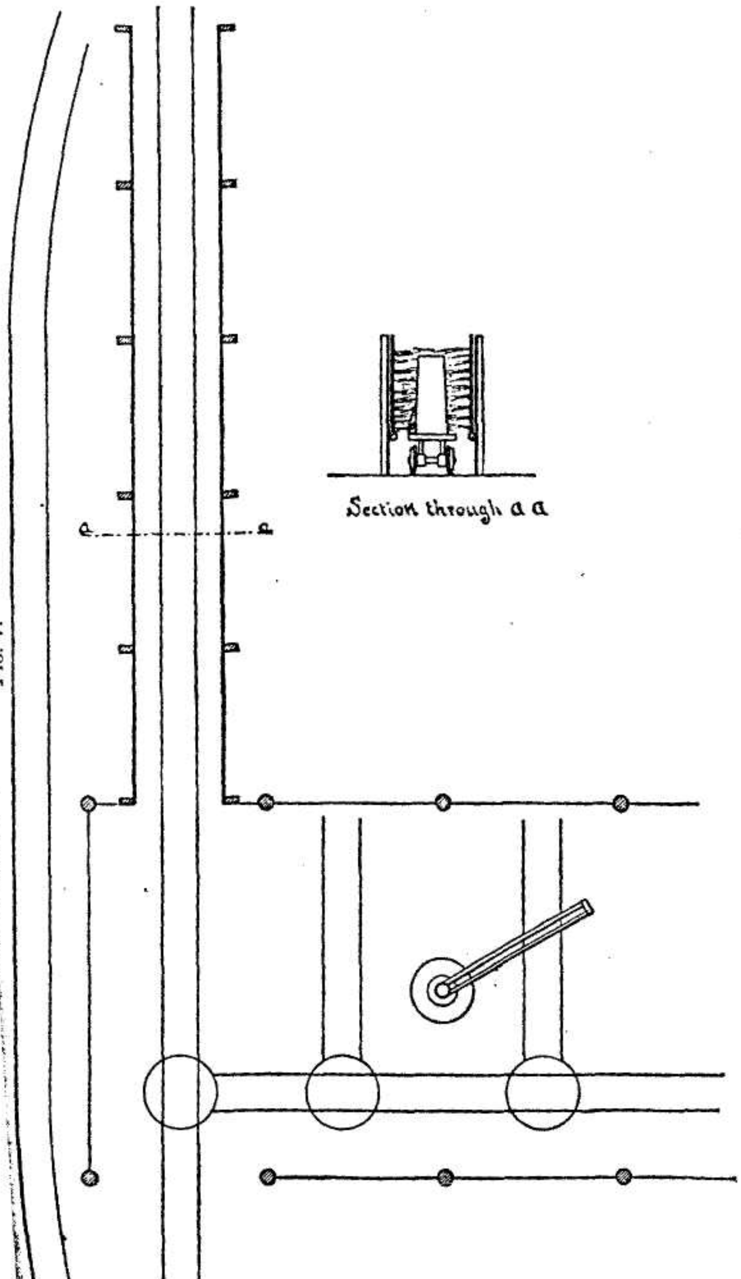
FIG. 6.



Mould Car.

examined. The arrangement shown in Fig. 7 is suggested. On each side of the truck a screen, somewhat higher than the top of the mould, is erected of any suitable material. On the inside of each screen and a few feet apart are placed vertical iron pipes about 3/4 inch diameter. Very small holes are drilled in these pipes at various angles, so that when water is forced through them a fine spray fills the space between the screens. The length of these cooling lanes is regulated by the number of moulds to be cooled, and two or more of them may be built in connection with the repair-shed. the hot-mould train backs in at one end, which backing-in causes a cold train to come out at the other end into the shed. The moulds and cars can be examined and the wash applied from a stationary plate

FIG. 7.



Arrangement for Cooling Moulds.

form. In case repairs are necessary, the car is placed on a turn-table and run into the shed.

In the construction of mould-cars certain contingencies will have to be provided against, and all movable parts, such as trunnions and hinges, must be protected from spilling. Judging from the record of works in which this practice has been prevalent, it is evident that there need be no apprehension of serious trouble. The practice obtains to a small extent in this country, and has given satisfactory results. Many ways will occur to practical engineers by which exposed parts of moulds and cars can be shielded.

Before closing I would say that a complete discussion of all the details connected with the subject would have carried us beyond the scope of a paper like the present one, which is meant only as a suggestion of methods likely to bring about a needed reform. The aim will be reached if it leads others to look for improvements in the same direction. The casting-pit as it exists in most steel works, both open-hearth and Bessemer, is certainly a costly nuisance, and as such should be speedily abated.

DISCUSSION.

ROBT. W. HUNT, Troy, N. Y.: Having examined Mr. Laurean's drawings some time ago, I freely admit that his plan shows much ingenuity, and that many things about it are likely to be of use. It promises to be advantageous for a small plant, and for cases in which it is desired to accomplish as much as possible with a small first expenditure. I presume that Mr. Laureau appreciates, as much as any other Bessemer engineer, the advantage of having, and of spending, a large sum in construction. If one is aiming for large product and heavy work, this large expenditure will prove true economy in the end. If I were going to build a Bessemer plant now, my idea would be to put in three vessels and casting-pit-, with cranes lifting from the casting-pits and delivering to other cranes, which would set the ingots in soaking-pits (provided with auxiliary gas), and then other cranes to take them to the blooming mill. But there are many things about Mr. Laureau's plan for which he deserves great credit.

W. F. MATTES, Scranton, Pa.: I notice that the moulds in Fig. 6 have the large end up; and this suggests to me that perhaps, by a reversal of the usual position of the mould, sounder ingots night be produced. We have noticed at Scranton that what we can "butts" almost invariably roll sound. Now is it not possible that by reversing the mould in casting the same result may be reached?

MR. LAUREAU. I have had correspondence with engineers in Europe on that question. That method of casting ingots, butt-end up, is followed, especially for soft steel, in Sweden, Germany and France: and it seems to be a general opinion that, for some steels at least, a sounder ingot is thus produced.

WILLIAM KENT, New York City: One of the causes of the cracking of ingots in rolling I believe to be the splashing of the steel from the nozzle on the sides of the mould. By turning the mould upside down, the amount of splashing might be diminished, and that would also tend to make the ingot better.

Mr. MATTES: That would hardly cover the case of the butts that I alluded to, because in that case we have the splash, just the same as with the ordinary arrangement.

H. M. HOWE, Boston, Mass.: Mr. Holley at one time thought that was the cause of cracking, and got over it by suspending in the mould a piece of sheet-iron tube. That tube was of course melted off when the sleel came to it. But although that prevented the splashing, it did not prevent the cracking of the ingots.

W. F. DURFEE, Bridgeport, Conn.: I should like to ask Mr. Hunt why he prefers auxiliary gas in the soaking-pits. I think we have sufficient evidence of the working of soaking-pits abroad to justify the belief that such auxiliary gas is unnecessary. The construction of the pits will be much more expensive when auxiliary gas is used, but that fact is perhaps not a matter of much moment with such of our Bessemer friends as believe in "using the largest amount of money possible" for the construction of their works.

At the Steel works of Scotland and at Seraing, as also at a number of other localities in Europe, it is daily demonstrated that soaking-pits can be used with entire success without any auxiliary gas. A number of our members have seen the working of the soaking-pits in Europe, and have testified to me of their success. There is certainly less danger of oxidizing the surface of the ingots in the simpler form of pits used abroad. In one instance, I saw ingots drawn from gas-heated pits with three-eighths of an inch of scale on them, which was knocked off with sledges before the ingots were sent to the rolls. It often happens that the air-valve of gas-fired pits is opened too wide* and a quantity of white-hot oxygen gets into the pits and causes great waste.

MR. HUNT : I do not for a moment wish to be understood as opposing the soaking-pit. It is all right, and I would use it; but I would take another good thing and be able to use it too. It is very easy to arrange the pits so that you can use the gas or not, Mr. Durfee knows perfectly well that you are constantly getting ingots that are too cold for your pits. Now you have got to do something with them. If you can use the pit and turn the gas on and take care of your cold ingots without having to put them on one side and take time to bring them up, I think you are doing a good thing. If everything is going smoothly, and you can use the pits without having the gas on, you are saving that much coal, of course,

MR. DURFEE : Mr. Hunt's objection to the introduction of cold ingots into the pits is obviated by having a single gas-furnace of the ordinary construction lighted, and charging all ingots too cold for the pits into that furnace. Abroad, the pits are successfully run on Monday mornings, by allowing those ingots of the first charge that are too cold when drawn from the pits to go to the reheating-furnace; but in most cases the ingots of the first charge are hot enough to go to the rolls without going to the furnace after leaving the piss. The pit-covers are sanded up on Saturday, and the pits are usually found hot enough on Monday morning.

A WATER-GAS OPEN-HEARTH FURNACE.

BY N. LILIENBERG, NEW YORK CITY.

THE success of European experiments in melting iron and steel with gases resulting from the decomposition of steam by incandes cent coal, has encouraged me to design, with the valuable assistance of Mr. George S. Dwight, a plan for producing and burning these gases in a manner economical and efficient for metallurgical purposes. That this direction is the right one, is demonstrated by the repeated efforts made in practice, to introduce as much steam as possible with the blast in ordinary producers, thus displacing a certain amount of nitrogen. Such attempts, however, must always be limited by the cooling influence of the steam.

The accompanying drawings represent the producers a'" steel-melting furnace, arranged according to our first ideas which may be susceptible of improvement in details when put into practical

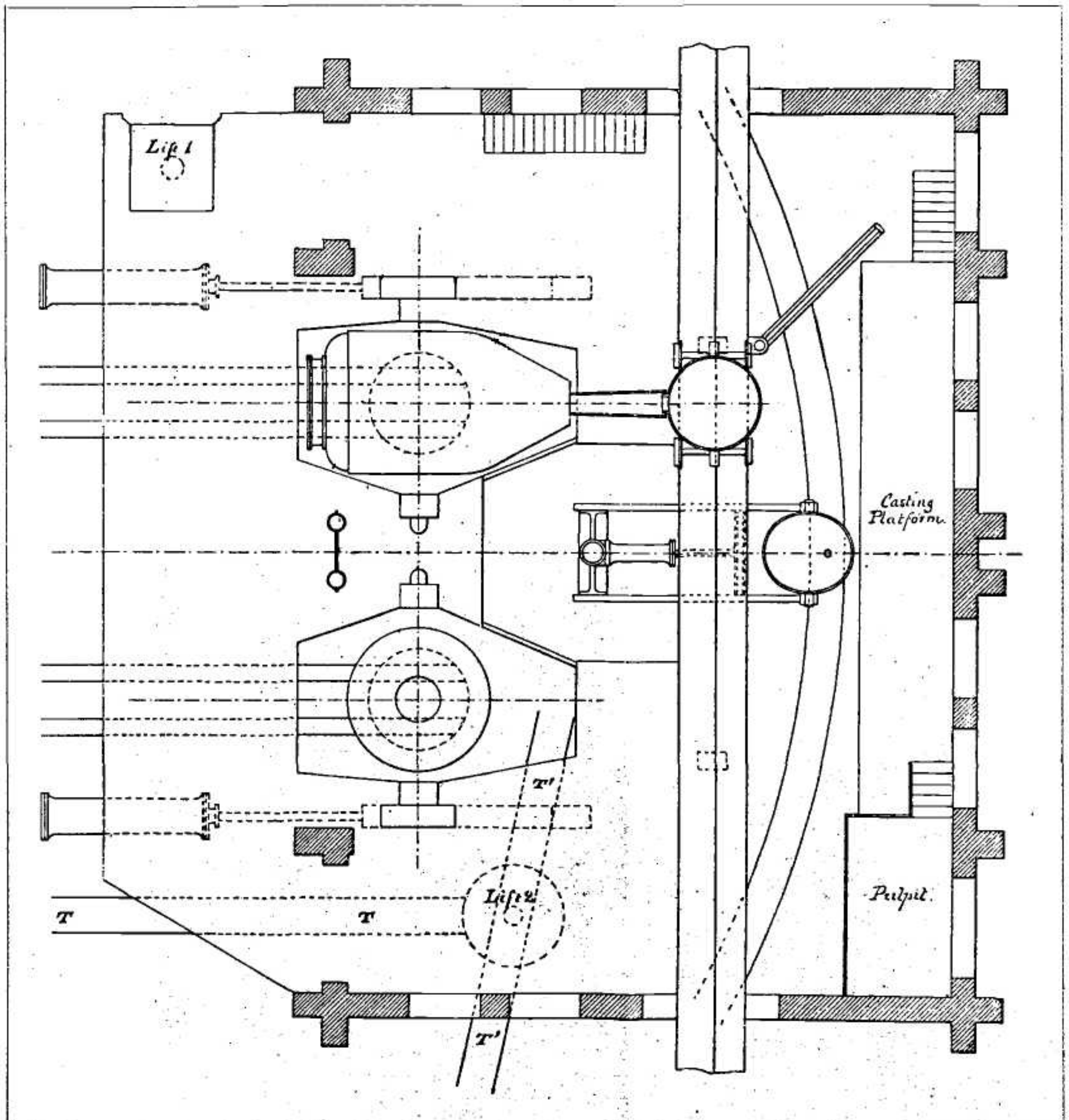


FIG. 2.—Plan of Laureau Bessemer Plant.

use. In the two plates the scale is the same, and the same lettering is employed.

The apparatus contains two above-ground circular producers *a, a,* provided with the ordinary bell and hopper for charging. The fire-brick lining is contracted above and below the middle. The upper parts contain outlets for the gas uniting into circular flues. The lower cones rest on cast-iron plates and circular pipes *b, b,* which are supported by angle-irons c, c. By hanging these with the irons *d, d,* the entire ash-pit is left free from obstructions and can be cleaned through four doors. It is important to have this free space, especially when air and steam operate alternately on the coal, because the ashes partly melted by the blast get cooled off by the steam, thus sometimes forming large lumps. The circular pipes *b, b,* have continuous openings and are united by a blast-pipe *e,* containing two valves *f,f,* placed at right angles and connected by a lever-apparatus. The inner and upper edge of the circular blast-pipes can be protected, if necessary, by a pipe with running water.

In the lower part of the producers are two outlets *g,g,* for the gases, which connect outside into the pipe *h.* They are alternately shut off by the slide-valves *i, i,* connected by a rod *k.* The blast- and gas-valves are operated simultaneously by the standing shaft *I,* having the levers m, *m,m.* The flues in the upper part of the producers are connected by an apparatus *n* similar to the slide-valve-regulator in a steam-engine, the valve o being operated by a combination of levers *p,p,* and a rocking shaft *q.* Steam is admitted into the chamber through the pipe *r,* and regulated by a valve, whereby .the admission of gas to the furnace is also regulated. Under the slide-valve runs the flue *s,* connecting with the pipe *t,* which terminates in a pit *u.*

It will thus be seen that in the position of the valves shown in the drawings, the blast passes upward through the left-hand producer. The escaping gases, consisting of carbonic acid partly converted into carbonic oxide, and containing the whole amount of nitrogen of the blast, pass off at the top and run under the valve nto the flue s and the down-comer *t.* On the other hand, steam passes above the valve into the other producer previously heated by bast; and the product, containing hydrogen, carbonic oxide and a race of nitrogen, passes off below into the pipes, *g* and *h.* Reversing the valves by means of the two levers reverses the currents, he steam then passing through coals previously heated and the blast through the coals cooled off by the steam.

There is consequently a constant supply in the pipe *t* of poor gas containing all the nitrogen of **the** blast, and a constant current in the pipe *h* of pure water-gas of high caloric power. By admitting air into the pit, or combustion-chamber u, the carbonic oxide is burnt, the flame passing off into the flues *v, v,* which constitute a heat-restorer. This part of the apparatus is constructed of 3-inch firebricks of 15 inch height covered with two layers of 3-inch bricks, leaving channels of 9-inch width. The water-gas passes from the main flue down into the four channels marked "Gas," and is preheated by conduction through **the** walls. The air passing through the four channels on the opposite side is pre-heated in a similar way. It will thus be seen that explosions could not take place by air and gas mixing through cracks in the brick walls. The waste gases continue through the flues *v, v,* clown into the chimney flue u. The air and water-gas continue **their** course and ascend into the flue X (Plate I., longitudinal section), which is divided by the wall x (Plate I., cross-section C-D).

If these producers are somewhat more complicated than the ordinary ones, the melting-furnace is cheaper in construction than the Siemens regenerative furnaces. The superstructure consists only of four flues 1, 1, separated by brick walls and arches, 2, 2, with an opening 4 in the center. The air- and gas-flues communicate on both sides with the flue x, while the inner and lower channels open into the flue marked " waste heat" (at the right-hand end of the longitudinal section), whence the escaping flame passes through the channels 5, 5 in a way similar to the flow of the waste gases from the producers at the opposite end. It will thus be seen that the air and the water-gas in a pre-heated state meet under an oblique angle, creating an intensely heated flame, turned directly on the metal in the deepest part of the bath. From thence the flame passes into the fine-through the channels terminating in the chimney-flue 6. The air and water-gas consequently pass towards the furnace through channels in which the heat gradually increases as the furnace is approached.

The repairs of the channels are effected by shoveling away the sand filling and lifting up the brick cover. This is not much more work than breaking through the walls in the ordinary Siemens regenerators.

The space between the producers and the furnace is used for the transport of raw materials for the furnace-charges. The furnace bottom is loose on wheels 7, 7, so that it can be easily removed and repaired. During the melting it is elevated on the two beams S, S.

thus relieving the wheels from strain. By taking away some wedges, it drops down on the wheels, disengaging itself from the superstructure. In this way it is also possible to use a bottom of basic materials, because they do not come in contact with the siliceous superstructure.

It is well known that the idea of continuous regeneration by conduction and radiation through brick-work is not new, as Ponsard and several others have constructed furnaces on this principle. But however good they may be for heating and welding, they have proved a failure for steel-melting; partly because the temperature of gas and air could not be raised sufficiently, partly because the elaborately constructed channels in the regenerators became cracked by repeated expansion and contraction. In the present construction, the heat-restorers are made so low as to have a single brick in height, thus doing away with the horizontal joints; and the heating-surface is thus spread out horizontally, making the construction strong enough. In regard to the sufficiency of the heat in this case, it need only be remarked that cold water-gas, taken from the gas-holder as made for illuminating purposes, and ignited with slightly pre-heated air, creates, according to recent experiments in Essen, sufficient heat for melting soft boiler-plates. The flame formed by intensely pre-heated air and pure water-gas, as in this case, must consequently give a higher temperature than in any other regenerative furnace, and enable metallurgists to obtain results not otherwise to be reached.

I need hardly point out the many ways of regulating the heat by the supplies of air and gas, by moving the chimney-dampers and the blast and steam-valves in. the producers.

According to Mr. George S. Dwight's experience in producing water-gas for illuminating purposes, the most economical results are obtained by a high pressure on steam and blast, and by short periods between the reversals.

If at any time the ordinary diluted gas charged with nitrogen (Siemens gas) should be preferred, one producer can be operated without reversing, openings being made at a sufficient number of points through the brick wall between the two flues.

It is evident that the system can be used also for welding or heating purposes, in which case the air and gas can be introduced at the end of the furnace instead of in the center.

I have frequently heard the objection that a flame of water-gas directed on iron or steel would tend to increase the waste, because the steam created by burning the hydrogen would become dissociated in contact with the metal. But experience has shown that such a dissociation does not take place under these circumstances. The best evidence of this is the fact that water gas is used advantageously in several places abroad for welding the joints of boiler-plate, which are more sensitive to burning than anything else.

DISCUSSION.

IT. M. HOWE, Boston, Mass.: I do not think that the main objection to the continuous regenerative system, which includes Mr. Lilienberg's furnace together with Ponsard's and Swindell's, and in which the incoming gas and air are separated from the outgoing products of combustion by brickwork, lies in any inherent difficulty in reaching a high temperature in the laboratory of the melting furnace. By giving suitable dimensions to furnaces of any of these inventors we can obtain temperatures which will rapidly destroy any refractory materials now known. The real disadvantage, and it is a radical one, with this type of regeneration is that we cannot fully abstract from the escaping products of combustion their heat and transfer it to the incoming gas and air : and it is on the completeness of this transfer that high fuel-economy in regenerative furnaces mainly depends. In continuous regenerative furnaces we cannot render this transfer of heat as complete as in furnaces of the Siemens type, because in the former the incoming gas and air are separated from the products of combustion by a brick wall, a very poor conductor of heat; the transfer of heat can only be rapid as long as the products of combustion remain very much hotter than the entering gas and air. In the Siemens system, however, the transfer of heat from products of combustion to incoming gas and air is not interfered with by the necessity of transmitting the heat through brickwork. The products of combustion in any one phase are exposed to the same surfaces of brickwork that the entering gas and air are in contact with during the preceding and succeeding phases. The heat is transferred from the products of combustion to the very same brick surfaces from which it is subsequently taken up by the incoming gas and air. Thus, as far as the apparatus for the transfer of heat is concerned. there is nothing in the Siemens system to prevent the transfer from being almost absolutely complete.

The disadvantage under which the continuous regenerative type of furnace labors in this respect would be largely removed if products of combustion, at least after their temperature had been considerably reduced, could be separated from the incoming gas and air by walls of some material which conducts heat rapidly, such as thin plates of copper; but the practical difficulties of this plan are very great.

Ponsard's and Swindell's furnaces have a compensating advantage in placing the gas-producer close to the furnace, so that the sensible heat developed in the gas-producer, always a very considerable part of the total calorific power of the fuel, can be utilized in the laboratory of the heating or melting-furnace. This mitigating feature, I fear, would be difficult to introduce into Mr. Lilienberg's furnace.

As regards water-gas in general, I never could see how it could compete with ordinary " producer " or "air "gas. The water-gas producers are necessarily much larger, and the loss of heat from radiation from their exteriors must be correspondingly larger than in the ease of air-gas producers.

PROF. T. EGLESTON, New York city: The producers which I saw at Essen, where I studied, last year, the metallurgical use of water-gas, were extremely small; and no fuel was used in them except the refuse taken from one of the grates. Moreover, I think these producers were cooler on the outside than any others I have seen. As to expense, one man took care of two of them.

MR. HOWE: If the water gas producers were extremely small, then, doubtless, still smaller air-gas producers could have been used. Moreover, we all know that as bad and probably worse fuel can be used in air-gas producers than in water-gas ones, and that the temperature of the outside of an air-gas producer can be kept as low as that of a water-gas producer, if not lower, especially as at least during part of the operation the interior temperature of the water-gas producer is necessarily extremely high. It seems to me perfectly clear that air-gas producers admit of being made much smaller for a given work than water-gas producers, and hence that, for equal temperatures of the external walls, the loss of heat from the former, always an important item, may be brought lower than is possible with the latter.

W. F. MATTES, Scranton, Pa.: Is it necessary to superheat the steam, before introducing it into these producers?

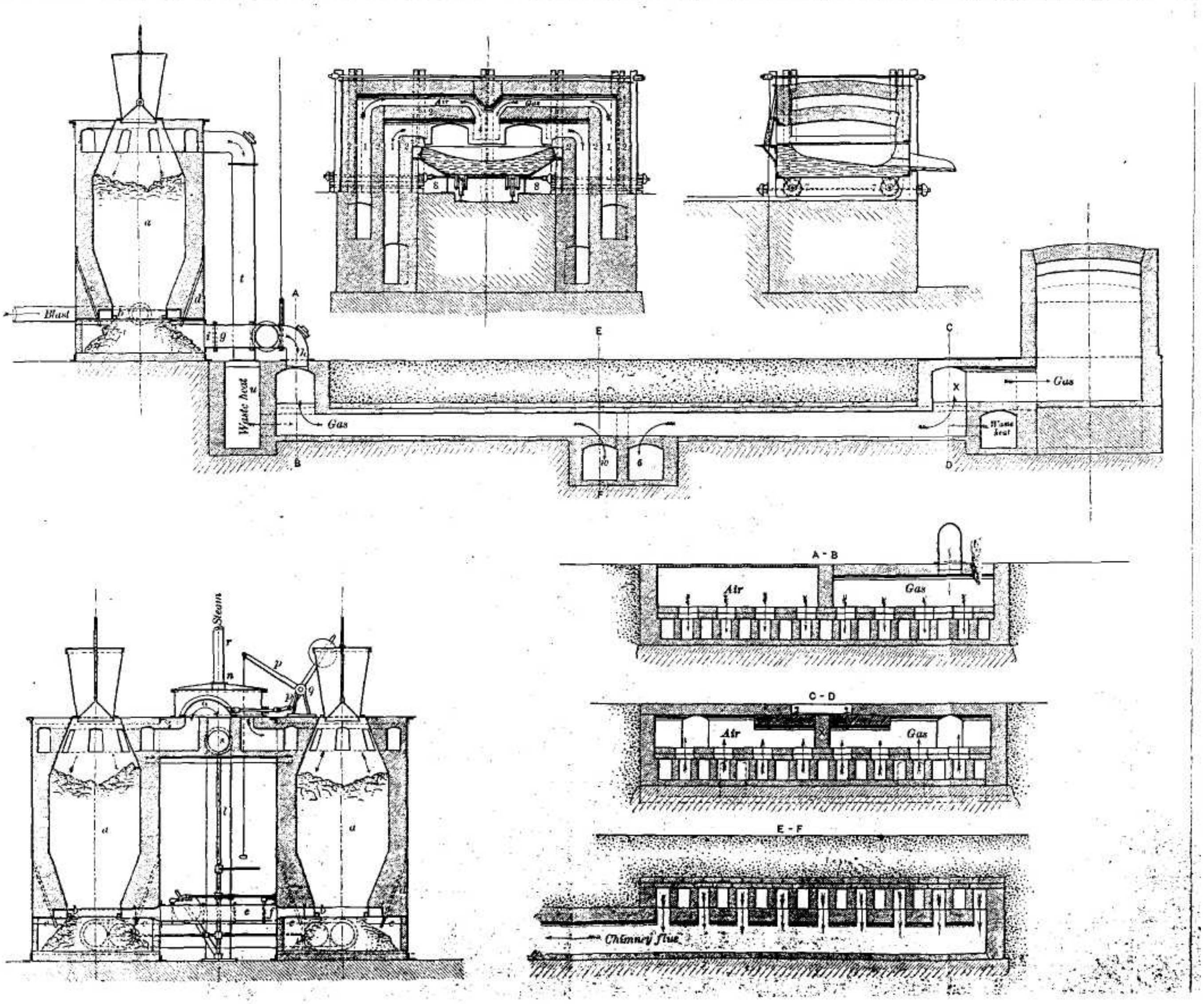
MR. LILIENBERG : That has been tried, but there is not so much benefit in superheating as was expected.

W. F. DURFEE, Bridgeport, Conn.: There is one feature in the behavior of all the continuous regenerative furnaces hitherto constructed that is, I think, fatal to their life. It is this : When such furnaces are used for the manufacture of steel on the open hearth, or for heating iron and steel, there is a great deal of incandescent oxide of iron carried into the chambers and channels of the regenerators ; this highly heated oxide of iron combines with the silica of the bricks, and in a short time the regenerative chambers become choked up ; therefore, the repairs of such furnaces have hitherto been very difficult and expensive. But in this new form of furnace the chambers are comparatively so simple that the objection named is of less moment than in the case of some of the older furnaces of this type, though it certainly is a very important consideration, and one that is often overlooked.

In the case of the Siemens furnace, the same effect occurs. A great deal of oxide of iron is carried into the regenerative chambers, which combines with the silica of the upper tiers of brick, and cements them together; but, by taking down the upper portion of the chamber doors, these brick can be readily replaced at little expense.

There is one fact relative to the working of the Siemens and kindred producers that may be of interest. It has been my practice, in the use of such producers, to mix from 25 to 30 per cent, of anthracite- or coke-dust with the bituminous coal employed. The purpose of the mixture is this; the carbonic oxide produced from the anthracite or coke dilutes the tar-vapor evaporated from the bituminous coal, and carries it forward into the furnaces, and it is there consumed. As an illustration of the advantage of this method of working, I will say that in the case of a works having ten producers, two puddling-furnaces, three heating-furnaces and a 24-pot melting-furnace, the flues were not opened for two and a half years, and they were not burned out in that time at all, but were finally opened, and but two buckets of liquid tar was found in the sump at the lowest point of the flues, whose whole interior was varnished with a coating about one-eighth of an inch thick, and so hard that it was difficult to make an impression on it with the finger. I think these flues could have been run indefinitely without burning out: whereas, had bituminous coal alone been used, there would have been trouble every two or three weeks.

In another case within my own experience, producers had been started on the system above described, and had run with entire success for nearly a year, when the manager of the works concluded that "anthracite coal-dust had no gas in it," and stopped its use, and


Blast
Air
Gas
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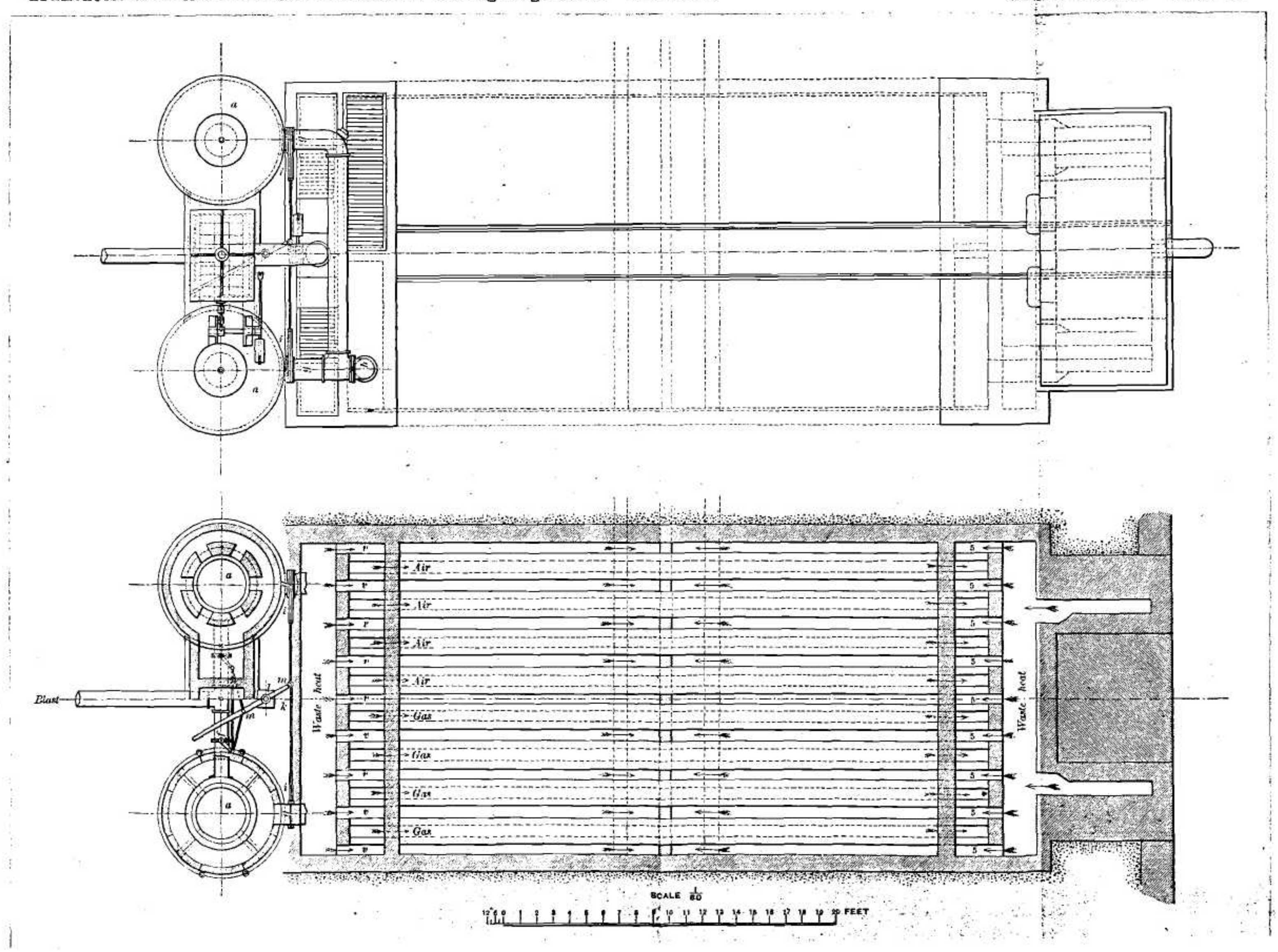
Steam
A - B
C - D
E - F
Chimney flue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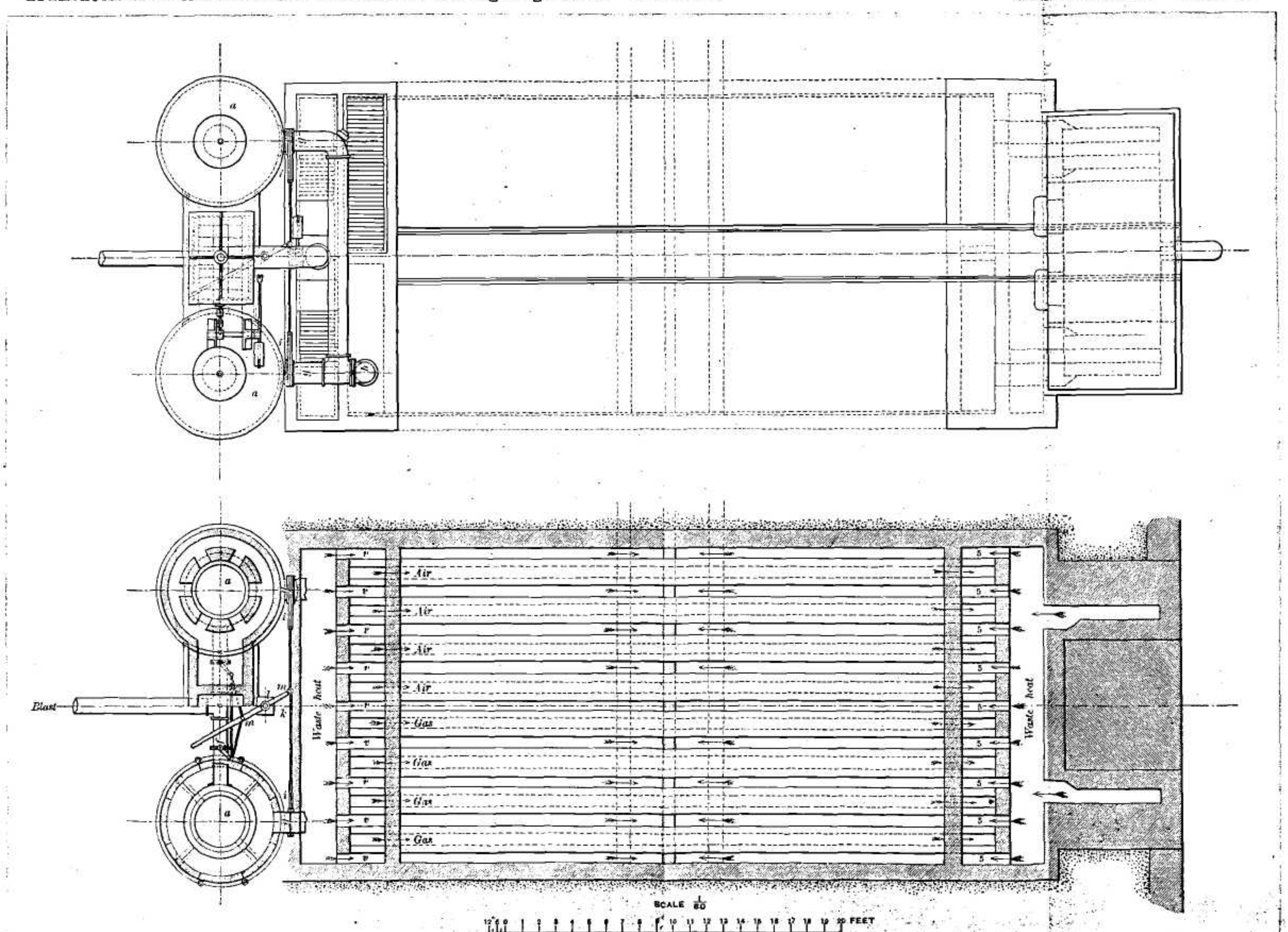
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as a consequence in a few weeks the main flues were so obstructed with tar that a man—hole had to be made through which to pump them out.

FUEL-ECONOMY IN ENGINES AND BOILERS.

BY P. BARNES, NEW YORK CITY.

IT cannot be said that this whole subject is a new one in respect to its presentation to the Institute, but the minute discussion of it has been looked upon as lying more strictly within the field of study of the societies which have to do chiefly with the construction and management of machinery as such. It must be true that the importance of close limits in steam-economy is as fully recognized among the members of this Institute as by any body of men who have to do with steam-machinery. In all directions, nevertheless, among manufacturers as well as among metallurgists, there may still be found those who do not give the same attention to exact methods in fuel-consumption as devoted to steam, as to other technical uses which, to say the least, are not more important.

The study of the most efficient methods of use of fuel in operations •which are more strictly metallurgical has been long-continued, and in some directions nearly or quite exhaustive. This has led to a rather close bringing-up, in those particulars, all along the line of technical work, of the establishments (and their managers) which had lagged behind. Yet, in the steam-departments of those works, there are too many reasons for believing that the name may still be legion of those whose methods and results are far from the best.

If there be room in any given case to suspect any imperfect working or waste of fuel in the steam-supply, the search for the evil, the clear fixing of its cause, and the application of the remedy are, or certainly ought to be, too obvious in their pressure for attention upon a manager to call for even so scanty a mention of them as can be.accorded in this paper. It is natural that men should be incredulous as to imperfections which may be noted as existing in their Machinery or methods. Still more are they likely to be altogether disinclined to admit that there may be thus an actual and palpable leakage in the compartment of their money-drawer devoted to coal-supplies. But the laws which govern the combustion of fuel, the absorption of heat by water, and the utilization of the heat-thus transferred to an engine, are too exact to permit any respect of persons. Those only who assure themselves, by rigid and frequent tests,, that their work goes on in conformity to these laws, can rest content that they do not somewhere suffer loss unawares.

Among the evils which are likely to be encountered in existing machinery are chiefly those due to old and worn fixtures, and these are too often an unprofitable inheritance handed down to present managers from an early clay. Even if it were true (and it is very far from true), that it is good policy to tolerate wasteful steam-maohinery in preliminary work, merely because it is supposed to involve a less first cost, the importance may still be justly urged of providing at the earliest moment the higher-class fixtures and machinery. Stern necessity itself ought, to suggest and compel the entire abandonment and replacement of antiquated or wasteful apparatus, on the instant of the assuming by the enterprise in question of any definite or permanent character. The use of high-class steam-machinery ought to be more fully recognized as a vital element of this permanence, even in the most modest undertaking. There uncertainly enough establishments to be found whose stability is based upon their closely studied steam-methods to warrant the strongest statements of the obligation resting upon managers, to see that their practice in this respect is equal to the best. The standards of excellence admit of the clearest definition, and. in these lines, as in most others, the best is at least as good as any, and, when once rigidly and patiently sought for, it is not difficult of attainment.

So far as the steam-engine is concerned, and the use of steam in it, upon which so large a proportion of our operations depend for prime movement, the study of its condition must be followed along two lines. One is obviously the general external condition of the engine as a whole, whether it is accurately maintained in line and level, and is properly cared for in respect to lubrication, and general connection and adaptation to the work to which it is applied. The other line of study is internal, and is likely to be far more important. Deviations from the right path in this respect in the use of steam, and the fuel upon which it depends, are unseen by the casual observer, and are not always detected by an expert, except after an expenditure of time and patience which, to some owners, appears quite uncalled-Mr and perhaps absurd. The *indicator* is the sole means by which this internal study of the working of an engine can be carried on, and though the most skilful use of this instrument may not invariably lead to relief from all the ills to which engine-flesh is heir, yet it has been found, in countless instances, a means of averting loss which would have proved quite fatal, as measured by a money-standard. It may be quite needless to say that the sole office of the indicator is to record the pressure in the engine-cylinder, at each point in the motion of the piston. An outline may thus be drawn which can be compared with standards established by long and exhaustive computation and experiment. Thus the correctness of the working of an engine can be determined, as depending upon the original construction, and the current adjustment of the parts. With older types of engine it frequently happens that a correct distribution of the steam in the cylinder cannot be effected, as called for by the varying loads under which the engine must expend the money paid out for coal or other fuel. When such cases are discovered (and too often their existence remains unsuspected for years), the best remedy is generally a radical one, viz., the entire replacement of the engine by one of modern build. Thus many refined elements of design can be brought into service, simple and trustworthy in the highest degree, which may secure this correct use and expenditure of the steam which must be paid for.

Next to this entire replacement, may be named the rearrangement of the parts concerned in the steam-distribution, so that their functions shall be more correctly discharged. This is practicable in many cases, and some notable improvements have been effected, by means which have appeared trifling in kind, but, when gauged by the money-saving effected, have shown a value of no mean degree. The possibility of such rearrangements should obviously be more carefully studied in a time of depression, when the call for economy is stringent, although the way may be hedged in too closely to permit more than the most fragmentary improvements. By such simple means it is sometimes practicable to bring up the indicator-diagram of an old engine to an extremely close approximation to the standard outline referred to. Thus there may be found remaining, in this respect, very little to be desired, and nothing farther to be accomplished, except by the additional and more radical means of an entire replacement.

In this connection, mention should be made of the advantage Which, in respect of fuel, attends the use of the compound engine. This type, in few words, secures the utilization of the heat developed *by* the combustion of the coal within wider limits of temperature than the simple engine, and hence of a larger proportion of this heat.

This use of temperatures is divided, in the engine, into parts or grades, so that the higher limit shall not be interfered with, or impaired in its expenditure, by contact with the lower. The use of three cylinders is common in the higher class of marine engines, so that these successive steps in the expansion of steam shall be fully provided for and correctly taken. It is a noteworthy fact that the exact possibilities of these close limits of economy have been most clearly shown in marine engines, in which, as a rule, the restrictions as to space and dead-weight of machinery are extremely close, and in which the possibilities are, therefore, the least of choice of arrangement of parts for obtaining the best results. It may also be noted in this connection that the objection, so frequently urged, of a supposed complexity in the compound engine should have weight enough, if it has any at all, to have prevented the adoption and wide application of the compound engine for sea-service. The exigencies of this service are more stringent, if possible, in respect of simplicity of parts and certainty of operation of the machinery, than in the limits of space and weight which are admissible ; yet it does not appear that time is lost, or that exact days and hours of sailing are missed, by reason of the complexity of the engine-fixtures, for years at a time.

The increasing use of this compound type of engine, already so highly perfected, suggests the remaining topic of this paper, *viz.*, the absolute call for higher initial pressures for the small or first cylinder of the engine. A limit of 160 pounds has long been carried on locomotives, and constitutes an important element in the economy of their performance, which is very marked, in spite of the obvious limit of space and weight which must be so closely observed in them. Few things can be named, perhaps none whatever, which will prove so definite a help in the study of economic working of steam as a large increase of boiler-pressure,--an increase, in fact, which shall border closely on the limit at which, in the present state of the art, the lubrication of the engine-parts becomes the chief question. This limit is not reached at a pressure of 300 pounds and hardly at 350 pounds. The addition is very important, which may thus be made to the range of temperature within which the steam may be used as a medium for the transformation of heat into work The proportion is correspondingly reduced of the losses from radiation which must be tolerated, and of imperfect condensation, at the foot of the scale of pressure to which the steam is finally brought.

This call for higher pressures must be met, and can be more in met by a radical departure from accepted forms of boilers than in any other way. This change of form need not introduce into the art of boiler-construction any untried features, for the compact box-form, which is now offered for consideration, based on the designs of Mr. Allan Stirling, of New York, was in some respects the earliest known for steam-boilers. In locomotives it has been continuously employed, and the absolute limit of track-gauge is leading to a. wider use of the flat, stayed surface for the high pressures now so common in locomotive practice. The possibility, thus rendered complete, of a safe dependence upon the tensile strength of stay-bolts is of the highest importance. No combination of riveted joints can be made, which shall not depend, in large part, upon such staying of fiat surfaces, and the interest of safety and economy in high-pressure construction clearly points to an abandonment of unstayed surfaces of any description.

Another essential point in boiler-construction should be named, since it is of vital importance in the maintenance of the strict economy of operation which this paper aims to promote. This is the need of a large, separating surface at the water-level within the boiler, at and through which, over its entire area, the steam may be quietly liberated from the body of water within which, in minute bubbles, it is generated. This is needful in order that the quantity of heat transferred from the boiler to the engine may be simply, and only, that duo to the quantity of steam withdrawn, and not that far larger quantity also, which is due to the presence in the steam of even a small fraction of suspended water. This water, when thus led away, acts as a hurtful absorbent of the heat developed in the burning of the coal, and this proportion of heat is wholly lost, so far as the subsequent production of useful work is concerned.

The adoption of a flat-sided box-outline, with stayed surfaces, for the body of a boiler, clearly suggests the use of water-tubes for heating-surface, which shall be wholly external to the box, and thus fully exposed, not only to the radiant heat of the fire, but also to the sharp contact of the currents of heated gas from the fire. In other words, the work of the boiler should be done by the exposure of the whole of the tube-surface to a quiet bath of intensely heated gas in an inclosing brick chamber, from which there shall be withdrawn, through a close damper, only so much of this gas as shall insure the maintenance of the whole at the full intensity due to the limit of pressure which must be preserved.

This combination suggests to the experienced man the simple drop-tube, so long and favorably known, with the internal feeding- or circulating-tube, by means of which the *tidal* circulation shall be maintained within the boiler which secures the persistent sweeping of the heated surfaces with large volumes of solid water. Thus the bubbles of steam are pushed up into the steam-space, and the hot tube-surfaces are kept covered with compact bodies of water in the best form to insure the prompt and most complete absorption of the heat from the gas which envelops the tubes. Thus it becomes possible to construct a boiler up to a capacity of several hundred horsepower, in which the pieces of plate employed need not exceed four in number, and in which also the stays shall be of the simplest, most fully approved kind.

Brief mention may be permitted of the possible need of greater watchfulness in the prevention of incrustation in boilers which are designed for higher pressures, and which must be therefore subject to a higher heat. Obviously the time-honored remedies or means of prevention for this persistent evil are as applicable to this ease as to any, however new may be the details of experience or management likely to be developed. This important consideration is worthy of note; that if the work of the boiler as a whole is done so economically as it may be through the use of the compound engine, a much larger loss of heat maybe reasonably tolerated through a more frequent blowing-down and refilling of the boiler hour by hour, as the advancing saturation of the water may indicate. It is certainly true, that if as much care and exact attention were devoted to this blowing-down during working-hours as is given by a skilful attendant to the feeding, some handsome gains of safety and durability would be made. No just reason can be given why this should not be expected and rigidly insisted upon, whatever may be THE pressure carried or the amount of work done by the boiler, so long as there is the slightest reason for suspecting the presence in the feed-water of any appreciable proportion of incrusting matter. It is clear, however, that only the least useful result can attend the somewhat common practice of feeding and blowing out through the same connection to the boiler, especially when a mud-drum is used into which it is expected and supposed that the particles of sediment will be gathered. The true thing to be done is simply to wash cut the boiler while under pressure, and at work, in the same way and by the same means as would be used if the whole were at a standstill and open, so that a hose and an open jet of water could be used. That is to say, the blowing-down at regular intervals and the coffee sponding feeding, with the resulting tendency to a complete sweeping of the surfaces, afford a means, of definite and high value, of keeping a boiler clean, if persistently and skilfully practiced. If in addition to this well-directed effort in the case of any first-class boiler the additional safeguard be present of a construction promoting this constant sweeping of the heated surfaces, a means is secured of the very Highest value of increasing both the efficiency and the durability of the whole. The drop-tube, which has been suggested as a detail of great value in this study of a high-pressure boiler-structure, has a very clearly marked and conclusive record, as tending to prevent the fixing on the heated surface of incrusting particles. The sharp circulation within the tube, directed so persistently against the lower or exposed end, appears under very trying conditions of practice to insure completely the maintenance of the surfaces in the most per-feet and unobstructed condition. In fact, instances are on record in which the incrusting salts, and other sedimentary matter, have been persistently thrown out of these tubes, and over into the water-legs, in marine boilers, to such an extent as to cause injury to the plates in these legs while the tubes themselves have remained perfectly free and clean.

The impression is not well founded that a much higher degree of skill is needed in the attendants who are placed in charge of compound engines and high-pressure boilers. Hundreds of locomotives can be found in which the carrying in ordinary work of 150 to 160 pounds pressure is an every-day occurrence, and in which there is developed, at speeds which are not excessive, fully 750 to 800 horsepower. The locomotive-men who manage these engines and boilers would not claim for themselves, as a class, either that they are persons of extraordinary skill or that, on the whole, they would be either unable or unwilling to take charge of any other type of engine of equal or greater power. In other words there are the best reasons for believing that with the highest grades of steam-machinery, referred to in this paper, no difficulty will ever be encountered through lack of attendants. The possession of ready wit and reasonable faculties only is required, such as can be found any day by the prudent selection which is exercised in the choice of men in other kinds of business, involving the care of interests of equal importance.

This brief study is thus submitted to the Institute as an effort to combine in a practicable and workmanlike manner a series of details of engine and high-pressure boiler which are neither new, untried, nor inexpedient. The call for improvement in prime movers has never been more pronounced than at the present moment, and the lagging steps of actual advance in steam-engineering appear likely to be spurred onward only by such departures as are here suggested and urged.

DISCUSSION.

PROF. R. H. THURSTON, Hoboken, N. J.: The directions of change pointed out in this paper are those that have undoubtedly been pursued for many years. In fact, from the time of Watt, the tendency has been toward a higher pressure, the use of higher piston-speeds, the more complete covering of cylinders and devices to prevent loss of heat and effect, and to secure thorough utilization of the heat supplied to the engine. But progress has been hampered from the beginning by limitations which have not always been recognized, even by engineers. To-day, however, the limitations of economical working of the steam-engine are tolerably well understood. In (Indirection of higher pressure we have been hindered by the difficulty of obtaining a boiler that would work satisfactorily and safely at these high pressures, and the change suggested by Mr. Barnes has been one that has been sought by engineers from the day steam engines were first invented. It was attempted certainly as long ago as 1804 by old Colonel John Stevens, who obtained in 1805 a patent for one of these forms of boilers. That boiler was built, and a section of it is preserved at the Stevens Institute. It was a lantern-shaped boiler. A fire was built in the interior, and circulated among the tubes. But in all such forms of boiler, difficulties have arisen in the endeavor to secure at once safety, convenience and economy of operation; and among these difficulties I do not know anything that has proved more serious than that of securing dry steam from boilers that shall be so constructed as to be safe against explosion. The principle involved in any boilers made with reference to safety consists in confining the water in small chambers, the explosion of any one of which will not be likely to do serious-damage. But in the endeavor to do this it is found extremely difficult to secure a good circulation, and especially to secure a means of separating the water from the steam at the point where it is liberated.

Some of the boilers now in use, and as safety-boilers certainly beyond criticism, are still found to present very great difficulties in operation, because of this lack of provision for the separation of the steam from the water at the point where both are liberated from the circulating steam. Where that provision can be introduced, as Mr. Barnes has proposed, it removes one of the great difficulties. We must find means of confining the water in small sections, and Dr. Albans, forty years ago, and Jacob Perkins before him, used steam experimentally of 1000 or 1500 pounds pressure to the square inch, and habitually of 100 and 200 pounds in just such boilers, and their practice resulted in the production of a combination of steam-boiler and engine which gave economies quite equal to engines and boilers of similar power to-day. The limit as to pressure has gradually been elevated from seven pounds in the time of Watt until now we are carrying 150 and sometimes 200 and 250 pounds on river-boat engines. In the sectional form of boiler, so-called, pressures have been carried in regular work, by Perkin's Sons as high as 300 or 400 pounds to the square inch. There seems no reason to doubt (hat we can get higher pressures if we find it advisable to do so. The difficulty of securing an ample separating surface can probably be overcome by allowing the separation to occur in a larger chamber, but this should be done at points where the flames may not strike the heating surface. In some of our modern safety-boilers all the beating-surface which is near the point of highest temperature is composed of tubes, and the steam is delivered to larger reservoirs where the separation can go on, so that the steam supplied to the engine may be found there fairly dry. The adoption of these forms of boiler will evidently remove all difficulty in the direction of the economical generation of steam; and we then come to the securing of economy in the engine itself. There the direction in which to work is obvious, and our success in that direction is still limited. We find that the engine demands as high a pressure as we can give it, and the steam should be expanded down to the minimum pressure, which should be the sum of the necessary back-pressure of the engine and its own friction; but this ratio of expansion, which would often be something like 25, and sometimes 50, is found to give less economy than where the expansion is restricted to one-half the minimum figure or less. The restriction of the expansion to such a point that the terminal pressure shall be 8 or 10 pounds to the square inch is found on the whole to be more economical practice. As we increase the expansion we must have more expensive machinery. There are certain causes of loss within the engine, such as condensation and leakage. The first is restricted by the use of very dry or superheated steam, which then being steam-gas, is not a good conductor, and does not receive or give up heat as readily as ordinary steam, and so this condensation becomes very much reduced.

Another method of securing economy, which has been adopted in all cases of considerable expansion from the time of Watt, has been the use of the " steam-jacket," clothing the cylinder with a warin casing, and thus preventing the metal of the cylinder from losing temperature. By that expedient, in some cases, this internal loss is very greatly reduced, —so much so that to-day the most efficient engines reported are those few pumping engines which have been supplied with high-pressure steam and fitted with steam-jackets, and in which the steam is also moderately superheated. The best figures given so far have been about 16 pounds of steam per horse-power per hour. That amount with such engines is about 150 per cent, of what theory would indicate as the limit to which we should approximate, so that even in such engines the loss of heat and steam is 50 per cent at least, and that represents the margin still remaining to be overcome; and the only way, apparently, to do this in practice is to find some way to secure an internal non-conducting surface for the engines. Experiments have been made by Mr. Emery. and years ago by Watt and Smeaton and others, but they have not resulted in anything of practical value.

These, in brief, seem to be the difficulties in the way of further improvement in the economy of the steam-engine. As we can see. the introduction of a form of boiler that shall be at once safe and economical is one of the essential steps. The other steps must be taken at the engine itself, and by such means as I have indicated the consumption of steam in the class of engines mentioned has been brought down from about 30 to 40 pounds of feed-water per horse power per hour to somewhere from 15 to 18, but more usually 20

WILLIAM KENT, New York city: One point made in the paper is the great waste of fuel in metallurgical works. From my own experience I am convinced that economy of steam in metallurgical works is not to be gained so much by inventing improved boilers or engines as by adopting the good boilers and engines already in existence. I have in mind an engine in an iron-works, which has been running for twenty-five years. A diagram from it was sent to an expert in indicator-diagrams, who was asked to figure the saving that might be made by substituting for it a better engine. Here ported that it would be anywhere from one to three thousand dole Jars a year, showing that the engine had lost from twenty-five to seventy-five thousand dollars during its lifetime—and the engine still running. This was three years ago. That kind of work is repeatedly found in iron- and steel-works of the older kind.

As to this particular boiler that has been presented to us, it looks very much like the Wiegand boiler, which was exhibited at the Centennial Exhibition in 1876, and which has proved practically a failare, especially where bad water is used. I know of one battery of these boilers that was in use in an iron-works about six years, and then thrown out and replaced by old-fashioned two-flue boilers on account of the great trouble given by this boiler in keeping it in order. It seems to me the same objection will hold in regard to Mr. Stirling's boiler, and I predict its failure with bad waters.

The author of the paper says the tendency of boiler-engineering at present is to avoid all boilers that are unstayed. I think the tendency is the other way. A stayed boiler is used on locomotives, because we cannot help it. We are restricted to certain shapes. But for boilers on land the avoiding of stayed surfaces is always desirable.

One of the causes of the failure of the Wiegand boiler was that the Field tubes, one tube inside the other, leaving such a small space for the circulation, filled up with scale, and that will happen with the boiler described in the paper, wherever there is bad water. But in New England, where there is good water, it might possibly have a long life.

As regards economy of fuel, the same economy can be reached in this boiler that is reached in a dozen other different kinds of boilers. There is nothing to be gained by this boiler in the way of economy. There is a good deal to be lost in the necessity for repairs and difficulties of cleaning, and there is a great deal to be lost, in case the crown-sheet should get scale on it, and the boiler should on that account explode.

A NEW REGENERATIVE HOT-BLAST OVEN.

BY JOHN C. LONG, E. M., MECHANICSBURGH, PA.

THE advantages of firebrick regenerative hot-blast ovens being thoroughly appreciated by those engaged in modern blast-furnace practice, the important question now is to obtain the best and most efficient apparatus.

The apparatus invented by the writer, and described in this paper, is proposed as an improved form, retaining all the advantages of those now in use, with the additional ones of a cheaper construction, and of being able to furnish a very much hotter blast and to vary and control the temperature thereof up to the limit of the resistance of the refractory materials composing the ovens.

To the practical blast-furnace manager the ability to control perfectly the temperature of the blast, so that an error of filling or a variation in the calorific power of the fuel may be corrected by suddenly and markedly changing the temperature of the blast, is a great desideratum. By this means the working of the furnace can be rendered much more economical and certain, and the grade of the iron more uniform than by waiting to correct the furnace by a change of burden.

This object is sought to be accomplished with the iron-pipe ovens and the regenerative brick ovens now in use, by keeping the temperature of the blast somewhat below the maximum; but as the range of variation is only slight and the temperature comparatively low, the resultant benefit is consequently small. With the apparatus described in this paper, the blast may be regularly kept much hotter and yet its temperature may be at any moment quickly and greatly raised.

Heretofore it has been customary to heat regenerative ovens by burning in them blast-furnace gas, the initial temperature of which is that which it had when leaving the tunnel-head, less what it has lost in its transmission to the oven in which it is burned. This temperature varies from 100° for charcoal, and 228° C. for coke (according to Kerf) upward, being lower as the furnace is economical of fuel. At the Mont Alto, Pa., charcoal furnace, which I have personally manage for the last three blasts, the gas temperature ran very low. During the last two months (November and December) of the blast of 1881 the gas-temperature and pressure were taken every hour, and the former averaged for this time, including the last half-day blowing out, 218° F., or, excluding the blowing-out, 210° F. For the eight days from November 20th to 28th, 1884, it averaged only 117 F. So cool was the gas that the vapor of water in it was con densed in the gas-flue and dropped out at quite a lively rate at the expansion-joint, not more than eight feet from the furnace temperatures were taken from a pyrometer kept in the gas-flue, and frequently by the writer, with a mercury thermometer held in the gas-flue.

Since the cooler the gases can be made to leave the blast-fun??

the better and more economically the furnace works, the tendency of modern practice is to reduce the temperature of the waste-gases as much as possible, and thus have the furnaces work with " cool tops." As a consequence of working cool at the top, less of the carbonic acid formed in the lower part of the furnace is reduced to carbonic oxide in the upper part at the expense of the fuel charged; and hence the escaping gas has less heating power, since it contains a greater proportion of nitrogen and carbonic acid, the heat-absorbing elements, and a smaller proportion of carbonic oxide, the principal heat-producer. This decrease in the calorific power of the blast-furnace gas was very markedly shown at the Mont Alto furnace during the last blast. When the furnace was carrying a burden of 2000 to 2100 pounds of ore and 500 to 525 pounds of limestone, on 720 pounds of charcoal, it was with the greatest difficulty that steam could be kept up and the blast heated to 550° to 600° F. by means of the gas, while with a lighter burden there was a surplus of gas—the quantity of blast entering the furnace being the same in both cases.

Hence, if an intensely hot blast is to be supplied to an economically-working furnace, means must be taken to heat the gas, the subsequent combustion of which is to heat the blast-ovens. The effect of such preheating may be shown by a simple calculation, in which, however, as absolute accuracy is not sought, no account will be taken of the moisture in the gas or air. Assuming the gas from a coke furnace to be composed by weight of*

Carbonic oxide,	7.31
Carbonic acid,	0.23
Nitrogen,	56.34

to have a temperature of 100° C, and to be burned with air having a temperature of 0° C., the temperature of combustion may be calculated as follows:

The amount of oxygen required to burn 27.34 carbonic oxide to carbonic acid is 4/7 the weight of the carbonic oxide or 15.62. Hence, the air required for the above case will be 67.91, of which 52.29 is nitrogen, and 15.62 oxygen; and the products of combustion will be, by weight,

$$CO2 = 16.23+ 27.34+ 15.62 = 59.19$$
$$N = 56.34+52.29 = 108.63$$
$$\text{Weight of products} = 167.82$$

* This analysis is taken from a paper by Mr. W. Hawdon, in the *Iron Age* of July 5, 18S3.

Multiplying each of the above products by its specific heat* we have:

$$
\begin{aligned}
59.19\ CO_2 &\times .2163 = 12.802797 \\
108.93\ N\ \ &\times .2438 = 26.483994 \\
\text{Heat-units for } 1° &\quad = 39.286791
\end{aligned}
$$

the number of heat-units contained in the products of combustion for each degree of temperature.

The heat carried by the gas at 100° C. must be added to that produced by the burning of its CO, and is found by multiplying each component by its specific heat to obtain the units carried for one degree and then multiplying their sum by the temperature of the gas for total amount carried, as follows:

Carbonic oxide, .	=	27.34	×	.2450	=	6.69830
Carbonic acid, .	=	16.23	×	.2163	=	3.51055
Nitrogen, . .	=	56.34	×	.2438	=	13.73569
Heat units for 1° C., ...					=	23.94454
" " 100° C., ...					=	2394.454

Since each pound of CO burned to CO_2 yields 2400 heat-units, the temperature of the products of combustion of blast-furnace gas of the assumed composition will be:

$$\frac{27.34\ CO \times 2400 + 2394.454}{39.28} = \frac{68010.454}{39.28} = 1731.4°\ C. = 3148.5\ F.$$

If the same gas be heated to 1000° C. (1832 F.) and burned with air at 0° C, then from the foregoing the heat carried by the gas will be 23944.54 units, and the resulting temperature of the products of combustion

$$\frac{65616 + 23944.54}{39.28} = 2280°\ C. = 4136°\ F.$$

or 31.7 per cent greater than when the temperature of the gas was 100° C.

In the regenerative hot-blast ovens now in use, the air for burning the gas is either employed at atmospheric temperature, or is heated by being caused to flow through passages in the walls of the combustion chamber immediately surrounding the flame; but it is evident that no advantage is gained from the latter arrangement, since the heat that the air for combustion carries to the flame has been taken

* The specific heats are taken from Ganot's *Physics.*

from the flame by the walls through which it passes, and hence there is no increase in either temperature or quantity of heat; whereas, by burning the highly heated gas with highly heated air, which has been heated otherwise than by the oven in which it produces com-.. bustion, the heat which this air carries is added to that carried in and produced by the combustion of the highly heated gas, and a great increase of temperature is produced over that resulting from the combustion of cool gas with cool air or cool gas burned with air heated in the oven in which it produces combustion.

Assuming the same blast-furnace gas as before to be at 100° C, and to be burned with air having the temperature of 1100° C, we must add the sensible heat carried by the air to that carried and produced by the gas.

Heat carried by air, . .	$= 67.91 \times .2374 \times 1100$	$= 17734.017$ units.
" " by gas, . .		$= 2394454$ "
" produced by CO, .		$= 65616.000$ "
Total heat of flame, .		$= 85744.471$ units.

$$\text{Temperature of combustion} = \frac{85744.471}{39.28} = 2182.9°\ C. = 3961.°\ F.$$

being 26 per cent greater than when gas at 100° C. is burned with air at 0° C.

Taking the same gas and heating it to 1000° C. and burning it with air at 1100° C, we have

Heat-units carried by gas at 1000° C., ...	$= 23944540$
" " " by air at 1100° C., ...	$= 17734.017$
" " produced by burning CO to CO_2, . .	$= 65616.000$
Total heat-units, ...	$= 107294.557$

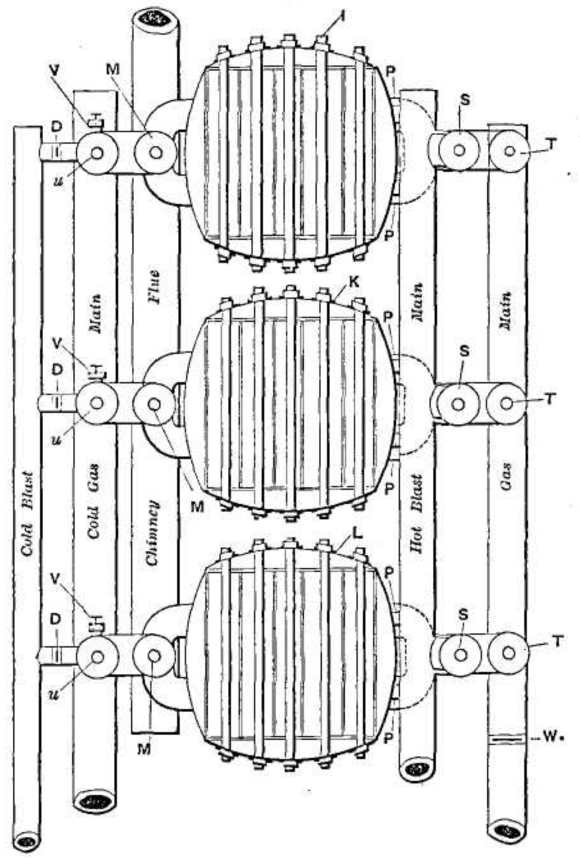
$$\text{Temperature of combustion} = \frac{107294.557}{39.28} = 2731°\ C. = 4947°\ F.$$

being 57.7 per cent. greater than when gas at 100° C. is burned with air at 0° C.

The apparatus proposed to secure these results consists in three of the regenerative hot ovens arranged as in Fig. 1, along hot and cold gas- and air-mains, so connected that each oven can be used : as desired, either for heating the blast or for heating the combustihle gas after it has left the blast-furnace and prior to its being burned to heat the apparatus.

Since the oven which is heating the blast will, after it has parted with all the heat which is effective to produce a blast of the desired temperature, yet contain a vast amount of heat, but of a lower temperature, the blast-oven can be used, without being specially heated therefor, to heat the combustible gas to nearly the temperature of

Fig. 1.



the blast, because the quantity of gas is much less than that of the blast, and the specific heat is about the same, while the heat-absorbing power is greater.

The air for combustion is either used at the atmospheric temperature, or it is taken from the hot-blast main, or parts in free communication with it; so that this hot air is heated otherwise than by *the* oven in which it produces combustion. Thus we command the advantage of heating the apparatus by means of highly heated gas, burned with air at atmospheric temperature or highly heated air, and thereby producing a most intense temperature and greatly increasing the efficiency of the apparatus.

For as the rate of cooling of a heated body increases in a geometrical ratio when the temperature increases in an arithmetrical ratio, it follows that an oven will become much more highly and quickly heated by this intensely hot flame than if the same quantity of heat were produced at a lower temperature by burning cool gas with cool air or air heated by the oven in which it produces combustion. And the time required to heat the oven will become so much shortened that the time required for the blast-oven to part with its effective heat will be sufficient to heat the oven in which the gas is being burned.

Referring to the accompanying drawings:

Fig. 1 is a plan of three ovens and connections.

Fig. 2 is a vertical section on line Y Y', Fig. 3.

Fig. 3 is a horizontal section on line X X', Fig. 2.

Fig. 4 is a horizontal section on line Z Z', Fig. 2.

Fig. 5 is a vertical section through combustion chambers.

Fig. 6 is a plan of three of the ovens now in use, showing the method of altering the apparatus to my system.

The oven is rectangular in shape, having curved supporting walls, A, of slag, red brick, or sand, as in Figs. 3 and 4, and encased in sheet-iron. It is divided transversely into combustion-chamber and regenerator, and longitudinally by the roof-supporting walls E, Figs. 3 and 4, into independent compartments through both combustion-chamber and regenerator, so that the products of combustion and blast must flow through the ovens in separate and equal currents.

In the circular ovens, as they are now used, there are no independent compartments, and the products of combustion take the most direct course through the oven and most highly heat the middle, while the blast, owing to the greater resistance to its flow in the hotter part, takes the cooler sides of the oven. Thus the oven is not operated to the best advantage.

The flues in the regenerator-portion of the compartments are arranged, as in Fig. 2, in sets forming a decreasing series from the combustion chamber, so that as the products of combustion impart their heat, become cooler and contract the areas of the flues and heat absorbing materials decreases, and conversely, when heating the blast the area of the flues and heat-imparting materials increases as the blast becomes heated and expands. As the rate of expansion and contraction of all gases is the same as that of air, the velocity is thus kept uniform throughout the oven and the friction decreased

both when heating the blast or gas and when heating the oven. Th
arrangement of the flues is an important matter, as air or g

Fig. 2.

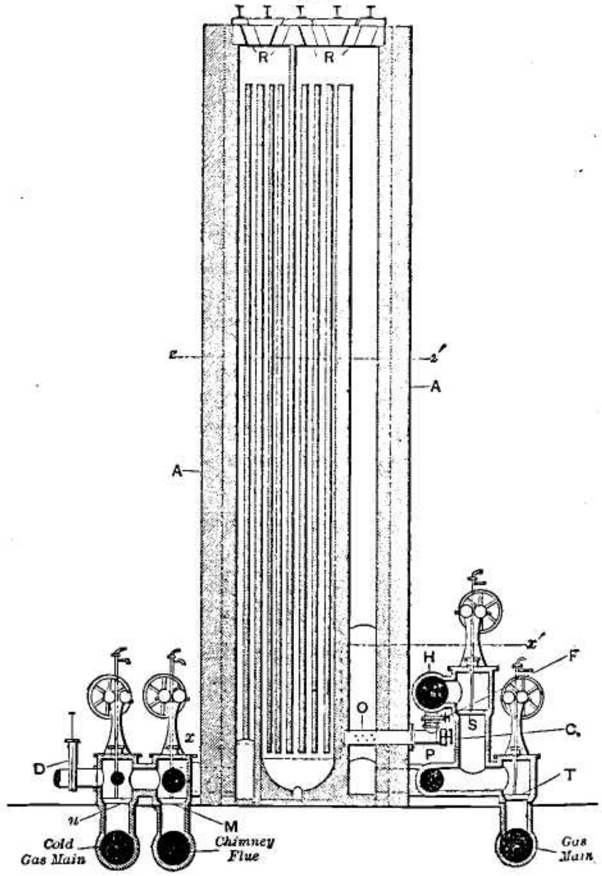
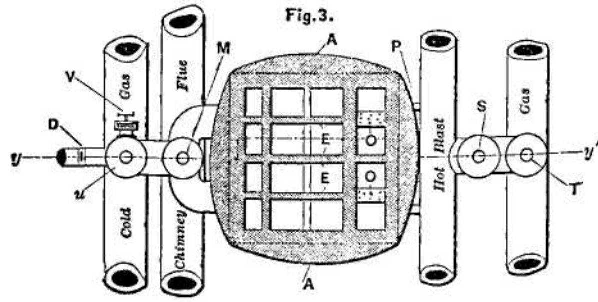


Fig. 3.



expands or contracts $^1/_{491}$ of its volume at 32° F., for each degree F. the temperature is raised or lowered; so that the volume of a given weight of air at 579° F. is double, at 1098° F. three times, at 1617° F. four times, and at 2136° F. five times, what it is at 60° F.

The compartments are either single or double, and each has separate gas-blast and chimney connections, so that it shall become equally heated and shall have an equal quantity of blast or gas to heat.

The roof is formed of flat-arch blocks R, resting on the walls E, and covered by strips of sheet-iron, as shown in Figs. 1 and 2.

The walls are formed of ordinary 9-inch firebrick or similarly shaped blocks, laid diagonally in reverse directions in adjacent courses, as shown in Fig. 4, thus providing for expansion and contraction, as the bricks are free to expand into the flues and can not transfer their linear expansions to the sides of the oven (as in walls of the ordinary construction) while the lateral expansion has *a* tendency only to turn the bricks to a greater angle. .Moreover, by this construction the heating surface is made nearly one-half greater than for a similar wall having a plane surface.[3] The wall is also much stronger than when laid in the ordinary manner, and hence can be made much lighter. As the depth to which the heat penetrates and is given off is supposed to be from 1 $^1/_2$ to 2 inches, the whole of the material of the bricks can by this construction be made effective for absorbing and giving out heat. Hence a much smaller oven can do more work than a larger one with plain walls.

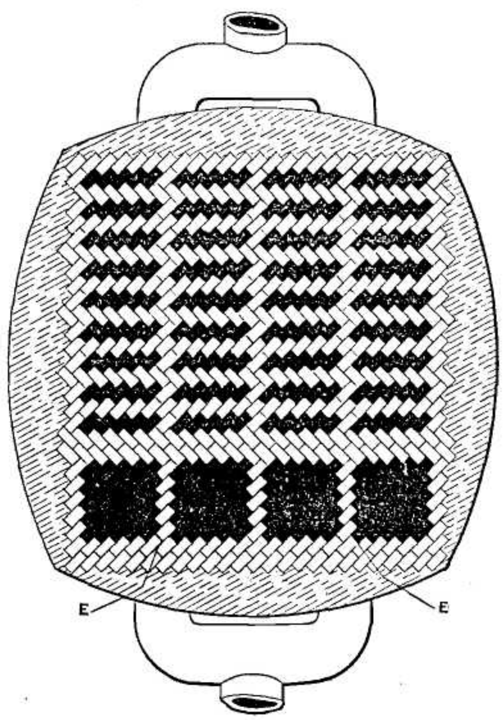
The air for combustion is either admitted at atmospheric temperature, by means of valves C, or is taken from the hot-blast main, H, or parts in free communication with it, by means of valves, F, and is introduced through pipes, P, Figs. 2 and 3, into the air-cylinder, O, having holes so arranged that the air-jets shall be perfectly distributed through the gas.

The valves used are positive-motion seat-valves, having a continuous coil of pipe through them, so that by increasing the pressure of the water or passing a jet of steam through them any sediment may be readily removed. The seats are similarly provided, and firmly fastened to the valve-easing to keep them properly in place.

Method of Working.—The method of working a plant consisting of three of the above-described ovens (as in Fig. 1) which are used for heating the blast and pre-heating the combustible gas, without being themselves heated specially for the latter purpose, and in which the gas is burned with hot air, is as follows:

All valves being closed, open in oven I (Fig. 1) the cold-blast Mast valve, D, then open the hot-blast valve, S, thus having blast pass through the oven and into the hot-blast main. Then open in oven K the cold-gas valve U, and then open the gas-valve T, so that gas will pass through the oven and into the hot-gas main formed by closing the valve W between the ovens and the blast-furnace. (When W is open this main can be used as ordinary gas-main to supply the ovens with gas directly from the blast-furnace.) Then

Fig. 4.

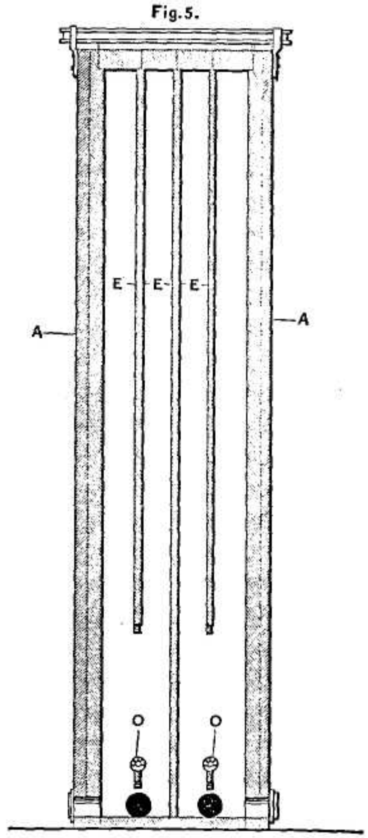


open in oven L first the chimney-valve M, next the gas-valve T, to admit the gas to be burned, then the hot-air supply-valve F, to furnish air for combustion, and ignite the gas through the eye-hole or dust-door.

After a suitable interval the apparatus is reversed, always commencing with the oven which is being heated by putting it on blast then put the oven which had been on blast to heating gas, and put the oven which is heating gas to being heated by burning gas. Thu-.

in oven L, which is being heated, close the gas-valve T and air-valve F and then close the chimney-valve M and open the cold-blast valve D and hot-blast valve S, and have hot-blast pass into the hot-blast main and to the furnace. Then in oven I (on blast) close the hot-blast valve S and cold-blast valve *D* and open the air-escape V (or the cold-air valve C, which can also be used for this purpose) to allow the compressed air to pass out, after which it

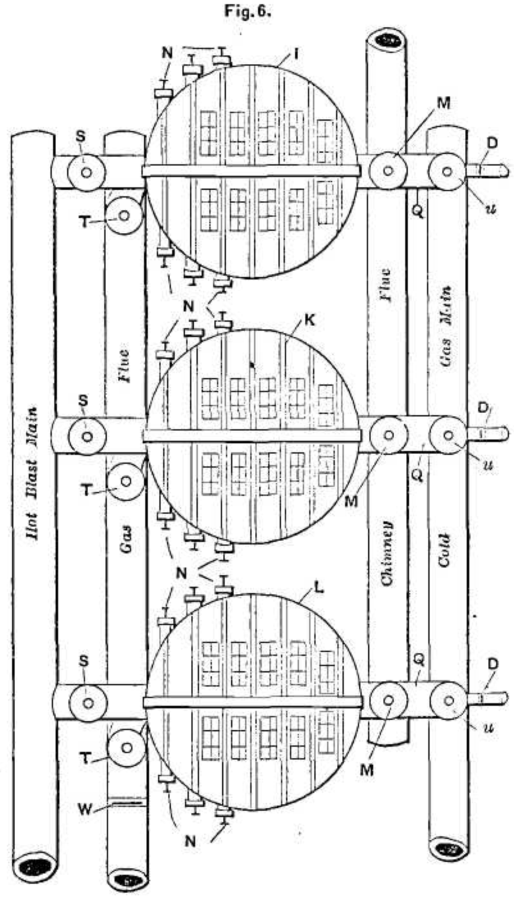
Fig. 5.



is closed again. Then open the chimney-valve M and the gas-valve T, and after a sufficient interval to allow the air in the oven to pass into the chimney and the oven to be filled with gas (in order to avoid the danger of an explosion from a mixture of air and gas in the oven and hot-gas main) close the chimney-valve M and open the cold-gas valve U and let hot gas pass into the hot-gas main. Then, in oven K(on gas) close the cold-gas valve U and open the chimney, valve M and the air-valve F to supply hot air for combustion.

After the oven which is heating the blast has parted with its effective beat, or the oven which is being heated has become sufficiently hot, the apparatus is again reversed in the manner and with the precautions above described.

Fig. 6.



After the first reversal, the apparatus is heated by burning cold gas with hot air, and hence in an equal interval the oven, which is being heated, will become several hundred degrees hotter than did the oven which was first heated by burning cold gas with cold air, and after the second reversal will furnish a blast several hundred degrees hotter than before, while the oven through which the gas is passing will heat it several hundred degrees hotter than it was when.

it came to the apparatus, and the oven which is being heated by burning this heated gas with hotter air, will in an equal interval become hotter than before, and after reversal will furnish still hotter blast to the furnace and for the combustion of still hotter gas, thus developing after each reversal a higher temperature of blast, provided the quantity of blast and gas are properly proportioned to the apparatus.

The regenerative hot-blast apparatus now in use can be readily altered to this improved system, as is shown in Fig. 6 for a plant of three Whitwell ovens, by putting a valve, W, in the gas-main between the ovens and the blast-furnace, thus forming a hot-gas main of the portion cut off, and also placing at the cool or chimney-side of the ovens a cold-gas main having connections, Q, and provided with valves, U, to admit the gas to be heated prior to its being burned to heat the apparatus. The air for combustion is admitted through the usual valves, N. The Siemens Cowper ovens can be similarly altered, and the method of working is the same as above-described for the special ovens, with the exception that the air for combustion is admitted through valves, N, instead of from the hot-blast main. Thus, at a slight cost, the efficiency of the present regenerative hot-blast apparatus can be markedly increased.

The apparatus can also be arranged with four of the above-described ovens, two of which can be used for heating the blast and two for heating the gas. In this case the reversal is simpler, and it will not be necessary to take the same precautions against explosive mixtures of gas and air. In the blast-ovens the hot-air valves, F, after being properly set, are left open, both when the oven is being heated and when it is on blast. The apparatus can also be arranged to use the gas without heating it prior to its being burned, by opening the valve W, when the method of working is the same as in ordinary regenerative apparatus, excepting when air for combustion is taken from the hot-blast main. Finally, the air for combustion can be used at atmospheric temperature by employing the valve C, instead of the valve F.

To sum up: This apparatus can be worked as an ordinary regenerative hot-blast apparatus by beating it by burning therein cool gas with cool air, and then the operator will have in reserve the increase of temperature due to burning cool gas with hot air, or hot gas with cool air, or the further increase due to burning hot gas with hot air.

Or the apparatus may be worked to produce a hotter blast than the above by heating the gas prior to its being burned, and .burning it with cool air *(i. e.,* at atmospheric temperature), and the operator will then have in reserve the further increase due to burning hot gas with hot air.

Or, finally, the cool gas can be burned with hot air, and the increase of temperature due to heating the gas and burning it with hot air may be held in reserve. Of these three systems the second is to be preferred.

CERTAIN INTERESTING CRYSTALLINE ALLOYS.

BY RICHARD PEARCE, DENVER, COL.

In the treatment of auriferous copper containing bismuth, I have recently observed a small quantity of a grayish-white alloy, which on examination, proved to be Bi containing in solution, as it were, a crystalline alloy of Bi and Au. This compound makes its appearance on the surface of the auriferous Cu in small globules us the latter cools.

These globules are rapidly attacked by nitric acid, and fine needle-shaped crystals of Bi and Au separate out. They are insoluble even in strong nitric acid.

On examination, the crystals were found to contain : Gold, 69.91 per cent.; silver, 0.63 per cent.; bismuth, 29.43 per cent. (No. 1).*

The residue is very fusible, and at a temperature considerably below its melting-point it oxidizes rapidly, changing from its original gray color to a greenish-yellow (No. 2). On melting in a crucible under 9ux, a bronze-colored alloy is formed that has the specific gravity 15.47—somewhat higher than the calculated specific gravity of a simple mixture of the two metals in the proportions named.

Alloys of Gold and Silver.—In following out my investigation-by repeated examinations of this alloy formed at different times, J found that, in dissolving a miscellaneous lot of the alloy in nitric acid, some gold-yellow crystals were formed, which I succeeded in separating from the BiAu alloy by washing. These yellow crystals. under the microscope, showed distinct, regular, octahedral faces, and on examination they were found to be a crystalline alloy of An and

* This and similar numbers following refer to the samples forwarded by the author to the Secretary, and now deposited at the National Museum, Washington D. C.

Ag in the proportion of 69 Au to 21 Ag (No. 3). The quantity was too small to admit of any very correct determinations of these crystals; but the peculiar feature was remarked that they contained Ag, while the BiAu crystals did not in any appreciable quantity.

My next experiment was to remelt some of the original Bi compound with Ag, so arranging that the Ag should exist in the melted alloy in the proportion of one atom of Au to one of Ag. The alloy was prepared by melting in a small crucible under a layer of borax, and then allowing the crucible, with its contents, to cool very slowly. This was done by placing the small crucible inside a larger crucible that had been previously made red-hot, and allowing the whole thing to stand until cold. The small crucible was then broken and the button of alloy detached. This alloy was found to be very brittle find crystalline. It was broken into lumps and treated in a flask with dilute nitric acid—one of acid to three of water. I found, after all the Bi had been attacked by the acid, that nothing was left behind but a beautiful crystalline alloy of Au and Ag (No. 4). There was an entire absence of any BiAu compound, which was found in former experiments. The solution of nitrate of Bi showed no trace of Ag. These crystals were found to contain: Gold, 62.164 per cent.; silver, 35.486 per cent.; Cu and Bi, 2.35 per cent. Further boiling of the crystals with strong nitric acid gave (No. 5): Gold, 65.21; silver, 33.19; copper, 1.60.

Alloys of gold and silver in all proportions may be obtained in this way, depending ou the amount of Ag used and also on the strength of nitric acid employed in the separation of the Bi. The largest and best formed crystals are, however, those in which the Au and Ag exist in the ratio of their atomic weights. Repeated boiling with strong nitric acid will, however, remove a portion of the Ag, without in any way damaging the crystals or effecting any very marked change in the color. In a number of experiments that I have made with the alloys of Au and Ag, the lowest percentage of Au resulting from treatment with HNO_3 was 58.51 (No. 6), and the highest 94.15 (No. 7).

Alloys of Gold and Copper.—Crystals of an alloy of Au and Cu may be obtained precisely in the same way by substituting Cu for Ag. The form of crystals is the same, that of the regular octahedron, but they are much smaller. A crop of crystals was obtained having the composition 61.52 Au and 38.48 Cu (No. 8). On treating these crystals with strong nitric acid and boiling for some time until there was no farther action, a large percentage of the Cu was dissolved out, and a product was obtained a little darker in color containing 93.49 Au and 6.51 Cu (No. 9).

Crystals were also obtained containing all three metals in the pro-portion : Gold, 60.16; silver, 21.21; copper, 18.63 (No. 10).

These experiments indicate that An will not combine with Bi if Ag or Cu are present in sufficient quantity. The crystals of An and Bi are in fine needle-shaped forms, the system of crystallization not determined ; but possibly rhomhohedral (the crystalline form of Bi).

Au, Ag, and Cu crystallize out together from a solution of these metals in Bi; the mother liquor, if I may use the expression, con-taining no Ag or Cu unless these metals are present in excess of what is required to form alloys that will resist the action of dilute nitric acid.

The following experiment was made with the view of determining the solvent action of Bi, melted at a low temperature,on the crystals of alloy of Au and Ag formed by the process that I have described :

An alloy was made by melting Au and Ag in about their atomie proportions with Bi, and allowing to cool slowly. The alloy was then heated in a small iron ladle until it became liquid, care being, taken not to increase the temperature much above the melting-point. The liquid portion was then poured off and the residue of crystals drained until a pasty mass was obtained. The temperature was then slightly increased, and a further quantity of molten Bi poured off. The percentage of each product was as follows: 56 per cent, of the total weight was poured off at the first melting at a low temperature ; 19 per cent, after a slightly increased temperature; the rest, 25 per cent. (the pasty mass), re-treated with dilute nitric acid, gave a crop of good crystals, which were found to contain : Gold, 59.06 ; silver, 37.21 (No. 11); Cu and Bi (by diff.), 3.73. Treated with strong nitric acid, their composition became: Gold, 68.53; silver, 27.51; copper, 3.93. I found in this experiment that the pasty residue in the ladle contained only about 62 per cent, of the total gold, the re-mainder being; carried off by the liquated Bi.

The ratios of the gold and silver in these three products were are follows:

The ratios of the gold and silver in these three products were as follows:

			(Approximately)
First liquation, ...	Au 74.16	Ag 25.84	Au_3Ag_2
Second liquation, . . .	Au 65.35	Ag 34.65	AuAg
Pasty residue, ...	Au 71.33	Ag 28.67	Au_4Ag_3

Iu all these alloys of Au, Ag, and Cu, the only crystalline form observed was that of the regular octahedron without any modifications.*

Alloys of Bismuth and Platinum.—Experiments were made to see how far it was possible to prepare in a similar way crystalline alloys of platinum and bismuth.

Pt and Bi were melted together and allowed to cool slowly in the usual way. The brittle alloy was treated first with dilute nitric acid and then with strong acid. A black crystalline powder was obtained, which, under the microscope, showed some few crystals, form not determined.

A second experiment was made with the addition of Cu to a similar mixture as before. A highly crystalline, jet-black residue was obtained, which, on examination, proved to be binoxide of platinum.

Crystalline alloys are obtained in the same way as with An ; but these compounds, unlike those containing An, are decomposed by nitric acid; the metals Bi and Cu that entered into the composition of the alloy being entirely replaced by oxygen, and this without destroying the structure of the crystal, as will be seen by examination (No. 12). The black crystals became red-hot in a current of hydrogen, water being condensed on the sides of the tube, a grayish-white powder of Pt being left behind (No. 13). A loss of weight was sustained in this experiment equal to 13.75 per cent., which is very near the amount of oxygen required by the formula PtO_2. On heating in a tube, it gives off O, a grayish-white powder of Pt remaining.

The black crystals can be ground easily in a mortar without showing the slightest evidence of metallic particles. Alcohol is readily oxidized by this compound. On heating the crystals, a trace of reddish-brown gas is given off, probably due to a small quantity of occluded nitric oxide.

If it were possible to attack the Bi by some acid that is not oxidizing, we should unquestionably obtain crystals of the alloy of Pt and Bi, or Pt and Cu, or perhaps Pt, Bi, and Cu; but on using nitric acid as the solvent, we have to be content with pseudomorphs of PtO_2 after the alloy.

In order to avoid the use of nitric acid, an experiment was made by substituting Zn for Bi, in the hope that crystals would be formed that could be separated by dissolving out the Zn with H_2SO_4. A

* The Bi used for most of these alloys was somewhat impure, containing notably a little copper.

black powder was obtained in this way, showing, however, noevidence of crystallization. On treating the black powder with nitric acid, Cu was dissolved to the extent of 20 per cent., and a grayisliblack residue was obtained, which, when dried, possessed highly oxidizing properties (No. 14). It instantly ignited a drop of alcohol and exploded a mixture of hydrogen and air. What the exact nature of this substance is, I have not determined; but it differs materially from the crystalline black substance prepared from the Bi alloy. From the loss sustained on ignition (less than one-half required for PtO2), it would appear to be finely divided platinum intimately mixed with PtO_2. Its oxidizing properties are, however, far more energetic than were shown by the previous compound.

These experiments to which I have drawn attention may be regarded as being of a preliminary character. They offer, however, a field for further investigation that would, in all probability, lead to some interesting facts connected with the composition of alloys.

POSTSCRIPT.

Since the foregoing paper was written I have made a new lot of crystals of the gold-bismuth alloy, the color of which is a beautiful • copper-red, and thus differs materially from that of the specimen marked No. 1. The composition of the red crystals is: Gold, 68.22; bismuth (by difference), 31.78. I forward a specimen, marked No. la.

TEE FAHNEHJELM WATER-GAS INCANDESCENT LIGHT.

BY R. W. RAYMOND, NEW YOKE CITY.

THE idea of obtaining light from incandescent solids is not new; nor is it new to make such bodies incandescent by holding them in a heating flame. But the successful combination of the right substance and form of the body to be heated with the right kind of flame and the right means of adjustment, has not, to my knowledge, been accomplished heretofore; and it seems to me that the water-gas incandescent light of Mr. Otto Fahnehjelm of Sweden, in which these objects appear to have been secured, is destined to become both famous and useful.

The first fact upon which this invention is based, is the intense temperature of the flame of water-gas. The combustion of this gas through an ordinary coal-gas burner, without blast or aid of any kind, will melt platinum wire.*

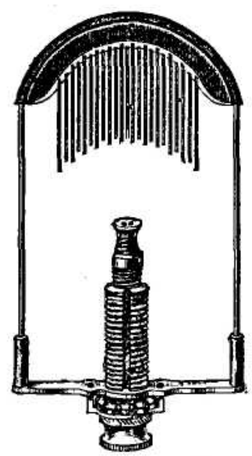
The next important basis of the invention is the form of the incandescent body. This is shown in the accompanying cut, which represents an ordinary fan-tail gas-burner, fitted with the necessary apparatus for producing the new incandescent light. A frame, movable by means of a screw, up and down along the burner, carries at its two extremities sockets to receive two iron wire standards, which carry a curved back, provided with two rows of long teeth. By turning the screw, these teeth can be brought as near the tip of the burner as may be desired. They are composed of magnesia, which has been first baked at a high temperature, then ground, and then moulded under high pressure, and with some agglutinating material, such as starch. The flat flame of the water-gas passes up between the two rows of vertical teeth, which thus receive its greatest heat, and do not come into contact with its comparatively cooler interior. They become immediately and beautifully luminous, with a perfectly white light, which does not, like gas or candle-light, change the day-light appearance of colors, and which can even be used for photographing. It is steadier than the incandescent electric. The flickering of the gas-flame (which is non-luminous, and when the comb is glowing, quite invisible), does not at all effect the steadiness of the light. If the gas is blown out, or if, by the use of a cock without a stop, it is turned off and then unwittingly on again, no evil results can follow in this case; for the comb goes on glowing for several seconds, and the gas consequently relights itself.

The magnesia teeth have before use the appearance of starch. When thoroughly well prepared, they should possess considerable strength. The best that have been made thus far, I believe, would sustain 8 ounces avoirdupois hung from the middle of the needle, which was laid across supports, one inch apart. Since the diameter is less than 1/16 of an inch, this indicates a good degree of strength. The needles are held in a composition of plaster of Paris, which fills the curved back of the comb. This back, like the side-wires, is of iron ; and the whole comb, with its side-wires, costs about 3 cents.

Apart from accidental breakage, such a comb endures from 80 to

* Mr. Otto Fahnehjelm, the inventor, who was present at the reading of this paper, demonstrated the truth of this statement experimentally before the audience.

150 hours of incandescence before it must be removed.. The first effect of the high white heat upon the needles is to make them translucent like porcelain. Probably this change is really a condensation, fusing into a continuous mass what had previously been but a compressed aggregate of particles. The result is a gradual



Burner for Water-Gas Incandescent Light.

shortening of the needles, so that after about 15 hours, it is necessary to turn the screw and bring the comb down towards the flume. This process is repeated from time to time, until at last the needles have become so short that the iron back would be in danger from the flame if they were brought fairly into it. Then the comb most be taken out, and a new long-toothed one substituted.

Exact photometric and economic tests have yet to be made under *American conditions,* and for water-gas produced by different processes. Speaking in a general way, I should say that the quantity of pure water-gas required to produce a given amount of light by this system, is about four-fifths (in volume) the quantity of *carburetted* water-gas, like the Tessié gas of the Municipal Company of New York, required to give the same amount of light. The cost of the non-carburetted water-gas is, of course, much smaller. It can be sold to large profit for 50 cents per thousand cubic feet.

We have then, in this invention, a light which is actually much cheaper than ordinary gas-light, while in quality it equals, and in steadiness, uniformity, and simplicity of management, far surpasses the electric incandescent light.

POSTSCRIPT.

My attention has been called to the fact that the gas of the Municipal Company is exceptionally high--according to my informant 29 1/2 candle-power, and that the above figure, based on comparisons with coal-gas abroad, is therefore too low. It would be safer to say that the quantity by volume of water-gas required to give the same amount of light would be about *five-fourths* (instead of four-fifths) that of Tessié gas.

THE CLAPP AND GRIFFITHS PROCESS.

BY J. P. WITHEROW, PITTSBURGH, PA.

THE Clapp and Griffiths steel-process may be considered a pneumatic system, similar to the Bessemer, with the difference that the converter is fixed or non-tilting, and that the blast is introduced around the lower section of the converter instead of through its bottom. Mr. Griffiths was engineer-in-chief of the Gilchrist & Thomas basic dephosphorizing process during all the time those gentlemen were experimenting and working up their system, as Mr. G. communicated to me. After separating from these gentlemen, he began developing the present Clapp and Griffiths type of converter. Dr. Clapp, of Nantyglow, Monmouthshire, was a prominent physician in a large iron district. Previous to his association with Mr. Griffiths, he took out some patents on a process of his own for the manufacture of steel, which patents stood in Mr. Griffiths' way; hence the consolidation. Early in the summer of 1883, my attention was called to the experiments of Messrs. Clapp & Griffiths in Great Britain by a friend who had just returned from England. Later in that summer I went to Newport, on the border of Wales, where I met Messrs. Clapp and Griffiths and their friends. After visiting two small converters of their type which were in operation at different works, and spending a few days in the iron-districts of Wales, I went to London, where I met my friend Henry W. Oliver, Jr., who had already heard of the new steel-process. We decided to revisit Wales and examine more fully the process, more especially that Mr. Oliver might have the opportunity of coming practically in contact with the men and the process himself, so that his judgment might not be influenced by my sanguine feelings. On arriving at Newport we were directed by Messrs. Clapp & Griffiths to the tin-plate works of the Messrs. Conway. On entering their works we saw, apart from their plant, what seemed a solitary little pot or kettle some 12 or 15 feet above the ground, puffing and blowing as if each breath was to be its last, without any building or covering to protect it or its attendants from the weather. This was the converter of Messrs. Conway. After remaining some time observing its operations and manipulations, everything being as crude as possible, we felt like concluding that it had little or DO merit. Soon, however, we were conducted into the mill and first saw the operations of the steam hammer, where the ingots were divided and hammered into suitable shapes to suit the rolls. From the hammer we passed on and viewed all the operations until we saw the finished steel tin-plate and examined and tested its wonderful ductility and superior quality. We then were conducted to the blacksmith-shop where we saw several welds of the steel as it was taken from the "sprues" at the converter. After spending some time at these works, Mr. Oliver's first unfavorable impressions began to disappear, and he was convinced that my former favorable opinions were not without a substantial basis.

Although we could not dispute the quality of the steel, or, as they termed it, "stuff" (which seems to be the term used for designating the product of all operations), we still hesitated to accept the proposition that the whole merit of this product was in the process as executed in this type of converter. We examined the pig-iron and found that less than one-third of that which they were putting in the converter was No. 1 Bessemer, the balance being gray forge and some mottled.

The next day we visited another converter at Margrin's, some 10 or 50 miles below Cardiff. This converter was of a size intended to blow three tons of iron at once, if required, whereas that at the works of Messrs. Conway only took from 1800 to 2000 pounds at a blow. At these works we saw several blows with the larger quantity and were still more impressed with the efficiency of the process, and were convinced that if from two to four converters were erected in one plant, each pair of them could be made to give an output of 100 tons in twenty-four hours, and that, therefore, if quantity as well as quality were required, this system would still be found adequate. As a result of these investigations, we obtained from Messrs. Clapp & Griffiths the patents for the United States, and Mr. Oliver, as soon as drawings were received, commenced the erection of a small plant at one of his mills at Pittsburgh.

The completion of Mr. Oliver's converter was much delayed, owing to our having decided to make it an exact copy of the 3-ton converter we had seen in Wales. We also bought bricks for the lining and for the tuyeres and tuyere-blocks in England, and had to await their arrival. From these causes we were not able to commence until the beginning of April. The materials for the converter were brought from abroad, simply because we wished to have everything the same as was in use there. When the converter was put in operation, everything seemed to go off satisfactorily, and the first blow, although it took much longer (everything being cold), made excellent steel. After starting up the next day and making a few blows, it was found that the tuyeres and the tuyere-blocks were burned off, and that the reactions of the converter had torn the lining all to pieces. The conclusion was at once reached that we had made a great mistake in ordering the firebrick from the Stour-bridge Works instead of from the firebrick factory in Wales, at which the parties there got their tuyeres and tuyere-blocks made. Mr. Oliver, therefore, at once cabled to have new tuyeres and tuyere-blocks sent from Wales, and operations at the converter were suspended until these should arrive. It required six weeks before they were delivered and the converter was ready for blast again.

Although at the second starting up much better work was done than before, still the tuyeres, tuyere-blocks, and linings did not resist the reactions much better than the first materials received, and it became evident that something else than brick must be used as lining. We then began to experiment with ganister for lining, and soon succeeded in making it answer for this purpose reasonably well. We were then in a position to do fairly good work. However, when those in charge of the plant began to make three blows per hour and work up to a reasonable output and efficiency, they discovered that the steam-cranes provided for handling the ingots were inadequate, and that that part of the plant would have to be remodeled. As Mr. Oliver had no blooming-mill, it was necessary to cast small ingots, and this resulted in great difficulty in getting the ingots out of the molds and in getting a sufficient number of molds prepared for the succeeding blow. Mr. Oliver, therefore, decided to replace the steam-cranes with hydraulic ones, and to erect a steam-hammer, so that he would be able to manipulate larger ingots. To do this it was necessary to again suspend operations. It was then midsummer; and the converter was not again operated until autumn, over two months being required to make the above changes. When we started up again, the plant worked very satisfactorily everything seeming to come up to reasonable requirements; and commencing at eight o'clock in the morning and stopping about half-past two, we were able to make from twenty-five to thirty tons of ingots.

After working for several weeks with fair success in this manner, it was discovered that still one important change would have to be made before the plant would be fitted and thoroughly equipped for large work night and day, viz., that it would be desirable to have the converters with movable bottoms, so that instead of having to stop and cool the converter in order to repair the lining of the. bottom, the entire bottom-section could be detached, lowered on to a car by means of a hydraulic piston, and removed, its place being at once supplied by a new bottom, elevated into place by the same means. Any repairs the lining may require can be done when the bottom is removed. In this way, we feel satisfied, the converters can be kept steadily at work, night and day, and nothing can occur to interrupt the process. This was decided on early in January, and the two old converters were at once dismantled and new ones were built at my shops. Besides the movable bottoms, changes will be made in many important parts, and we may expect to have the new plant in operation between the 23d and 25th proximo, when we cordially invite any practical ironmasters or experts from any part of the country to critically inspect and investigate our plant and its operations and results, to decide for themselves whether our statements are well-founded.

I am not insensible to the fact that, in view of the interruptions which we encountered from the beginning, in consequence of the reasons I have given, and which caused a suspension of operations at three or four different times during the summer and fall, it was assumed quite generally and conceded by our Pittsburgh friends, and by some outside of that city, that the process was a failure. I will not assume (even if I were qualified both theoretically and practically to enter the field as an expert on the steel business) to submit to you any of the chemical and physical tests that have been made, as we have desired and requested Captain Hunt to handle this question from an impartial standpoint, as viewed through the spectacles of one of our great Bessemer chieftains, who, I assure you will not be disposed to give praise to anything that does not deserve it, apart from the Bessemer operations.

I will, therefore, confine myself to a few remarks on the commercial aspect of the process, and the developments that we made amid all our troubles and stoppages. When I first saw the process in use in Wales, I remarked that I saw in this type of converter the greatest boon to ironmasters and the iron-interests of the United States that had been introduced into America daring the last twenty-five years. I at once conceived the idea that these converters should be placed adjacent to the casting-houses of blast-furnace plants, when the iron could be taken from the furnace every four hours, being run directly into an iron car, lined with brick and drawn by a light locomotive, precisely as many of our modern furnaces now dispose of their cinder with our improved cinder curs. The car would pass on an elevated track alongside the converter, the molten iron being poured into an intermediate ladle and weighed, and a proper quantity of it charged into the converter to be blown. This operation would be at once very simple and very efficient, and would enable our furnace-men to sell their product as steel or ingot-iron instead of pig-metal. The steel or ingot-iron would have fully double the value of the pig-iron, and would not cost its manufacturer more than $4 more than the pig. The men now employed in the casting-house and in piling iron could be transferred to the converter. It requires only about fifteen men to manipulate the converter and handle the ingots, and eight or ten of these could be spared from the casting-house. It is probable, therefore, that the whole cost of the process, including labor, refractory materials for the converters, ferromanganese, and all other expenses pertaining to maintaining and handling the converters, would not make the cost of the finished ingots exceed that of the pig iron more than from $3 to $4 per ton, which would include the 10 or 12 per cent, waste. If, therefore, the owners of blast-furnaces by an expenditure of some $30,000 can convert their products into ingots instead of pig-iron at a cost not exceeding from $3 to .$4, the change nearly doubling its value, it certainly places the blast-furnaces in a different position from the one they occupy at present; and I think that no improvement has ever been introduced at a more opportune time or deserved a warmer welcome than such a process, applied at this time to blast-furnace practice.

From a commercial point of view, we have made at the Oliver plant during the past summer and fall about 2000 tons of steel; and, apart from what he consumed himself, much of this was sold to parties through whom he wished to introduce it to the trade; and all parties who have used it have ordered more. We have carefully kept account of our expenses while making these 2000 tons, and find that, including cost of ferromanganese, coke and keeping up the plant, expenses for steam power, labor and everything connected with the process, its cost did not exceed $6.50 per ton over the price of the pig-iron used. It should be remembered that while making these 2000 tons we experienced all the backsets and interruptions I have referred to; and, the plant being the first experimental one, the expense for labor, etc., was much larger than with our present experience it will be hereafter. We feel, therefore, that we are safe in assuming that the process can be conducted in mills at a cost not exceeding $6 per ton, and at blast furnaces, in the manner I have described, for from $3 to $4 per ton, as above stated.

Now, since it requires an expenditure of $12.50 to convert a ton of pig-iron into muck-bar (which is the general cost at our Pittsburgh mills), and since by our process a ton of pig-iron can be converted into steel blooms at a total cost of about $6 in mills, and from $3 to $4 at furnaces (in the latter case saving also, a part of the freight on the pig-iron to the mills), you can from these data form some estimate of what the economy to our iron trade will be when this process shall be in general use at our mills and furnaces.

I am not insensible to another important consideration which, I have no doubt, has presented itself to the minds of many, viz.: Will not the quality of the product be entirely dependent on the quality of pig-metal the furnace is producing, and will not the many changes that blast furnaces undergo, both in quality and grade of pig-metal, materially affect, if not destroy, the application of such converters to blast-furnace practice as I assume?

In the first place I would state that I am satisfied, after you hear Captain Hunt's paper, you will be convinced that our development-have demonstrated that phosphorus is not the devil which it has been heretofore held and maintained as being when existing as one of the unavoidable constituents of iron or steel. When we have convinced you that from pig-iron containing from .5 to .6 per cent. phosphorus we have made rods which have withstood a tensile strain of 70,000 pounds per square inch with 25 per cent, elongation and 36 per cent, reduction of area; that said steel was made into plates, and the most superior nails in the country produced therefrom ; that we have welded it as shown by the specimens we herewith submit, we think yon must then admit that when carbon, silicon and other metalloids are completely expelled from molten iron and steel the presence of phosphorus develops different properties from those which have heretofore been conceded to it. Indeed, such results have been quite a surprise to us, and we have made many experiments in this direction. If, therefore, from pig-iron containing from 5 to 6 per cent, of phosphorus this superior steel or ingot-iron can be made and adapted to nearly all commercial purposes, this question of phosphorus will henceforth be placed in a different light and assume a different position in our metallurgical views, conceptions and requirements.

If this process supersedes puddling (which assuredly it must do) there will be no mill-cinder to be used in blast-furnaces, and, consequently, the amount of phosphorus which is ever being accumulated by the use of mill-cinder will be cast aside, and the quantities of phosphorus in two-thirds of the leading brands of our irons will not exceed .5 per cent. Therefore, phosphorus will no longer be the great obstacle in the path of the iron-manufacturer it has heretofore been assumed to be, and thus will be opened up a new avenue for the conversion into steel of various brands of iron that have been absolutely forbidden and set aside as unfit for the commonest Bessemer. We have all heretofore bowed to the will of the Bessemer king, his mandates have been imperative, and his assertions had to be taken for granted everywhere as absolute demonstration, without questioning the philosophy or reasons therefor. It will, ." therefore, be gratifying to the blast-furnace interests generally, if they are able to take a position on this question and make a steel superior for all commercial purposes to that of the Bessemer. Indeed, as you will soon know from our actual developments and experiments, we find that our steel is of fully as good a quality and more uniform than that of the open-hearth process when made from the same pig-metal, and when the costs of making steel by these two methods are contrasted, the difference is largely in favor of our system.

One thing I would state, before closing, relative to the application of this type of converter directly to blast-furnaces, and to the question whether we will not experience difficulty in keeping the metal liquid between casts. As you are well aware, at many plants abroad the molten iron is conveyed from 8 to 10 miles from the blast-furnace to the Bessemer converters, and then often it has to wait a considerable time before being poured. And, as you are also aware, at all Bessemer works, such as our great Edgar Thomson plant, where the direct process is used, the molten iron frequently-remains in the cars from 3 to 4 hours before being poured into the converter. I have assumed that a blast-furnace using this type of converter would cast every 4 hours, and that the whole cast would be run into two or three cars, according to its amount--into two cars if the quantity would be from 15 to 20 tons; that these cars would be heavily lined with fire-brick, which would be washed and dried, so as to prevent, as much as possible, the adhesion of the iron ; that a movable lid would be placed thereon, which also would be heavily lined with fire-brick, which cover would be lifted by a-crane when the car arrived at the converter. The contents of the first car would then be converted into iron or steel (say it would hold 10 tons) in less than 1 hour. Thus, within 2 hours one converter would make over 12 tons of steel, and, indeed, this one converter would be capable of converting within 3 hours, say, the whole 20 tons. But as there would be two or more converters, it would be easy to have the contents of all the cars converted into steel or ingot-iron within 1½ hours. However, should the iron at any time become a little chilled while standing, though still remaining liquid enough to run into the converter, an arrangement can be *made,* which I have designed, for blowing the converter for a time with hot or superheated blast. That is to say, a pipe from the hot-blast-main of the furnace to the cold-blast-main of the converter can be established and so governed by valves that hot or superheated blast can be applied in a moment, should it be required. And as the pressure of the engines can be regulated for that few minutes to the needs of the converter, the process can go on as if the iron were very hot and highly charged with silicon. Moreover, it is well to introduce this feature of a communication between the hot-blast-main and the converters, because a great deal of steel scrap can be put in the converters before pouring the molten iron therein, and to overcome the cooling effects of this scrap, provided the iron is low in silicon, the hot blast can be used for any portion of the time of the blast. Thus, by this means, any desired quantity of scrap can be easily mixed with the charge.

As a matter of course, as soon as this process and type of converter is applied to our blast-furnaces, we will have the benefit of the experience of all the blast-furnace engineers, with their ever-fertile brain-, improving and perfecting this system; and, as they are continually exchanging opinions and profiting by experience, it is safe to assume that in a short time the manipulation will be as simple and almost as cheap as running the iron into the pig-bed, apart from the waste in the converter and the cost of ferromanganese.

[NOTE.—The discussion of this paper will be found at the end of the paper of Mr. R. W. Hunt, on the same subject.]

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*THE CLAPP AND GRIFFITHS PROCESS**

BY ROBERT W. HUNT, TROY, N. Y.

HAVING devoted considerable time to the investigation of the Clapp-Griffiths converter and the metal produced in it, it may perhaps be of interest to the Institute to learn the conclusions which I have formed. Of course, it is well known that the stationary converter of small size is the very oldest type of vessel need in the pneumatic process. Hence it will be only necessary to call your attention to the points which are special features of the Clnpp-Griffiths. This converter has a slag tap-hole, situated at such a height in relation to the metal under treatment that, when the cinder is formed and boils up as the blow progresses, it can run off and thus be removed from contact with the iron, and will also be out of the way when the decarbonized metal is tapped into the casting ladle and the manganiferous alloy added. The manner of shutting off the blast, when the process is completed and the metal is being tapped, is another distinctive feature. The tuyeres are situated around the sides of the vessel, and enter the interior some little distance above the bottom; they are provided with plugs through the centers of which there are small openings. When the blow is completed, these plugs are forced forward into the outer orifices of the tuyeres, thus shutting off the blast, excepting the small quantity entering through the passages named. While this is sufficient to keep the metal from running into the tuyeres, it reduces to the minimum the action of the blast while the metal is being tapped. Of course, this is of great importance, as in an ordinary stationary converter any delay in getting open the tap-hole means overblowing, and even while the first part of the charge is running out the oxidation is in full force. Duplicate of movable bottoms are used, thus more than doubling the possible output of the plant. The pressure of blast is quite light, never ex-

* The diagrams appended to the present paper, and the Discussion which follow?, belong equally to the paper of Mr. Witherow on the same subject, read on the same occasion.

ceeding 8 pounds, and usually only 5 pounds is used. To the Bessemer engineer, accustomed to large converters and great output, a plant of converters having a capacity of some 4000 pounds at each heat seems like a plaything and one with which it would be impossible to compete against the larger plants. Certainly such were my first impressions; but I can assure you the matter will bear investigation. In the first place, a complete plant of two vessels can at the present time be constructed for not over §55,000, including all buildings; and I am satisfied that 80 gross tons of ingots per twenty-four hours can be made in it with the greatest ease, and no doubt this output could be brought up to 100 gross tons. The strain upon all the parts of the plant being so light, the item of repairs is very low, and the general operating expenses are small. I, therefore, believe the Clapp-Griffiths converter will be found desirable for existing works whose products in the past have been exclusively wrought-iron. By a comparatively small outlay, they can meet the growing demand for steel, and thus give the world its advanced material without rendering idle and useless many thousands of capital. ,We have so often doomed the puddling-furnace, in spite of which it has, continued in ■full life, that I will not again announce its death-knell, but will say that the possibilities of the Clapp-Griffiths do not seem to favor its continued vigor. In estimating the cost of producing soft-steel ingots in a properly arranged Clapp-Griffiths plant, my figures are as follows :

Iron,	$17.00
Fifteen per cent. loss,	2.55
Labor,	1.50
Coal,	.57
Ferromanganese,	.63
Refractories,	.20
Molds,	.15
Expenses and repairs,	.50
Total,	$23.10

This is for metal made from an ordinary Bessemer iron, but if, as I will show later, for many purposes a cheaper iron can be used, my figures would be :

Iron,	$16.00
Fifteen per cent. loss,	2.47
Other items,	3.55
Total,	$21.95

Either of these figures is certainly under the cost of muck-bar in the most favored localities; but it may be said that we have in the one case ingots which have to be broken down, and in the other, bars which may be piled and rolled direct. I think this account will fully balance itself in this way—for all large sizes of iron made from puddled bar you must have a reworked top and bottom, and for very small ones, billets, while by using proper sized and shaped ingots, and careful work in the steel-pit, they can be rolled direct into many things. It is in this respect that the small plant differs from the large one. With a product of 400 to 500 tons per day, it is impossible to submit to the delay incident to casting small ingots. With the smaller product, but still one which is up to the maximum of economy of the plant, no delay is caused. The next thing to be considered after the cost of making the product in the Clapp-GrifSths converter is the quality of the metal produced. In the Clapp-Grirtiths plant of Messrs. Oliver Bros. & Phillips many hundreds of tons of this metal have been made and placed on the market in different forms, such as tacks, rivets, wire-rods, telegraph-wire, lightning-rods, horse-shoe nails, pipe-strips, plates, sheets, bars, angles, shovels, spades and stamping-iron, and, so far as I have been able to ascertain, great satisfaction has been obtained in its use for these various purposes. In fact, large quantities have been used in the place of imported Swedish bars with success, and the workmen manipulating it were none the wiser. When first starting the works the best brands of English Bessemer irons were used, and the steel produced was of a most satisfactory quality. But I am assured that this grade of pig was continued for a very short time. Indeed, I am under the impression that altogether less than 100 tons of this iron was ever purchased for the works. The metal produced so far exceeded all requirements that the use of iron of a lower standard was ventured upon, hundreds of tons of ingots being made from pig carrying from .09 to .14 of phosphorus. The metal possessed an ever-constant welding property, with great toughness. My attention having been called to the process by Mr. James P. Witherow, who had witnessed its working in England, and had, with Mr. Henry W. Oliver, Jr., secured the control of the patents in this country, Mr. Oliver kindly gave me every facility to investigate what they were * doing, as well as putting the works at my disposal to try any experiments I might desire. Being anxious to determine to what extent the use of high-phosphorus iron was possible, I first had a mixture tried which gave a metal with about .34 per cent, of that element. To my surprise this worked so well that I ventured further and doubled my proportion of high-phosphorus pig, obtaining a steel with .54 per cent, of phosphorus, and my surprise certainly did not decrease when I saw the test-piece bend double, cold, and, the metal work beautifully when hot. Thinking these results might be instances of those accidents which sometimes defy explanation, I had the experiments repeated, with like results, and since then many tons of this high-phosphorus metal have been made and used for various purposes. Some of the ingots were rolled into slabs and sent to the works of the Albany and Rensselaer Iron and Steel Company, at Troy, where they were rolled into nail-plate and cut into nails at the factory of that company. These samples which I have before me are some of them, and I think no one can question their quality being all that could be desired. In fact, they possess a stiffness which is valuable, while their ability to stand torture speaks for itself.

This partly finished shovel was also made from Clapp-Griffiths metal. As you see, the metal has been turned over, a perfect weld made, and the strap cut in two. The lower end was quenched in water and turned over cold without producing more of a flaw than you see. Mr. J. M. Sherrerd, chemist of the Albany and Rensselaer Iron and Steel Company, finds it contains:

Carbon,	11
Silicon	014
Sulphur,	126
Phosphorus,	346
Manganese,	53

This shovel is not an isolated case, but hundreds of them have been made from the same, grade of metal. These other samples are also from the phosphorus metal, while these button-head bolts, bent double in the thread, are from metal made from ordinary Bessemer pig. Several physical tests have been made from these phosphorus steels, some from pieces rolled from **the** sprues or gates made in bottom-casting, and others from specimens rolled from perfect ingots. From the latter, which are the only fair tests, the results have been :

	Tensile Strength. Pounds.	Elastic Limit. Pounds.	Elongation. Per cent.	Reduction of area. Per cent.
October 27, 1884,	74,790	55,070	25.25	48.8
November 11, 1884,	80,030	55,060	23.0	26.9
November 11, 1884,	80,270	56,290	22.75	30.6
November 11, 1884,	80,420	56,290	17.5	14.3
November 11, 1884,	78,730	56,410	14.25	15.3
February 4, 1885,	80,940	58,570	24.00	36.4
	79,870	58,570	23.25	36.4
	80,670	60,240	23 00	32.5
	79,700	59,550	23.25	37.6

In all cases one-half inch round test-pieces were used, eight inches long.

The steel tested on February 4th had the following composition:

Carbon,	.08
Silicon,	.01
Phosphorus,	.50
Manganese,	.48
Sulphur,	.09

How far and with what certainty the use of high-phosphorus irons can be carried remains to be determined. The works of Messrs. Oliver Bros. & Phillips have been so pressed with orders that I did not feel at liberty to further interfere with their running. The demand for Clapp-Griffiths metal increased to such an extent that it became evident they must be altered to permit of a greater output. This is about completed, and when they resume I have no doubt the experiments will be continued. While at this time not entering into the discussion of the effects of silicon in metals, one very striking peculiarity of the steel made in the Clapp-Griffiths converter claims our attention. In all the determinations of silicon in this metal which I have seen, and they have been many, there have been but four showing over .02 per cent, of that element, and they were from spoilt heats, while 50 per cent, of the analyses have given but .01, and in 12 per cent, of them the silicon has been too low for estimation.

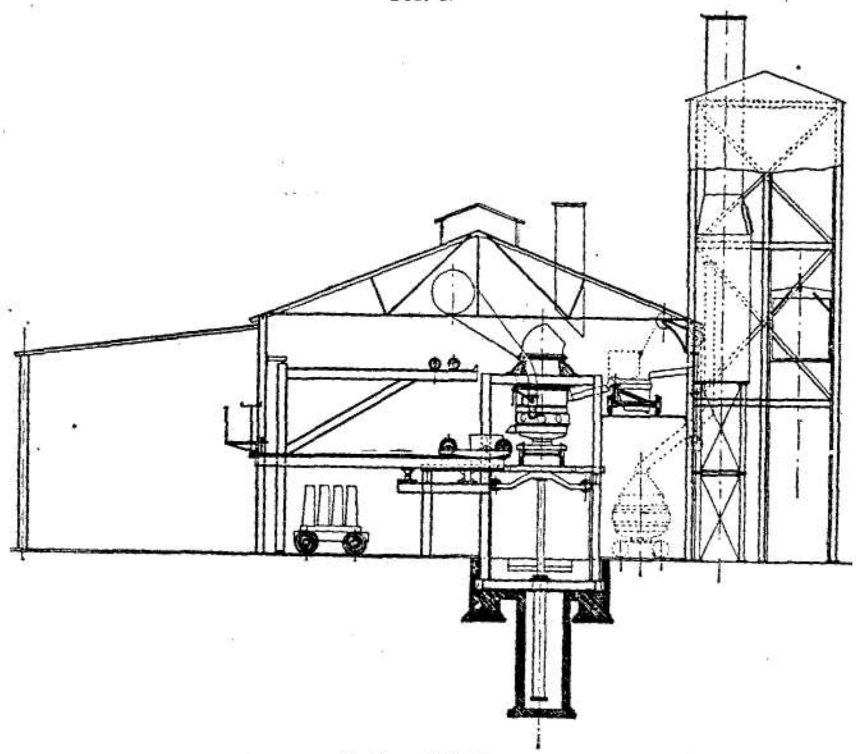
The nails shown had but .009 silicon, and the shovel but .014 per cent. Does not this low silicon permit of the high phosphorus? The loss in the process is much higher than in the ordinary Bessemer converter. No doubt this comes from the column of iron being so shallow over the tuyeres. It is a marked peculiarity of the blows that red smoke from burning iron appears at the very commencement, but clears away toward the middle of the heat. The cinder soon rises and runs off at the tap-hole. Presently this flow of cinder entirely ceases. Now, is it not plausible that the early oxidation of iron furnishes a base which carries off the silicon of the bath? And does not this, with the low blast-pressure, account for the constant small percentages of silicon in the metal? There must be a reason for it. The percentages of silicon in the pig used vary largely; but something constantly eliminates it. Low-silicon steel is and can be made in the ordinary Bessemer converter, bat I have never, to my knowledge, made steel having silicon so low as .01 per cent., and we well know that it is not a constant characteristic. I do not speak of the higher-carbon steels, for in their manufacture considerable silicon is introduced with the recarbonizer. I am fully convinced that the Clapp-Griffiths converter possesses great value for this country. While believing that it cannot make rails or ship-plates in competition with the regular Bessemer plants, it can compete with them in small products, even if it does not make an article which they cannot produce. And most certainly the open hearth is out of the race, so far as cost of product is concerned.

Professor Tunner has lately taken position against both the A vesta and Clapp-Griffiths or any other small converter, so far as their value relates to making low-carbon steels. He admits that they may be of use to certain Alpine districts of Austria, but for producing soft metals he favors either the basic or Siemens-Martin processes. It is with great hesitation that I venture to differ from so eminent an authority. My excuse must be that I speak for America, he for Continental Europe.

To place a basic plant on an equality with an acid one in the matter of costs, it seems to be well established that the basic iron must be quite $3 per ton cheaper than the pig for the acid process. Then the plant is a very expensive one--much more so than the regular Bessemer. You must build both a steel-works and a brickyard; In Continental Europe, where labor is so illy paid and the phosphorus ores so much cheaper than the purer ores, the status is no doubt quite different. This is leaving out of consideration any use of high-phosphorus irons in the Clapp-Griffiths. But if further experience proves, that for many purposes we can take either a mixture of 50 per cent. Bessemer at $17 and 50 per cent, mill-iron with 1 per cent, of phosphorus at §15, making pig cost §16; or take cheap irons, which can be made in so many sections with from .30 per cent, to 50 per cent, phosphorus, we ought to produce, as previously shown, a metal for $21.95 per ton of ingots, and these ingots of a size and shape to be rolled into many finished products. As intimated before, the demand for low steels is constantly increasing. Take steel nails for instance. If they have not already replaced iron ones in the market, they are rapidly doing so, and all the resolutions of lodges of the Amalgamated Association will not stop the irresistible march of events. To supply this demand, in my judgment, the modest Clapp-Griffiths converter offers peculiar advantages.

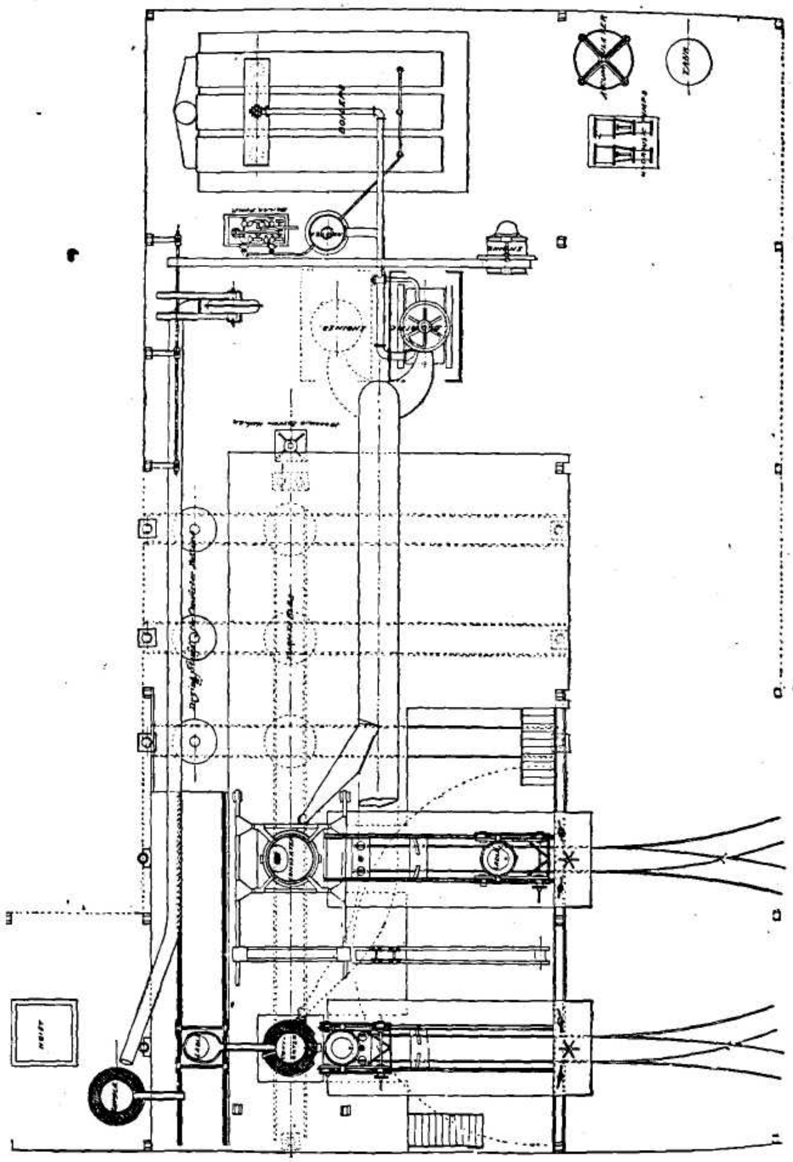
The accompanying drawings, exhibited in connection with the papers of Messrs. Witherow and Hunt, represent the improved constructions about to be put in operation at Pittsburgh, at the works of Messrs. Oliver Bros. & Phillips. Figs. 1, 2 and 3 give a section, plan and elevation, respectively, of the works. They contain two 3-ton converters, back of which is a cupola, with a stock-hoist, room being left for a second cupola, which will be erected when the plant is to be run up to its full capacity. This cupola discharges its con-

FIG. 1.



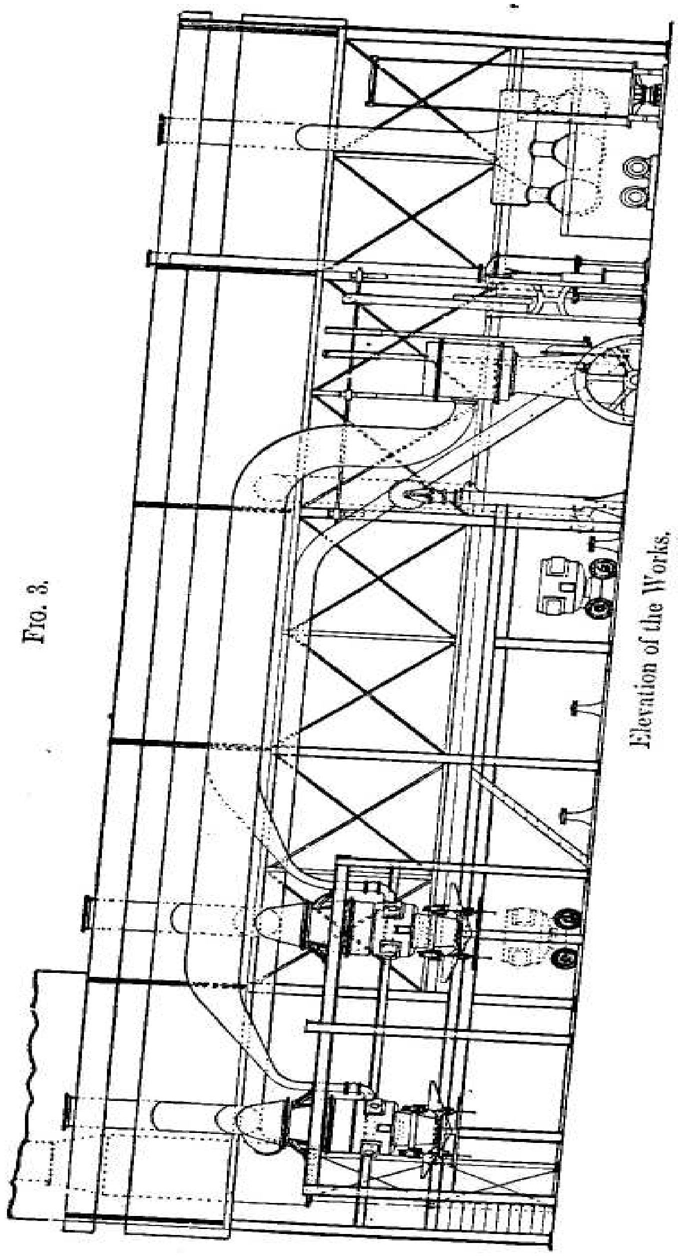
Section of Works.

tents into an intermediate weighing-ladle (shown in the section and in the plan) which travels along a track parallel to the row of converters. From this ladle the pig is poured into the spouts leading to the respective converters in the manner indicated by dotted lines in the section. The converters themselves are hung in a wrought-iron framework, raising them some distance above the floor-line and



Plan of Clapp-Griffiths Steel Works.

Fig. 3.



Elevation of the Works.

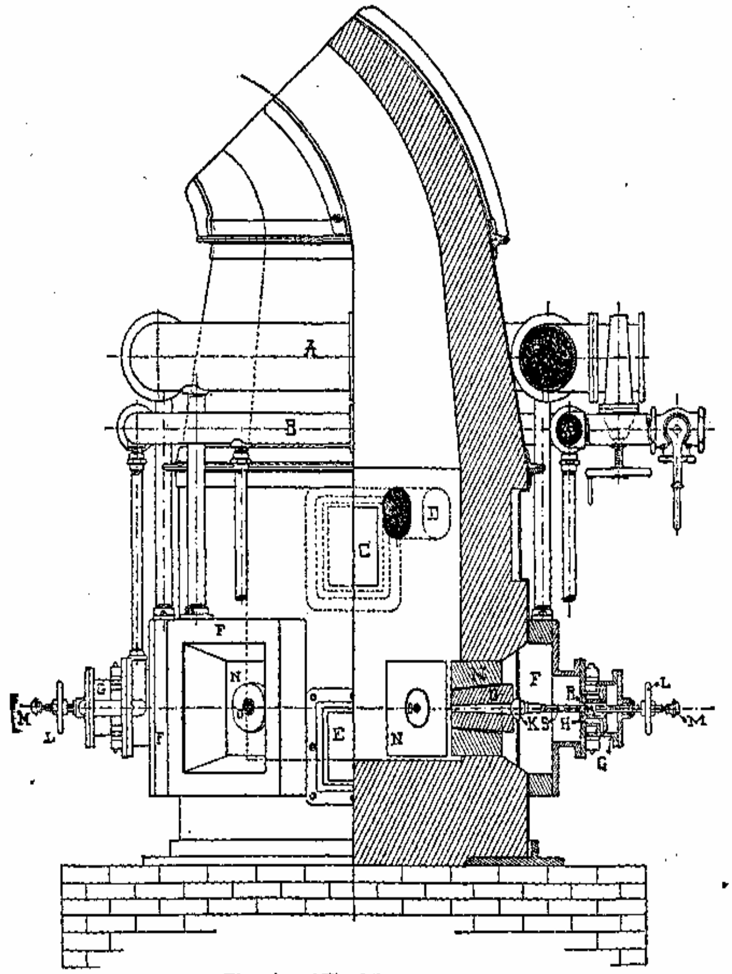
making the working-floor about 10 feet above the general level. The bottoms are handled by means of a carriage. When a bottom is defective, the hydraulic hoist, shown in the section, is run up with the carriage upon it, the bottom is loosened, the blast-connection broken and the whole is lowered to the ground-floor. The truck, supporting the bottom, is drawn along the track to the last turn-table by means of a vertical hydraulic cylinder with chain and sheaves. This vertical hydraulic cylinder is shown in the elevation, with the position of the main sheave at its highest point indicated, by dotted lines. A new bottom, which has been previously prepared, is then taken from the drying-stove nearest the converters, run out upon the turn-table opposite, and placed upon the hoist, which is then lifted and the bottom fastened into place, the joints made and operations resumed. It will be observed from the plan that there are three of these drying-stoves. The dotted lines on the plan indicate the trucks and the turn-table arrangements upon which the bottoms are conveyed.

In front of each converter is a peculiar swinging track, arranged for conveniently tapping from the steel-ladle into the ingot-molds, which stand upon a truck below in nests of four, five or six, as may be desired. The mold-truck stands upon a track leading out of the building. The blast for the cupola is furnished by a Sturtevant blower, operated by a small vertical engine placed nearest the hydraulic pumps. A larger engine with 16-inch steam cylinder, 48-inch blowing cylinder, and 30-inch stroke, furnishes the blast for the converters. Room has been left for a second engine of the same size. The blast is conveyed *to* the converters in the manner shown. Steam is furnished to the engines and pumps by three boilers, 44 inches in diameter and 26 feet long, with two flues in each. There boilers are fed with a "doctor" boiler-pump, the water passing first through a feed-heater. The power for the hydraulic lift and bottom-truck-hauling cylinder is provided by hydraulic pumps and an accumulator.

It is estimated, upon the basis of work done with the old plant, that this remodeled plant will, with two cupolas, have a daily capacity of 150 tons of ingots in 24 hours, provided there are sufficient hydraulic cranes and other appliances for handling the ingots.

Figs. 4-7 present two different forms of converter, the first shown in Figs.4and 5, being similar in design and construction to the fixed-bottom converters at the Margriu Works, Wales, and a number of other works in England. It is a counterpart of the ones first erected at the works of Messrs. Oliver Bros. & Phillips, Pittsburgh. A is the main wind-pipe carrying blast for the tuyeres, and controlled by a large valve. B is a subsidiary pipe carrying the same pressure of blast, leading into the chamber G containing a differential piston.

Fig. 4.

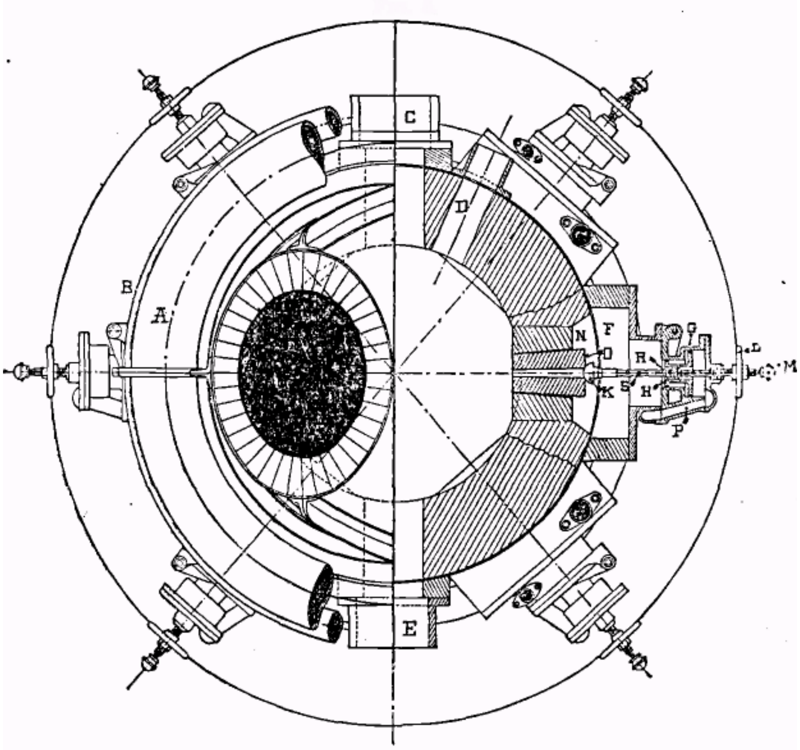


Elevation of Fixed-Bottom Converter.

C is the charging-hole; D the cinder-notch or slag-tap, and E the tapping-hole. F is the main wind-box, into which the blast from the pipe A is conveyed, and from whence it passes through the tuyeres

O into the converter. G is the differential-piston cylinder; H the differential piston ; K the stopper; L the stopper-rod hand-wheel ; M peep-hole cap; N the tuyere block, and O the tuyeres. P is a passage from down-take from the pipe B to the back of the differential piston H. R is the stopper-rod adjusting-screw, and S the stopper-rod.

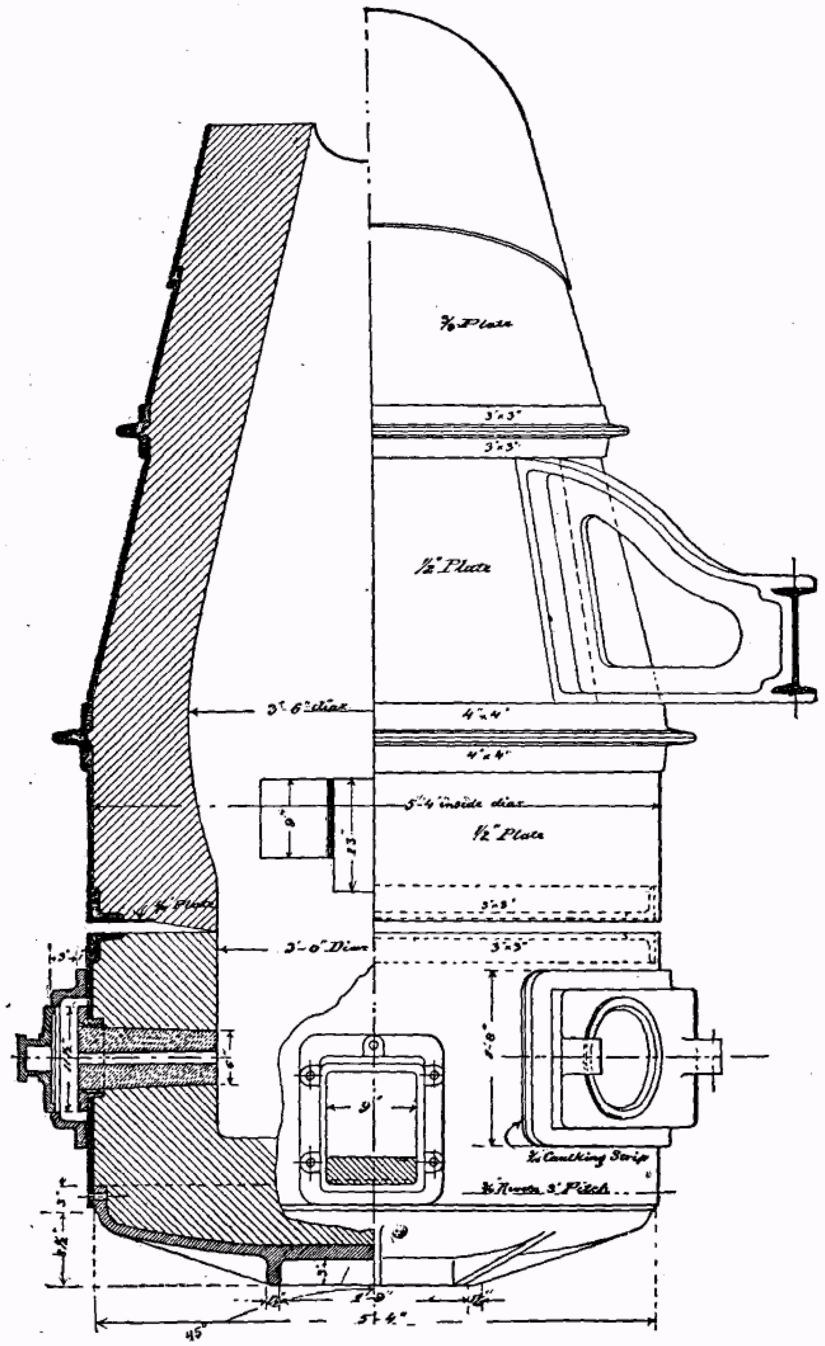
FIG. 5.



Plan of Fixed-Bottom Converter.

The automatic closing of the tuyeres is effected thus: At the moment the blow is finished, the valve leading to the secondary pipe B is opened fully, driving the blast through the passageway P (shown on plan) into the cylinder G behind the larger end of the piston H. The pressure of blast being the same in the cylinder G as in the wind-box F, as the piston H is double-faced, having one end of considerably larger diameter than the other, the same pressure of blast per square inch introduced into the chamber G forces the piston and stopper-rod against the end of the tuyere O, closing the hole therein, except for a small aperture in the stopper K, fed by the holes showing

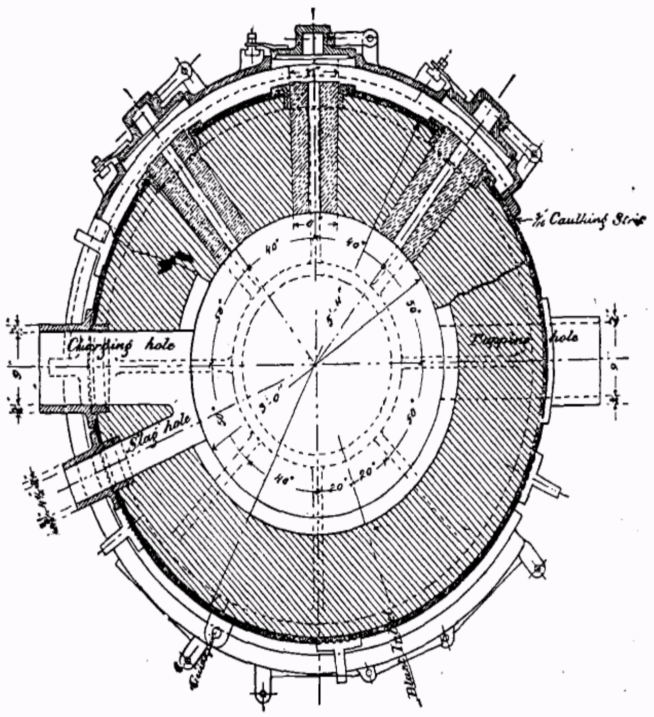
FIG. 6.



Elevation of Removable-Bottom Converter.

through the hollow stem S. This small amount of blast suffices to keep the molten metal from running back into the tuyeres, keeping them free and open. The metal is then tapped out. This operation is simply reversed when the molten metal has been poured into the converter, the blast remaining on in the main-pipe A as long as operations are continued. As soon as the molten metal has reached a sufficient depth, and the blow is to begin, the valve of the pipe B

FIG. 7.



Section of Removable-Bottom Converter.

is dosed, the pressure removed from the back end of the differential piston H, and the effect of the blast in the wind-box F is to drive the piston H out, driving back the stopper.

In the new converters, illustrated in Figs. 6 and 7, this arrangement was not adopted, because the removable bottoms rendered it undesirable, the wind-box and tuyere arrangements being entirely different. No pipes whatever corresponding to the pipes A and of the old converters are used. The blast is simply led into an annular chamber or wind-box surrounding the bottom of the converter, except for a short distance on the front side, to allow room for the tapping hole. The blast at the end of the blow is not entirely cut off, but its pressure is regulated and reduced by any one of several patented devices, which makes it possible to keep a uniform pressure at the noses of all the tuyeres, thus accomplishing the same purpose as the differential piston and stopper of the old converter, viz., to keep the tuyeres free from molten metal or slag. In practice it is found that this works with perfect certainty. Before pouring the metal for the next blow, it is necessary to open the doors, introduce a light pricker-bar and break off the slight film of chilled metal which may form over the nose of the tuyere. Opening the door, as shown in Figs. 6 and 7, is very easily effected, it being only necessary to twist the handle about 12° or 15°, which releases the three spring-catches and allows the door to open.

The lining of the converter, which is ganister, is 12 inches thick, the centres of the tuyeres are 9 inches above the bottom of the converter, and the depth of metal above the centre of the tuyeres is 8 to 10 inches above the bottom of the converter. The smallest ingots thus far cast, at the works at Pittsburgh have been 6 inches square.

DISCUSSION.

WILLIAM KENT, New York city: We ought to have more complete data to enable us to understand these interesting results. Mr. Hunt has told us, for instance, that iron is oxidized early in the operation. I would like to know whether any estimate has been made of the temperature and of the changes of flame at the different periods of the process. As to the cause of the good quality of the resulting metal, in spite of the presence of phosphorus--a result which Mr. Hunt ascribes to low silicon--may it not be rather due to the fact that there is less oxide of iron in this metal ? Also, what is the total time of the operation?

MR, HUNT: Exact determinations of temperature have not been made. That it is not a low temperature (speaking as a Bessemer engineer) I should infer from the fact that of all the heats I have seen . made at these works, and from all the records which have been given me, I have found only one instance where there were any "sculls" in the ladle. As I have said, we have volumes pouring out at the very commencement, of brown iron-oxide smoke. The whole thing looks as the Bessemer converter does when it is turned over, with air blowing across the top of the metal, as undoubtedly Mr. Kent knows is often done when we have a " cold heat." I agree with Mr. Kent that the absence of oxide of iron has a great deal to do with the good quality of the final product. So has the fact that the slag has been got rid of, and is not in the ladle when ferro-manganese is added. As to the time of the operation, to blow 4000 pounds takes ten to eleven minutes, and sometimes runs up to fourteen.

G. W. MAYNARD, New York city: In 1878 I had occasion to examine the Smyth process at Gorton near Manchester, England. The process was one of the many delusions where small doses of chemicals were to make good iron or steel out of poor stock ; so I will not occupy your time with an account of the claims, but will only call your attention to the vessel, called the metal-receiver, in which the so-called operation of refining was carried on, and the re- . suits therein obtained. The vessel was an arched oblong box with a central opening at the top to permit the escape of the products of combustion, and had the following inside dimensions: length 6 ft. 6 in., width 3 ft., height to slagging holes 1 ft. 6 in. " The tuyere openings are brought to the *level* of the bottom, *whereby the blast in made to pass through the entire column of metal.* A blast pressure of 2 to 3 pounds is found to be sufficient." These words I quote from the patent claim of the inventor.

From a long series of tests I select the following as a fair average of the results obtained :

The iron treated was Bolckow Vanglian's No. 4 pig. Nine consecutive blows of 5 tons each were made. The analysis of the pig showed the following composition :

Carbon,	3..9400
Silicon,	1.7200
Manganese,	.6628
Sulphur,	0250
Phosphorus,	1.7807

In the first two blows the resultant metal showed an increase of phosphorus, while in the last five there was an average decrease of .1421 per cent. which was brought about by drawing off the cinder twelve to fifteen minutes before the metal was tapped. Total duration of blow, 25 to 30 minutes. Three charges were analyzed for silicon, showing respectively a decrease of .9366, .7459 and .0608. The metal was, of course, valueless except for farther manipulation in the puddling furnace, where it eventually found its way. I call attention to these experiments for the purpose of showing how greatly the results differ from those given by Mr. Hunt, although the method of treatment is apparently so nearly identical. If the excellent results claimed are really due to the raising of the tuyere nozzle, it would be interesting to determine the exact point of *best* results by depressing the tuyeres to the bottom of the vessel, and then raising them by stages, of say an inch at a time, and noting the changes by chemical and physical tests. There is certainly a wide field for chemical research. For the details of my investigation of the Smyth process, I refer to the *Metallurgical Review,* of April, 1878.

WILLARD P. WARD, Ph. D., New York city: The extraordinarily good quality of this steel, considering the large amount of phosphorus, can be explained, I think, by the low silicon which it contains. The fact that good steel can be made, with much more than the amount of phosphorus contained in Bessemer metal, is not new, I would call attention to a paper read by Mr. William Hackney before the English Institution of Civil Engineers, Session 1874--75, showing that eleven years ago it had been pointed out to steel manufacturers that a steel tough enough and strong enough for most purposes could be made from iron containing much more phosphorus than is generally allowed in Bessemer pig, if "the carbon and probably also the silicon were kept low enough." The development of the Clapp-Griffiths process, producing a pneumatic metal so low in silicon, proves, I think, the correctness of Mr. Hackney's proposition, and shows that at an early day he had a clear insight of things not generally understood, or at any rate not put in practice.

As Mr. Kent has spoken of the oxide of iron causing red-shortness, it may be interesting to know what Mr. Hackney's views were on this point. He says that in red-short, low-carbon steel two conditions are found, viz.: the presence of oxygen or oxide of iron, and a low percentage of manganese, but in high-carbon steels, which contain no oxygen or oxide of iron, red-shortness shows itself as soon as the percentage of manganese falls below the proper limit. The author was evidently of the opinion that had sufficient manganese been added, neither the low-carbon steel nor the high-carbon steel would have been red-short.

MR. HUNT: In this connection there may be interest in the analysis of a steel rail which once before did duty at a Pittsburgh Meeting of the Institute, when it was brought forward by Captain Jones. The rail was a Terre Noire high-phosphorus rail, having carbon .12, silicon .025, phosphorus .223, manganese .387.* It showed a tensile strength of 78,000 pounds, elastic limit 39, and an elongation of 37 per cent. These rails were made in a Siemens-Martin furnace you remember, and they could not be made to compete with the cheap Bessemer rails.

Mr. Holley, in 1877, investigated a process brought out in Boston, known as the Sherman process, that sought to eliminate phosphorus, or at least to make good steel out of iron that had plenty of phosphorus. His report was not favorable.

That steel was not worth a cent. You could not do anything with it. I tried to roll it and do the best I could with it. In the testing-machine it showed tensile strength, but it ended at that. It would not hear heating. But in every case analysis gave silicon .075, .090, .074, .094, .087. I believe that is the reason the steel was good for nothing. If he had got rid of that silicon Mr. Sherman would undoubtedly have floated his process.

FRANK FIRMSTONE, Glendon, Pa.: If I recollect aright, the first trial of the Bessemer process at an iron-works was made at Dowlais, and the first blow produced good material, which they were unable to get again in subsequent blows. So far as I know that was never accounted for. I believe no analyses of that first good steel at Dowlais were published, but it does not seem possible that they could at that time have got even by accident any pig-iron low enough in phosphorus to rank as a Bessemer iron according to present standards. It would be interesting now to see whether by some fortunate accident they did not blow it by the Clapp-Griffiths process.

This paper seems to throw light on another point, namely, the lack of a satisfactory explanation hitherto of the fact that bar-iron with a good deal of phosphorus in it was not bad, while Bessemer steel containing vastly less phosphorus was utterly worthless. It now appears that a good Bessemer metal may be made containing a comparatively large percentage of phosphorus.

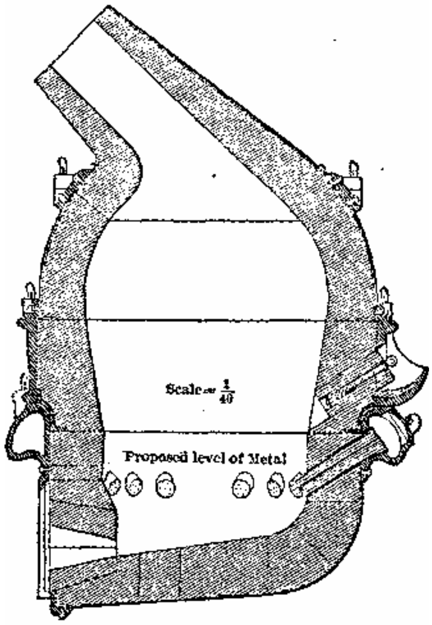
W. F. DURFEE, Bridgeport, Coun, (by letter to the Secretary): In continuing the discussion of the very interesting and valuable papers of Messrs. Witherow & Hunt,I take great pleasure in saying

* NOTE BY THE SECRETARY.--Mr. Ward and Mr. Hunt can find still earlier and more striking instances in vol iii. p. 132 of these *Tiamadions,* where analyses of soft Martin boiler-plate steel, made by F. J. Slade in 1869, are given, with comnients from Sandberg, Britton, Hewitt, and others. One analysis shows P., 0 :75: C., 0.12: S., 0.025. Mr. Slade made several hundred tons of such steel and found it excellent.

that I regard the process described as destined to occupy a very important, if not a commanding position among the methods by which the steel of the near future is to be produced.

This opinion is not altogether the result of a study of the process described, but, as regards two of its distinctive features (a stationary converter having a tap-hole similar to that of an ordinary cupola, and the low pressure of blast employed), originated at the time I was engaged in the supervision of the experimental steel works at Wyandotte in the years 1863-64, and I then designed and erected a stationary converter, a vertical section of which is shown in the accompanying drawing:

FIG. 8.



The Durfee Stationary Converter.

This converter was the joint invention of the late Z. S, Durfee and myself; it was provided at the outset with a removable bottom (this feature, I am told, is one of the recent improvements in the Clapp-Griffiths process), and, as a result of my study of the working of the Bessemer converter, I decided to " blow " with a pressure of blast not exceeding eight pounds, which was but half that used in the Bessemer converter.

It will be noticed that the tuyeres are inclined, and have their outer ends in a wind-box above the proposed level of the metal. This construction I regard as decidedly better than the horizontal valve-closed tuyeres of the Clapp-Griffiths converter.

Only a few heats were blown in the converter illustrated above, and these were blown, after I ceased to be connected with the Wyandotte Works, by Mr. R. *W.* Hunt. For reasons, doubtless satisfactory to the owners of the works at the time (but which I have always regarded as fallacious), the experimental work with the stationary converter described was not continued, and the opportunity of making a substantial and valuable progress in the metallurgy of iron and steel was lost.

MR. HUNT (by letter to the Secretary): Owing to defects in the refractory lining of the stationary converter, and our want of knowledge of an alloy containing a large percentage of manganese--in fact, ferro-manganese--and thinking we had to run the melted spiegel into the converter, together with other reasons not necessary to mention, but a few heats were attempted in Mr. Durfee's converter, and it was replaced by a regular rotating one.

THE SOURCE AND BEHAVIOR OF FIRE-GAS IN THE JOHNSTOWN MINES.

BY JOHN FULTON, **JOHNSTOWN,** ***FA.***

JOHNSTOWN is the site of the extensive iron, steel, and wire-works of the Cambria Iron Company. It is situated at the western base of the Alleghany Mountain, 275 miles from Philadelphia, and 78 miles from Pittsburgh. The valley in which the town and its iron-works are located, has an average elevation of 1160 feet above tide water. Johnstown, in its main features, is a modified duplicate of Pittsburgh. It is located at the confluence of the Little Conemaugh and Stony Creek rivers, which, by their union, form the Conemaugh River, just as Pittsburgh is situated at the junction of the Allegheny and Monongahela rivers, which together make the Ohio River.

The site of Johnstown is in a cutting through the lower productive coal measures, 500 ± feet deep, with steep slopes along the valley-limits, exposing, in sharp-cut terraces, the outcrops of the coal and iron-ore beds; the whole surmounted by the shales and sandstones of the barren measures.

Pittsburgh is flanked by the upper coal-measures, just as Johnstown is environed by the lower coal-measures.

The valley of Johnstown is threaded by the double-track main line of the Pennsylvania Railroad, and also by a branch of the Baltimore and Ohio, entering through Somerset County by the Stony Creek Valley.

The Cambria Iron Company was organized in 1852. From its charter until 1855, it struggled under efforts to construct furnaces and rolling-mill. At the latter date, having suspended, the works were leased to Messrs. Wood, Morrell & Co., who had become creditors of the old company. Under the new management the furnaces, rolling-mill, and other works were completed, coal and iron-ore mines were opened, and a vigorous and progressive policy was initiated. In 1862, on the termination of the lease, the Cambria Iron Company was reorganized, and the business has since been conducted in its name.

The accompanying map will show the topographical and other features of Johnstown and its works.

The columnar sections exhibit the stratigraphy and thickness of the coal and iron-ore beds, outcropping at different levels above the valley, along its steep inclosing slopes.

It will be noted that six coal-mines and the iron-ore mine are all above the valley water-level from 10 to 200 feet. Only one mine, now closed, has been operated under water-level. This (the blast-furnace mine) was opened by a slope 50 feet under water-level. From the foot of this slope a gangway was driven 16 feet wide, affording room for double tracks and ample way for ventilation. Fire-gas was found in this mine in small quantities, generally in the advanced workings. A large cleft in the roof-rock in the main gangway afforded the mule-driver-boys an opportunity *of "flashing"* the gas, collected at intervals in this crack.

Although this mine was ventilated by a furnace, yet, at times, the gas would accumulate in the old workings, up the dip, scorching some miners in these places. The only fatal accident in the mine occurred in 1872, when a boy, entering the mine with his father's dinner, lost his way, wandered into old workings, and, igniting a collection of gas, was instantly killed. The mine was closed in 1879: Its coal is 3 feet thick. It is the second workable bed of the lower coal measures, called locally the Miller seam. In the second geological survey it is called bed B, or Kittanning lower coal.

The shaded sections on the map exhibit the extent of the workings of all the mines of the Cambria Iron Company at this place.

The Rolling-Mill Mine is the most extensive of the mines of this Company at Johnstown. It supplies to the rolling-mills and their auxiliary works from 500 to 800 tons of coal per day, delivered in these works in the mine cars. The mine is opened into the third workable seam of the measures, 3½ to 4 feet thick, called the Cement seam, from the presence of a bed of feriferous limestone, 5 feet thick, immediately under the fire-clay floor of this coal. The main way of this mine is over two miles in length, and the connected workings are extensive. It was opened in 1856. It is 1223 feet above tide-level, and 77 feet above the ordinary level of the water in Stony Creek. It has a covering of the upper coal-beds and barren measures, of 400 to 500 feet.

From the opening of this mine, fire-gas, in small quantity, was found. It did not affect the miners in the direct working of the (30 feet wide) rooms, but in the narrow working of the old single system of headings,occasional " flashes " of gas gave warning of the presence of this dangerous element. Early in 1858, two miners were slightly burned in a heading. The "flash" did not cause them to quit work, but it was much more serious than any experienced previous to that time.

About a year after this, in a heading in the northwestern portion of this mine, two miners and a gray mule were severely scorched by an explosion of gas.

This large mine was ventilated by furnace up to 1879, at which time a Murphy fan was introduced affording 60,000 cubic feet of air per minute. Mine-locomotives were also used at the same time in this mine, for underground as well as outside haulage.

From 1874 to 1884, occasional flashes of gas were noticed, but not in magnitude to excite alarm until March, 1884, when an explosion of fire-gas occurred, burning, rather severely, four miners, near the end of a double heading in the southwest section of the mine. This explosion occurred on a Monday morning, and was caused by a small collection of fire-gas, near the end of the heading, which had gathered over Sunday. Since that time, brattice-cloth is used in all narrow works in advance of ventilating currents.

Another slight explosion occurred, January 6, 1885, in the middle southwest section of the mine, where pillars were being drawn. It is supposed that the fall of roof, following the drawing-back of coal-pillars, forced a small collection of gas to the working-places, where it ignited. Mr. J. M. Watt, State Inspector of Mines, and Mr. Thomas Fulton, Superintendent of Mines, were in the mine at the time of the explosion and visited the locality soon after its occurrence. They found air-currents of over 14,000 cubic feet per minute, passing through this place, and could not determine, other than as above suggested, the cause of this explosion.

The fire-gas comes up through the floor of the coal-bed and follows the working-places of the mine. It is found in the advanced new workings and is readily ignited along the "undercutting" or " bearing in" at these places, giving along this strip a series of jets of blue flames. As it comes up through the floor, it makes a gurgling droning sound which is the only indication the miner receives of its presence. So far as has been discovered in this or the other mines, the supply of this fire-gas becomes exhausted soon after being opened by the first direct mining workings and rarely has it been found in old workings or in the goaf. It is only encountered in certain localities of the mines, where cracks or fissures occur in the floor.

This mine has always been quite dry ; only at a few places in it has water been found. On the whole it must be regarded as a very dry mine.

The Cushon mine is opened into coal-bed E, the Upper Freeport of Prof. Lesley's State Geological Survey, and called locally the Lemon or Coke-yard seam. This is the topmost bed of the lower coal-measures at this place. It is 3½| feet thick. The mine is 1367 feet above ocean-level and 197 feet above the Little Conemaugh River. It is the driest mine of all. It is dust-dry. It has been worked since January, 1880, and was opened to supply the neighboring large steel and wire-works of the Gautier Department of the Cambria Iron Company.

Only one well authenticated " flash " of fire-gas has been known in this mine. This, however, clearly indicated the presence of gas; but as the mine is well ventilated and is worked under the double-heading system, no explosion of gas has occurred in it yet. The mine has a covering of 200 feet, more or less. I may note here that its exemption from gas is also due to the cutting off of the gas by two mines, the Lower Gautier and the Wood vale, which are being worked under a large portion of the Cushon mine.

The dust in this mine is several inches thick at places; but careful investigation has failed to disclose any " flashing" from blasting in this mine.

Conemaugh mine, supplying coal to coke ovens at Conemaugh Spiegel-furnace, is in the same bed (E) as the Cushon. It is 1297 feet above tide. Its gangway enters the hill at water-level. No gas has yet been observed in this; small mine.

Lower Gautier mine, immediately in front of and partly under the Cushon mine, is 1179 feet above tide and 14 feet above the Little Conemaugh river. It is in bed B, Kittanning lower coal, the second seam of the lower coal-series.

Gas has been found in this little mine, but not in volume to excite alarm as yet.

The adjoining coal mine, Woodvale, is in the same bed, and very dry. No fire-gas has been observed in it up to this time, although it has been worked during the past ten years.

The iron-ore mines of this Company occupy a horizon 50 feet above the highest workable coal bed, F (Upper Freeport).

The ore is the carbonate of the coal measures, in two benches, together 18 inches to 2 feet thick. The mining of this ore continued from about 1851 to 1883. The ore-bed has a soft roof of drab-colored shales, and its floor is composed of soft silicious shales. The mines in this ore-deposit are all muddy, as the inclosing shales disintegrate readily in contact with air. In working these mines the occasional presence of fire-gas was well known ; bnt, with care, explosions were generally avoided. In 1865, however, a violent explosion occurred in the old workings at Prospect, instantly killing two men, crippling a third and injuring severely three others. The mining of iron-ore at this portion of the mine had been finished, and these men were sent into the exhausted workings to remove mine-rails, etc. They exploded the gas collected in these workings, with the results above stated. The fire-gas came up from below at this place because of the disturbance of the floor of the mine by the fall of the roof of an exhausted coal mine 50 feet beneath the iron-ore mine. This afforded openings in the intervening rocks to let up the gas readily.

It will be noted that three of these mines, the Rolling-Mill, Cushon and Woodvale, are dry mines with considerable coal-dust in their main ways. Four mines, the Blast Furnace (now closed), Lower Gautier, Conemaugh and the Iron-Ore mine are all rather wet. The most destructive explosions so far have occurred in the wet mines.

In the mining operations in these mines, about 100 kegs of blasting powder and a small quantity of giant powder are used each month.

The following table of analyses exhibits the composition of the coals in these mines.

Name of Mine.	Name of Coal Bed.	Mois-ture.	Vola-tile matter.	Fixed Car-bon.	Sul-phur.	Ash.	Remarks.
Blast Furnace, . .	B.	1.18	16.54	74.46	1.86	5.96	A. S. McCreath.*
Rolling Mill, . . .	D.	1.05	15.53	76.87	0.47	6.55	T. T. Morrell.
Cushon, ...	E.	1.00	18.66	74.49	0.70	5.85	"
Conemaugh, . . .	E.	1.00	18.66	74.49	0.70	5.85	"
Lower Gautier, . .	B.	1.38	21.00	68.50	1.12	8.18	"
Woodvale, ...	B.	1.38	21.00	68.50	1.12	8.18	"

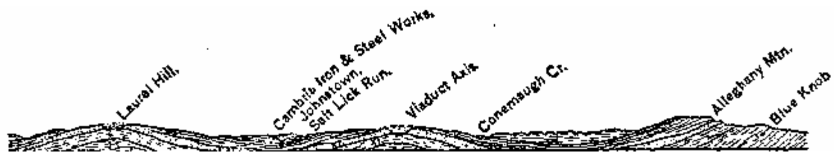
These analyses show the series of coals in the Johnstown subbasin to be exceptionally low in volatile matter.

The two principal seams, B and E, as mined in the Johnstown basin, increase in volatile matter both eastwardly and westwardly. At Bennington, 28 miles east of Johnstown, these coal beds are found as follows :†

	B,	E.
Moisture,	0,910	0.9GO
Volatile matter,	2(5.340	26.400
Fixed carbon,	04.373	65 586
Sulphur,	1.792	2.274
Ash,	6.585	4.780
	100	100

Westward the coals of the lower productive measures increase regularly in volatile combustible matter until the maximum is reached near Pittsburgh. The Johnstown coals contain 16 to 21 per cent., while equivalent beds at Blairsville, 25 miles west, have 24 and 25 per cent. of volatile combustible matter.

The following cross-section shows the geological structure of the eastern portion of the Appalachian coal-field:



Section of coal-measures from Lanrel Hill to Alleghany Mountain.
(First Pennsylvania Geological Survey).

The source of fire-gas, causing these flashings and explosions in mines, has not received as careful consideration as its importance seems to demand.

* Pennsylvania Geological Survey, Report HH., p. 103.
† Chemist A. S. McCreath, Pa. Geol. Survey, Report HH., pp. 18, 23.

From the fact that it has been found in all the coal-beds mined into at Johnstown, it has been inferred that each coal-bed, with its associated rich bituminous shales, has produced the gas met with in the respective mine-workings.

This inference was doubtless suggested, in part at least, from the condition of the anthracite fields in the northeast section of the state. For it appears evident that the fire-gas found in these large coal-beds was eliminated by the heat that fused the normal coal into its present condition of glassy anthracite, each bed of coal affording more or less fire-gas, and being itself the chief source of the gas. It is quite possible that, in the mining operations in the anthracite fields, gas may ascend from the lower to the upper beds of coal, if the latter are first mined into.

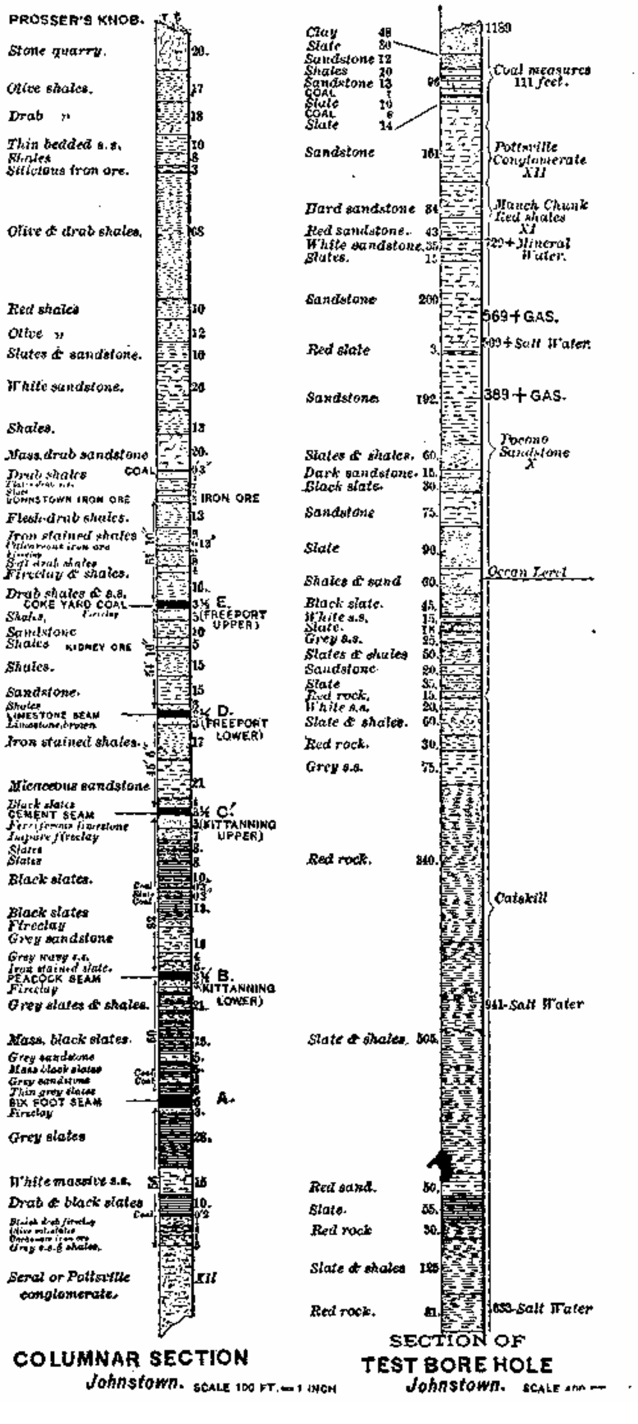
Three objections seem to overwhelm the assumption that the coal-beds of the Allegheny are the sources of fire-gas:

First.--Where one coal-bed has been mined in part or entirely under another, the workings on the upper coal-bed are entirely free from gas. The Cushon mine is an example of this proposition, which has been verified also at other mines in this locality, operated under similar conditions.

Second.--If the coal-beds are the sources of fire-gas in this portion of the Allegheny field, then all the mines eastward in the same field should produce fire-gas. But no gas has yet been found in the large number of mines east of Johnstown, and the absence of fire-gas distinguishes the mines of the Clearfield region. In the mines of the Broad Top field, fire-gas is unknown. These mines have been extensively worked, above and below water-level, during the past twenty-five years without the least evidence of its presence. The same can be said of the absence of gas in the Cumberland coal field. The coal of the beds in these localities is quite similar in quality to that of the Johnstown beds. As a general rule, they hold a little more volatile matter than the coal in the beds of the Johnstown sub-basin.

Third.--The discoveries of *natural gas, the fire-gas* of the mines, during the past year, in such large quantities *under* the Lower Coal Measures in Western Pennsylvania, beginning at Johnstown and increasing westward to Pittsburgh, afford a definite indication, in this portion of the Appalachian field at least, of the true source of natural gas or mine fire-gas.

During the general interest in the discovery of natural gas, which occupied the latter portion of 1884, the Cambria Iron Company


PROSSER'S KNOB.
COLUMNAR SECTION
Johnstown. SCALE 100 FT.=1 INCH
SECTION OF
TEST BORE HOLE
Johnstown.

had a test-well sunk on its grounds a short distance north of the Pennsylvania Railroad passenger station, at Johnstown. The top of this test-well is 1189 feet above ocean-level, and 12 feet under the Cement coal-bed, the third workable bed of the Lower Coal Measures.

The accompanying columnar section shows the character of the measures traversed by this five-inch drill-hole, and the elements discovered during the progress of the work.

At a depth of 640 feet in the well, or 549 feet above tide, natural gas was reached, extending down 40 feet--beginning in slate, and continuing in hard sand-rock until salt water was reached. This gas was ignited at the top of the drill-hole, affording a flame 3 feet high. The supply, however, soon showed signs of weakening, indicating very decidedly the moderate volume of gas at this level.

At 800 feet below the top of the well a second gas-horizon was reached, 389 feet above tide. This was found less productive than the upper one. No more gas was found in this test-well below this second horizon.

Salt water was reached at 680 feet below the top of the well, or 509 feet above tide. A second large supply of salt water was struck 2130 feet below the top of the well (941 feet below tide-level), which continued until the boring ceased at 2800 feet (1611 feet below tide). Partial analyses of these saline waters showed 2 to 3 per cent. of salt.

This test bore-hole indicated very clearly the location or the source of the gas met with in these coal and iron-ore mines of the Cambria Iron Company. The gas has evidently ascended through the cracks, cleavage planes, openings, and fissures of the intervening rocks, reaching the coal and iron-ore beds above. This is corroborated by the fact that all issues of gas yet discovered have been found in portions of the mines where the strata of underlying rocks have; been bent and broken, affording openings for the upward movement. of the gas. The rapid exhaustion of these jets of tire-gas in the disturbed places in the floor of the mines, is in harmony with the rapid exhaustion of the source of it in the test-well. As this drill-hole is on the border of the old Blast Furnace mine, it is possible that a portion of the natural gas in this locality may have been dissipated in those workings.

It is difficult to establish the exact place of the gas in the rocks here, and decide whether the horizons in which the gas was found have been its normal home, or secondary reservoirs ; it seems reasonable to infer that it had its source in the Pocono sandstone (X), the equivalent of the Butler, Clarion; and Venango oil sands, and also near the horizon of the proto-carboniferous measures of eastern Pennsylvania and Virginia.

Of the flashes and explosions of fire-gas in these mines, the gas itself has always been the originating cause. The fine dry dust has not been observed to contribute materially to the energy of the explosions. If very dry, fine coal-dust alone could produce flashes or explosions, then the two or three dry and dusty mines of this company would have been "dark and bloody ground " indeed.

It is reasonable to accept the fact that *certain qualities* of fine, dry coal-dust in mines would aggravate the destructiveness of explosions; but the originating cause, in all cases of flashes or explosions experienced here, has *been fire-gas.*

From the foregoing considerations it appears that these mines of the Cambria Iron Company at Johnstown are situated on the eastern border of the great natural gas-belt which underlies the western section of the State of Pennsylvania. Its western border has not yet been defined. It is quite probable that natural gas may be found underlying portions of the States of Ohio, Indiana, and Illinois. From Johnstown, the volume of natural gas increases westwardly, having, so far, developed its largest product at Pittsburgh, Leechburg, and Tarentum.

It is not the design of the writer to assume that the source of the fire-gas met with in bituminous coal mines, is always to be found under the Coal Measures, but from the developments at Johnstown the inference leans in this direction, qualified by exceptional localities. The horizons of the gas-wells in Western Pennsylvania are all beneath the Coal Measures.

It will also be evident that in coal-mining operations, since this gas may be met with at uncertain places, without warning, and since its gravity is so low, and it is seldom sensible to smell, always invisible, and only occasionally audible, great difficulty must continue to exist in defending the mines from explosions. Moreover, in dealing with so subtle an element great caution of statement should be exercised in attributing carelessness of management in cases where the localities of outgushes of fire-gas could not be approximately predetermined.

The danger from this fire-gas increases, as a general rule, westward*;* the past terrible explosions in the Connellsville region are examples in point.

The only present well-assured preventives consist in ample ventilation, and the use of brattice-cloth and safety-lamps in advanced workings. Even with all these, occasional explosions of fire-gas may be expected.

DISCUSSION.

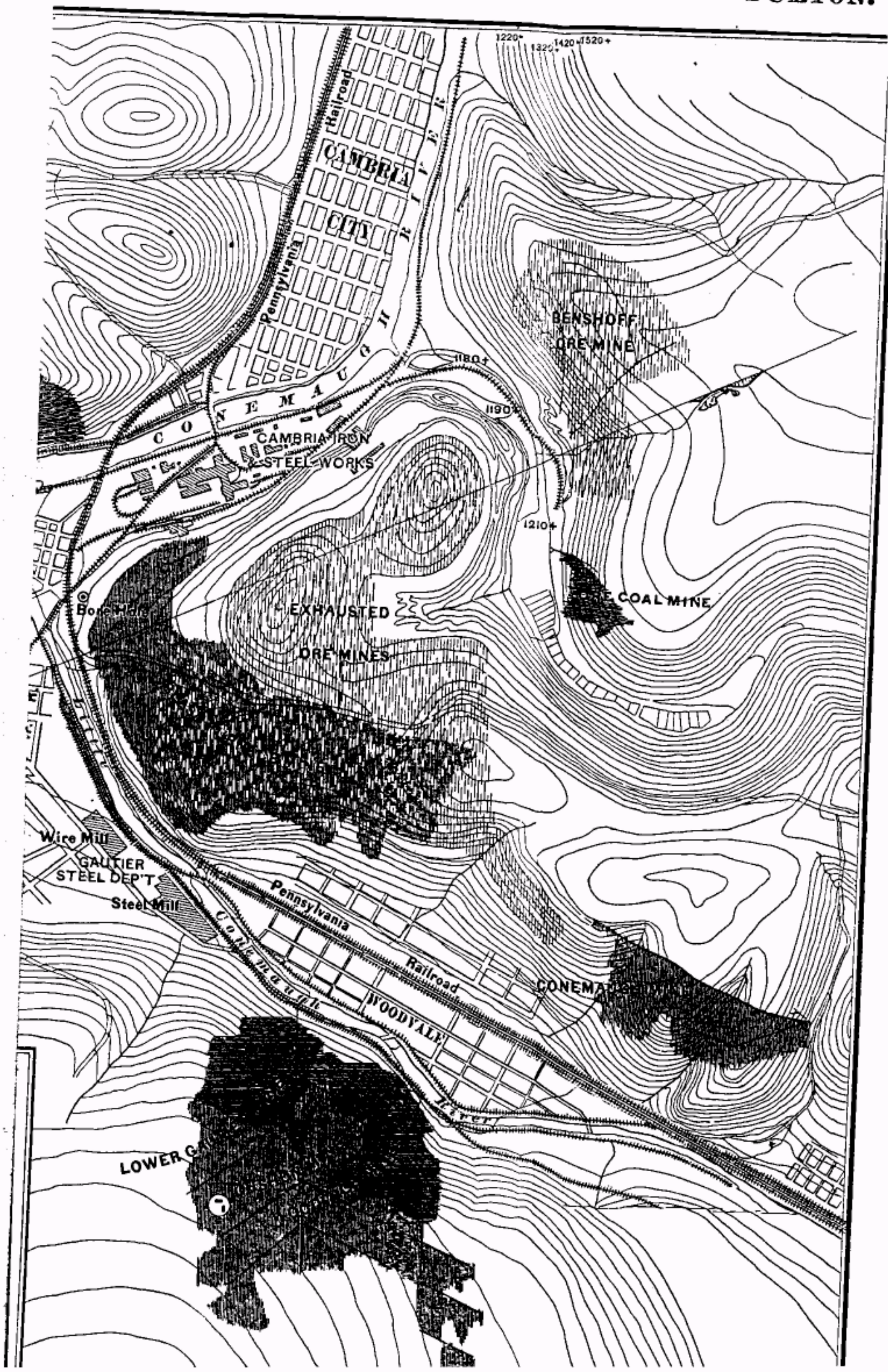
DR. T. STERRY HUNT, Montreal, Canada: Mr. Fulton makes an interesting statement with regard to the distribution of natural gas which I beg to confirm. He says that the seat of the natural gas is, in all cases in Western Pennsylvania, below the Coal Measures. That we know to be the case with regard to petroleum. In parts of Ontario, where I have studied the occurrence of petroleum, I have repeatedly noticed in association with it a large quantity of inflammable gas; and far to the east of that, we find this gas as low down as the horizon of the Trenton limestone. I can mention three or four cases near Montreal where it is produced. That gas has been, since the days of the old French colonists, an object of interest and attraction. It has been gathered and used occasionally for illuminating purposes, rather as a curiosity than otherwise. There is a discharge of the gas also in the St. Lawrence. A considerable amount is constantly discharged in that river, keeping the waters in ebullition. There is another place, on the north side of the St. Lawrence, at St. Leon, and another on the Ottawa, where the gas is discharged. These three cases in which the gas rises through the Trenton limestone, and other cases where it comes from the shales immediately overlying, are illustrations of the wide distribution of this natural gas and of its low geological horizon.

BIOGRAPHICAL NOTICE OF BENJAMIN SILLIMAK.

BY DR. T. STERRY HUNT, MONTREAL, CANADA.

THE American Institute of Mining Engineers, and American science in general, have sustained a great loss in the death of 1 rot. Benjamin Silliman, deceased at New Haven, Connecticut, on the 14th of January, 1885, at the age of sixty-eight.

But a month has passed since, as one of the pall-bearers, I paid the last tribute to the remains of my old friend and honored master.



1220
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Railroad
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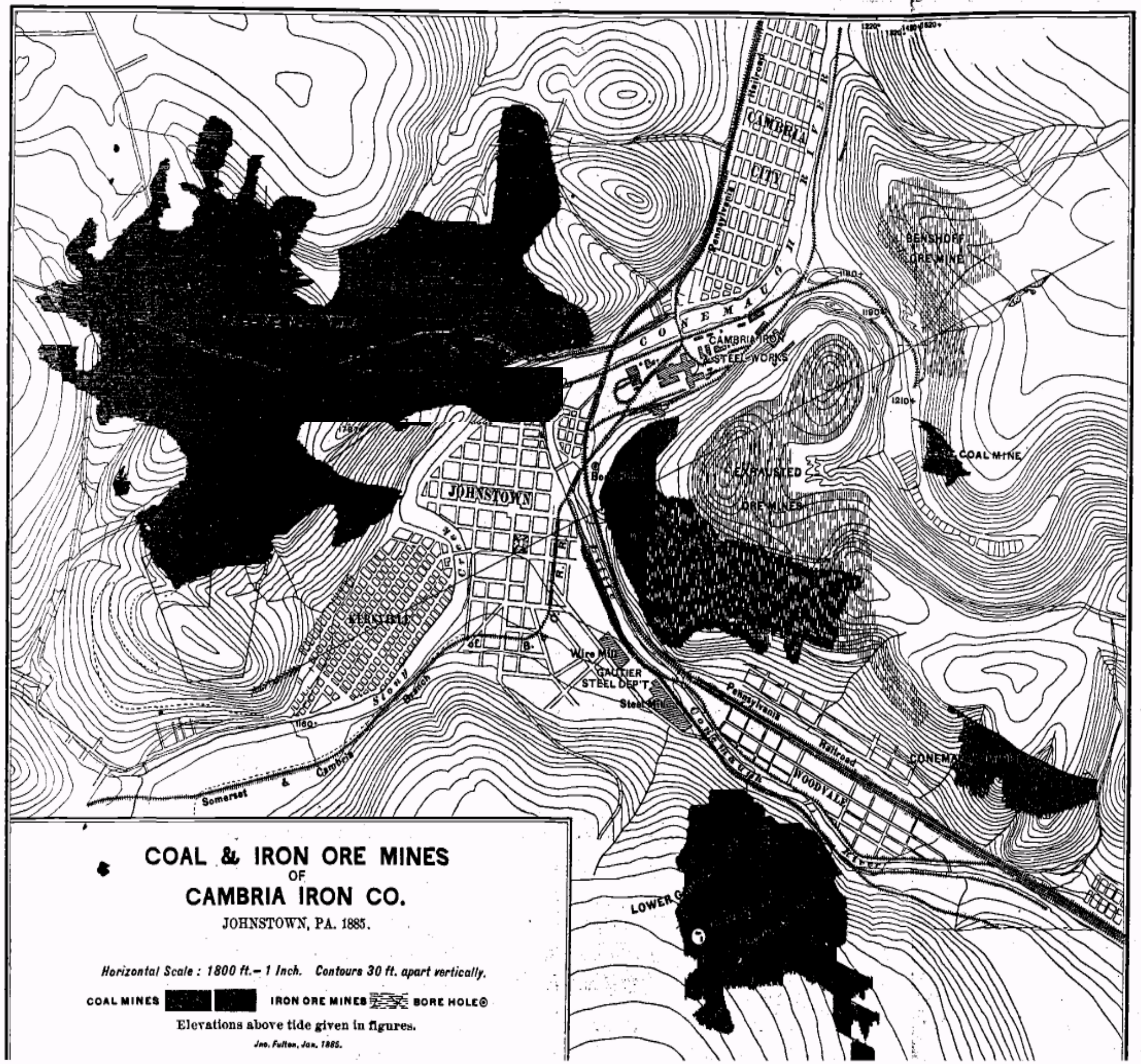
CITY
Pennsylvania
CONEMAUGH
RIVER
1180
1190
BENSHOFF
ORE MINE
CAMBRIA IRON
& STEEL WORKS
1210
EXHAUSTED
ORE MINES
COAL MINE
Wire Mill
GAUTIER
STEEL DEP'T
Steel Mill
Pennsylvania
Railroad
Conemaugh
WOODVALE
River
LOWER


COAL & IRON ORE MINES
OF
CAMBRIA IRON CO.
JOHNSTOWN, PA. 1885.
Horizontal Scale : 1800 ft.– 1 Inch. Contours 30 ft. apart vertically.
COAL MINES
IRON ORE MINES
BORE HOLE
Elevations above tide given in figures.
Jno. Fulton, Jan. 1885.
CAMBRIA CITY
CONEMAUGH RIVER
CAMBRIA IRON & STEEL WORKS
BENSHOFF ORE MINE
COAL MINE
EXHAUSTED ORE MINES
JOHNSTOWN
Wire Mill
GAUTIER STEEL DEP'T
Steel Mill
Pennsylvania Railroad
WOODVALE
Somerset & Cambria
Stony Creek
LOWER
1210
1190
1180

Nearly forty years ago, in the early spring of 1845, I became, at the age of eighteen, a student with the Sillimans, father and son, at Yale College. It was my privilege during the two following years to be the chemical assistant of the elder Silliman, and afterwards, with that title, to take, in June last, a part in the solemn service of unveiling a bronze statue erected to the memory of that patriarch of science, in the grounds of the university of which, for more than half a century, he was a distinguished ornament. Benjamin Silliman, the elder, passed away at the age of eighty-five, in the year 1864, and his son, as he stood last summer by his father's monument, gave no signs of that fatal disease which was soon to remove him from us.

He was of an ancient and honorable lineage; the Sillimans, early colonists in Connecticut, and of Italian origin, gave to our country in its struggle for independence, a century since, a distinguished officer, General Silliman, whose son, Benjamin Silliman the elder, married a daughter of Governor Trumbull, of Connecticut, a name revered in our revolutionary annals. Out of a large family from that marriage, our deceased colleague was the only son. He graduated at Yale College in 1837 (Chief Justice Waite and Senator Evarts being among his classmates), and henceforth devoted himself to chemistry and mineralogy. He became for some time a student in the private laboratory of the late Dr. Charles T. Jackson, of Boston, a graduate of the *École des Mines* of Paris, and one whose early work in chemistry, mineralogy and geology, especially in Maine, New Hampshire, Rhode Island, and northern Michigan will never be forgotten in American science. Thus prepared, Benjamin Silliman returned to New Haven and organized there a laboratory for instruction in chemistry, where among his earliest pupils were Prof. J. P. Norton and Dennison Olmstead, both deceased, and myself. The history of the work carried on by Silliman in the two years which I passed in that laboratory is instructive. Then and there were examined many of the materials brought home by the Wilkes Exploring Expedition, and the ores from Lake Superior and from Mine La Motte in Missouri, besides which a series of studies of potable waters was undertaken for the city of Boston. From that laboratory of chemistry and mineralogy, and from the instruction then and there given by the younger Silliman and myself grew the Sheffield Scientific School, organized in 1847, in which year I left New Haven to take a position in the geological survey of Canada. My place as chemical assistant was soon filled by our distinguished colleague Prof. George J. Brush, who labored zealously with Silliman in laying the foundations of the Sheffield School, of which he has for many years been the honored head.

Of Silliman's work for some years as professor of chemistry in (he Medical College at Louisville, Kentucky, and later in that at Yale College, I need not now speak, except to say that his studies in the. application of his favorite science to the medical art were extended and valuable. His numerous and varied investigations in American mineralogy will be found extending over many years in the pages of the American Journal of Science. Of this journal, founded by his father, and familiarly known throughout the scientific world as Silliman's Journal, our late colleague was, during forty years, and until the time of his death, one of the editors. His acquaintance with the history of his favorite science in America was very intimate, and his memory was remarkable, so that he, better than any one else, was fitted to be its annalist. In 1874, when American chemists, at the grave of Priestley, in Northumberland, Pennsylvania, celebrated the centenary of modern chemistry, and the present speaker and J. Lawrence Smith and Silliman were chosen as the orators, the latter presented as his contribution a sketch of American chemists and their labors, which, as subsequently elaborated by him, and separately published, is an invaluable record and at the same time a monument of his learning and patient research.

But it is principally in his studies of the practical applications of science that Silliman's work belongs to the Institute of Mining Engineers; and the partial record of it in his later years may be found in the published volumes of our *Transactions*. Those familiar with the literature of American petroleum are aware that. his early experiments in the refining of the oils of Pennsylvania, laid the foundations of that industry. His studies of coal-gas and water-gas, and their applications to heating and illumination, and his researches in gas-analysis, partly in connection with Prof. Henry Wurtz of this city, are of great value, and it is worthy of remark that his last communication to the Institute, only a few months since (in September last), was a study of the application of the natural gas of western Pennsylvania to the Siemens furnace, the revision of which paper occupied the last weeks of his life and was left unfinished. His illness, dependent on cardiac disturbance, entailed upon him several months of severe suffering, but he met death with the composure of a philosopher and a Christian.

Of the details of his social life, one who as a life-long friend has known much, may be permitted to say a few words. He was early united to the woman of his choice, who, after nearly forty years of happy married life, died in 1878. Five children survive him, including one son, who perpetuates the honored family name, and four daughters. All five were married beneath the same roof-tree under which they were born, To the wide circle of those who shared for many years the generous hospitalities of his home and his household, Silliman was known as a genial, cordial and unselfish friend. Dead before his time, his memory will live in the hearts of grateful pupils and students of science throughout the continent, and will not soon be forgotten by the members of this Institute, of which he was one of the most faithful members, and to the *Transactions* of which he was one of the most valued contributors.

BIOGRAPHICAL NOTICE OF SIDNEY GILCHRIST THOMAS.

BY GEORGE W. MAYNARD. NEW **YORK CITY.**

IN the *Journal of the Iron and Steel Institute* for the year 1878, in the account of the proceedings of the annual meeting in March of that year, when, Mr, Bell read his paper *On the Separation of Phosphorus from Pig-Iron,* occurs the following statement, as part of the reported discussion of that paper:

" Mr. Sidney Thomas stated that he had succeeded in effecting the almost complete removal of phosphorus in the Bessemer process. Experiments had been carried on at Blaenavon, with the co-operation of Mr. Martin, on quantities varying between 6 lbs. and 10 cwt., and some hundred analyses made by Mr. Gilchrist (who had the conduct of the experiments from the first) showing the removal of from 20 per cent. to 99.9 per cent. of phosphorus in the converter. He believed the practical difficulties in the way had been overcome, and that Cleveland pig might be made into good steel without any intermediate process. He hoped on a future occasion to lay full details before the Institute."

I was present at that meeting, and I doubt if any one in the hall knew, either by sight or name, the young man who had dared to rise in that august body and claim that he had accomplished that after which the great metallurgists of Europe had been unsuccessfully striving ever since Mr. Bessemer's great discovery. I remember distinctly the pitying smile of derision and the stony stare which pervaded the countenances of the distinguished assemblage. No one thought it worth while to refer to Mr. Thomas's claim or ask him " How he did it?" except that Mr. Bell, in replying to the criticisms on his paper, remarked, " With regard to what Mr. Sidney Thomas hoped to do with the Bessemer converter, he was so much interested in freeing iron, and particularly Cleveland iron, from phosphorus, that he should hail as a public benefactor, any gentleman who would come forward and do the work more perfectly or more economically than *he* had been able to effect this object himself."

Thus were Mr. Thomas and his process brought to the attention of the metallurgical world; and it is safe to say that no further thought was given to him or his claims until he *compelled* attention by his paper prepared for the Paris meeting of the Iron and Steel Institute, in September, 1878.

Mr. Thomas was born in April, 1850. He was educated at Dulwich College with the intention of entering the profession of medicine, but, on the death of his father, he entered the civil service at the age of seventeen. The particular branch which he had selected made a knowledge of law desirable, though not absolutely necessary ; so he went into a course of law-reading, which he found very beneficial in his later business earner. As his general reading became more extended, he soon learned that metallurgical chemistry offered a wider field for his active brain. During the day he was closely confined to his regular duties, so that his only opportunity for study was in the evenings. At his cottage on the south side of the Thames, his time was occupied in the most unselfish manly devotion to his mother and sister, and in the little laboratory where he was working out one of the most important metallurgical problems of the day. He managed to spend considerable time, however, in the laboratories of Mr. Arthur Vacher and Mr. George Chaloner. He also entered for the examinations of the Royal School of Mines, and passed successfully such as he undertook.

It is said that the idea of dephosphorization first took strong hold upon his mind while attending a course of lectures on metallurgy, at the Birkbeck Institution, in 1870; and at that time he was fond of quoting the saying: "The man who eliminates phosphorus by means of the Bessemer converter, will make his fortune." Mr. Thomas prepared for his great discovery by making himself thoroughly conversant with everything that had been done, as far as he could find out from existing literature and patents. I call to mind now, how he used to haunt the library of the Patent Office, and how he seemed to have at his tongue's end the name of every patentee at home and abroad, who had done anything in the purification of iron or steel. His discovery was in no sense an accidental one. He began with knowing what he wanted to do, and his next step was to learn what had been done, and wherein other investigators had failed; and he qualified himself for the inquiry by a sound chemical knowledge of the changes which take place at ordinary metallurgical temperatures.* He reasoned that the high temperature of the converter or the open hearth could not alone, if at all, account for the persistent presence of such an easily volatilized element as phosphorus. He therefore looked for a chemical reason, and found it in the well-known fact that phosphates are decomposed at high temperatures in the presence of free silica, and that the phosphorus is thus left to combine again with the metallic iron. Professor Williamson had brought out this fact very clearly in the discussion of Dr. Siemens's paper on *The Production of Iron and Steel by a Direct Process,* at the Newcastle meeting of the Iron and Steel Institute, in September, 1877, where he said : " First of all, he ought to remind the meeting that silica, at high temperatures, expels phosphoric acid from its salts. That was a perfectly well known thing. If they had got a salt--he meant a compound of phosphoric acid, say, with an oxide of iron--and if they heated that in contact with a reducing agent and with silica; they could turn out the phosphoric acid, and get it reduced to phosphorus in proportion as they turned it out, which would combine with the iron and again form phosphide of iron,"

Notwithstanding it " was a perfectly well known thing," neither Prof. Williamson nor the other metallurgical chemists had thought of doing just what Thomas had been quietly doing for a year or more, viz., keeping free silica away from the phosphate of iron formed in the converter in the course of the blow.†

* Previous to Thomas's discovery, it had become customary to assume that phosphorus could be measurably eliminated at a low temperature only.

† Mr. George Snelus forms an exception to this general statement. He had used a basic lining, and had observed its effect in the elimination of phosphorus. But Mr. Thomas had independently gone much further in the study and elaboration of the details; and while Snelus, Biley and Thomas (who united their interests commercially) all shared in the merit and profit of the new process, there is no doubt, as I think his associates would be swift to declare, that to Mr. Thomas belongs (and has been given) the largest dividend of praise and fame.

Without the enthusiastic co-operation of his cousin Mr. Percy C. Gilchrist, chemist at the Cwm-Avon works, and afterwards at Blaenavon, he could not have achieved success as soon as he did; for in his small laboratory in London he could not possibly work out his theories in a practical way. Mr. E. P. Martin, manager of the Blaenavon works, cordially seconded the efforts of these young men in a very practical way by affording them the opportunity of blowing charges up to half a ton, and Mr. Menelaus of Dowlais also allowed them to experiment with a five-ton vessel.

In November, 1877, Mr. Thomas took out his first patent. At the Paris meeting of the Iron and Steel Institute, a paper on *The Elimination of Phosphorus* was presented by Sidney G. Thomas and Percy C. Gilchrist. For some reason, not yet clearly explained, the Council did not call for the paper at that meeting. It was in print, however, and was extensively circulated. Mr. Holley, who had attended the Paris meeting, sent me a copy of the paper. I was so impressed with the claims made by the authors that I immediately put myself in communication with Mr. Thomas and met him on his return to London. I then learned that Mr. Windsor Richards had already expressed great interest in the process and promised to test it on a commercial scale at the works of Bolckow and Vaughan.*

Mr. Riley's ingenious device in basic brick-making was recognized by Mr. Thomas in a liberal manner. Improvements and patents now followed one another in rapid succession, as did the large army of inventors who "had done it years ago," but had never thought of making their discoveries public until they found that Thomas and Gilchrist were likely to reap some benefit from it. Although great German works were arrayed against them, the spe-

* Just at this time the writer was carrying on some investigations for the Standard Iron and Steel Company of Manchester, and, as their efforts had been directed to the utilization of phosphoric pig, urged upon them the importance of trying the basic lining. An oblong iron box called the "receiver," which I have described in *The Metallurgical Review* for April, 1878, was set up at the Acklam Works at Middlesborough and lined with the Thomas basic mixture. A blast-pressure of 2½ to 3½ pounds was obtained from the blast-furnace blowing-engine. The first heat was made on the 18th of December, 1878. The charge was 5 tons of No. 3 iron, containing 1.63 per cent. of phosphorus. In one case the resultant metal contained 0.45 phosphorus and no silicon (and the cinder 7.05 phosphoric acid and 31.00 silica), and in another, 0.28 phosphorus, silicon, a trace. The metal was remarkably malleable. I believe this to have been the first blow in a large way after the South Wales experiments, but to Mr, Richards is due the credit of having made the first commercial success; and the facilities which he afforded foreign investigators for studying the process cannot be too highly commended.

cial commission appointed by the German Patent Office decided in favor of the claim of Thomas and Gilchrist. The interferences and claims of priority which sprang up in the United States, are well known to all who have taken any interest in the subject. Eight patents in all were taken out by Thomas and Gilchrist for furnace-linings, dephosphorizing iron, and the manufacture of steel, and others for the utilization of the slag in the manufacture of super-phosphates.

In a communication received from Mr. Thomas early this year, he states that the total make of basic steel for the year ending September 30th, 1884, was 864,000 tons, of which 685,000 tons was made on the Continent, and 179,000 tons in England. He estimated that the total for 1885 would be over 1,000,000 tons.

Dr. Hermann Wedding, in his late work on the Basic Process, which was published in 1884, gives the following list of basic works then built or building.

LIST OF THE BASIC BESSEMER STEEL WORKS.

	No of converters.	Capacity each. Tons.	Total capacity. Tons.
Germany:			
Hoerde,	3	10	30
Rheinische Stahlwerke,	2	6.5	13
Bochum,	3	4.5	13.5
Oberhausen,	2	6	12
Union	2	9.5	19
Hoesch (building),	3	10	30
Phoenix,	3	10	30
Eothe Erde,	3	10	30
Peine,	4	10	40
Neunkirchen,	2	10	20
Hayingen (De Wendel),	4	8	32
Dudlingen (Luxemburg Co.),	4	10	40
Friedenshütte (Upper Silesia),	3	10	30
Königshütte (Upper Silesia),	1	7.5	7.5
Königshütte building (UpperSilesia),	2	10	20
Austria :			
Kladno	3	5	15
Teplitz,	2	6.5	13
Witkowitz,	2	8	16
Russia :			
Warsaw,	2	10	20
Belgium :			
Angleur,	2	6	12
Athus,	2	10	20

	No, of converters.	Capacity each. Tons.	Total capacity. Tons.
France:			
Crensot,	2	7	14
Joeuf,	4	10	40
Commentry,	2	10	20
Longwy,	3	10	30
Valenciennes	2	10	20
England:			
Eston (Middlesborough),	6	15	90
Northeastern (Middlesborough),	.4	10	40
Sellerhall Co. (Middlesborough),	.1	4	4
Staffordshire Steel and Ingot Co.,	,3	5	15
Merry & Cunningham, Glengarnock,	2	9	18
Glasgow Iron Co., "Wishaw,	3	7	21
United States :			
Harrisburg,	2	10	20

Recapitulating, we have the following:

	No. of works.	No. of converters.	Total capacity.
Germany,	13	41	367
Austria,	3	7	44
Russia	1	2	20
Belgium	2	4	32
France,	5	13	124
England	6	19	188
United States	1	2	20
Total,	31	85	705

Mr. Thomas, in a letter to *The Iron Age,* uses the following language : "The most noteworthy feature about this return is, however, the evidence it gives of the superior enterprise and quicker appreciation of the advantages of improved methods of manufacture-shown by Continental metallurgists." If an Englishman can make a comparison so unfavorable to his own countrymen, what shall we of the United States say of our manufacturers, who boast of being so keenly alive to the newest and best processes?

Many of us remember Mr. Thomas's visit to this country in the spring of 1880, and how he endeared himself to all with whom he came in contact. He was with us again in 1883 on his homeward way in a trip around the world. It was quite evident to his friends at that time that he could not long survive, unless he gave up work absolutely. To one of his temperament this was impossible, and it seemed to be equally impossible for him to take prudent care of himself. In the enthusiasm of observation, study, and experiment, he was sure to forget the limitations set to his strength by a delicate frame and an insidious disease. This I observed during my daily intercourse with him in that exceptionally cold winter of '78 and '79 in England, during which period I think he must have contracted, or at least confirmed, the pulmonary weakness which became fatal a few years later.

It has rarely fallen to the lot of one so young to add so much to the world's knowledge and wealth as did Sidney Gilchrist Thomas, who, after a short but full day's work, fell asleep February 1st, 1885.

The following pathetic note from his sister to me will appropriately close this poor tribute to his memory :

"DEAR MR. MAYNARD :

No doubt you have heard the fact of our great loss from friends in England, but I wish to write one line to tell you my dear brother had wished to write you for some weeks before his death, but had not the strength. It took him two days to write a few last words to Mr. Gilchrist, a word or two at a time, and he could still less dictate. Until his weakness overpowered him, his brain was as active as ever, working out problems and ideas in his stronger hours."

TRANSACTIONS

OF THE

AMERICAN INSTITUTE OF MINING ENGINEERS.

VOL. XIII.

FEBRUARY, 1884, TO JUNE, 1885.

NEW YORK CITY:
PUBLISHED BY THE INSTITUTE,
AT THE OFFICE OF THE SECRETARY.
1885.

PHILADELPHIA:
SHERMAN & CO., PRINTERS.

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* The names in this list are those of the foreign members elected before February, 1880, at which time (see Proceedings of the New York Meeting, Transactions, vol. viii., p. 281) Rules I., II. and V. were so amended as to abolish the distinctive class of foreign members, as previously existing. All foreign members elected since that date are included in the general list of "Members and Associates" on page viii.

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Members and Associates.

MAY, 1885.

THOSE MARKED THUS * ARE MEMBERS; MARKED THUS † ARE ASSOCIATES. THE FIGURES AT THE END OF THE ADDRESS INDICATE THE YEAR OF ELECTION.

*ABADIE, EMILE R., ... New Almaden, Cal. '76
*ABBOTT, ARTHUR V., ... 311 Broadway, New York City. '82
*ADAMS, J. M., ... 109 California Street, San Francisco, Cal. '73
*ADAMS, WILLIAM H., ... 159 Front Street, New York City. '80
*ADDY, MATTHEW, ... Cincinnati, O. '84
*AGASSIZ, PROF. ALEXANDER, ... CAMBRIDGE, MASS. '77
*AIKEN, ROBERT H., ... Wickes, Montana. '84
*AINEY, WILLIAM H., ... Allentown, Pa. '84
*ALDEN, P. E., ... Monroeton, Pa. '84
*ALDRICH, TRUMAN H., ... SOUTHERN AVENUE, CINCINNATI, OHIO. '78
*ALDRICH, W. F., ... Aldrich, Alabama. '81
*ALEXANDER, ARCH. A., ... San Antonio, Texas. '82
*ALEXANDER, CURTIS, ... Maryyille, Mo. '84
*ALEXANDER, JOHN S., ... 1935 Arch Street, Philadelphia. '72
*ALLEN, JOSEPH H., ... Hanoverville, Md. '82
*ALLEN, JNO. H., ... Box 733, Pueblo, Colorado. '84
*ALMY, WILLIAM F., ... Fall River, Mass. '80
†AMY, ERNEST J. H., ... 18 W. Twenty-Seventh Street, New York City. '85
*APPLETON, E. C., ... Canajoharie, Montgomery Co., N. Y. '80
*ARENTS, ALBERT, ... P. O. Box 15, West End, Alameda Co., Cal. '82
*ARMSTRONG, H. W., ... Metcalf, Paul & Co., Pittsburgh, Pa. '79
*ARNBERG, C T., ... Albany & Rensselaer Iron And Steel Co., Troy, N. Y. '81
†ARNOLD, J. B., ... Aurora, Ill. '76
*ARNOLDS, HUGO, ... P. O. Box 46, Prescott, Arizona. '82
*ASHNURNER, CHARLES A., ... 907 Walnut Street, Philadelphia. '75
*ASHBURNER, WILLIAM, ... 1014 Pine Street, San Francisco, Cal. '72
*ASMUS, GEORGE, ... 93 John Street, New York City. '72
*ATHA, BENJAMIN, ... Newark, N. J. '84
*ATKINS, C. M., JR., ... Hawkinsville, Ga. '83
*ATKINS, G. J., ... Forest City Iron Works, Cleveland, Ohio. '82
*ATKINS, WILLIAM, ... Pottsville, Pa. '81
*ATTWOOD, GEORGE, 26 Ulster Place, Regent's Park, London, N.W., England. 75
*AUCHY, GEORGE. .... Riegelsville, Pa.'81

*AUSTIN, J. B., ... Roanoke, Va. '83
*AUSTIN, T. S., ... Salt Lake City, Utah. '83
*AUSTIN, W. LAWRENCE, ... Toston, Montana. '82
*AYRES, W. S., ... Allamuchy, N. J. '73
*BACHMAN, F. E., ... Phoenixville, Pa. '80

*BACON, CHAS. A., Care H. S. King & Co., Bankers, Cornhill, London, E. C. '85
*BAILEY, EDWARD, ... Pottstown, Pa. '84
*BAILEY, EDWARD, JR., ... 31 S. Front Street, Harrisburg, Pa. '83
*BAILEY, GILBERT E., ... Rapid City, Dakotah. '82
*BAILEY, JACKSON, ... 96 Fulton Street, New York City. '80
†BAKER, CHARLES HENRY, ... Care Metcalf, Paul & Co., Pittsburgh, Pa . '82
*BAKER, RICHARD D., ... 1414 Arch Street, Philadelphia. '82
*BAKER, S. C., ... Altoona, Pa. '84
*BALDWIN, S. W, ... 160 Broadway, New York City. '78
*BANKS, JOHN H., ... 345 W. Fifty-Seventh Street, New York City. '83
*BARNES, O. W, ... Mills Building, New York City. '81
*BARNES, PHINEAS, ... Lock Box 1479, Pittsburgh, Pa. '75
*BARNES, WALTER U., ... Littleton, Mass. '80
*BARNHILL, B. B., ... Joggins Mines, Nova Scotia. '84
†BARNS, GEORGE T., ... 224 S. Fourth Street, Philadelphia. '84
*BARR, J. N., ... Milwaukee, Wis. '84
*BARTLETT, J. C., ... Taunton, Mass . '77
*BARTOL, GEORGE, ... Otis Iron And Steel Co., Cleveland, Ohio. '79
*BARUS, CARL, ... U. S. National Museum, Washington, D. C. '84
*BAYLES, JAMES C., ... 83 Reade Street, New York City. '78
*BEATTIE, JAMES F., ... CONNELLSVILLE, PA. '82
*BEEBE, ALFRED L., ... School Of Mines, New York City. '83
*BEEGER, HERMANN, ... Denver Club, Denver, Colorado. '82
*BEL, J. MARC, ... 8 Rue D'odessa, Paris, France. '84
*BELL, DR. ROBERT, ... Geological Survey, Ottawa, Canada. '85
†BEMIS, FRED. P., ... 1223 Third Avenue, Davenport, Iowa. '85
*BENEDICT, W. DE L., ... 32 Liberty Street, New York City. '83
*BENTLEY, ROBERT, ... Lowellville, Ohio. '84
*BERDELL, THEODORE, ... 42 E. Twenty-Fifth Street, New York City. '82
*BERG, WALTER G., ... Ass't Eng'r's Office, L. V. R. R., Mauch Chunk, Pa. '81
*BERLIN, PROF. A. P., ... Slatington, Pa. '82
*BERTOLET, ALFRED S., ... Crown Point, Essex Co., N. Y. '75
*BEVERIDGE, ROBERT, ... Walkerville, Montana. '84
*BIDDLE, WILLIAM F., ... 209 S. Third Street, Philadelphia. '81
*BIERWIRTH, L. C., ... Dover, N. J. '75
*BILLIN, CHARLES E., ... 186 Dearborn St., Chicago, Ill. '75
*BILLING, G., ... P. O. Box 211, Socorro, N. M. '82
*BILLING, G. H., ... Norway Iron Works, Boston, Mass. '77
*BINSSE, HENRY, ... 40 W. Nineteenth Street, New York City. '75
*BIRKINDINE, JOHN, ... 152 S. Fourth Street, Philadelphia. '75
*BLAIR, ANDREW A., ... 919 Chant Street, Philadelphia. '75
*BLAIR, GEO. D., ... SPRUCE CREEK, PA. '84
*BLAKE, F. C., ... MANSFIELD VALLEY, ALLEGHENY CO., PA. '77
*BLAKE, FRANCIS H., ... Pinal, Arizona. '84
*BLAKE, THEODORE A., ... New Haven, Conn. '80

*BLAKE, PROF. W. P., ... New Haven, Conn. 71
*BLAKSLEE, A. P.,.. Delano, Pa. 84
*BLANDY, JOHN F., ... Agua Frio, Arizona. '71
*BLEECKER, CHARLES P.,........................ 11 West 129th Street, New York City. '80
†BLISS, ARTHUR W., ... Uniontown, Fayette Co., Pa. '77
*BLOSS, RICHARD P., ... Palmer's Falls, N. Y. '83
*BLOW, A. A.,... P. O. Box 228, Leadville, Colorado. '82
*BOEHMER, MAX, ... Box 765, Leadville, Colorado. '84
*BOGART, JOHN, ... 127 East Twenty-Third Street, New York City. '76
*BOGGS, WILLIAM R.,JR., ... Box 104, Winston, N. C. '82
*BOLLER, A P., ... 71 Broadway, New York City. '80
*BOOTH, HENRY, ... 26 Garfield Place, Poughkeepsie, N. Y. '74
*BORDA, E.,.. P. O. Box 1696, Philadelphia. '75
*BOVEY, PROF. HENRY T., ... 31 Mctavish Street, Montreal, Canada .'78
*BOWDEN, J. H., ... Lock Box 784, Wilkes-Barre, Pa. '71
*BOWER, ANTHONY S., ... St. Neots, Hunts, England. '83
*BOWIE, A. J., JR.,.................................. P. O. Drawer 2220, San Francisco, Cal. '72
*BOWRON, JAMES, ... Nashville, Tenn. '78
*BOWRON, WILLIAM M.,.. South Pittsburg, Tenn. '81
*BOYD, C. R., ... Wytheville, Va. '76
*BOYD, JOHN D.,... Uniontown, Fayette Co., Pa. '80
*BOYER, JEROME L., ... Reading, Pa. '84
†BOYLE, CHARLES E., ... Uniontown, Fayette Co., Pa. '82
*BRADLEY, G. L.,... Pomfret Center, Conn. '74
*BRAEM, HENRI M.,... 52 Broadway, New York City. '80
*BRAINERD, ALFRED F.,.. Birmingham, Ala. '79
*BRAMWELL, J. H., ... Roanoke, Va. '71
*BRANNER, JOHN C,.. Scranton, Pa. '84
†BRASCHI, V. M.,......................... 400 W. Twenty-Third Street, New York City. '81
*BRAY, WILLIAM A., ... Leadville, Colorado . '80
*BRECKENRIDGE, CABELL,............................. 1045 Scott Street, Covington, Ky. '84
*BRIDGMAN, H. L., ... 1203 Locust Street, Des Moines, Iowa . '79
*BRINLEY, CHARLES A.,............................ 247 S. Sixteenth Street, Philadelphia. '79
*BRINSMADE. HENRY N., ... Everett, Bedford Co., Pa. '81
*BRITTON, J. BLODGET.,.................................... 339 Walnut Street, Philadelphia. '72
*BROCK, CHARLES, ... Manhattanville, New York City. '81
*BRODHEAD, CALVIN E.,.. Hustontown, Pa. '76
*BRODIE, W. M.,... Batopilas, Chihuahua, Mexico. '72
*BROOKE, GEORGE, ... Birdsboro. Berks Co., Pa. '81
*BROOKS, R. G., ... Lock Box 124, Scranton, Pa. '84
†BROOKS, T. B.,... Newburgh, N. Y. '72
*BROSIUS, M. L., ... Lewistown, Pa. '76
*BROUN, P. H.,.. Middleburg, Loudoun Co., Va. '83
†BROWN, A. C., ... Marinette, Wis. '80
*BROWN, ALEXANDER E., ... 40 Fifth Ave., Cleveland, Ohio. '75
*BROWN, D. P.,.. Lost Creek, Schuylkill Co., Pa. '72
*BROWN, EDWARD L., ... 14 Metropolitan Block, Chicago, Ill. '81
†BROWN, FAYETTE, ... 863 Euclid Avenue, Cleveland, Ohio. '75
*BROWN, HARVEY H.,............................... 101 St. Clair Street, Cleveland, Ohio. '76
*BROWN, J. STUART, ... Brown & Co., Pittsburgh, Pa. '81
*BROWN, WALTER LEE, ... Lock Box 1820 Aurora, Ill. '84

*BROWNING, F. D.,	Chicago Sugar Refining Co., Chicago, Ill.	'82
*BRUCKMAN, FREDRICK,	138 Clarkson Street, Denver, Colorado.	'82
*BRUNER, ABRAM,	P. O. Box 146, Allegheny, Pa.	'82
*BRUNTON, D. W.,	P. O. Box 2470, Denver, Colorado.	'83
*BRUSH, PROF. GEORGE J.,	New Haven, Conn.	'75
*BRYDEN. ALEXANDER,	Care of Andrew Bryden, Pittston, Pa.	'82
*BRYDEN, ANDREW,	Pittston, Pa.	'71
*BUCK, STUART M.,	Coalburgh, Kanawha Co., W. Va.	'71
†BUCKINGHAM, F. E.,	915 Third Avenue, Brooklyn, N. Y.	'83
*BULKLEY, F. G.,	P. O. Box 883, Leadville, Colorado.	'82
*BULKLEY, HENRY W.,	149 Broadway, New York City.	'79
†BULKLEY, DR. L. DUNCAN,	4 E. Thirty-seventh Street, New York City.	'82
*BULLEY, REGINALD H.,	Canton, Ohio.	'78
*BULLOCK, M. C.,	199 Lake Street, Chicago, Ill.	'74
*BUNNING, CHAS. Z.,	Warora, Central Provinces, East Indies.	'85
*BUNSEN, ROBERT,	P. O. Box 1980, Leadville, Colorado.	'76
*BURCHELL, H. C.,	St. John's, Newfoundland.	'83
*BURCHELL, JAMES T,	Big Glaer, Cape Breton, Nova Scotia.	'83
*BURDEN, H. H.,	Troy, N. Y.	'83
*BURDEN, HENRY,	Troy, N. Y.	'79
*BURDEN, I. TOWNSEND,	Troy, N. Y.	'76
*BURDEN, JAMES A.,	Troy, N. Y.	'76
†BURDEN, WILLIAM F.,	111 First Street, Troy, N. Y.	'83
†BURKE, M. D.,	55 W. Fifth Street, Cincinnati, Ohio.	'74
*BURLINGAME, E. E.,	446 Lawrence Street, Denver, Colorado.	'82
†BURNET, S. F.,	St. Louis Water Works, St. Louis, Mo.	'81
†BURNHAM, WILLIAM,	220 S. Fourth Street, Philadelphia.	'76
*BURT, CHARLES S.	Newberry, Mich.	'82
†BUTLER, CYRUS,	24 Cliff Street, New York City.	'72
*BUTTERS, CHARLES,	52 Broadway, New York City.	'83
†CABEEN, F. VON A.,	400 Chestnut Street, Philadelphia.	'82
*CABOT, JOHN W.,	Box 961, Bellaire, O.	'80
*CADLE, CORNELIUS, JR.,	Blocton, Bibb Co., Alabama.	'83
†CALMAN, ALBERT,	332 W. Fifty-sixth Street, New York City.	'81
*CAMP, JAMES M.,	131 Rebecca Street, Allegheny, Pa.	'83
*CAMPBELL, H. H.,	Steelton, Dauphin Co., Pa.	'81
*CANBY, R. C.,	Pueblo, Colorado.	'82
†CANFIELD, A. CASS,	60 W. Fifty-fourth Street, New York City.	'76
*CANFIELD, FRED. A.,	Dover, N. J.	'74
*CARNEGIE, THOMAS M.,	48 Fifth Avenue, Pittsburgh, Pa.	'78
*CARSON, A. C.,	Butte City, Montana	'84
*CARSON, JAMES P.,	16 Exchange Place, New York City.	'82
*CARTER, FRANK,	Pottsville, Pa.	'73
†CARTER, GEORGE T.,	62 Wood Street, Pittsburgh, Pa.	'81
*CHADWICK, WALTER M.,	Bergen Point, N. J.	'83
*CHALFANT, JOHN W.,	Pittsburgh, Pa.	'73
*CHAMBERLAIN, H. S.,	Chattanooga, Tenn.	'75
*CHANCE, DR. H. MARTYN,	2433 Fairmount Ave., Philadelphia.	'74
*CHANNING, J. PARKE,	Houghton, Mich.	'84
*CHANUTE, ARTHUR,	P. O. Box 750, Leadville, Colorado.	'82

*CHANUTE. O., ... Kansas City, Mo. '79
*CHAPER, MAURICE, ... 31 Rue St. Guillaume, Paris, France. '79
*CHAPIN, P. E., ... Johnstown, Pa. '83
*CHARLETON, A. G., ... Rushton, Charters Towers, Queensland, Anstralia. '81
*CHASE, FRANK D., ... Box 701, Pueblo, Colorado. '84
*CHAUVENET, S. H., ... Robesonia, Berks Co., Pa. '81
*CHAZAL, PHILIP E., ... Box 362, Columbia, S. C. '81
*CHEEVER, PROF. B. W., ... University of Michigan, Ann Arbor, Mich. '82
*CHERRY, WILLIAM S., ... Streator, La Salle Co., III. '75
*CHESS, HARVEY B., ... Chess, Cook & Co., Pittsburgh, Pa. '80
*CHESTER, PROF. A. H., ... Hamilton College, Clinton, Oneida Co., N. Y. '71
*CHILDS, ALBERT H., ... 83 Fourth Avenue, Pittsburgh, Pa. '79
*CHISOLM, FREDERIC F., ... Denver, Colorado. '83
*CHISM, RICHARD E., ... Saltillo, via Laredo, Texas. '80
*CHOUTEAU, PIERRE, ... St. Louis, Mo. '76
*CHRISTY, PROF. S. B., ... State University, Berkeley, Cal. '83
*CHURCH, HENRY S., ... Troy, N. Y. '83
*CHURCH, PROF. JOHN A., ... Prescott, Arizona. '72
*CHURCH, JOHN B., ... Geneva, N. Y. '81
*CHURCH, TOWNSEND V., ... 400 Chestnut Street, Philadelphia, Pa. '82
*CHURCH, W. D., ... Topeka, Kansas. '84
*CHURCH, WALTER S., ... 215 Stewart Building, Broadway, New York City. '81
*CHURCHILL, A. D., ... 39 Broadway, New York City. '80
†CHYNOWETH, B. F, ... Greenland, Mich. '76
†CLAGHORN, CLARENCE R., ... Bernice, Pa. '84
*CLAPP, GEORGE H., ... 98 Fourth Avenue, Pittsburgh, Pa. '83
*CLARK, ELLIS, JR., ... 462 N. Sixth Street, Philadelphia. '74
*CLARK, F. W., ... Institute of Technology, Boston, Mass. '82
*CLARK, R. NEILSON, ... Leadville, Colorado. '72
*CLARK, WILLIAM, ... Carrie Furnace Co., Pittsburgh, Pa. '81
†CLARK, WILLIAM A., ... Butte, Montana. '82
*CLARKE, E. A. S., ... Union Steel Co., Chicago, III. '85
*CLARKE. THOMAS C., ... 18 Broadway, New York City. '76
*CLAUSSEN, F. F., ... U. S. Mint, New Orleans, La. '76
*CLAYPOOL, M. S., ... Georgetown, Colorado. '83
†CLAYPOOL, W. M., ... Bentonville, Ark. '84
*CLAYTON, JAMES E., ... P. O. Box 266, Baltimore, Md. '75
*CLAYTON, JOSHUA E., ... P. O. Box 366, Salt Lake City, Utah. '74
*CLAYTON, W. S., ... P. O. Box 266, Baltimore, Md. '83
*CLEMENS, FRANK G., ... Lost Creek, Schuylkill Co., Pa. '81
*CLEMENS, GEO. S., ... Ashland, Pa. '84
*CLEMES, JOHN H., ... Falmouth, England. '81
*CLIFF, JOHN, ... Hancock, Mich. '80
*CLYMER, EDWARD T., ... Temple, Berks Co., Pa. '82
*COE, W.W., ... Roanoke, Va. '83
*COFFIN, CHARLES E., ... Muirkirk, Md. '82
*COGGIN, F. G., ... Lake Linden, Mich '80
*COGSWELL, W. B., ... 109 Willow Street, Syracuse, N.Y. '72
*COLBURN, HENRY B., ... Liberty, Bedford Co., Va. '76
*COLBY, ALBERT L., ... South Bethlehem, Pa. '83
*COLLINGWOOD, FRANCIS, ... Elizabeth, N. J. '82

†COLLINS, H. E., ... 34 Sims Block, Pittsburgh, Pa. '76
*COLTON, CHARLES A., ... 21 West Park Street, Newark, N. J. '74
*COLTON, HENRY E., ... Chattanooga, Tenn. '83
*COLVIN, CLARENCE K., ... Idaho Springs, Colorado. '82
*COLVIN, VERPLANCK, ... Adirondack Survey Office, Albany, N. Y. '81
*COMSTOCK, GEORGE S., ... Mechanicsburg, Cumberland Co., Pa. '81
*COMSTOCK, THEO. B., ... 25 Euclid Ave., Cleveland, O. '80
*CONANT, T. P., ...are of Harper & Bros., Franklin Square, N. Y. City. '81
'81*CONE, JNO. J., ... 618½ Jersey Ave., Jersey City, N. J. '85
*CONRAD. C. F., ... Roanoke, Va. '83
*CONSTABLE, C., ... 44 Exchange Place, New York City. '75
*CONSTABLE, JAMES, JR., ... Glendon Iron Works, Easton, Pa. '79
*CONVERSE, JOHN H., ... Baldwin Locomotive Works, Philadelphia. '83
*COOK, EDGAR S., ... Warwick Iron Co., Pottstown, Pa. '77
*COOK, PROF. GEORGE H., ... State Geologist, New Brunswick, N. J. '74
*COOK, ROBERT A., ... Bethlehem, Pa. '83
*COOLIDGE, WALTER G., ... 1st Nat. Bank Building, Chicago, Ill. '82
*COOPER, EDWARD, ... 17 Burling Slip, New York City. '74
*COOPER, H. P., ... Parryville. Pa. '81
*COOPER, JAMES R., ... Honghton, L. S., Michigan. '80
*COOPER, WILLIAM H., ... 60 William Street, New York City. '83
†CORNELL, A. B., ... Youngstown, Ohio. '72
*CORNING, ERASTUS, ... 87 State Street, Albany, N. Y. '78
*CORNING, FREDERICK G., ... 78 Broadway, New York City. '77
*CORYELL, MARTIN, ... Lambertville, N. J. '71
*CORYELL, TORBERT, ... Lambertville, N. J. '83
*COURTIS, W. M., ... 449 Fourth Avenue, Detroit, Mich. '71
*COUTIE, WM., ... Troy, N. Y. '84
†COXE, ALEXANDER B., ... Drifton, Luzerne Co., Pa. '80
*COXE, ECKLEY B., ... Drifton, Luzerne Co., Pa. '71
*COXE, W. E. C., ... Reading, Pa. '74
*CRAFTS, WALTER, ... 3 Deshler Block, Columbus, Ohio. '71
*CRANZ, W. S., ... Darwin Mine, via Tubac, Arizona. '82
*CRAWFORD, HUGH A., ... 411 N. Third Street, St. Louis, Mo. '75
*CRAWFORD, JOHN J., ... Placerville, El Dorado Co., Cal. '73
*CRAWFORD, JOHN L., ... Newcastle, Pa. '84
*CREMER, J. H., ... Edgar Thomson Steel Works, Braddock, Pa. '75
†CRERAR, JOHN, JR., ... 109 Dearborn Street, Chicago, Ill. '84
*CROCKER, A. L., ... Minneapolis, Minn. '80
*CROCKER, GEORGE A., ... 32 Cliff Street, New York City. '79
*CROCKER, WILLIAM B., ... 32 Cliff Street, New York City. '79
*CROOKER, RALPH, 3D., ... Care Nat. Tube Works Co., McKeesport, Pa. '81
*CROOKSTON, A. W., ... 19 Wellington Street, Glasgow, Scotland. '80
*CROWE, THOMAS., ... N. Chicago Rolling Mill Co., South Chicago, Ill. '84
*CROWTHER, BENJAMIN, ... Etna, Allegheny Co., Pa. '76
*CROXTON, SAMUEL W., ... Canal Dover, Ohio. '75
*CROZER, S. A., JR., ... P. O. Box 13, Chester, Pa. '83
*CUMMER, F. D., ... Cleveland, Ohio. '83
*CUMMINGS, GEORGE P., ... Marquette, Mich. '81
*CUNNINGHAM, JAMES S., ... Everett, Bedford Co., Pa. '83
*CUNNINGHAM, J. L., ... Ringwood, Passaic Co., N. J. '82

*CURRY, HENRY M., ... Lucy Furnaces, Pittsburgh, Pa. '79
*CURTIS, GRAM, ... 35 Broadway, Room 97, New York City. '80

*DABNEY, CHAS. W., ... Jr.,Raleigh, N. C. '84
*DAGGETT, ELLSWORTH, ... Salt Lake City, Utah. '73
*DAGRON, JAMES G., ... Care Keystone Bridge Co., Pittsburgh, Pa. '84
†DALLIBA, JAMES H., ... Scofield Building, Cleveland, Ohio. '82
*DALLIBA, WILLIAM S., ... 186 Dearborn Street, Chicago, Ill. '83
*DANFORTH, A. H., ... South Pueblo, Colorado. '82
*DANIELS, FRED. H., ... 132 Lincoln Street, Worcester. Mass. '76
*DARLEY, E. C., ... 322 Pine Street, St. Louis, Mo. '83
*DAVENPORT, C. W., ... Erie, Pa. '81
*DAVENPORT, RUSSELL W., ... Midvale Steel Works, Nicetown, Philadelphia. '77
*DAVIDSON, GEORGE M., JR., ... 64 S. Clinton Street, Chicago, Ill. '81
*DAVIES, EDWARD S., ... Pottstown, Pa. '81
*DAVIS, CHESTER B., ... 52 Montauk Block, Chicago, Ill. '78
*DAVIS, PROF. FLOYD, ... Blacksbnrg, Va. '83
*DAVIS, HENRY C., ... 205 Walnut Place, Philadelphia. '81
*DAVIS, LOUIS M., ... Bolivar, Venezuela (care Harriman & Co., Trinidad). '84
†DAYTON, L. M., ... 184 N. Second Street, Cincinnati, Ohio. '84
*DE CAMP, ALFRED H., ... Musquodoboit Harbor, Halifax Co., N. S. '83
*DE CAMP, E. F., ... Halifax Club, Halifax, N. S. '85
*DE CAMP, W. S., ... Lyons Falls, N. Y. '75
*DE CRANO, E. G., ... Union Club, San Francisco, Cal. '72
*DE DEKEN, ALBERT, ... Edgar Thomson Steel Works, Braddoek, Pa. '84
*DE SAULLES, A. B., ... Oliphant Furnace, Fayette Co., Pa. '71
*DE SCHWEINITZ, P. B., ... South Pueblo, Colorado. '82
*DERLAND, ASBURY, ... Boiling Springs, Cumberland Co., Pa. '82
*DESLOGE, JOHN M., ... Bonne Terre, St. François, Co., Mo. '81
*DEVEREUX, W. B., ... Aspen, Colorado. '80
*DEWEY, FRED. P., ... Smithsonian Institution, Washington, D. C. '77
*D'INVILLIERS, E. V., ... 711 Walunt Street, Philadelphia. '82
*DISSTON, H. C., ... Philadelphia, Pa. '84
*DISSTON, W M., ... Philadelphia, Pa. '84
*DIXON, DOUGLAS, ... 6 Crosby Square, Bishopgate Street, London, Eng. '84
*DODGE, WALLACE H., ... Dodge Manuf. Co., Mishawaka, Ind. '84
*DODS, JOHN C., ... Danville, Pa. '81
*DOMINICK, F. J., ... Clintonville, N. Y. '82
*DONALDSON, WILLIAM J., ... 226 Walnut Street, Philadelphia. '81
*DORSEY, E. B., ... American Exhibition, 7 Poultry, London, Eng. '79
*DOWNS, W. F., ... Dixon Crucible Co., Jersey City, N. J. '83
*DOYLE. PAT., ... Care of Rev. James Doyle, Madras, India. '79
*DRINKER, H. S., ... 218 S. Fourth Street, Philadelphia. '71
*DU BOIS, PROF. AUG. JAY, ... New Haven, Conn. '75
*DUDLEY, ... Dr. Charles B.,Altoona, Pa. '78
*DUDLEY, P. H., ... 66½ Pine Street, New York City. '75
*DUDLEY, PROF. W. L., ... American Iridium Co., Cincinnati, Ohio. '84
*DUFF, JOHN, ... 14 Sheafe Street, Charlestown, Mass. '83
*DUMONT, JOHN M., ... Idaho Springs, Colorado. '82
*DUNCAN, JOHN, ... Calnmet, Houghton Co., Mich. '80
*DUNCAN, M. M., ... Roekwood, Tenn. '84

†DUNLAP, THOMAS, ... Stapleton Mills, Amherst Co., Va. '81
*DU PUY, HERBERT,.................................. 171 Western Avenue, Allegheny, Pa. '79
*DURFEE, W. F., ... 89 Courtland Street, Bridgeport, Conn. '76
*DURKEE, HENRY R., ... 87 Dearborn Street, Chicago, Ill. '84
†DWIGHT, ARTHUR S., ... Colorado Smelting Co., South Pueblo, Colorado. '85

*EARLE, FRANK C., ... P. O. Box 15, Tombstone, Arizona. '84
*EARNSHAW, ALFRED., ... 203 Walnut Place, Philadelphia. '81
*EARNSHAW, EDWARD H., ... Chester Furnace, Chester, N. J. '84
*EASTWOOD, PROF. J. F., ... Bethany, W. Va. '82
*ECKERT, HENRY S., ... Reading, Pa, '84
†ECKERT, HUNTER, ... New Ringgold, Schnylkill Co., Pa. '81
*ECKMAN, JOHN W., ... Port Kennedy, Pa. '84
†EDMUNDS, FRANK W.,.. P. O. Box 133, Troy, N. Y. '83
*EDWARDS, J. WARNER,....... Delaware Avenue And Green Street, Philadelphia. '76
*EGAN, JOHN M. S., ... P. O. Box 24, Georgetown, Colorado. '82
*EGLESTON, DR. THOMAS, ... 35 West Washington Square, New York City. '71
*EILERS, A.,.. South Pueblo, Colorado. '71
*ELLIOT, MATTHEW P., ... Crystal Plate Glass Works, Crystal City, Mo. '85
†ELY, E. B., ... Washington Building, 1 Broadway, New York City. '79
*ELY, THEODORE N., ... Altoona, Pa. '79
*EMANUEL, W. H.,.. Box 2065, Denver, Colorado. '81
*EMERSON, B. F., ... Copper Falls, Keweenaw Co., Mich. '76
*EMERSON, PROF. G. D., ... Rolla, Phelps Co., Mo. '71
*EMERY, A, H., ... Stamford, Conn. '82
*EMERY, CHARLES E.,.................................. 22 Cortlandt Street, New York City. '80
*EMMERTON, F. A.,.. Joliet, Ill. '84
†EMMONS, ARTHUR B., ... Newport, R. I. '85
*EMMONS, S. F., ... U. S. Geological Survey, Denver, Colorado. '77
*ENGLE, GEORGE U., ... 912 Mahontongo Street, Pottsville, Pa. '77
*ENGELMANN, HENRY, ... La Salle, Ill. '72
†ENOS, FRANK, ... 28 Monroe Place, Brooklyn, N. Y. '84
*EOFF, CHARLES W.,............................. 1322 Jefferson Street, Kansas City, Mo. '84
*ESTABROOK, J. D.,........................... Coulter Street, Germantown, Philadelphia. '72
*EURICH, E. F., ... Aurora, Ill. '74
*EUSTACE, GEORGE W.,.. Helstone, Cornwall, England. '82
*EUSTIS, W. E. C., ... 4 Pemberton Square, Boston, Mass. '76
*EVANS, JOHN D., ... Chester, Morris Co., N. J. '80
*EYRE, THOS. T., ... Carlisle, N. Mexico. '85
*FABER DU FAUR, A., ... 93 John Street, New York City. '72
*FACKENTHAL, B. F., JR.,... Riegelsville, Pa. '80
*FACKENTHALL, MICHAEL, ... Hellertown, Pa. '80
*FAIRCHILD,................................ A. C.Passaic Rolling Mill Co., Paterson, N. J. '77
*FALDING, FREDERICK J.,................................... 81 New Street, New York City. '84
*FARRELL, AUSTIN,........................ Care Crozer Iron & Steel Co., Roanoke, Va. '80
*FEGELY, ISAAC,.. Pottstown, Pa. '83
*FELTON, EDGAR C., ... Steelton, Dauphin Co., Pa. '81
*FELTON, S. M., ... 208 S. Fourth Street, Philadelphia. '81
*FERGUSON, E. M., ... 104 Fifth Avenue, Pittsburgh, Pa. '78
†FERGUSON, J. H., ... P. O. Box 2124, Denver, Colorado. '84
†FERGUSON, SAMUEL T.,.. Minneapolis, Minnesota. '84

*Ferguson, Walton,	104Fifth Avenue, Pittsburgh, Pa.	'79
*Ferris. J. C.,	Carthage, Ill'83	
*Feustman, L. P.,	P. O. Box 375, Leadville, Colorado.	'82
*Field, Robert P.,	237 S. Forty-second Street, W. Philadelphia.	'73
*Fillebrown, John P.,	Secaucus, Hudson Co., N. J.	'79
*Findlay, Charles Farquhar,	Trinity Hall, Cambridge, England.	'82
*Finley, C. B.,	Philipsburg, Pa.	'81
*Firmstone, Frank,	Glendon Iron Works, Easton, Pa.	'71
*Firmstone, H.,	Longdale, Alleghany Co., Va.	'75
@Fischer, Anthony C.,	906 G Street, N. W., Washington, D. C.	'83
*Fisher, Clark,	Trenton, N. J.	'71
*Fisher, Harvey,	Duncannon, Perry Co., Pa. '76	
*Fisher, H. H.,	Allentown, Pa.	'80
*Fisher, John J.,	Allentown, Pa.	'81
*Fitzhugh, Charles L,	Shoenberger & Co., Pittsburgh, Pa.	'79
*Flagler, John H.,	104 John Street, New York City.	'82
*Fleming, H. S.,	117 W. 8th Street, Chattanooga, Tenn.	'84
*Fohr, Franz,	Leadville, Colorado.	'75
*Foote, Emerson L.,	411 N. Third Street, St. Louis, Mo.	'82
*Foote, Herbert C.,	37 Arlington Court, Cleveland, Ohio.	'75
*Ford, E. L.,	Youngstown Steel Co.,Youngstown, Ohio.	'79
*Ford, S. Alfred,	Edgar Thomson Steel Co., Pittsburgh, Pa.	'75
*Ford, Robert G.,	Bellwood, Blair Co., Pa.	'82
*Forsyth, Robert,	Union Steel Co., Chicago, Ill.	'75
*Forsyth, William,	Aurora, Ill.	'84
*Foster, Ernest Le Neve,	Georgetown, Colorado.	'75
Foucar, Edonard L.,	P. O. Box 107, El Paso, Texas.	
*Fowler, A. L.,	Tombstone, A. T.	'84
*Francklyn, Charles G.,	48 Wall Street, New York City.	'80
*Franklin, Walter S.,	Ashland, Baltimore Co., Md.	'79
*Frazer, Dr. Persifor,	201 S. Fifth Street, Philadelphia.	'71
*Frazer, Robert,	209 S. Third Street, Philadelphia.	'76
*Frazier. Prof. B. W.,	Lehigh University, Bethlehem, Pa.	'71
*Frecheville, R. J.,	5 Holyrood Place, Plymouth, England.	'84
*Frecheville, William,	Hoover Hill, Randolph Co., N. C.	'84
*Freeland, Francis T	Box 2279, Denver, Colorado.	'85
*Freeman, H. C.,	Box 1, Alto Pass, Union Co., Ill.	'78
@Freeman, William Coleman,	Cornwall, Lebanon Co., Pa.	'77
*Frick, H. C.,	104 Fifth Avenue, Pittsburgh, Pa.	'79
*Fricke, F. G.,	Buffalo Gap, Va.	'79
*Frink, George S.,	Irondale, N. Y.	'85
*Fritz, John,	Bethlehem, Pa.	'72
*Fry, John E.,	Springfield Iron Co., Springfield, Ill.	'75
*Fuller, Homer T.,	Worcester, Mass.	'84
*Fulton, Henry,	Georgetown, Colorado.	'81
*Fulton, John,	Cambria Iron Co., Johnstown, Pa.	'72
*Fulton, R. C.,	Conshohocken, Pa.	'83
*Furman. Howard V.,	137 W. Thirty-fourth Street, New York City.	'80
*Fusz, Paul A.,	941 N. Second Street, St. Louis, Mo.	'79
*Gaertner, Erich G.,	Chicago, Ill.	'84

*GARDNER, G. CLINTON,	15 Broad Street, New York City.	'78
*GARDNER, GEORGE C,	Room 35, Portland Block, Chicago, Ill.	'83
*GARRETT, ALBIN,	208 S. Fourth Street, Philadelphia.	'82
*GARRETT, WILLIAM,	Oliver & Roberts Wire Co., Pittsburgh, Pa.	'81
*GARRISON, FRANK L.,	1523 Girard Ave., Philadelphia.	'83
*GARTHWAITE, E. H.,	Care of W. W. Garthwaite, Oakland, Cal.	'82
@GATEWOOD, R.,	Care Navy Department, Washington, D. C.	'84
*GAY, HARRY S.,	Wilkes-Barre, Pa.	'85
*GAYLEY, JAMES,	Birdsboro, Pa.	'80
@GAZZAM, JOSEPH P.,	Joliet, Ill.	'84
*GENTH, F. A., JR.,	4014 Chestnut Street, W. Philadelphia.	'77
*GEORGE, RICHARD,	Dover, N. J.	'75
*GEORGE, S. W.,	Chester, N. J.	'84
*GEORGE, W. R.,	Dover, N. J.	'81
@GIBB, FRANK W.,	Little Rock, Ark.	'82
*GIBSON, C. H.,	Lock Box 1705, New York City.	'82
*GILBERT, EDWARD G.,	Troy, N. Y.	'83
*GILL, JOHN L., JR.,	32 N. 5th Street, Philadelphia.	'76
*GLADWIN, F. E.,	Care Dr. F. C. E. Mueller, El Plomo, Sonora, Mexico.	'84
*GLENN, WILLIAM,	South Strafford, Vermont.	'81
*GOETZ, GEORGE W.,	Otis Iron and Steel Co., Cleveland, Ohio.	'82
*GOGIN, GEORGE W.,	Norway Iron Works, Boston, Mass.	'77
*GOING, CHARLES B.,	Cincinnati, Ohio.	'83
*GOODALE, CHARLES W.,	Tombstone, Arizona.	'76
@GOODWIN, H. STANLEY,	Bethlehem, Pa.	'71
*GOODYEAR, S. W.,	Waterbury, Conn.	'82
*GOODYEAR, WATSON A.,	Blake Crusher Co., New Haven, Conn.	'71
*GORDON, ALEXANDER,	Hamilton, Ohio.	'84
*GORDON, FRED W.,	226 Walnut Street, Philadelphia.	'80
*GORHAM, AUSTIN G.,	21 Cortlandt Street, New York City.	'81
@GORTON, FRANK S.,	Chicago Forging Co., Chicago, Ill.	'84
*GOSLING, EDGAR B.,	School of Mines, New York City.	'83
@GOWEN, FRANKLIN B.,	119 N. Fourth Street, Philadelphia.	'72
*GRAHAM, FRANK,	P. O. Box 280, Georgetown, Colorado.	'84
*GRAHAM, JOHN, JR.,	Camden Iron Works, Camden, N. J.	'83
@GRAHAM, THOMAS,	233 S. Third Street, Philadelphia	'75
*GRAHAM, THOMAS H.,	400 Chestnut Street, Philadelphia.	'81
@GREEN, EDWARD M.,	Troy, N. Y.	'83
*GRIDLEY, EDWARD,	Wassaic, Dutchess Co., N. Y.	'77
*GRIFFEN, GEORGE S.,	Phœnixville, Pa.	'80
@GRIFFEN, H. M.,	Georgetown, Colorado.	'82
*GRIFFITH, J. K.,	Midvale Steel Works, Nicetown, Philadelphia.	'80
@GRIFFITHS, HOWARD B.,	2327 Ridge Avenue, Philadelphia.	'77
*GRISCOM, SAMUEL E.,	324 N. Eighth Street, Philadelphia.	'76
*GRISWOLD, CHESTER,	11 Pine Street, New York City.	'79
*GRISWOLD, FRANCIS B.,	Troy, N. Y.	'83
*GRISWOLD, J. WOOL,	Troy, N. Y.	'83
*GRITTINGER, HENRY C.,	Cornwall, Lebanon Co., Pa.	'79
*GROESBECK, J. D.,	P. O. Box 96, Tombstone, Arizona.	'82
*GROSS, HENRY S.,	119 Market Street, Harrisburg, Pa.	'81
*GROSS, LOUIS N.,	Box 411, Deadwood, Dakota.	'85

*GROVE, JOHN H., ... Danville, Pa. '80
*GURLEY, WILLIAM, ... Troy, N. Y. '83

*HABIRSHAW, W. M., ... 159 Front Street, New York City. '84
*HACKETT, WILLIAM H., ... 56 W. Harris Street, Atlanta, Ga. '81
*HACKNEY, HERBERT, ... Portland, Oregon. '83
†HADLEY, WALTER C., ... Las Vegas, N. M. '83
*HAGERMAN, J. J., ... 86 Michigan Street, Milwaukee, Wis. '75
*HAGUE, ARNOLD, ... University Club, New York City. '74
*HAHN, ALBERT G. C., ... 64 Perry Street, New York City. '85
*HAHN, IGNATIUS, ... P. O. Box 155, Sharpsburg, Allegheny Co., Pa. '79
*HAHN, O. H., ... P. O. Box 8, South Pueblo, Colorado. '71
*HAINES, REUBEN, ... 123 West Chelten Ave., Germantown, Philadelphia. '82
*HALBERSTADT, BAIRD, ... Pottsville, Pa. '84
*HALE, PROF. ALBERT C., ... P. O. Box 65, Brooklyn, N. Y. '82
*HALE, ALBERT W., ... 71 Broadway, New York City. '75
*HALL, C. C., ... 313 Iron Street, S. St. Louis, Mo. '82
*HALL, EDWARD J., JR., ... 80 Astor House, New York City. '76
*HALL, HENRY J., ... Palace Hotel, San Francisco, Cal. '80
*HALL, ROBERT W., ... 3 W. Fifty-Sixth Street, New York City. '76
*HALSEY, FRED A., ... 23 Park Place, New York City. '82
*HALSEY, WILLIAM S., ...Care Of F. M. Davis, 8th & Larimer Sts., Denver, Col. '82
*HAMILTON, ALEXANDER., ... Drawer Pp., Johnstown, Pa. '78
*HAMILTON, WILLIAM G., ... 24 West Street, New York City. '7
*HAMMOND, CHARLES L., ... 40 S. Clark Street, Chicago, Ill. '78
*HAMMOND, JOHN HAYS, ... 56 Wall Street, New York City. '81
*HAMMOND, W. B., ... Deadwood, Dakota. '83
*HARDEN, E. B., ... 537 N. Thirty-Third Street, Philadelphia. '73
*HARDEN, ... J. H.Phoenixville, Pa. '71
*HARDMAN, JOHN E, ... Oldham Gold Mines, Nova Scotia. '82
*HARKER, O. H., ... Leadville, Colorado. '82
*HARNICKELL, ... A.P. O. Box 2503, New York City. '74
*HARRINGTON, DR. B. J., ... Mcgill College, Montreal, Canada. '77
*HARRIS, JOSEPH S., ... 226 S. Third Street, Philadelphia. '72
*HARRIS, O. D., ... Ste. Genevieve, Mo. '84
*HARRISON, RUSSELL B., Superintendent U. S. Assay Office, Helena, Montana. '77
*HART, PROF. EDWARD, ... Lafayette College, Easton, Pa. '81
†HART, WILLIAM R., ... 224 S. Third Street, Philadelphia. '77
*HARTMAN, JOHN M., ... 1235 N. Front Street, Philadelphia. '75
*HARTRANFT, S. S., ... Custom House, Philadelphia. '77
*HARTSHORNE, J., ... Care Pottstown Iron Co., Pottstown, Pa. '73
*HARTY, WILLIAM, ... P. O. Box 207, Portsmouth, Ohio. '79
†HARVEY, WILLIAM H., ... Commonwealth Iron Co., Cleveland, Ohio. '80
*HASTINGS, ROBERT E., ... 819 Filbert Street, Philadelphia. '84
*HAWS, H. Y., ... Johnstown, Pa. '81
*HAYDEN, DR. F. V., ... 1803 Arch Street, Philadelphia. '81
*HAYDON, J. C., ... Jeansville, Luzerne Co., Pa. '74
*HEARD, JOHN, ... Care Aug. Heard, 39 Nassau Street, N. Y. '83
*HEARNE, FRANK J., ... Wheeling, West Va. '74
*HEARTT, JONAS S., ... Troy, N. Y. '83
*HECKSCHER, A., ... 212 Walnut Street, Philadelphia. '79

*HEGELER, EDWARD C.,.. La Salle, Ill. '81
*HEINRICH, OSWALD J., ... Drifton, Luzerne Co., Pa. '73
*HEMENWAY, E. P., ... Cambria Iron Co., Johnstown, Pa. '81
*HEMPHILL, JAMES, ... Twelfth And Pike Streets, Pittsburgh, Pa. '75
*HENDERSON, C. HANFORD,............................ 201 S. Fifth Street, Philadelphia. '83
*HENRICH, CARL,.. Noble, Richland Co., Ill. '82
*HERNDON, EDWARD L.,.............................. 210 N. Third Street, St. Louis, Mo. '82
*HERR, H. B.,... P. O. Drawer 132, Chicago, Ill. '76
*HERRICK, J. A., ... 6 Crosby Square, Bishopgate Street, London, Eng. '76
*HERRICK, J. T., ... Fairplay, Park Co., Colorado. '82
*HEWETT, G. C., ... Winifrede, Kanawha Co., W. Va. '83
*HEWITT, ABRAM S., ... 17 Burling Slip, New York City. '71
*HEWITT, GEORGE H.,... 2 Wall Street, New York City. '80
†HEYWOOD, GEORGE H., ... Gardner, Mass. '83
*HIBBARD, HENRY D., ... Norway Iron Co., S. Boston, Mass. '79
*HIBBS, JAMES M.,................................. 1330 Buttonwood Street, Philadelphia. '83
†HICKOX, CHARLES V.,................................. 175 Dearborn Street, Chicago, Ill. '84
†HILDRETH, R. W.,.. 25 Madison Ave., New York City. '85
†HILDRETH, WALTER E.,..................................... 52 Broadway, New York City. '75
*HILL, FRANK A.,... 1600 Arch Street, Philadelphia. '83
*HINCHMAN, CHARLES S.,............................. 208 S. Fourth Street, Philadelphia. '79
*HITCHCOCK, PROF. C. H., ... State Geologist, Hanover, N. H. '79
*HITCHCOCK, E. A., ... St. Louis Ore And Steel Co., St. Louis, Mo. '80
*HOATSON, THOMAS,... Calumet, Michigan. '80
*HODGES, A. D., JR.,................................ 97 Mt. Pleasant Ave., Roxbury, Mass. '84
*HOFFMAN, E. O., ... Care Barney & Smith M'f'g Co., Dayton, O. '84
*HOFFMAN, JOHN W., ... 208 S. Fourth Street, Philadelphia. '76
*HOFFMANN, OTTOKAR, ... Corner 5th And Bryant Streets, San Francisco, Cal. '84
*HOFMAN, H. O., ... 2102 Mt. Vernon Street, Philadelphia. '82
*HOFFSTOTT, F. N.,.. P. O. Box 177, Pittsburgh, Pa. '82
*HOLBROOK, F. N., ... El Paso, Texas. '75
†HOLBROOK, LEVI, ... P.O. Box 536, New York City. '78
*HOLLENBECK, J. I.,.. Audenried, Carbon Co., Pa. '82
*HOLLERITH, HERMAN,........................... 617 Seventh Street, Washington, D. C. '83
*HOLLOWAY, J. F.,........................ Detroit And Center Streets, Cleveland, Ohio. '75
*HOLMAN, F. C.,.. Mansfield Valley, Pa. '81
†HOLT, GEORGE H., ... Crested Butte, Gunnison Co., Colorado. '82
*HOOKER, W. A.,... 2 Wall Street, New York City. '80
*HOOPER, WILLIAM, ... Ticonderoga, N. Y. '78
*HORTON, N. W.,.. 23 Park Place, New York City. '77
*HOTCHKISS, JED., ... Staunton, Va. '79
*HOUGHTELING; JAMES L.,............................... 244 S. Water Street, Chicago, Ill. '84
*HOUSTON, C. B., ... Thurlow, Delaware Co., Pa. '83
*HOUSTON, T. J.,.. Thurlow, Delaware Co., Pa. '82
*HOWALD, FERDINAND, ... Fire Creek, Fayette Co., W. Va. '84
*HOWE, FRANK P.,.. Danville, Pa. '79
*HOWE, HENRY G., ... P. O. Box 196, Tombstone, Arizona. '83
*HOWE, HENRY M., ... 75 State Street, Boston, Mass. '71
*HOWELL, BENJAMIN P.,... Scottdale, Pa. '84
*HUBER, H., SOCORRO, ... N. M. '82
*HULBERT, EDWIN J.,.. Middletown, Conn. '74

†HULBERT, THOMAS H., ... Middletown, Conn. 81
†HULICK, WILLIAM H., ... Easton, Pa. '82
*HULST, NELSON P., ... 300 Knapp Street, Milwaukee, Wis. '76
†HUMBERT, WILLIAM S., ... 7 Nassau Street, New York City. '83
*HUMPHREY, CHAS., ... Carlisle, N. M., Via Lordsburg. '85
*HUMPHREY, D. W., ... 902 Cedar Avenue, Scranton, Pa. '82
*HUMPHREY, GEORGE S., ... Ithaca, N. Y. '84
*HUMPHREYS, ALEX. C., ... 333 Walnut Street, Philadelphia. '85
*HUMPHREYS, A. W., ... 45 William Street, New York City. '72
*HUNGERFORD, W. S., ... Low Moor, Va. '82
†HUNICKE, AUG., ... Washington University, St. Louis, Mo. '83
*HUNT, ALFRED E., ... 98 Fourth Avenue, Pittsburgh, Pa. '79
*HUNT, FRED. F., ... P. O. Box 335, Quebec, Canada. '80
*HUNT, JOSEPH, ... Catasauqua, Pa. '71
*HUNT, JOSHUA, ... Catasauqua, Pa. 78
*HUNT, ROBERT W., ... Albany And Rensselaer Iron And Steel Co., Troy, N. Y. '74
*HUNT, DR. T. STERRY, ... Montreal, Canada. '71
†HUNTINGTON, FRED. W., ... 109 S. Oxford Street, Brooklyn, N. Y. '85
*HUTCHINSON, E. S., ... Newtown, Pa. '80
*HUTTER, E. S., ... Honston Mines, Botetourt Co., Va. '83
*HUTTON, FRED. R., ... 6 W. Thirty-Third Street, New York City. '75
*HUTTON, WILLIAM R., ... 35 Broadway, New York City. '82

*IHLSENG, AXEL O., ... Golden, Colorado. '82
†INGHAM, WILLIAM A., ... 320 Walnut Street, Philadelphia. '72
*INMAN, ALVIN L., ... Plattsburgh, N. Y. '76
*IRVING, PROF. ROLAND D., ... University Of Wisconsin, Madison, Wis. '72
*IRVING, WILLIAM, ... Chicago Club, Chicago, Ill. '81
†IRWIN, JOHN H., ... Morton, Delaware Co., Pa. '81

*JACKSON, EDWARD F., ... 3706 Washington Avenue, St. Louis, Mo. '83
*JAMES, ISAAC E., ... Duncan, Arizona. '82
*JAMES, REESE, ... South Pueblo, Colorado. '79
*JAMES, SAMUEL, JR., ... Rico, Colorado. '76
*JAMES, THOMAS, ... Braddock, Pa. '83
†JAMES, DR. WALTER M., ... 1123 Spruce Street, Philadelphia, Pa. '84
†JAMES, WILLIAM, ... St. James, Phelps Co., Mo. '82
*JAMME, GEORGE, ... Londonderry, Nova Scotia. '79
*JANIN, ALEXIS, ... 610 Hyde Street, San Francisco, Cal. '85
*JANIN, HENRY, ... 12 Fifth Avenue, New York City. '72
*JANIN, LOUIS, ... 310 Pine Street, San Francisco, Cal. '72
*JANNEY, MORRIS P., ... Pottstown, Pa. '74
†JARVIS, W. F., ... 34 Campan Building, Detroit, Mich. '84
*JENNEY, WALTER P., ... Box 283, Hailey, Idaho. '74
*JENNINGS, E. P., ... Sterlington, Rockland Co., N. Y. '76
*JENNINGS, HENNEN, ... Quicksilver Mining Co., New Almaden, Cal. '84
*JENNINGS, W. H., ... C. H. V. & T. Railway, Columbus, O. '84
*JETER, J. TINSLEY, ... Wilkesbarre, Pa. '84
*JEWELL, EDWARD E., ... Calumet I. & S Co., Cummings, Ill. '84
*JEWETT, ELIOT C., ... U. S. Assay Office, St. Louis, Mo. '81
*JOHNSON, LIEUT. D. D., ... Fort Monroe, Va. '82

*JOHNSON, ISAAC G.,	Spuyten Duyvil, New York City.	'79
*JOHNSON, J. E.,	Longdale, Alleghany Co., Va.	'80
*JOHNSON, W. G.,	Pine Grove, Pa.	'84
*JOHNSTON, WALTER N.,	Buchanan, Botetourt Co., Va.	'81
*JOLLIFFE, WILLIAM,	Lexington, Va.	'81
*JONES, B. F.,	Jones & Laughlin's Works, Pittsburgh, Pa.	'78
*JONES, D. N.,	Colorado Coal And Iron Co., Bessemer, Colorado.	'75
*JONES, GRIFFITH,	Pottstown, Pa.	'81
*JONES, JOHN T.,	Quinnesec, Menominee Co., Mich.	'80
*JONES, R. R.,	Union Iron And Steel Co., Chicago, Ill.	'82
*JONES, T. CATESBY,	Va. Nail & Iron Works, Lynchburg, Va.	'81
*JONES, THOMAS D.,	Ebervale, Pa.	'75
†JONES, THOMAS D.,	33 Portland Block, Chicago, Ill.	'84
*JONES, W. R.,	Braddock, Pa.	'75
*JONES, WASHINGTON,	1632 N. Fifteenth Street, Philadelphia.	'81
*JOPLING, JAS. E.,	Marquette, Mich.	'84
*JOUET, C. H.,	Roselle, N. J.	'83
*JUDSON, JNO. N.,	2201 Park Ave., St. Louis, Mo.	'84
†JULIAN, FRANK,	Iron Mountain, Menominee Co., Mich.	'81
*KAERCHER, EDW. E.,	Shamokin, Pa.	'84
*KAUFMAN, WILLIAM M.,	Reading, Pa.	'84
*KAY, PROF. EDGAR B.,	18 Fourth Street, Troy, N. Y.	'83
*KEAN, JOHN, JR.,	Elizabeth, N. J.	'81
*KEARNEY, HENRY S.,	P. O. Box 338, Leadville, Colorado.	'82
*KEBLER, ELIOT A.,	Newport, Ky.	'84
*KEBLER, JULIAN A.,	Ottumwa, Iowa.	'85
*KEELEY, JEROME,	206 Walnut Place, Philadelphia.	'76
*KEEN, BARTON L.,	175 Dearborn Street, Chicago, Ill.	'84
†KEITH, H. A.,	Chicago, Ill.	'84
*KEITH, N. S.,	9 Murray Street, New York City.	'76
*KELLER, ARTHUR H.,	P. O. Box 48, Silverton, Colorado.	'83
*KELLER, HERMANN A.,	P. O. Box 267, Leadville, Colorado.	'81
*KEMP, WILLIAM,	Troy, N. Y.	'83
*KEMPTON, C. W.,	61 Broadway, New York City.	'75
KENNEDY, HUGH,	Etna, Allegheny Co., Pa.	'81
*KENNEDY, JOHN S.,	Lock Box 5, Steelton, Dauphin Co., Pa.	'81
*KENNEDY, JULIAN,	Braddock, Allegheny Co., Pa.	'79
*KENT, JOSEPH C.,	Phillipsburg, N. J.	'72
*KENT, R.,	Standard Steel Works, Lewistown, Pa.	'84
*KENT, WILLIAM ST. G.,	Phoenixvillle, Pa.	'72
*KENT, WILLIAM,	Babcock & Wilcox Co., 30 Cortlandt St., New York City.	'76
†KERR, THOMAS B.,	110 Diamond Street, Pittsburgh, Pa.	'82
*KERR, PROF. W. C.,	Raleigh, N. C.	'76
*KEYES, W. S.,	P. O. Box 1716, San Francisco, Cal.	'72
*KIDDIE, THOMAS,	P. O. Box 44, New Brighton, Staten Island, N. Y.	'82
*KIMBALL, HIRAM,	City Forge, Cleveland, Ohio.	'82
*KIMBALL, DR. J. P.,	Lehigh University, Bethlehem, Pa.	'72
*KINEALY, JAMES R.,	Baden, St. Louis City. Mo.	'83
*KING, CHARLES F.,	Steelton, Dauphin Co., Pa.	'80
*KING, DANIEL,	Pine Grove Furnace, Cumberland Co., Pa.	'81

*KING, FRANK, ... Van Buren Furnace, Shenandoah Co., Va. '81
†KING, J. H., ... Painesville, Lake Co., Ohio. '80
*KING, THOMAS M.,... B. & O. R. R., Pittsburgh, Pa. '82
*KINGSLEY, J. COOK, ... P. O. Box 48, Silverton, Colorado. '82
*KINKEAD, MAX., ... Altoona, Pa. '82
†KIRBY, EDMUND B., ... Oregon Avenue And Juniata Street, St Louis, Mo. '84
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*KNIGHT, E.,.. Albany Iron Works, Troy, N. Y. '83
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*KNOX, JOHN H., ... Lebanon, Hunterdon Co., N. J. '80
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*LANDSBERG, E., ... Aachen, Germany. '83
*LANGDON, N. M.,... Pen Argyl, Pa. '81
*LATHROP, W. A.,.. Snowshoe, Center Co., Pa. '83
*LAUDER, GEORGE,............................ Larimer's Station, Westmoreland Co., Pa. '78
*LAUREAU, L. G., ... 226 Walnut Street, Philadelphia, Pa. '78
*LAWRENCE, BENJAMIN B.,......................... Montezuma, Summit Co., Colorado. '82
*LAWRENCE, W. L., ... Burden, Columbia Co., N. Y. '83
†LEARY, DANIEL J.,.. 138 Keap Street, Brooklyn, N. Y. '81
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†LEE, GEO. B., ... School Of Mines, New York City. '85
*LEE, R. H., ... Lewistown, Pa. '76
*LEE, R. H., JR., ... Lewistown, Pa. '83
*LEE, RICHARD HENRY, ... Duluth, Minn. '76
*LEGGETT, THOMAS H., ... Flushing, L. I., N. Y. 82
*LEHMAN, A. E, ... 711 Walnut Street, Philadelphia. '83
†LEHMAN, F. L.,.. 99 John Street, New York City. '82
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†LEWIS, SAMUEL W., ... 55 Broadway, New York City. 82
*LILIENBERG, N., ... 150 Broadway, New York City. '84
*LILLY, WILLIAM,.. Mauch Chunk, Pa. '79
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*LINDGREN, WALDEMAR,............................ P. O. Box 2160, San Francisco, Cal. '84
*LINDSLEY, STUART,.. Orange, N. J. '82
*LITTLE, FRANK J.,.................... North Chicago Rolling Mill Co., S. Chicago, Ill. '84
*LIVINGSTON, HERMAN,........................... Catskill Station, Columbia Co., N. Y. '82
*LOBANOFF, PAUL F., ... 277 Lasalle Avenue, Chicago, Ill. '83
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*LOISEAU, OSCAR, ... Ougrée, Belgium. '82
*LONG, JOHN C., ... Mont Alto, Franklin Co., Pa. '81
*LONG, WILLIAM H.,.. Fairlee, Vermont. '82
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†LUCE, EDWARD M., ... Milwaukee, Wis. '84
†LUDLAM, JOSEPH S.,.. Lowell, Mass. '81
*LUKENS, JAWOOD E.,... Conshohocken, Pa. '84
†LUNN, MAURICE J., ... Lewis Block, Pittsburgh, Pa. '84
*LUTHER, HENRY M.,.. Ashland, Pa. '84
*LUTHER, R. C., ... Pottsville, Pa. '84
*LUTSCHER, GAUDENZ,..................... Care Of Otis I. & S. Co., Cleveland, Ohio. '85
*LUTTGEN, EBERHARD,... Catasauqua, Pa. '85
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*MCCANDLESS, E. V.,.. Pittsburgh, Pa. '79
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*MCCLELLAN, ARTHUR, ... Drifton, Luzerne Co., Pa. '71
*MCCLURE, ROBERT J., ... C. B. & Q. R. R. Co., Chicago, Ill. '84
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*MCKEOWN, S. W., ... Youngstown, Ohio. '83

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*McLeavy, John,	Punxsutawney, Pa.	'75
*McLeod, H. S.,	Troy, N. Y.	'83
*McMillan,	Prof. Chas., Princeton, N. J.	'84
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*Macy, Arthur,	Silver King, Arizona.	'76
*Maffet, W. R.	Wilkes-Barre, Pa.	'74
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*Markham, Alfred,	Markhamville, N. B, Canada.	'82
*Markle, John,	Jeddo, Luzerne Co, Pa.	'79
*Marple, William M.,	Scranton, Pa.	'81
*Mars, John H.,	Albany, N. Y.	'81
*Marshall, Charles A.,	P. O. Box 766, Johnstown, Pa.	'82
*Martin, E. P.,	Dowlais, Glamorgan, Wales.	'81
*Martin, R. L.,	Fairchance, Fayette Co., Pa.	'81
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*Marvin, Selden E.,	Albany, N. Y.	'78
*Mason, Prof. William P.,	Troy, N. Y.	'83
†Massie, Frank A.,	Vesuvius, Va.	'82
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*Mathis, T. S.,	Telluride, Colorado.	'79
*Mattes, W. F.,	Scranton, Pa.	'81
*Matthiessen, F. W.,	Lasalle, Ill.	'84
*Maury, M. F.,	Avondale, Cincinnati, Ohio.	'74
*Maxon, John H.,	2305 Washington Avenue, St. Louis, Mo.	'74
*Maxwell, J. R.,	Hamilton, Ohio.	'84
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*May, William A.,	Lock Box 173, Scranton, Pa.	'77
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*Mayo, James H.,	1 Broadway, New York City.	'82
*Meade, Spencer,	N. Central Railway Co., Elmira, N. Y.	'81
†Means, Archibald,	Peru, La Salle Co, Ill.	'82
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*Mercur, Frederick,	Wilkes-Barre, Pa.	'71
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*Merritt, William Hamilton,	15 Toronto Street, Torouto, Canada.	'79

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*MEYER, CARL., ... Limburg, A. D. L., Germany. '83
*MICHAELIS, CAPT. O. E.,............................... Frankford Arsenal, Philadelphia. '82
*MICKLEY, EDWIN, ... Hokendauqua, Pa. '74
*MILLER, CHARLES W., ... Aspen, Colorado. '84
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*MILLS, JAMES E., ... Quincy, Plumas Co., Cal. '77
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*MOFFAT, E. S., ... Scranton, Pa. '71
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*MORGAN, T. R., ... Alliance, Ohio. '78
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*MORRELL, T. T.,... Cambria Iron Co., Johnstown, Pa. '79
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*NEFTEL, KNIGHT, ... 32 Liberty Street, New York City. '81
*NEILL, JAMES W.,... Mine La Motte, Madison Co., Mo. '79
*NEILL, WILLIAM L., ... Solvay Process Co., Syracuse, N. Y. '80
*NEILSON, JAMES,... Youngstown, Ohio. '79
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†PAINTER, WILLIAM R., ... Carrollton, Mo. '82
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*PEARSON, JOHN M., ... Hudson, Columbia Co., N. Y. '82
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*PEASE, F. N., ... Altoona, Pa. '82
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*PECKITT, LEONARD, ... Reading Iron Works, Reading, Pa. '83
*PEELE, R., JR., ... Bloomfield, N. J. '83
*PERKINS, H. C., ... El Callao Mining Co., Ciudad-Bolivar, Venezuela, Via Port Of Spain. 81
*PERRY, NELSON W., ... 238 Auburn Avenue, Cincinnati, Ohio. '76
*PERRY, W. A., ... 86 Liberty Street, New York City. '83
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*PETTJGREW, CHARLES, ... Joliet, Ill. '84
*PETTIT, ROBERT E., ... Jersey City, N. J. '81
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*PHILLIPS, ENOCH, ... Radford, Pulaski Co., Va. '83
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*PIERCE, H. N., ... 448 Madison Avenue, New York City. '84
*PIERCE, WILLARD IDE, ... 104 W. 129th Street, New York City. '77
*PIERCE, W. W., ... Franklin Furnace, N. J. '84
†PINKHAM, W. F., ... Bridgeport, Conn. '82
*PITCAIRN, ROBERT, ... Pittsburgh, Pa. '81
*PITMAN, PROF. S. M., ... Lonsdale, R. I. '73
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*PORTER, J. A., ... Durango, Colorado. '74
*PORTER, J. C., ... Spang Steel And Iron Co., Pittsburgh, Pa. '82
*PORTER, JOHN B., ... Cincinnati, Ohio. '83
*POTT, JOHN N., ... Pottsville, Pa. '76
*POTTER, EDWARD C., ... North Chicago Rolling Mill Co., Chicago, Ill. '79
*POTTER, O. W., ... 17 Metropolitan Block, Chicago, Ill. '75
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*POTTS, F. L., ... Barneston, Chester Co., Pa. '82
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*RICHARDS, JOHN THOMPSON, ... Scorries, Cornwall, England. '84
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*RICHARDS, WILLIAM L., ... Blossburg, Tioga Co., Pa. '80
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*RICKARD, REUBEN, ... Berkeley, Cal. '84
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*RILEY, LEWIS A., ... Ashland, Schuylkill Co., Pa. '76
*RILEY, S. M., ... Ashland, Schuylkill Co., Pa. '82
*RINARD, JOHN, ... Braddock, Allegheny Co., Pa. '79
*RIORDAN, D. M., ... Flagstaff, Arizona. '82
*RIOTTE, EUGENE N., ... 104 Washington Street, New York City. '83
*RISQUE, J. B., ... Albuquerque, N. M. '83
*RITER, THOMAS B., ... Riter & Conley, Pittsburgh, Pa. '81
†RITTERSKAMP, LOUIS H., ... 206 Vine Street, St. Louis, Mo. '81
*ROBBINS, G. COLLIER, ... Amherstburg, Ontario, Canada. '79
*ROBERTS, PERCIVAL, ... 261 S. Fourth Street, Philadelphia. '81
*ROBERTS, PERCIVAL, JR., ... 261 S. Fourth Street, Philadelphia. '77
†ROBERTS, P. WILLIAMSON, ... 261 S. Fourth Street Philadelphia. '83
*ROBERTSON, DAVID, ... Dagus Mines, Pa. '85
*ROBERTSON, KENNETH, ... Seacaucus Iron Co., Seacaucus, N. J. '82
*ROBERTSON, W. F., ... 245 Mountain Street, Montreal, Quebec. '81
†ROBINSON, NEIL, ... Coalburgh, W. Virginia. '85
†ROBINSON, THEODORE W., ... 200 West Springfield St., Boston, Mass. '84
*ROBY, LUTHER A., ... Otis Iron And Steel Co., Cleveland, Ohio. '79
*ROEPPER, CHARLES W., ... Alliance, Ohio. '73
*ROGERS, A. N., ... Central City, Colorado. '82
*ROGERS, C. L., ... 2601 Archer Avenue, Chicago, Ill. '80
*ROGERS, E. M., ... Central City, Colorado. '82
*ROLKER,. CHARLES M., ... 63 Broadway, New York City. '74
*RONALDSON, CHARLES E., ... 1001 Chestnut Street, Philadelphia. '84
*RONEY, C. HENRY, ... Franklin Institute Building, Philadelphia. '77
*RONEY, C. J, ... Organ, Doña Ana Co., N. M. '82
*RONEY, W. R., ... Las Cruces, N. M. '82
†ROOD, JAMES, JR., ... 9 Metropolitan Block, Chicago, Ill. '84
†ROSE, WILLIAM J., ... 12 N. Third Street, Harrisburg, Pa. '81
*ROSE, WILLIAM W., JR., ... P. O. Box 2287, Denver, Colorado. '82
*ROSECRANS, GEN. W. S., ... San Francisco, Cal. '76
*ROTHWELL, R. P., ... P. O. Box 1833, New York City. '71
*RUSSELL, EDWARD H., ... Park City, Utah. '84
†RUSSELL, S. BENT, ... 711 Pine Street, St. Louis, Mo. '81
*RUTHERFORD, J. GEORGE, ... Albion Mine, Stellarton, Nova Scotia. '83
*RUTTMANN, FERD. S., ... 51 Broadway, New York City. '81

*SAINT, WILLIAM, ... Porth, South Wales. '84
*SALOM, PEDRO G., ... Continental Hotel, Philadelphia. '80
*SANDBERG, C. P., 19 Great George St., Westminster, London, S. W., England. '81
*SANDERS, JOHN D., ... Mine La Motte, Missouri. '79
*SANDERS, RICHARD H., ... 737 Walnut Street, Philadelphia. '76
*SANDS, FERDINAND, ... 62 William Street, New York City. '81
*SARGENT, GEORGE W., ... Lake George, York Co., N. B., Canada. '82
*SAUNDERS, WILLIAM S., ... 10 Park Place, New York City. '83

†SAWYER, HENRY H., ... Easthampton, Mass. '82
†SCAIFE, OLIVER P.,.. 119 First Avenue, Pittsburgh, Pa. '78
*SCAIFE, WILLIAM LUCIEN,... Pittsburgh, Pa. '79
*SCHAEFFER, PROF. CHARLES A.,..................... Cornell University, Ithaca, N. Y. '74
*Schamberg, Meyer, ... Care W. G. Wilson, 212 N. Front Street, Philadelphia. '83
*SCHARAR, C. H., ... 2073 N. Main Ave., Scranton, Pa. '82
*SCHAUFUSS, ERIC C., ... Wilkesbarre, Pa. '83
*SCHELLENBERG, F. Z., ... Irwin's, Westmoreland Co., Pa. '79
*SCHMITZ, E. J., ... 202 E. Seventy-Sixth Street, New York City. '83
*SCHNEIDER, ALBERT F., ... P. O. Box 211, Socorro, N. M. '74
*SCHULZE-BERGE, H.,...................................... P. O. Box 2178, New York City. '81
†SCHWARTZ, J. E.,... P. O. Box, 1532, Pittsburgh, Pa. '76
*SCHWARZ, T. E.,.................. P. O. Box 114, Silverton, San Juan Co., Colorado. '76
*SCOTT, C. A., ... Halifax, Nova Scotia. '82
†SCOTT, FRANK,... 83 Fourth Avenue, Pittsburgh, Pa. '84
*SCRANTON, W. H., ... Oxford, N. J. '71
*SCRANTON, W. W., ... Scranton, Pa. '75
*SEAMAN, H. J., ... Catasauqua, Pa. '82
†SEARLE, J. M.,... Stanhope, N. J. '84
*SEARS, EDWARD H., ... Collinsville, Conn. '81
*SELIGMAN, A. J., ... Helena, Montana. '82
*SELLERS, MORRIS,... 6 Ashland Block, Chicago, Ill. '84
*SELLERS, WILLIAM,................................... 1600 Hamilton Street, Philadelphia. '75
*SETZ, GUSTAV, St. Joseph Lead Mines, Bonne Terre, St. François Co., Mo. ... '77
*SHARPLES, S. P.,.. 13 Broad Street, Boston, Mass. '78
*SHAW, H. C.,.. Care Dr. Shaw, Pittsburgh, Pa. '81
*SHAW, R. C., ... Tombstone, Arizona. '84
*SHEAFER, A. W., ... Pottsville, Pa. '80
*SHEAFER, P. W.,... Pottsville, Pa. '74
*SHEAFER, S. TAYLOR,.. Fairmount City, Pa. '85
*SHEAFER, W. LESLEY, ... Pottsville, Pa. '81
*SHED, NATHANIEL W., ... Nashua, N. H. '82
*SHERMAN, GEORGE R.,... Port Henry, Essex Co., N. Y. '78
*SHERRERD, ALEXANDER H., ... Lackawanna Iron And Coal Co., Scranton, Pa. '75
*SHERRERD, JOHN M.,..... Albany And Rensselaer Iron & Steel Co., Troy, N. Y. '80
*SHIMER, PORTER W.,... Easton, Pa. '79
*SHINN, WILLIAM P., ... 22 Cortlandt Street, New York City. '75
*SHOCKLEY, W. H., ... Candelaria, Esmeralda Co., Nevada. '83
†SHOEMAKER, A. T., ... 11 Pine Street, New York City. '83
*SHOENBAR, JOHN, ... West Sullivan, Hancock Co., Maine. '77
*SHUMWAY, W. ADAMS,.................................. Geol. Survey, Washington, D. C. '81
*SILLIMAN, PROF. J. M.,....................................... Lafayette College, Easton, Pa. '71
†SIMPSON, T. W., ... Roanoke, Va. '83
*SIMS, H. N.,.. Orbisonia, Pa. '83
*SINGER, WILLIAM H., ... 83 Water Street, Pittsburgh, Pa. '73
*SINGER, R. R., ... 83 Water Street, Pittsburgh, Pa. '79
*SLADE, F. J.,.............................. New Jersey Steel And Iron Co., Trenton, N. J. '74
*SLUDER, EDWIN E., ... Cerillos, N. Mexico. '83
*SMALL, GEO. W., ... Oconomowoc, Wis. '85
*SMALLEY, W. A., ... Silver City, New Mexico. '80
*SMITH, FRANK C., ... Richland Center, Wis. '84

*SMITH, HAMILTON, JR., ... Care Lauidlaw & Co., 14 Wall St., New York City. '77
*SMITH, H. S., ... Joliet, Ill. '75
*SMITH, J. WILLIAM, ... Solvay Process Co., Syracuse, N. Y. '81
†SMITH, LORIN X., ... Silver City, N. M. '82
*SMITH, MICHAEL, ... North Chicago Rolling Mill Co., S. Chicago, Ill. '84
*SMITH, OBERLIN, ... Bridgeton, N. J. '84
*SMITH, T. GUILFORD, ... P. O. Box 251, Buffalo, N. Y. '71
†SMITH, WEBSTER D., ... Paint Creek, Kanawha Co., W. Va 83
*SMITH, WILLIAM ALLEN, ... 16 Exchange Place, New York City. '73
*SMITH, GEN. WM. SOOY, ... Havre De Grace, Md. '76
*SMOCK, PROF. JOHN C., ... N. Y. State Museum, Albany, N. Y. '73
*SMYTH, C. H., ... Franklin Iron Works, Oneida Co., N. Y. '82
*SNYDER, J. F., ... 1015 Vine Street, Scranton, Pa. '76
*SOULE, R. H., ... Frankfort, N. Y. '81
*SPEER, JOHN Z., ... Shoenberger & Co., Pittsburgh, Pa. '79
†SPENCER, WILLIAM, ... Buck Mountain, Carbon Co., Pa. '72
†SPERR, FRED W., ... Care A. W. Thurman, Columbus, Ohio. '82
*SPIES, ALBERT, ... 901 Summit Avenue, Jersey City, N. J. '81
*SPILSBURY, E. G., ... Haile Mine, S. C. '73
*SPRINGER, DR. ALFRED, ...P. O. Box 573, Cincinnati, Ohio. '84
*SQUIRE, JOSEPH, ... Helena, Shelby Co., Alabama. '71
*STAFFORD, C. EDWARD, ... Care Shoenberger & Co., Pittsburgh, Pa. '74
*STALMANN, OTTO, ... Lake Linden, Mich. '83
*STAMBAUGH, H. H., ... Youngstown, Ohio. '82
†STANTON, JOHN,` .... 76 Wall Street, New York City. '77
*STAUNTON, WILLIAM F., JR., ... Tombstone, Arizona. '83
*STEARNS, I. A., ... Wilkes-Barre, Pa. '71
*STEARNS, THOMAS B., ... Colorado Machinery Co., Denver, Colorado. '81
*STETEFELDT, C. A., ... 63 Broadway, New York City. '81
†STETSON, GEORGE W., ... 69 Wall Street, New York City. '83
*STEVENS, GEORGE W., ... 89 Madison Avenue, Chicago, Ill. '83
*STEVENSON, JOHN, JR., ... New Castle, Pa. '76
*STEYERN, BALTZAR VON, ...Fainn, Sweden. '85
*STIRLING, W. R., ... Joliet Steel Co., Chicago, Ill. '84
*STOCKETT, LEWIS, ... Mahanoy City, Pa. '81
*STOIBER, EDWARD G., ... Silverton, Colorado. '77
*STONE, GEN. CHARLES P., ... 55 Liberty Street, New York City. '84
†STONE, GEORGE C., ... N. J. Zinc And Iron Co., Newark, N. J. '80
*STORRS, A. H., ... Shamokin, Pa. '84
*STRAUCH, JOHN H., ... Pottsville, Pa. '83
*STRAUSZ, ALEXANDER, ... Independence, Preston Co., W. Va. '81
*STRICKLAND, HERBERT, ... 31 Priory Road, Kilburn, London, N. W., Eng. '84
*STRIEBY, PROF. WILLIAM, ...Colorado College, Colorado Springs, Colorado. '77
*STROBEL, V. O., ... 226 Walnut Street, Philadelphia. '84
*STRODE, PROF. H. A., ... Amherst, Va. '81
*STUTZ, SEBASTIAN, ...P. O. Box 112, Pittsburgh, Pa. '79
*SUPPES, MAX,. .... Troy, N. Y. '83
†SWAIN, A. E., ... 902 Prospect Street, Cleveland, Ohio. '80
*SWETT, GEORGE W., ... Troy, N. Y. '83
*SWINDELL, WILLIAM, ... 48 Esplanade Street, Allegheny, Pa. '79
*SYMINGTON, W. N., ... P. O. Box 2011, New York City. '73
*SYMONS, W. R., ... Pottsville, Pa. '71

*Tasker, Charles P.,.................. Morris, Tasker & Co., Limited, Philadelphia. '82
*Taylor, Fred. W.,.. Lake Valley, New Mexico. '81
†Taylor, P. A.,.. Pottsville, Pa. '80
*Taylor, Percyvale, ... 6 Rue De Caumartin, Paris, France. '81
*Taylor, W. J.,.. Chester, Morris Co., N. J. '75
*Tefft, Walter, ... Mineville, Essex Co., N. Y. '75
*Thacher, Arthur, ... Nicholia, Lemhi Co., Idaho. '75
*Thackray, George E.,... Box 117, Sharpsburgh, Pa. '80
*Thaw, William, Jr., ... Pittsburgh, Pa. '82
*Thies, A.,.. Concord, N. C. '78
*Thomas, Alexander,.................................... Bolton Steel Co., Canton, Ohio. '81
*Thomas, D. H.,.. Hokendanqua, Pa. '80
*Thomas, Edwin, ... Hokendauqua, Pa. '79
*Thomas, Fred. F.,.. Jerome, Yavapai Co., Arizona. '84
*Thomas, John,... Hokendauqua, Pa. '71
*Thomas, Samuel, ... Catasauqua, Pa. '71
*Thomé, Samuel W.,................................. 397 Fulton Street, Brooklyn, N. Y. '81
*Thomlinson, William, ... West Hartlepool, England. '81
*Thompson, E. Ray, ... Troy, N. Y. '79
†Thompson, George S., ... Troy, N. Y. '83
*Thompson, Heber S.,.. Pottsville, Pa. '76
*Thompson, Robert M., ... 37 Wall Street, New York City. '81
*Thomson, John L.,............. P. O. Box 44, New Brighton, Staten Island, N. Y. '81
*Thonard, Leon, ... Sofia, Bulgaria. '79
*Thurston, Prof. R. H.,................................. Cornell University, Ithaca, N. Y. '75
*Tierney, John J.,.. Pocahontas, Va. '83
*Tilemann, J. N.,... Sandy, Utah Ter. '81
*Todd, James,....................................... 127 North Avenue, Allegheny City, Pa. '83
*Tonnelé, Theodore,... Mckeesport, Pa. '84
*Torrance, H. C., ... Care Oliver Bros. & Phillips, Pittsburgh, Pa. '81
*Torrance, J. Fraser, ... Marlow P. O., Beauce Co., P. Q. '76
*Torrey, Dolphus, ... 216 Adams Street, Brooklyn, N. Y. '78
*Torrey, Herbert G.,.............................. U. S. Assay Office, New York City. '81
*Toucey, Donald B.,....................... 43 W. Fifty-Third Street, New York City. '81
*Tower, A., ... Poughkeepsie, N. Y. '78
*Towne, Linwood O., ... Rico, Dolores Co., Colorado. '81
*Townsend, David, ... 1723 Wallace Street, Philadelphia. '80
*Townsend, Henry T.,................................. 218 S. Fourth Street, Philadelphia. '79
*Trent, L. C., ... 423 Blake Street, Denver, Colorado. '78
*Trippel, Alexander,...................................... 181 Broadway, New York City. '83
*Trowbridge, Prof. William P., ... School Of Mines, New York City. '77
*Tucker, Alfred, ... 220 Walnut Street, Philadelphia. '81
*Tyler, Alfred L., ... Woodstock Iron Co., Anniston, Ala. '75

*Valentine, M. D.,.. Woodbridge, N. J. '76
*Van Arsdale, W. H., ... Aurora, Ill. '72
*Van Blarcom, E. C., ... P. O. Box 2085, San Francisco, Cal. '79
*Van Diest, P. H., ... 379 Twenty-Second Street, Denver, Colorado. '82
*Vandling, A. H., ... Scranton, Pa. '82
*Van Lennep, D., ... Granite Basin, Via Buck's Ranch, Plumas Co., Cal. '72
*Van Slooten, Wm.,... 95 Milk Street, Boston, Mass. '84

*VAN TASSEL, HOWARD A.,...................... Atlantic Mine, Honghton Co., Mich. '81
*VAN VOORHIS, W. W.,.................................... Manhattanville, New York City. '79
*VEEDER, HERMAN,............................ Care C. G. Hussey & Co., Pittsburgh, Pa. '80
*VEZIN, HENRY A.,.................................... P. O. Box 144, Leadville, Colorado. '74
*VIVIAN, GEORGE G., ... Freeland, Clear Creek Co., Colorado. '82
*VULTÉ, HERMANN T.,................................. 79 E. 111th Street, New York City. '81

*WAGNER, E. C.,... Girardville, Pa. '85
*WAIT, PROF. CHARLES E.,.................................... Rolla, Phelps Co., Missouri. '79
*WAITE, GEORGE R.,.................................... 220 S. Broad Street, Philadelphia. '76
*WALKER, J. C.,.. 238 Bissell Street, Chicago, Ill. '83
†WALKER, JOHN A.,.. P. O. Box 21, Jersey City, N. J. '78
*WALKER, T. B.,.. Ashland, Ky. '84
*WALKER, W. R.,........................... Care Spang Steel & Iron Co., Pittsburgh, Pa. '81
*WALLER, DR. ELWYN,................................. School Of Mines, New York City. '83
*WALLIS, PHILIP, ... Box 1973, Aurora, Ill. '84
*WALSH, EDWARD, JR.,...................... 3021 Washington Avenue, St. Louis, Mo. '74
*WALTER, T. FRANK,.. Mauch Chunk, Pa. '84
*WARD, WILLARD P., ... 80 Madison Avenue, New York City. '71
*WARREN, GEORGE HENRY, JR., ... 520 Fifth Avenue, New York City. '81
*WARREN, WALTER P.,.. Troy, N. Y. '83
*WARTENWEILER, ALFRED,.. Butte City, Montana. '75
*WATERMAN, H. L., Care Of C. H. Odell, 15 Broad Street, New York City. '81
*WATERS, J. H. E.,... Silverton, Colorado. '82
*WATTS, DAVID,.. 223 Market Street, Harrisburg, Pa. '81
*WEAVER, V. W., ... Coplay, Lehigh Co., Pa. '82
*WEBB, H. H.,.. 405 Front Street, San Francisco, Cal. '85
*WEBB, H. WALTER,.. 37 Wall Street, New York City. '82
*WEEKS, JOSEPH D., ... P. O. Box 1547, Pittsburgh, Pa. '75
*WEIDMAN, BARGE C., ... P. O. Box 175, S. Bethlehem, Pa. '84
*WEIMER, P. L., ... Lebanon, Pa. '75
*WEIR, CHARLES G.,... Cheyenne, Wyoming. '82
*WEISER, FRANK P.,.. Ashland, Pa. '84
*WEITZELL, RICHARD S., ... Logan, Ohio. '85
*WELLMAN, S. T.,.............................. Otis Iron And Steel Co., Cleveland, Ohio. '75
*WELLS, BARD, ... Pottsville, Pa. '80
†WELLS, CALVIN, ... A. French & Co., Pittsburgh, Pa. '73
*WELLS, H. L.,.......................... Sheffield Scientific School, New Haven, Conn. '81
*WENDT, ARTHUR F.,.. Box 1600, New York City. '74
*WENTZ, J. S.,.. Mauch Chunk, Pa. '82
*WERNER, AUGUSTIN,... Mapimi, Durango, Mexico. '82
*WESTBROOK, CHARLES R.,.................... Ogdensburgh, St. Lawrence Co., N. Y. '80
*WESTBROOK, C. S., ... Spragueville, St. Lawrence Co., N. Y. '83
*WESTESSON, JOSEF P. L.,............................ Chester Rolling Mill, Thurlow, Pa. '84
*WHEELER, H. A.,................................... Washington University, St. Louis, Mo. '81
*WHEELER, MOSES D.,................. P. O. Box 539, Stapleton, Staten Island, N. Y. '75
*WHEELER, WILLIAM D., ... U. S. Assay Office, Helena, Montana. '81
*WHEELOCK, JEROME, ... Worcester, Mass. '82
*WHINERY, S., ... Somerset, Ky. '80
*WHITAKER, THOMAS D., ... Cedar Grove, Frankford, Philadelphia. '84
*WHITCOMB, GEORGE D., ... Dearborn & Monroe Streets, Chicago, Ill. '83

*WHITE, WILLIAM, JR., ... Braddock, Allegheny Co., Pa. '79
*WHITING, HENRY A.,............. Care S. A. Blatchford, 16 Exchange Place, N. Y. '85
*WHITING, S. B.,.. Pottsyille, Pa. '71
†WHITMAN, JAMES N, ... P. O. Box 380, Beverly, Mass. '83
†WHITNEY, ELI, JR.,........................... Whitneyville Armory, New Haven, Conn. '75
*WICKES, GEORGE T.,.. Bozeman, Montana. '76
*WIESTLING, GEORGE B.,.. Mont Alto, Franklin Co., Pa. '77
*WIGHT, SIDNEY B., ... Newberry, Mich. '80
*WILES, EDWIN L., ... Springfield Iron Co., Springfield, Ill. '82
*WILEY, WILLIAM H.,....................................... 15 Astor Place, New York City. '81
*WILHELM, A., ... P. O. Box 178, Harrisburg, Pa. '77
*WILKES, JOHN, ... Charlotte, N. C. '83
*WILLIAMS, ALBERT, JR.,.. Box 591, Washington, D. C. '82
*WILLIAMS, BEN.,.. Bisbee, Arizona. '82
*WILLIAMS, DAVID,... 83 Reade Street, New York City. '80
*WILLIAMS, PROF. EDWARD H.,....................... Jr.,P.O. Box 463, Bethlehem, Pa. '76
*WILLIAMS, FREDERICK H., ... Box 502, Orange, N. J. '80
*WILLIAMS, PROF. J. F., ... Troy, N. Y. '83
*WILLIAMS, HENRY, ... Butte City, Montana. '75
*WILLIAMS, JOHN J., ... 32 Merchants' Exchange, San Francisco, Cal. '83
*WILLIAMS, JOHN T., ... Forty-Fourth Street And East River, New York City. '74
*WILLIAMS, LEWIS,... Bishee, Arizona. '83
*WILLIAMS, SAMUEL T., ... Care Of Henry Disston & Sons, Philadelphia. '79
*WILSON, EUGENE B.,.................................. Cross Creek Collieries, Drifton, Pa. '83
*WILSON, JOHN A., ... 435 Cherstnut Street, Philadelphia. '76
*WILSON, J. CHESTER, ... 419 Walnut Street, Philadelphia. '84
*WILSON, JOHN T.,.................................. Wilson, Walker & Co., Pittsburgh, Pa. '79
*WILSON, JOSEPH M., ... 49 Monument Ave., Charlestown, Mass. '82
*WILSON, N. R.,... P. O. Box 517, Leadville, Colorado. '81
*WILSON, WILLIAM A.,.. Park City, Utah. '83
*WINSLOW, ARTHUR,... P. O. Box 274, Raleigh, N. C. '81
†WISHON, WALTER W., ... Colorado Springs, Colorado. '82
*WISTER, JONES,... 230 S. Fourth Street, Philadelphia. '79
*WITHERBEE, FRANK S., ... Port Henry, Essex Co., N. Y. '76
*WITHERBEE, T. F.,.. Port Henry, Essex Co., N. Y. '71
*WITHERBEE, W. C., ... Port Henry, Essex Co., N. Y. '80
*WITHEROW, J. P., ... Lewis Block, 6th Ave. And Smithfield St., Pittsburgh, Pa. '76
*WITHERSPOON, JAMES,... Laredo, Texas. '81
†WITTMACK, CHARLES A.,` .... P. O. Box 1032, New York City. '82
*WITTMAN, N. B.,.......................... Pittsburgh Steel Casting Co., Pittsburgh, Pa. '84
†WOLCOTT, HENRY R., ... Denver, Colorado. '82
*WOLF, THEODORE G., ... Scranton, Pa. '79
*WOLFE, ALBERT H., ... 696 W. Monroe Street, Chicago, Ill. '82
*WOLFF, DR. FR. M., ... 12 Hohenzollernstrasse, Berlin, W., Prussia. '82
*WOLISTON, R. T.,.. Galena, Colorado. '85
*WOOD, A. B., ... Ann Arbor, Mich. '82
*WOOD, FREDERICK W., ... Steelton, Danphin Co., Pa. '79
*WOOD, THOMAS D., ... Mckeesport, Pa. '79
†WOOD, W. DEWEES,.. 111 Water Street, Pittsburgh, Pa. '83
*WOOD, W. J., ... Collinsville, Conn. '81
*WOODBURY, L. S., ... Calumet, Mich. '80

*WOODWARD, E. H., ... 54 Cliff Street, New York City. '81
*WOODWARD, W. H., ... Wheeling, Ala. '84
*WORTHINGTON, CHAS. C., ... 145 Broadway, New York. '85
*WRIGHT, CHARLES E., ... Marquette, Mich. '80
*WRIGHT, JAMES N, ... Calumet, Mich. '79
*WRIGHT, WHITAKER, ... 413 Walnut Street, Philadelphia. '81
*WURTS, CHARLES P., ... New Haven, Conn. '81
*WÜRGLER, A., ... 7 Rue Viéte, Paris, France. '85

*YARDLEY, THOMAS W., ... Troy, N. Y. '83
*YEATMAN, POPE, ... 503 Ware Ave., St. Louis, Mo. '83
*YOUNG, JAMES B., ... Phoenix Roll Works, Pittsburgh, Pa. '79
*YOUNG, W. D., ... Corner Fifteenth And Etna Streets, Pittsburgh, Pa. '83

*ZACHARIAS, H. C., ... Shamokin, Pa. '84
†ZUKOSKI, EDMUND L., ... 1829 Kennett Place, St. Louis, Mo. '84

Honorary Members, 6; Members, 1202; Associates, 153; Foreign Members, 48.

NOTE.--The Following Names Of Persons Elected At The XLIId Meeting, at Chattanooga, May, 1885, are Not Included In The Above List:

*ANDERSON, J. F. T., ... Tredegar Iron Co., Richmond, Va.
*BARTLETT, JAMES H, ... Standard Building, Montreal, Canada.
†BERRY, WILTON G., ... School Of Mines, New York City.
*CHENHALL, JAMES W., ... Anaconda, Montana.
*COLYAR, LEWIS S., ... Chattanooga, Tenn.
*FROSSARD, JOHN D., ... Montreal, Canada.
*HARGREAVES, HENRY W., ... Dayton, Tenn.
*HILL, J. T., ... Whiteside, Tenn.
*HIMROD, CHARLES, ... 186 Dearborn St., Chicago, Ill.
*JOHNS, L. W., ... Pratt Mines, Ala.
*JOHNSTON, JAMES, ... 417 Straight St., Paterson, N. J.
*LEAVENS, H. W., ... 411 Larimer St., Denver, Colo.
*LIPPINCOTT, J. E., ... Swift's I. & S. Mills, Cincinnati, O.
*MCLENNAN, J. S., ... Sidney, Cape Breton, N. S.
*MALO, ALBERT, ... Puente De Sta. Ana, No. 6 Mexico, Mex.
*MARKLE, ALVAN, ... Hazleton, Pa.
*MILLER, GEORGE S., ... Benwood, W. Va.
*NORTON, S., ... Burden, N. Y.
†OSTERHELD, TH. W., ... Yonkers, N. Y.
*PILLSBURY, D. B., ... Whiteside, Tenn.
*POWELL, WM. H., ... Belleville, Ill.
*RICKARD, THOMAS., ... 58 Lombard St., London, Eng.
*RUEGER, R. C., ... Anaconda, Mont.
*SCOVELL, MINOR, ... Pittsburgh, Pa.
*SHOOK, A. M., ... Tracy City, Tenn.
*SIMPSON, C. D., ... Scranton, Pa.

*STOCKWELL, N. S., ... U. S. Patent Office, Washington, D. C.
*THROPP, JOSEPH E., ... Edge Hill, Pa.
*VAN HISE, C. R., ... Madison, Wis.
†WALKER, JOSEPH R., ... Salt Lake City, Utah.
*WEIMAR, ASA A., ... Lebanon, Pa.
*WEIMAR, JOHN A., ... Lebanon, Pa.
*WESTON, FRANCIS E., ... Upland, Pa.
*WILDER, J. T., ... Chattanooga, Tenn.

Deceased.

BLOSSOM, T. M., ... 1876
BRIGGS, ROBERT, ... 1882
BRINSMADE, J. B., ... 1884
BROWN, A. J., ... 1875
CALDWELL, W. B., JR., ... 1880
CAMERON, JAMES R., ... 1881
CHISHOLM, HENRY, ... 1881
CLARK, HENRY G.. 1881
CLEMES, J. P., ... 1876
CONVERSE, JAMES B., ... 1883
DADDOW, S. H., ... 1875
D'ALIGNY, H. F. Q., ... 1875
DAVIDSON, D. R., ... 1884
DE PEIGER, R. F. J., ... 1883
DICKSON, THOMAS, ... 1884
DRESSER, CHARLES A., ... 1878
DWIGHT, W. S., ... 1883
FERNEKES, ANTON, ... 1884
FIRMSTONE, WILLIAM, ... 1877
FULLER, JOHN T., ... 1880
GOULD, ROBERT A., ... 1878
GRIFFEN, JOHN, ... 1884
GRUNER, L., ... 1883
HALL, JAMES F., ... 1884
HARRIS, STEPHEN, ... 1874
HEALY, MORRIS, ... 1881
HOLLEY, A. L., ... 1882
HUNT, THOMAS, ... 1872
HUSSEY, C. C., ... 1884
HYNDMAN, E. K., ... 1884
INGERSOLL, S. WARREN, ... 1884
JENNEY, F. B., ... 1876
JERNEGAN, J. L., ... 1881
LEE, WASHINGTON, ... 1872
LEISENRING, JOHN, ... 1884
LIEBENAU, CHARLES VON, ... 1875

TABLE

SHOWING THE OFFICERS OF THE INSTITUTE FROM ITS ORGANIZATION TO THE PRESENT TIME.

The offices of President, Vice-President, Manager, Secretary and Treasurer are indicated by their initials.

	1871	1872	1873	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884	1885
Alexander, John S.,......	…	…	…	M	M	M	…	…	…	…	M	M	M	…	..
Ashburner, C. A.,..........	…	…	…	…	…	…	…	..	..	..	…	…	…	…	M
Asmus, George, ...	…	…	…	…	…	…	…	M	M	M	..	..	…	..	..
Bayles, James C., ...	…	…	…	…	…	…	…	…	…	M	M	M	..	P	P
Birklnbine, John, ...	…	…	…	..	..	..	…	…	…	…	…	…	M	M	M
Blair, Thomas S., ...	…	…	…	M	M	M	..	…	…	…	…	…	…	…	..
Blake, William P., ...	V	V	V	V	…	V	V	…	…	…	…	…	…	…	..
Blandy, John F.,............	V	V	V	…	…	…	…	V	V	…	…	…	…	…	..
Brooks, Thos. B., ...	…	M	…	…	…	…	…	…	…	…	…	…	..	…	..
Buck, Stuart M., ...	…	…	…	…	…	…	…	…	…	..	…	…	M	M	M
Burden, James A., ...	…	…	…	…	…	…	…	…	…	V	V	…	…	…	..
Burnham, William,.......	…	…	…	…	…	…	…	…	…	…	…	M	M	M	..
Church, John A., ...	…	…	…	…	…	…	…	…	M	M	M	…	…	…	..
Cogswell, W. B.,...........	…	…	…	V	V	…	…	…	…	…	…	…	…	…	
Cook, Edgar S., ...	…	…	…	…	…	…	…	…	…	…	…	…	…	M	M
Coryell, Martin,..........	S	S	M	M	M	…	…	…	…	…	…	…	…	…	..
Cox, E. T.,.......................	…	…	…	…	…	…	M	M	M	…	…	…	…	…	..
Coxe, Eckley B., ...	V	V	V	V	…	V	V	P	P	…	…	…	…	V	V
Coxe, Wm. E. C., ...	…	…	…	…	…	…	…	…	M	M	M	…	…	…	M
Drinker, Henry S.,........	…	…	…	…	…	…	…	…	…	…	…	…	…	…	..
Drown, Thomas M., ...	…	M	S	S	S	S	S	S	S	S	S	S	S	…	..
Dudley, Charles B., ...	…	…	…	…	…	…	…	…	…	V	V	…	…	…	..
Egleston, Thomas, ...	M	V	V	V	…	V	V	…	…	…	…	…	…	V	..
Eilers, Anton, ...	…	…	…	M	M	M	…	…	…	…	…	M	M	M	V
Ely, T. N.,......................	…	…	…	…	…	…	…	…	…	…	…	V	V	…	..
Emmons, S. F., ...	…	…	…	…	…	…	…	…	…	…	…	…	V	V	..
Firmstone. Frank,.........	…	…	M	..	V	V	..	…	…	…	…	…	…	M	..
Frazer, Persifor	…	…	…	…	…	…	…	…	…	V	V	…	…	…	M
Frazier, B. W., ...	…	…	…	M	M	M	…	M	M	M	…	…	…	…	..
Fritz, John, ...	…	…	…	…	V	…	…	…	…	…	…	…	…	…	..
Gaujot, E., ...	…	…	…	…	…	…	…	…	…	…	…	…	…	…	
Heinrich, Oswald J.	M	M	…	…	..	..	..	…	…	…	…	…	…	…	V
Hewitt, Abram S., ...	…	…	…	..	M	M	M	…	…	…	…	…	…	…	..
Holley, A. L., ...	…	M	M	M	M	P	…	..	…	…	…	…	…	…	..
Howe, H. M., ...	…	…	…	V	P	…	M	M	M		…	…	…	…	..
Hunt, Robert W., ...	…	…	…	…	…	…	…	…	V	V	…	…		…	..
Hunt, T. Sterry,............	…	…	…	…	…	M	M	M	…	…	…	…	P	…	..
Kent. Joseph C.,............	…	…	M	M	M	…	P	…	…	…	…	…	…	…	..
Kerr, W. C., ...	…	…	…	V	V	…	…	…	…	…	…	…	…	…	..
Keyes, W. S., ...	…	…	…	…	…	…	…	…	…	…			V	V	..
Kimbali., J. P., ...	…	…	…	…	…	…	…	…	…	M	M	M	…	…	..
Lesley, J. P.,..................	…	…	…	…	…	…	…	…	…	…	V	V	…	…	..
Lewis, James F., ...	…	M	M	M	…	…	…	…	…	…	…	…	…	…	..
Macdonald, Charles, ..	…	…	…	…	…	…	…	…	M	M	M	…	…	…	..
Maynard, George W., ..	…	…	…	…	…	…	…	…	…	…	…	V	V	…	..
McCreath, Andrew S.,.	M	M	M	M	…	…	…	…	…	…	…	…	…	M	..
McNair, T. S., ...	…	…	…	…	…	…	…	…	…	…	…	M	M	M	M
Metcalf, William,........	M	…	…	…	…	…	…	…	…	…	…	…	…	…	..
Moffat, E. S.,.................	…	…	…	…	…	…	…	V	V	…	P	…	…	…	..
Munroe, H. S., ...	…	…	…	…	…	…	…	…	…	…	…	…	M	M	..
Newberry, J. S., ...	…	…	…	…	…	…	…	…	…	…	M	M	M	…	M
Pearse, Richard, ...	…	…	…	…	…	M	M	M	…	…	…	…	…	…	..
Pearse, John B., ...	…	…	…	…	…	…	V	V	…	…	…	…	…	…	..
Pechin, E. C., ...	…	M	V	…	V	V	…	…	…	…	…	…	…	V	V
Petherick, Thomas, ...	M	M	…	…	…	…	…	…	…	…	…	…	…	…	V
Pettee, Wm. H.,.............	…	…	M	…	…	…	…	…	…	…	V	V	…	…	..
Potter. William B., ...	…	…	…	…	…	…	…	M	M	M	…	…	…	…	..
Powell, J. W., ...	…	…	…	…	…	…	…	…	…	…	…	V	V	…	..
Prime, Fred., Jr.,...........	M	M	M	…	…	…	…	…	…	…	…	…	…	…	..
Pumpelly, Raphael,......	M	…	…	…	…	…	…	…	…	…	…	…	…	…	..
Rand, Theodore D., ...	…	…	T	T	T	T	T	T	T	T	T	T	T	T	..
Randolph, J. C. F., ...	…	…	…	…	…	…	…	…	…	…	M	M	M	…	T
Raymond. R. W.,...........	V	P	P	P	…	V	V	…	…	…	…	…	…	S	..
Richards, Robert H.,....	…	…	…	…	…	…	…	…	V	V	…	…	…	…	S
Roberts, Percival, Jr., .	…	…	…	…	…	…	…	…	…	M	M	M	…	…	..
Rothwell, Richard P., .	M	V	V	…	V	V	…	…	…	…	…	P	…	…	..
Shinn, William P., ...	…	…	…	…	…	…	V	V	…	P	…	…	…	…	..
Smock, John C., ...	…	…	…	..	M	M	M	…	…	…	…	…	…	…	..
Spilsbury, E. G., ...	…	…	…	…	…	…	..	..	…	…	…	…	…	…	..
Stetefeldt, C. A.,..........	…	…	…	..	…	…	…	…	…	…	…	…	…	…	M
Swoyer, J. H.,................	V	…	…	..	…	…		..	…	..	…	…	…	…	V
Symons, W. R., ...	V	V	M	M	…	…	…	..	…	..	..	..	…	…	..
Thurston, Robert H., ...	…	…	…	…	…	…	…	V	V	..	..	..	..	..	..
Thomas, David, ...	P	…	…	…	…	…	…	…	…	..	..	..	..	..	..
Thomas, Samuel,...........	..	…	…	…	…	…	…	…	V	V	..	…	..	..	..
Thompson,Charles O., .	…	…	…	…	…	..	..	..	…	…	V	V	..	..	..
Wellman, S. T., ...	…	…	…	..	..	..	..	..	…	..	..	..	V	V	..
Williams, T. M., ...	M	…	…	..	..	..	..	..	…	..	..	..	..	..	..
Williamson, J. Pryor,.....	T	T	…	..	..	..	..	..	…	..	..	..	..	..	..
Witherbee, Thos. F., ...	…	…	…	..	..	M	M	M	…	..	..	..	..	..	..

LIST OF THE MEETINGS OF THE INSTITUTE AND THEIR LOCAL-ITIES FROM ITS ORGANIZATION TO FEBRUARY, 1885.

Number.	Place.	Date.	Transactions.	
I.	Wilkesbarre, Pa.,*	May, 1871,	i.	3
II.	Bethlehem, Pa.,	August, 1871,	i.	10
III.	Troy, N. Y.,	November, 1871,	i.	13
IV.	Philadelphia, Pa.,	February, 1872,	i.	17
V.	New York, N. Y.,*	May, 1872,	i.	20\
VI.	Pittsburgh, Pa.,	October, 1872.	i.	25
VII.	Boston, Mass.,	February, 1873,	i.	28
VIII.	Philadelphia, Pa.,*	May, 1873,	ii.	3
IX.	Easton, Pa.,	October, 1873,	ii.	7
X.	New York, N. Y.,	February, 1874,	ii.	11
XI.	St. Louis, Mo.,*	May, 1874,	iii.	3
XII.	Hazleton, Pa.,	October, 1874,	iii.	8
XIII.	New Haven, Conn.,	February, 1875,	iii.	15
XIV.	Dover, N. J.,*	May, 1875,	iv.	3
XV.	Cleveland, O.,	October, 1875,	iv.	9
XVI.	Washington, D. C.,	February, 1876,	iv.	18
XVII.	Philadelphia, Pa.,†	June, 1876,	v.	3
XVIII.	Philadelphia, Pa.,	October, 1876,	v.	19
XIX.	New York, N. Y.,	February, 1877,	v.	27
XX.	Wilkesbarre, Pa.,*	May, 1877,	vi.	3
XXI.	Amenia, N. Y.,	October, 1877,	vi.	10
XXII.	Philadelphia, Pa.,	February, 1878,	vi.	18
XXIII.	Chattanooga, Tenn.,*	May, 1878,	vii.	3
XXIV.	Lake George, N. Y.,	October, 1878,	vii.	103
XXV.	Baltimore, Md.,*	February, 1879,	vii.	217
XXVI.	Pittsburgh, Pa.,	May, 1879,	viii.	3
XVII.	Montreal, Canada,	September, 1879,	viii.	121
XXVIII.	New York, N. Y.,*	February, 1880,	viii.	275
XXIX.	Lake Superior, Mich.,	August, 1880,	ix.	1
XXX.	Philadelphia, Pa.,*	February, 1881,	ix.	275
XXI.	Staunton, Va.,	May, 1881,	x.	1
XXXII.	Harrisburg, Pa.,	October, 1881,	x.	119
XXXIII.	Washington, D. C.,*	February, 1882,	x.	225
XXXIV.	Denver, Col.,	August, 1882,	xi.	1
XXXV.	Boston, Mass.,*	February, 1883,	xi.	217
XXXVI	. Roanoke, Va.,	June, 1883,	xii.	3
XXXVII.	Troy, N. Y.,	October, 1883,	xii.	175
XXXVIII.	Cincinnati, O.,*	February, 1884,	xii.	447
XXXIX	Chicago, Ill.,	May, 1884,	xiii.	3
XL.	Philadelphia, Pa.,	September, 1884,	xiii.	287
XLI.	New York, N. Y.,	February, 1885,	xiii.	587

* Annual meeting for the election of officers. The rules were amended at the Chattanooga meeting, May, 1878, changing the annual election from May to February.

† Begun in May at Easton, Pa., for the election of officers, and adjourned to Philadelphia.

PUBLICATIONS.

The publications of the Institute comprise:

1. The minutes of the Proceedings of each Meeting, published in pamphlet form.

2. Such of the papers presented or read by title at each Meeting as are furnished by the authors and approved by the Council for full publication. (In nearly all cases in which papers, the titles of which appear in the Proceedings, are not subsequently published, they have been with drawn by the authors.) These papers are published separately in pamphlet form, and are marked "Subject to Revision."

3. Annual volumes of *Transactions,* containing the list of officers and members, rules, etc.; the Proceedings and the papers, *revised for final publication*. (In this revision after the preliminary publication, authors are permitted to use the largest liberty; and the changes and additions made in papers are sometimes important. It should be borne in mind, by those who study or quote a paper in the preliminary edition, that they may not have in that form the ultimate and deliberate expression of the author's views. It should be added, however, that in the majority of cases there is no essential change, the correction of typographical errors and additions of later information being the usual alterations.)

4. Special editions of separate papers, for which there is demand. These are fully revised, and usually issued in pamphlet covers.

5. Books. (Under this head the only publications thus far have been an Index to Vols. I. to X. inclusive, a Glossary of Mining and Metallurgical Terms, and a Memorial of Alexander Lyman Holley.)

All the foregoing publications are sent free to members and associates *not in arrears at the time of publication*. They are also for sale at the office of the Secretary, or are sent to purchasers by mail or express, charges paid, on receipt of the price by the Secretary, as follows:

Classes 1 and 2, above mentioned,-price not uniform-a small sum, in no case exceeding 20 cents per copy, to cover cost of printing, storage, clerk-hire, postage, etc.

Class 3 (*Transactions*), at $5 per volume in paper covers, or $6 bound in half-morocco.

Class 4. This class now includes " Steel Rails " (Papers by Messrs. Sandberg, Dudley and Holley, and discussions at two meetings in 1881, from vol. ix. of the *Transactions),* price $1; "Technical Education"

(Papers and discussions at the XVIIth [Philadelphia] meeting, in 1876 -mostly not in the Transactions), price 50 cents; "The Law of the Apex" (including the Appendix), by R. W. Raymond, price 25 cents; " List of Members, Rules, etc.," price 25 cents.

Class 5. Index to Vols. I. to X., inclusive, of the *Transactions*, price, in paper covers, $1; in half-morocco, $2. "Memorial of Alexander Lyman Holley," in cloth, with frontispiece-portrait, price $2. "Glossary of Mining and Metallurgical Terms," by R. W. Raymond (from vol. ix. of the *Transactions)*, in cloth, price 50 cents.

All communications and remittances should be addressed to R. W. Raymond, Secretary, P. O. Box 223, New York City.

RULES

ADOPTED MAY, 1873. AMENDED MAY, 1875, MAY, 1877, MAY, 1878, FEBRUARY, 1880, and FEBRUARY, 1881.

I.

OBJECTS.

THE objects of the AMERICAN INSTITUTE OF MINING ENGINEERS are to promote the Arts and Sciences connected with the economical production of the useful min erals and metals, and the welfare of those employed in these industries, by means of meetings for social intercourse, and the reading and discussion of professional papers, and to circulate, by means of publications among its members and associates, the information thus obtained.

II.

MEMBERSHIP.

The Institute shall consist of Members, Honorary Members, and Associates. Members and Honorary Members shall be professional mining engineers, geologists, metallurgists, or chemists, or persons practically engaged in mining, metallurgy, or metallurgical engineering. Associates shall include all suitable persons desirous of being connected with the Institute, and duly elected as hereinafter provided. Each person desirous of becoming a member or associate shall be proposed by at least three members or associates, approved by the Council, and elected by ballot at a regular meeting upon receiving three-fourths of the votes cast, and shall become a member or associate on the payment of his first dues. Each person proposed as an honorary member shall be recommended by at least ten members or associates, approved by the Council, and elected by ballot at a regular meeting on receiving nine-tenths of the votes cast; Provided, that the number of honorary members shall not exceed twenty. The Council may at any time change the classification of a person elected as associate, so as to make him a member, or vice versa, subject to the approval of the Institute. All members and associates shall be equally entitled to the privileges of membership; Provided, that honorary members shall not be entitled to vote or to be members of the Council.

Any member or associate may be stricken from the list on recommendation of the Council, by the vote of three-fourths of the members and associates present at any annual meeting, due notice having been mailed in writing by the Secretary to the said member or associate.

III.

DUES.

The dues of members and associates shall be ten dollars per annum, payable in advance at the annual meeting; Provided, that persons elected at the meeting following the annual meeting shall pay eight dollars, and persons elected at the meeting preceding the annual meeting shall pay four dollars as dues for the current year. Honorary members shall not be liable to dues. Any member or associate may become, by the payment of one hundred dollars at any one time, a life member or associate, and shall not be liable thereafter to annual dues. Any member or associate in arrears may, at the discretion of the Council, be deprived of the receipt of publications, or stricken from the list of members when in arrears for one year; Provided, that he may be restored to membership by the Council on payment of all arrears, or by re-election after an interval of three years.

IV.

OFFICERS.

The affairs of the Institute shall be managed by a Council. consisting of a President, six Vice-Presidents, nine Managers, a Secretary and a Treasurer, who shall be elected from among the members and associates of the Institute at the annual meetings, to hold office as follows:

The President, the Secretary, and the Treasurer for one year (and no person shall be eligible for immediate re-election as President who shall have held that office subsequent to the adoption of these rules, for two consecutive years), the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. At each annual meeting a President, three Vice-Presidents, three Managers, a Secretary and a Treasurer shall be elected, and the term of office shall continue until the adjournment of the meeting at which their successors are elected.

The duties of all officers shall be such as usually pertain to their offices, or may be delegated to them by the Council or the Institute; and the Council may in its discretion require bonds to be given by the Treasurer. At each annual meeting the Council shall make a report of proceedings to the Institute, together with a financial statement.

Vacancies in the Council may occur by death or resignation; or the Council may, by a vote of the majority of all its members, declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the Council meetings or perform the duties of his office. All vacancies shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; Provided, that the said appointment shall not render him ineligible at the next annual meeting.

Five members of the Council shall constitute a quorum; but the Council may appoint an Executive Committee, or business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary, and recorded by him with the minutes.

V.

ELECTIONS.

The annual election shall be conducted as follows: Nominations may be sent in writing to the Secretary, accompanied with the names of the proposers, at any time not less than thirty days before the annual meeting; and the Secretary shall, not less than two weeks before the said meeting, mail to every member or associate (except honorary members), a list of all the nominations for each office so received, stamped with the seal of the Institute, together with a copy of this rule, and the names of the persons ineligible for election to each office. And each member or associate, qualified to vote, may vote, either by striking from or adding to the names of the said list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing said altered or prepared ballot with his name, and either mailing it to the Secretary or presenting it in person at the annual meeting: Provided, that no member or associate in arrears since the last annual meeting shall be allowed to vote until the said arrears shall have been paid. The ballots shall be received and examined by three Scrutineers, appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices shall be declared elected, and the Scrutineers shall so report to the presiding officer. The ballots shall be destroyed, and a list of the elected officers, certified by the Scrutineers, shall be preserved by the Secretary.

VI.

MEETINGS.

The annual meeting of the Institute shall take place on the third Tuesday of February, at which a report of the proceedings of the Institute and an abstract of the accounts shall be furnished by the Council. Two other regular meetings of the Institute shall be held in each year, at such times and places as the Council shall select, and notice of all meetings shall be given by mail, or otherwise, to all members and associates, at least twenty days in advance. Special meetings may be called whenever the Council sees fit; and the Secretary shall call a special meeting on a requisition signed by fifteen or more members. The notices for special meetings shall state the business to be transacted, and no other shall be entertained.

Every question which shall come before any meeting of the Institute, shall be decided, unless otherwise provided by these Rules, by the votes of a majority of the members then present. Any member or associate may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

VII.

PAPERS;

The Council shall have power to decide on the propriety of communicating to the Institute any papers which may be received, and they shall be at liberty, when they think it desirable, to direct that any paper read before the Institute, shall be printed in the Transactions. Intimation, when practicable, shall be given, at each general meeting, of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting. The reading of papers shall not be delayed beyond such hour as the presiding officer shall think proper; and the election of members or other business may be adjourned by the presiding officer, to permit the reading and discussion of papers.

The copyright of all papers communicated to, and accepted by, the Institute, shall be vested in it, unless otherwise agreed between the Council and the author. The author of each paper read before the Institute shall be entitled to twelve copies, if printed, for his own use, and shall have the right to order any number of copies at the cost of paper and printing, provided said copies are not intended for sale. The Institute is not, as a body, responsible for the statements of fact or opinion advanced in papers or discussions at its meetings, and it is understood that papers and discussions should not include matters relating to politics or purely to trade.

VIII.

AMENDMENTS.

These Rules may be amended at any annual meeting by a two-thirds vote of the members present, provided that written notice of the proposed amendment shall have been given at a previous meeting.

INDEX.

[NOTE.-In this Index, authors' names are printed in SMALL CAPITALS, and the titles of papers in italics. Casual references, giving little or no information about the subject referred to, are indicated by inclosing the page-numbers in brackets. The distinction between such references and those not thus marked is not always sharply definable. A bracketed number opposite the title of a paper refers to the first mention of the paper, i.e., to the record, in the Proceedings, of its presentation. Where the name of a paper is followed by a bracketed number only, it is indicated that the paper, though presented at a meeting, has not been printed in the Transactions. It sometimes happens that the authors desire to change the titles of their papers after the Proceedings have been printed. In some such cases, the papers are indexed under both titles, but only one of the titles is indexed under the author's name.]

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