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*JONES, W. R., ... Edgar Thomson Steel Works, Pittsburgh, Pa.
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*KENT, WILLIAM ST. G.,. .... Phillipsburg, N. J.
*KENT, WILLIAM,. .... Stevens Institute, Hoboken, N. J.
*KERR, PROF. W. C.,.......... State Geologist, Raleigh, N. C.
*KEYES, W. S., ... care Messrs. George & Loughborough, San Francisco, Cal.
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*KING, CLARENCE,. .... 23 Fifth Avenue, New York City.
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*KNAPP, JOHN A.,. .... Swansea, Inyo Co., Cal.
*KUDLICH, EDGAR,. .... Drifton, Jeddo P. O., Luzerne, Co., Pa.
*LAMBORN, DR. ROBT. H., ... 216 South Fourth Street, Philadelphia
.†LAUDER, WILLIAM,. .... Riddlesburg, Bedford Co., Pa.
†LAUGHLIN, HENRY A.,. .... Pittsburgh, Pa.
†LAWRENCE, ROBERT,. .... Flushing, Long Island, N. Y.
*LEAVITT, E. D., JR.,. .... 60 Magazine Street, Cambridgeport, Mass.
*LEE, R. H.,. .... Lewistown, Pa.
*LEE, RICHARD HENRY,. .... Phillipsburg, Montana.
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*LEWIS, JAMES F.,.......... Amenia, Dutchcss Co., N. Y.
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†LORD, N. W.,. .... Riverside, Cincinnati, Ohio.
*LORENZ, WILLIAM,.......... 227 South Fourth Street, Philadelphia.
*LYMAN, BENJAMIN SMITH,. .... Yokohama, Japan.

*MCCLELLAN, ARTHUR,. .... Drifton, Jeddo P.O., Luzerne Co., Pa.
†MCCLINTOCK, ANDREW H.,. .... Wilkes-Barre, Pa.
*MCCRMICK, HENRY, ... Harrisburg, Pa.
*MCCREATH, ANDREW S., ... 223 Market Street, Harrisburg, Pa.
*MCDERMOTT, WALTER, ... 730 Jefferson Street, Detroit, Mich.
*MCINTIRE, DR. CHARLES, JR., ... Easton, Pa.
*MCKEE, W M. WEIR, ... Twenticth and Tioga Streets, Philadelphia, Pa.
*MCKEAVI, JOHN, ... Dunbar, Fayette Co., Pa.
*McNair, THOMAS S.,.......... Hazleton, Pa.

†McVICKER, JOHN,. .... Salt Lake City, Utah.
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*MACMARTIN, ARCHIBALD, ... .168 Fifth Avenue, New York City.
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*MACY, ARTHUR,. .... 159 Henry Street, 1 York City.
*MAFFET, W. R.,.. Wilkes-Barre, Pa.
†MAGHEE, J. HOLME,. .... 16 East Fifty-fourth Street, New York City.
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†MANNING, HENRY, ... Youngstown, Ohio.
MARKS, PROF. W. D.,................................ University of Pennsylvania, Philadelphia.
*MATHEWS, OLIVER, ... Burlington, Wisconsin.
*MAURY, M. F., ... Charleston, Kanawha Co., West Va.
*MAXON, JOHN H.,. .... 324 North Third Street, St. Louis, Mo.
*MAYNARD, GEORCE W.,... 24 Cliff Street, New York City.
†MEEKER, A. B.,. ....92 Washington Street, Chicago, Ill.
*MEIER, E. D.,. .... 26 North Main Street, St. Louis, Mo.
*MEIER, JOHN W.,... 26 North Main Street, St. Louis, Mo.
*MRLLISS, D. ERNEST,. .... 52 Broadway, New York City.
*MERCUR, FREDERICK,. .... Wilkes-Barre, Pa.
*MERRY, HENRY,...Negaunce, Marquette Co , Mich.
*METCALF, WILLIAM,. .... Pittsburgh, Pa.
*MEYER, ARTHUR H.,. .... 907 Hickory Street, St. Louis, Mo.
*MICKLEY, EDWIN,. .... Hokendauqua, Pa.
*MICKLEY, J. W.,. .... Hokendauqua, Pa.
*MILLER, REUBEN,... Pittsburgh, Pa.
*MILLHOLLAND, JAMES A.,. .... Mount Savage. Md.
*MOFFAT, ED. S.,... Dover, N. J.
*MOORE, JAMES,........................... Sixteenth and Buttonwood Streets, Philadelphia.
*MOORE, PHILIP N., ...Lexington, Ky.
†MOREWOOD, HENRY FRANCIS, 45 W. Thirty-seventh Street, New York City
*MORGAN, CHARLES H., ... Worcester, Mass.
*MORRELL, D. J.,. .... Johnstown, Pa.
†MORRIS, ISRAEL W.,..238 South Third Street, Philadelphia.
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*NORWOOD, CHARLES J., ... Lexington, Ky.
*NOURSE, CHARLES J.,.. Columbia, Lancaster Co., Pa
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*PARDEE, I. P., ... Hazleton, Pa.
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*PARKES, JOHN C., ... North Chicago Rolling Mill Co., Chicago, Ill.
*PARKIN, CHARLES, ... Pittsburgh, Pa.
†PARSONS, CHARLES B., ... Cadet, Missouri.
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*PETERS, JOHN R., ... Dover, New Jersey.
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*PISTOR, WILLIAM, ... 35 Broadway, New York City.
*PITMAN, S. MINOT, ... College Hill, Mass.
*PLATER, JOHN E., ... Eureka, Nevada.
*PLATT, FRANKLIN, ... 139 South Fifth Street, Philadelphia.
*PLATT, JOSEPH C., JR., ... Waterford, New York.
*PLATT, W. G., ... 139 S. Fifth Street, Philadelphia.
*PLEASANTS, GEN. HENRY, ... Pottsville, Pa.
*PLUMB, W. H., ... Mauch Chunk, Pa.
*POLHEMUS, J. S., ... 59 State Street, Albany, N. Y.
*POLLOCK, WM. B., ... Youngstown, Ohio.
*PORTER, J. A., ... Silverton, San Juan Co., Colorado.
*POTTER, O. W., ... North Chicago Rolling Mill Co., Chicago, Ill.
*POTT, JOHN W., ... Tremont, Schuylkill Co., Pa.
*POTT, PROF. WILLIAM B., ... Washington University, St. Louis, Mo.
*POTT, JOSEPH, ... Schellbourne, White Pine Co., Nevada.
*POTTS, J. THORPE, ... 119 S. Fourth Street, Philadelphia.
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*PRIME, PROF. FREDERICK, JR., ... Lafayette College, Easton, Pa.
*PROCTOR, JOHN R., ... Lexington, Ky.
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*RADER, CHARLES I., ... 133 South Sixth Street, Easton, Pa.

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*RAND, ADDISON D., ... 21 Park Row, New York City.
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*ROEPPER, CHARLES W., ... Bethlehem, Pa.
*ROLKER, CHARLES M., ... P. O. Box 899, New York City.
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*SANDERS, RICHARD H, ... 139 South Fifth Street, Philadelphia.
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*SCHIRMER, J. F. L., ... Denver, Colorado.
†SCHNEIDER, ... Albert F., 325 Vine Street, Cincinnati, Ohio.
*SCHROPP, ABRAHAM S., ... Bethlchem, Pa.
†SCOTT, N. I., ... Twenty Mile Stand, Ohio.
*SCRANTON, W. H., ... Oxford, N. J.
*SCRANTON, W. W., ... Scranton, Pa.
†SCHWARTZ, J. E., ... Pennsylvania Lead Co., 44 Wood St., Pittsburgh, Penna.
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*SHEAFER, P. W., ... Pottsville, Pa.

*SHEPHERD, PROF. FORREST, ... St. Louis, Mo.
*SHERRERD, ALEXANDER H., ... Scranton, Pa.
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*SHINN, WILLIAM P., ... Pittsburgh, Pa.
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*SINGER, WILLIAM H., ... Pittsburgh, Pa.
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*SMITH, H. S., ... Jollet, Ill.
*SMITH, DR. J. LAWRENCE, ... Louisville, Ky.
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†STAMBAUGH, JOHN, ... Youngstown, Ohio.
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*STEINBACH. E., ... Del Norte, Rio Grande Co., Colorado,
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*ST. JOHN, I. M., ... Chesapeake And Ohio Railroad, Richmond, Va.
*STONE, A. B., ... Cleveland Rolling Mill Co., Cleveland, Ohio.
*STOKES, JOSEPH, ... New Jersey Steel And Iron Co., Trenton. N. J.
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*SYMONS, W. R., ... Pottsville, Pa.

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*WARD, WILLARD P., ... Cartersville, Bartow Co., Ga.
*WARREN, H. L. J., ... Hotel Vendome, Boston, Mass.
*WARTENWEILER, ... Alfred, Musquiz, Coabuita, Mexico (Via Eagle Pass,Texas).
*WEBERLING, CHARLES, ... Panamint, Inyo Co., California.
†WEBSTER, B. C., ... Bethlehem, Pa.
*WEBSTER, WM. R.,... 1426 Sprace Street, Philadelphia.
†WEEKS, HORACE H., ... School Of Mines, New York City.
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*WEIMAR, P. L.,.. Lehanon, Pa.
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*WELCH, ASHBEL, ... Lambertville, N. J.
†WELCH, BENJAMIN G., ... Riverside, Northumberland Co., Pa.
*WELLMAN, S. T.,.. Cleveland, Ohio.
†WELLS, CALVIN, ... Pittsburgh, Pa.
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*WERTH, JAS. R., ... Clover Hill R. R. Co., Richmond, Va.
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*WETHERILL, J. PRICE,... Tremont, Schuylkill Co., Pa.
*WETMORE, EDWIN A., ... Marquette, Mich.
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*Whitehill, H. R., ... Carson City, Nevada.
*Whiting, S. B., ... Pottsville, Pa.
†Whitney, A. J., ... Harrisburg, Pa.
†Whitney, Eli, Jr., ... Whitneyville Armory, New Haven, Conn.
†Wick, Caleb B., ... Youngstown, Ohio.
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*Wood, Henry, ... Streator, La Salle Co., Ill.
*Woodward, Richard W., ... Lake City, Colorado.
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†Wright, Harrison, ... Wilkes-Barre, Pa.
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Deceased.

Blossom, T. M., ... 1876
Brown, A. J., ... 1875
Daddow, S. H., ... 1875
D'aligny, H. F. Q., ... 1875
Harris, Stephen, ... 1874
Hunt, Thomas, ... 1872
Jenney, F. B., ... 1876
Lee, Col. Washington, ... 1872
Liebenau, Charles Von, ... 1875
Lord, John C., ... 1872
Painter, Howard, ... 1876
Steitz, Augustus, ... 1876
Stoelting, Hermann, ... 1875
Witherbee, J. G., ... 1875

RULES.

ADOPTED MAY, 1873. AMENDED MAY, 1875.

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 minerals 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 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, and members and associates permanently residing in foreign countries, 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, duo notice having been mailed in writing by the Secretary to the said member or associate.

RULES.

III.

DUES.

The dues of members and associates shall be ten dollars, payable upon election, and ten dollars per annum, payable in advance at the annual meeting; Provided, that persons elected at the February meeting shall not be liable to dues at the first annual meeting following; and members and associates permanently residing in foreign countries, excepting Canada, shall be liable to such annual or other payments only as the Council may impose, to cover the cost of supplying them with publications. 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 Council elected under the former rules of the Institute at the annual meeting of 1873, shall continue in office until the adjournment of the annual meeting of 1874; and the Vice-Presidents and Managers shall classify themselves by lot or otherwise, so that three Vice-Presidents and three Managers shall retire and be ineligible for re-election in 1874, and three Managers shall retire and be ineligible for re-election in 1875, after which the terms of office shall be as hereinbefore provided. 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 vote of a 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 proposes, 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, or foreign members or associates), 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 two 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.

General meetings of the Institute shall take place on the fourth Tuesday of February, May, and October; and the May meeting shall be considered the annual meeting; at which a report of the proceedings of the Institute, and an abstract of the accounts, shall be furnished by the Council. 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. All notices may be given by circular, mailed to members and associates, or through the Bulletin, published in the regular organ of the Institute, at the discretion of the Council.

Every question which shall come before meeting of the Institute, shall be decided, unless otherwise provided by these Rules, by the votes of the majority of the members then present. The place of meeting shall be fixed in advance by the Institute, or, in default of such determination, by the Council, and notice of all meetings shall be given by mail, or otherwise, to all members and associates, at least twenty days in advance. 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 factor 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 MEETINGS,

MAY, 1875, TO FEBRUARY, 1876.

ANNUAL MEETING, DOVER, N. J.,

May, 1875.

THE meeting was opened, Tuesday evening, May 25th, by an address from the President, R. W. Raymond. The following persons having been duly proposed for members and associates of the Institute, were recommended by the Council for election. They were unanimously elected

MEMBERS.

Florian Alexander	Newark, N. J.
Charles A. Ashburner,	Philadelphia, Pa.
Phineas Barnes,	Pittsburgh, Pa.
J. Y. Bergen	Chicago, Ill.
Leopold C. Bierwirth,	Dover, N. J.
Charles E. Billin,	Philadelphia, Pa.
Jerome L. Boyer,	Temple, Berks County, Pa.
William S. Cherry	Streator, Ill.
Thomas Couch,	Salt Lake City, Utah.
W. S. De Camp	Boonton, N. J.
Thomas Donaldson	Boise City, Idaho.
H. Firmstone,	Longdale, Va.
Franz Fohr,	New York City.
Richard George,	Dover, N. J.
John M. Hartman	Philadelphia, Pa.
C. W. Kempton	Newburyport, Mass.
James B. Lewis,	Dover, N. J.
James F. Lewis,	Amenia, Dutchess County, N. Y.
Arthur H. Meyer,	St. Louis, Mo.
Edward H. Morrison,	Boonton, N. J.
Charles J. Norwood,	Lexington, Ky.
John B. Peters	Dover, N. J.
Charles I. Rader,	Vinton Furnace, Ohio.
W. M. Rees,	Stockton, Luzerne County, Pa.
George Richards,	Dover, N, J..
Alexander H. Sherrerd,	Scranton, Pa.
W. S. Sweeny,	Easton, Pa.
W. J. Taylor	Chester, N. J.
Walter Tefft	Mineville, Essex County, N. Y.
J. Alexander Tyler,	New York City.
J. D. Weeks	Pittsburgh, Pa.
William Wheatley, Jr.,	New York City.
Moses D. Wheeler,	Virginia, Nevada.
Henry Woods,	Streator, Ill.

ASSOCIATES.

Thomas D. Jones,.................................. Ashton, Carbon County, Pa.
N. I. Scott, ... Easton, Pa.

After announcement of programme for excursions and sessions by the local committee, Professor J. C. Smock, of the New Jersey Geological Survey, addressed the Institute on the ore-districts of Northern New Jersey, with especial reference to the mines to be visited by the members in the projected excursions.

The second session was held on Wednesday evening. The President, on behalf of the Council, presented the following annual report:

The Council of the Institute reports that during the past year the usual three meetings have been held--to wit., in St. Louis, Mo., Hazleton, Pa., and New Haven, Conn.

At these meetings there were elected 100 members, 47 associates, and 5 foreign members--in all 152. The membership of the Institute now comprises 4 honorary members, 4 life members, 46 foreign members, and 377 members and associates--in all 431.

Fifty-five papers have been contributed and read at the meetings. During the year the second volume of *Transactions of the Institute* has been published, covering the period from May, 1873, to February, 1874.

The finances of the Institute are in a satisfactory condition. The report of the auditors appointed to examine the Secretary's and Treasurer's accounts, show a balance on hand on May 4th, of $160.40. and no liabilities. The amount received for the year was $3261.94.

The Institute has lost three of its prominent members by death during the year--Mr. S. H. Daddow, of St. Clair, Pa.; Mr. Hermann Stoelting, of Georgetown, Colorado; and Dr. Burkhart, of Bonn, Prussia.

The Council has appointed as Committee on the reception of foreign mining engineers and metallurgists during the Centennial Exhibition, Messrs. E. B. Coxe, Thomas Egleston, J. S. Alexander, and R. W. Raymond.

The excursions incident to the meetings have been productive of great professional profit and social enjoyment. Among the most prominent may be mentioned those to Iron Mountain, Pilot Knob, Mine La Motte, in Missouri, and the prominent iron and zinc works in the vicinity of St. Louis; the Block Coal Fields at Brazil, Indiana, and the collieries and shops at or near Hazleton. . At New Haven, the Institute had the opportunity of inspecting the rare and valuable collections, and the laboratories of the various departments of Yale College.

Mr. Pechin proposed to amend Rule VI, by changing the annual meeting from May to February. After some discussion the amendment was withdrawn.

Mr. Raymond offered the following amendment to Rule Ill, to insert after "foreign countries," *excepting Canada.*

Mr. Raymond explained that the exemption of foreign members from regular dues was but just, since they could not attend the meetings of the Institute, but that residents of Canada lived as near the usual places of meeting as many of our own members, and that exemption in such cases did not seem called for. The amendment was adopted.

Mr. E. B. Coxe proposed the following amendment to Rule IV: "That each retiring president shall be *ex officio* member of the Council for one year."

After some discussion the amendment was lost.

Dr. Drown exhibited a specimen of sylvanite which he had received from Mr. McDermott, of Silver Islet, who gave the following account of its occurrence. The specimen was obtained from the Shebandowan gold mine,--a vein discovered some three years ago, about one hundred miles west of Silver Islet, on, or rather near, the route to Red River. The vein is quartz, and occurs in a talcose slate belt associated with massive diorite and occasional bands of magnetic iron ore. The vein carries large quantities of copper pyrites, zinc blende, and some galena. Native gold is found in portions of the rock, and generally accompanied by the sylvanite, which is, in parts, quite massive.

Dr. Drown exhibited also a specimen of white, and apparently pure, cyanide of potassium taken from a disused tuyere at the Crane Iron Works at Catasauqua. Mr. Joseph Hunt, who sent the specimen, said that he removed the deposit from the tuyere every day, and that he had taken out in all sixty pounds or more, not, however, all in so pure a condition as the sample.

Mr. Thomas Donaldson, of Boise City, Idaho, gave an account of the discovery and exploitation of the great Bonanza on the Cornstock Lode.

Prof. W. P. Blake then read a paper on Mining Machinery on the Pacific coast, concluding the evening session.

The third session was held on Thursday afternoon.

Mr. E. B. Coxe proposed that the rules be amended to increase the number of vice-presidents to nine, and of managers to fifteen. After discussion, the subject was laid over for one year.

Mr. E. C. Pechin proposed the following amendment to Rule VII, to add: " *Provided*, That written notice of the proposed amendment shall have been given at a previous meeting." This amendment was adopted.

Mr. J. B. Pearse proposed the following amendment to Rule VII, to add, "and it is understood that papers or discussions should not include matters relating to politics or purely to trade." The amendment was adopted.

Mr. A. L. Holley then read a short communication from Mr. T. S. Blair, of Pittsburgh, on his direct process for the production of iron. Prof. G. H. Cook, State Geologist of New Jersey, followed with a paper on some points in the geology of Northern New Jersey.

A paper by Ellis Clark, Jr., of the Pennsylvania Geological Survey, on the Subterranean Water-courses in the Magnesian Limestones of Schuylkill County, Pa., was then read in the absence of the author.

The session concluded by a communication by Prof. T. Egleston, on the Bastie Annealed Glass.

At the fourth session on Thursday evening the following papers were read:

On the Repairing of the Upper Part of a Furnace Lining, by Mr. F. Firmstone, of Easton, Pa.

On Puddling with Natural Gas near Pittsburgh, by Mr. A. L. Holley, of New York.

On the Causes and Prevention of Fire in Coal Mines, by Mr. R. P. Rothwell, of New York.

On a Classification and Enumeration of the Principal Useful Minerals and Mineral Products, by Prof. W. P. Blake, of New Haven, Conn.

The Swansea Silver Smelting and Refining Works, by Mr. J. L. Jernegan, of Chicago.

The scrutineers of election, Messrs. J. M. Silliman and H. M. Howe, appointed at a previous session, reported the following officers elected:

President--ALEXANDER L. HOLLEY.
Vice-Presidents--R. P. ROTHWELL, EDMUND C. PECHIN, FRANK FIRMSTONE.
For unexpired term of Mr. Holley--JOHN FRITZ.
Managers--OSWALD J. HEINRICH, ANTON EILERS, JOHN C. SMOCK.
Treasurer--THEODORE D. RAND.
Secretary--THOMAS M. DROWN.

Mr. E. C. Pechin then offered the following resolutions, which were unanimously adopted, after which the Institute adjourned:

Resolved, That the thanks of the Institute be conveyed through the Secretary to Mr. A. Raesoner, Superintendent of the Morris and Essex Railroad, for his kindness in providing railroad facilities for our excursions; to the Young Men's Christian Association of Dover, for the use of their room; to the Chester Iron Company, and the officers of the Hibernia and Ogden Mine Railroads for their courtesy in offering the pleasant excursions which have been so highly enjoyed by the Institute; to Messrs. George, Richards, and Taylor, for courtesies tendered, and to the Local Committee for their admirable arrangements.

Resolved, That the members of the Institute desire to express, in the most emphatic manner, their high appreciation of the thoughtful energy, the, tact, judgment, and graceful administration of Mr. R. W. Raymond, who, for nearly four years, has presided over the deliberations of the Institute.

Excursions.--The programme for excursions for the meeting, arranged by Mr. E. S. Moffat and the Messrs. Canfield, included visits to the principal magnetic ore deposits in the vicinity of Dover, and the zinc and Franklinite deposits at Sterling and Franklin.

On Wednesday morning the Institute left by special train on the Morris and Essex Railroad for the Canfield, Dickerson, and Byram mines. An opportunity was here afforded by the Messrs. Canfield for the inspection of their valuable, and in many respects unique, collection of minerals. The minerals of Northern New Jersey are here represented in the greatest richness and profusion.

At noon the Institute proceeded on its trip to the Hacklebarney mine of the Chester Iron Company, and subsequently were hospitably entertained by the company at dinner at Chester. After dinner the Hedge mine of the North Jersey Iron Company was visited, under the direction of its manager, Mr. W. J. Taylor.

On Thursday morning the Hibernia mines were inspected, including the workings of the Andover, Glendon, and Bethlehem Companies.

On Friday, at 7.30 A.M., a special train left for Hopatcong Station, on the Morris and Essex Railroad. Here the members embarked on the little steamer Stella, which bore the party pleasantly through canal and lake to Nolan's Point, where cars of the Ogden Mine Railroad were in waiting to take the party to the Hurd, Ford, Dodge, Ogden and other mines on the line of the road.

At the Ogden mine teams were taken to Ogdensburg, a distance of two miles and a half, where the party dined. The afternoon was devoted to visits to the remarkable mineral localities of Sterling and Franklin. At the latter place the members of the Institute were courteously received, and hospitably entertained by the President and officers of the New Jersey Zinc Company. The party then dispersed to their respective homes.

CLEVELAND MEETING,

October, 1875.

THE sessions of the Institute were opened on Tuesday evening, October 26th, at Garrett's Hall, by Mr. Charles A. Otis, Chairman of the Local Committee of Arrangements, who welcomed the Institute to Cleveland, and introduced Col. Charles Whittlesey, who addressed the Institute briefly on the coal deposits of Ohio.

Col. Whittlesey described the situation and character of the coal-beds of the State, and gave a short history of the use of raw coal in the manufacture of pig-iron, and spoke of the excellent quality of metal produced. The aid that a body of scientific miners and metallurgists were capable of giving in the development of coal and other mineral resources was dwelt upon, and the hope expressed that the visit of the Institute to Cleveland might be profitable as well to its members as to the citizens of the State.

The President, Mr. A. L. Holley, responded to the welcome of Mr. Otis and of Col. Whittlesey, and read an introductory address on Some Pressing Needs in the Iron and Steel Manufacture.

The following members and associates, duly proposed and indorsed by the Council, were then elected

MEMBERS.

Alfred S. Bertolet,	Youngstown, Ohio.
Henry Binnse,	Chicago, Ill.
John Birkinbine,	Philadelphia.
Andrew A. Blair,	Watertown Arsenal, Mass.
Ogden Bolton,	Canton, Ohio.
Lloyd Booth,	Youngstown, Ohio.
E. Borda,	Philadelphia.
N. P. Bowler,	Cleveland, Ohio.
Alexander E. Brown,	Cleveland, Ohio.
C. F. Brush,	Cleveland, Ohio.
S. M. Carpenter,	Cleveland, Ohio.
James Cartwright,	Youngstown, Ohio.
Henry Chisholm,	Cleveland, Ohio.
Wilson B. Chisholm,	Newburgh, Ohio.
W. H. Clarke,	Millertown, Pa.
James E. Clayton,	Ore Knob, N. C.

J. H. Cremer, ...	Chicago, Ill..
Samuel W. Croxton, ...	Canal Dover, Ohio.
H. J. Detwiller, ...	Bethlehem, Pa.
P. H. Dudley, ...	Cleveland, Ohio.
R. H. Emerson, ...	Pittsburgh, Pa.
F. A. Emmerton, ...	Joliet, Ill.
S. A. Ford, ...	Pittsburgh, Pa.
James J. Fronheiser, ...	Johnstown, Pa.
John E. Fry, ...	Johnstown, Pa.
E. C. Garlick, ...	Indianapolis, Ind.
D. E. Garrison, ...	St. Louis, Mo.
Gen. Q. A. Gillmore, ...	New York City.
James J. Hagerman, ...	Milwaukee, Wis.
Homer Hamilton, ...	Youngstown, Ohio.
Henry Harley, ...	Titusville, Pa.
James Hemphill, ...	Pittsburgh, Pa.
Charles Himrod, ...	Youngstown, Ohio.
J. F. Holloway, ...	Cleveland, Ohio.
George Jenkins, ...	Bethlehem, Pa.
David A. Johnson,.	Broad Top, Pa.
Daniel N. Jones, ...	Johnstown, Pa,
W. R. Jones, ...	Pittsburgh, Pa.
Charles Kennedy, ...	Cleveland, Ohio.
Prof. John W. Langley, ...	Ann Arbor, Mich.
Andrew S. McCreath, ...	Harrisburg, Pa.
John McLeavy, ...	Dunbar, Pa.
Charles Macdonald, ...	New York City.
William D. Marks, ...	Chattanooga, Tenn.
William Metealf, ...	Pittsburgh, Pa.
Reuben Miller, ...	Pittsburgh, Pa.
James Moore, ...	Philadelphia.
D. J. Morrell, ...	Johnstown, Pa.
Charles A. Otis, ...	Cleveland, Ohio.
John C. Parkes, ...	Chicago, Ill.
Charles Parkin, ...	Pittsburgh, Pa.
W. G. Platt, ...	Philadelphia.
William B. Pollock, ...	Youngstown, Ohio.
O. W. Potter, ...	Chicago, Ill.
J. Thorpe Potts, ...	Philadelphia.
Charles Ridgely, ...	Springfield, Ill.
James M. Reno, ...	Youngstown, Ohio.
W. W. Scranton, ...	Scranton, Pa.
William Sellers, ...	Philadelphia.
W. P. Shinn, ...	Pittsburgh, Pa.
David Smith (Chief Engineer), . . .	Washington, D. C.
H. S. Smith, ...	Joliet, Ill.
William C. Stevens, ...	Bethlehem, Pa.
A. B. Stone, ...	Cleveland, Ohio.
Prof. R. H. Thurston, ...	Hoboken, N. J.
Alfred L. Tyler, ...	Anniston, Ala.
Charles H. Vannier, ...	Succasunna, N. J.

James E. Walker,	Troy, N. Y.
William R. Webster,	Philadelphia.
P. L. Weimar,	Lebanon Pa.
Ashbel Welch,	Lambertville, N. J.
Dr. A. Wendel,	Troy, N. Y.
Joseph R. Werth,	Richmond, Va.
Col. Charles Whittlesey,	Cleveland, Ohio.
Prof. Henry Wurtz,	Hoboken, N. J.
Thomas W. Yardley,	Cincinnati, Ohio.

ASSOCIATES.

S. C. Baldwin,	Cleveland, Ohio.
C. E. Bingham,	Cleveland, Ohio.
Henry O. Bonnell,	Youngstown, Ohio.
William B. Davock,	Cleveland, Ohio.
S. A. Fuller,	Cleveland, Ohio.
M. A. Hanna,	Cleveland, Ohio.
Henry Manning,	Youngstown, Ohio.
A. B. Meeker,	Chicago, Ill.
John Stambaugh,	Youngstown, Ohio.
Caleb B. Wick,	Youngstown, Ohio.
Edward Behr,	School of Mines, New York City.
Charles L. Constant,	" " " "
George B. Cornell,	" " " "
Herbert C. Foote,	" " " "
William W. Hance,	" " " "
Prank S. Helleberg,	" " " "
Walter E. Hildreth,	" " " "
Francis N. Holbrook,	" " " "
Frederick R. Hutton,	" " " "
William Kelly,	" " " "
James R. Priest,	" " " "
S. Albert Reed,	" " " "
William Henry Smeaton,	" " " "
Arthur Thacher,	" " " "
Horace H. Weeks,	" " " "

FOREIGN MEMBERS.

Julien Deby,	Brussels, Belgium.
Arm. Résimont,	Seraing, "
J. Ramon de Ybarrola,	City of Mexico.

Dr. R. W. Raymond, in the absence of the Chairman of the Centennial Committee of the Institute, presented verbally the report of the committee. Mr. Eckley B. Coxe had been elected chairman, and Mr. J. S. Alexander secretary. The committee had issued the following circular to members and associates:

CENTENNIAL COMMITTEE OF THE
AMERICAN INSTITUTE OF MINING ENGINEERS,
206 SOUTH FOURTH STREET, PHILADELPHIA, July 5th, 1875.

DEAR SIR : The undersigned, appointed by vote of the Institute, a committee to make arrangements for the convenience of members and associates, and of foreign visitors, who may attend the Centennial Exhibition, have decided provisionally upon the following plan, additions or amendments to which you are respectfully invited to suggest. The object of the committee has been to devise a simple, practicable, and useful programme, neither ostentatious nor likely to intrude upon ground occupied by other societies, and at the same time capable of such expansion as circumstances may indicate and means permit.

1. The committee will ask of the Institute, at the next (October) meeting, a vote authorizing the adjournment of the annual meeting of May, 1876, to the third Tuesday of June, the adjourned session to be held in Philadelphia.

2. The committee will endeavor, by special invitation, to secure the attendance, at the Philadelphia meeting, of English and continental mining engineers and metallurgists, and, if practicable, to give to the meeting an international character.

3. The committee proposes to engage suitable rooms in Philadelphia for the period of the Exhibition, to furnish them with technical periodicals and books of reference concerning the resources and industries of the United States, to secure the attendance of a competent secretary, and to keep these rooms open, day and evening, as the Centennial headquarters of the American Institute of Mining Engineers. The practical object of this measure will be to afford to members and associates a place for social reunion, for writing and receiving letters, and for obtaining desired information or introductions. Foreign visitors interested in mining or metallurgy would, on making themselves known to the committee, receive cards entitling them to the privileges of the rooms, and particularly to the services of the secretary in charge, who would be able to assist them in any line of inquiry which they might wish to pursue, giving them statistics, general information, directions, advice, and letters of introduction to all parts of the country. The same cards would enable them to take part in the proceedings or excursions of the Institute. The addresses and prospective movements of the members or visitors

could be posted in books kept for the purpose; and letters could be forwarded to them regularly, or friends advised of their whereabouts. The committee has received assurances of co-operation in various respects, tending to add still more to the pleasures and facilities which may be gathered around this idea. But the object of the present circular is to sketch briefly the outline of what is proposed as a minimum. You will perceive that the only necessary part of the plan involving extra expense is the maintenance of the Centennial headquarters.

The committee estimates that the sum of $5000 will be ample for the purposes of rent, furnishing, lighting, stationery, care of rooms, and salary of attendant secretary. This sum it is proposed to raise by a voluntary subscription; and you are respectfully requested, if the plan meets your approval, to notify Mr. J. S. Alexander, at the above address (which is the temporary office of the committee), of the amount which you are willing to subscribe. The names and amounts will not be made public; there is no obligation on your part to subscribe, other than such as your free wish to co-operate for this object may impose upon you, within the limit of your convenience. It may be added, to show the range of subscriptions thus far, that there have been received already from members and associates a number of subscriptions of $100 each, and others of smaller sums, down to $10. The subscriptions will be payable on or before January 1st, 1876, provided a sufficient amount, shall have been pledged to warrant the committee in going forward. But you are earnestly requested to inform the committee at once of your purpose in the matter, since there is a very large foreign correspondence to be carried on, if this plan is to be made practically profitable to the profession. Awaiting your early reply, we are

Yours, very truly,

ECKLEY B. COXE,
THOMAS EGLESTON,
J. S. ALEXANDER,
R. W. RAYMOND,
Committee.

In response to this circular, 82 out of 403 members and associates had responded with subscriptions amounting thus far to $2470. The committee had taken rooms at 1123 Girard Street, Philadelphia, and its arrangements for the Centennial were progressing. For the present, the provisional office, at 206 South Fourth Street, Philadelphia, would be retained for use, the Centennial headquarters being engaged from April to December. Dr. Raymond explained at length some of the plans proposed by the committee for the profit and convenience of members and guests of the Institute during the Exhibition. The following resolution was passed at the request of the Centennial Committee:

Resolved, That after the annual election of officers, and without the transaction of other business, or the reading of papers, the May meeting of 1876 shall be adjourned to the third Tuesday of June, or such later day as the council may determine, the adjourned session to be held at Philadelphia.

Mr. E. C. Pechin then read a paper on Blast Furnace Hearths and In-walls. After announcement by President Holley of the programme arranged by the Local Committee for the excursions and entertainments of the meeting, the session was adjourned.

The second session was held in the room of the Common Council, on Tuesday morning, when the following papers were read:

Memoranda relating to two ninety-feet Chimneys for Siemens' Heating Furnaces at the Edgar Thomson Steel Works, by Phineas Barnes, of Pittsburgh.

Bessemer Converter Bottoms, by Robert Forsyth, of the N. Chicago Rolling Mill.

Improved Bessemer Plant, by John B. Pearse, of Philadelphia.

Deceptive Coal-seams near the Limestone, or in the Silurian Rocks of Virginia, by Martin Coryell, of Richmond, Va.

On the Discovery of the Vespertine Coal-beds in the Rock of Sideling Hill, Huntingdon County, Pa., by Charles A. Ashburner, of the Second Geological Survey of Pennsylvania.

The Mass Copper of Lake Superior and the Method of Mining it, by Prof. W. P. Blake, of New Haven, Conn.

On the Shrinking of Pig-iron, by Mr. A. B. Cornell, of Youngstown, Ohio.

Before adjournment, Professor Egleston offered the following resolution, which was adopted:

Resolved, That a committee be appointed to consider that part of the President's address which relates to the appointment of a commission to examine refractory materials.

A resolution was also passed, requesting the President to appoint the committee to include himself.

President Holley appointed Professors Egleston and Blake.

The third session was held on Wednesday evening, at 8 o'clock.

The discussion of Mr. Cornell's paper on the Shrinking of Cast-iron, was resumed and concluded.

The papers read at this session were:

On Furnace Hearths, by George Asmus, of New York.

Mr. Asmus also exhibited specimens of "mineral wool," produced by the action of a jet of steam on blast-furnace slag. Mr. Asmus said that attempts were making in Austria to anneal tin's product, so that the fibres could be worked into fabrics.

The Effects of Heat on Steel, by William Metcalf, of Pittsburgh.

Iron and Carbon Mechanically and Chemically Considered, by J. B. Pearse, of Philadelphia.

The Mahoning Valley Coal Region, by Andrew Roy, of Columbus, Ohio.

The fourth session was held on Friday evening.

After the election of members, Dr. R. W. Raymond offered the following resolution, which was unanimously carried:

Resolved, That the thanks of the American Institute of Mining Engineers be conveyed to the Cleveland Union Club, the Standard Oil Company, Mr. J. F. Holloway, the Otis Iron and Steel Company, the Cleveland Rolling Mill Company, the Union Steel Screw Company, the Atlantic and Great Western, Cloveland and Pittsburgh, and Cleveland, Tuscarawas Valley and Wheeling Railway Companies, and the Press of Cleveland, for the courtesies they have freely extended to the Institute; to Messrs. M. D. Leggett & Co., for the offer of their rooms to members; to Col. Charles Whittlesey, for his cordial and interesting welcoming address ; and to Messrs. J. S. Newberry, C. A. Otis, Fayette Brown, S. A. Puller, W. C. Andrews, and M. A. Hanna, the efficient Local Committee, for their unwearied efforts and admirable arrangements to promote the comfort of members, and the profit and pleasure of this meeting.

Prof. T. Egleston said that the committee appointed to consider that part of the President's address relating to refractory materials had held several meetings, and begged to report that, in view of the important results of similar commissions appointed by the Governments of France and Germany, in the early part of the present century, when metallurgical processes required, as now, a much better refractory material, the Institute is justified in seriously considering the question of the appointment of such a commission, and the committee beg to present the following resolutions:

Resolved, That the suggestion made in the President's address, regarding the appointment of a commission to examine refractory materials, is most heartily approved by the Institute.

Resolved, That a committee of five, of which the President shall be one, be appointed to endeavor to engage the interest of manufacturers in this subject, and to prepare a report of what such a commission may be expected to accomplish, to be presented to the next meeting of the Institute, and that the committee may have power to add to its numbers.

The President subsequently appointed Messrs. T. Egleston, W. P. Blake, A. B. Stone, and T. M. Drown.

Professor Egleston then offered the following resolutions, which were adopted:

Resolved, That the American Institute of Mining Engineers consider the appointment of the United States Board for Testing Iron, Steel, and other Metals, as one of the most important steps in the interest of engineering science ever undertaken by the United States Government;

Resolved, That the Institute tender its earnest sympathy to the Board in the work it has undertaken, and

Resolved, That a committee of three be appointed, with power to add to its numbers, to co-operate with the United States Board.

President Holley appointed Messrs. T. Egleston, William Sellers, and William Metcalf.

Dr. R. W. Raymond exhibited specimens of the rock from the Calumet and Hecla mine, Lake Superior, and from the Nonesuch, a new mine, in Ontonagon County. The former was conglomerate, the latter sandstone, containing disseminated native copper. The Nonesuch vein or bed is about 8 feet wide at the depth of 190 feet attained by the mine, and a zone of 4 feet in it carries fine copper—about 4 per cent. The Calumet rock now yields 5 per cent.

The papers read at this session were:

Comparison of Blast-furnace Results, by Frank Firmstone, Glendon Iron Works, Easton, Pa.

Comparison of Results from Open-Topped and Closed-Topped Furnaces, by Frank Firmstone.

On the World's Production of Silver, by Dr. R. W. Raymond, of New York.

On the Coking of Indiana Block Coal, by J. S. Alexander, of Philadelphia.

On Evidence of Streams during the Deposition of Coal, by John F. Blandy, of New Bethlehem, Pa.

What is Steel? By A. L. Holley, of New York.

On a Formula for Carbon Duty in Blast-furnaces, by John M. Hartman, of Philadelphia.

The following papers were read by title, after which the meeting adjourned:

On the Martin Steel Process, by Dr. R. W. Raymond.

Note on the Occurrence of Siderite at Gay's Head, Martha's Vineyard, by Prof. W. P. Blake.

On the Velocity of Gases in Blast-Furnaces, by J. A. Church.

On the Compression of Gases, by C. F. Brush.

EXCURSIONS.

The following excursions to places of interest, in and around Cleveland, were arranged by the Local Committee, with the co-operation and support of the citizens of Cleveland and the officers of the different railroads:

On Wednesday afternoon the members were taken in carriages to the Water Works, the Standard Oil Works, and the ore docks in Cleveland. On Thursday morning, at 8 o'clock, a special train, on the Cleveland and Pittsburgh Railroad, left the Union Depot for the Otis Iron and Steel Works, the Union Steel Screw Works, and the mills and Bessemer works of the Cleveland Rolling Mill Company, at Newburgh. In the afternoon, the members were entertained by the Cleveland Union Club at dinner, and visited the new opera house in the evening. Friday morning, at 8 o'clock, a special train left the Atlantic and Great Western Depot for Youngstown and vicinity, stopping *en route* at Leavittsburg, to see the apparatus for shifting car trucks from broad to narrow gauge, and *vice versa*. At Youngstown, the hoop-iron rolling mill of Messrs. Cartwright, McCurdy & Co. was visited. The party, here largely reinforced in numbers, were then taken to the Church Hill bank, and the Holliday's bank (block coal), to Hubbard's Furnace, the rail mill of Messrs. Wick, Ridgway & Co., and, finally, to Himrod's Furnace, returning to Cleveland at 6.30 P.M. Saturday morning, a special train left on the Cleveland, Tuscarawas Valley, and Wheeling Railroad. The Mountain bank of the Roach Coal Company was first visited, whence the party proceeded through Massillon to Port Washington, to see the “Scotch" Furnaces and the black band ore mines. At Port Washington, the members going east took the Pan Handle train, the remainder returning to Cleveland.

WASHINGTON MEETING,

February, 1876.

THE first session of the Institute was held at the Smithsonian Institution, on Tuesday evening, February 22d. The members were welcomed to Washington and to the Smithsonian by Prof. Joseph Henry. President Holley responded to the cordial welcome of Professor Henry, and then read an introductory address on the subject of Technical Education.

Following the discussion on President Holley's address the following persons, duly proposed and indorsed by the Council, were elected members and associates of the Institute:

MEMBERS.

Emile R. Abadie, ...	St. Louis, Mo.
R. J. Anderson, ...	Pittsburgh, Pa.
Commander L. A. Beardslee, . . .	Washington, D. C.
Charles Bender, ...	New York City.
Channing M. Bolton, ...	Richmond, Va.
Thomas E. Bowman, ...	Silverton, Colorado.
Calvin E. Brodhead, ...	Bethlehem, Pa.
M. L. Brosius, ...	Lewistown, Pa.
Harvey H. Brown, ...	Cleveland, Ohio.
James A. Burden, ...	Troy, N. Y.
J. P. Clemes, ...	Sonora, Mexico.
N. H. Cone, ...	Nederland, Colorado.
W. F. Durfee, ...	New York City.
Robert Frazer, Jr., ...	Ashland, Pa.
Joseph E. Galigher, ...	Bingham, Utah.
William Golding, ...	Steel Works P. O., Pa.
Samuel E. Griscom, ...	Pottsville, Pa.
Gen. E. Burd Grubb, ...	Beverly, N. J.
Arthur R. Guerard, ...	Charleston, S. C.
Edward Hart, ...	Easton, Pa.
Prof. Lewis M. Haupt, ...	Philadelphia.
E. S. Hawley, ...	Buffalo, N. Y.
John W. Hoffman, ...	Philadelphia.
Nelson P. Hulst, ...	Milwaukee, Wis.
H. C. Humphrey, ...	Philadelphia.
Ed. P. Jennings, ...	Ithaca, N. Y.
B. F. Jones, ...	Pittsburgh, Pa.

N. S. Keith, ...	New York City.
H. P. Kinsman, ...	Cleveland, Ohio.
R. H. Lee, ...	Lewiston, Pa.
Ambrose E. Lehman, . . .	Philadelphia.
Prof. Charles McMillan, . .	Princeton, N. J.
Arthur Macy, ...	New York City.
Max Morehead, ...	Pittsburgh, Pa.
Henry W. Oliver, ...	Pittsburgh, Pa.
B. A. Oxnard, ...	Brooklyn, N. Y.
William Pistor, ...	New York City.
James S. Polhemus, . . .	Detroit, Mich.
Major J. W. Powell, ...	Washington, D. C.
S. P. Raber, ...	High Bridge, N. J.
Lewis A. Riley, ...	Ashland, Pa.
Gen. W. S. Rosecrans, . . .	Egan Canyon, Nevada.
B. H. Sanders, ...	Philadelphia.
Dr. J. Lawrence Smith, . . .	Louisville, Ky.
Gen. William Sooy Smith, . .	Maywood, Ill.
Ed. Squire, ...	Cleveland, Ohio.
E. Steinbach, ...	Del Norte, Colorado.
John Stevenson, Jr., ...	Pittsburgh, Pa.
H. G. H. Tarr, ...	Orbisonia, Pa.
Samuel W. Thome, ...	Philadelphia.
Heber S. Thompson, ...	Pottsville, Pa.
M. D. Valentine, ...	Woodbridge, N. J.
George R. Waite, ...	Philadelphia.
James T. Walker, ...	Troy, N. Y.
H. L. J. Warren, ...	Boston, Mass.
J. Price Wetherill, ...	Tremont, Pa.
J. T. Wilder, ...	Chattanooga, Tenn.
Frank S. Witherbee, ...	Port Henry, N. Y.
James P. Witherow, ...	Ironton, Ohio.
A. J. Womelsdorf, ...	Pottsville, Pa.

ASSOCIATES.

William Burnham, ...	Philadelphia.
H. E. Collins, ...	St. Louis, Mo.
Jerome Keeley, ...	Philadelphia.
James F. Rhodes, ...	Cleveland, Ohio.
H. L. Thayer, ...	Denver, Colorado.
O. C. Woolson, ...	Chicopec, Mass.
Charles E. Buckley, ...	School of Mines, New York City.
A. Cass Canfield, ...	" " " "
John B. Cauldwell, ...	" " " "
Anton Fernekes, ...	" " " "
H. L. Haas, ...	" " " "
Robert W. Hall, ...	" " " "
Henry F. Morewood, ...	" " " "
William W. Shotwell, ...	" " " "

The second session was held on Wednesday morning.

Mr. E. B. Coxe made a statement on behalf of the Centennial Committee of the Institute, of the work which had been accomplished, and of the plans in view for the convenience and comfort of members and of foreign engineers during the Centennial. About $3800 had already been subscribed, but $1200 more would probably be needed to enable the Committee to carry out all its plans. The assistance and co-operation of many of the State governments and large railway corporations had been obtained in providing reports, maps, etc.

The discussion of Prof. Holley's paper, of the evening previous, was then resumed.

Dr. T. Sterry Hunt read a paper on the Cornwall Iron Ore Deposits of Pennsylvania, followed by Prof. B. Silliman, on the adjacent copper deposits, and the description of a new muffle furnace for working the so-called “clay” copper ores of this region.

Prof. T. Egleston, chairman, presented the following report of the Committee on Refractory Materials: The committee has held several sessions, and begs to report that the rapid improvement in metallurgical operations demands the most serious attention being given to the subject of refractory materials. It is of the opinion that this investigation must be made in the direction of artificially prepared materials, rather than the use of natural substances, and thinks that the investigation should be chemical, mechanical, and microscopical, the researches to be made both before and after the proposed material has been subjected to high temperatures, under conditions similar to those in which it is to be used; as not only a good material is required, but it is also necessary that every stage of the operation should be carefully conducted (as a material, otherwise excellent, may fail from defective manufacture). The committee is of the opinion that the co-operation of all branches of the profession, those who make and those who use the materials, should be solicited. A large part of the investigation would, necessarily, be synthetical in the way of systematic making and testing of mixtures, and, subsequently, the use of laboratory methods to reproduce what has been proved to be good in actual practice. The committee intends to propose an organized plan of investigation, the results of which, it hopes, will not only be of general advantage, but also very materially advance private interests. The committee begs, therefore, to be continued to report at a future meeting.

A motion to continue the committee was carried.

Prof. Egleston then read a paper on the subject of Refractory Materials.

The third session was held on Wednesday evening.

President Holley reported on behalf of the Council the following resolutions for action of the Institute:

Resolved, That Messrs. E. B. Coxe, W. P. Shinn, and A. L. Holley be appointed a committee on excursions and transportation during the Centennial Exhibition.

Resolved, That a committee of three, to consist of Messrs. E. W. Raymond, A. L. Holley, and E. B. Coxe, be appointed to confer with a similar committee of the American Society of Civil Engineers, to prepare proper presentation of the subject of Technical Education for discussion at the June meeting.

The resolutions were unanimously adopted.

Mr. Oswald J. Heinrich read a paper on the Midlothian Colliery in 1876.

Dr. Henry Wurtz read a paper on Geometrical Chemistry, which was introduced by a few prefatory remarks by Dr. T. Sterry Hunt.

Dr. H. S. Drinker, of Philadelphia, made some remarks on a work on Modern Tunnelling, which he had in preparation and for which he desired to ask the co-operation of his fellow-members.

Mr. Drinker said that since the presentation of his paper on the Musconetcong Tunnel at the New Haven meeting, in February, 1875, he had been actively engaged in the collection of data, for a general work on Modern European and American Tunnelling, describing the various methods of soft and hard ground driving in vogue abroad and in this country. The portion of the work treating especially of the English, Belgian or French, German, Austrian, etc., systems of excavating, timbering, and arching, with a resume of the history of European drilling machinery, was being prepared by contributing engineers in Europe, and that valuable contributions had been and were continually being received from many American engineers, having experience in tunnelling, embodying a record of direct practical interest.

It was proposed in addition to a general description of methods of work, to supplement each department with tabulated lists, showing the location, cost, rate of driving, cross-section adopted, material passed through, etc., of all tunnels, of which any record, however small, could be obtained.

Mr. Drinker concluded by presenting to those present a list of questions which he proposed circulating among the members of the Institute, requesting their assistance in the collection of data.

Dr. E. W. Raymond, of New York, spoke of the great practical benefit to be derived by engineers from the work of Mr. Drinker. He had already placed at Mr. Drinker's disposal all the materials and references at his command, and hoped others would do likewise. Messrs. E. B. Coxe and R. P. Roth well expressed the gratification they felt that Mr. Drinker had taken upon himself the task of collecting all the facts on American Tunnelling, and hoped he would receive the hearty co-operation of individual members of the Institute. President Holley also commended Mr. Drinker's scheme, and believed the work would be of great value to engineers.

The fourth session was held on Thursday morning, when the following papers were read:

What Steel is, by Prof. Fred. Prime, Jr., of Lafayette College, Easton, Pa.; The Effect of Manganese on Bessemer Metal, by Dr. A. Wendel, of Troy, N. Y.; The Manufacture of Ferro-Manganese in Austria, by Prof. W. P. Blake, of New Haven, Conn.; The Manufacture of Ferro-Manganese in Georgia, by W. P. Ward, of Cartersville, Georgia; Canfield's Mineral Dresser, by Prof. T. Egleston, of New York; Alchemy, the Foundation of Chemistry, by George Asmus, of New York.

Mr. E. B. Coxe gave notice, in accordance with the rules, that, he intended to propose an amendment to the rules at the next annual meeting to increase the number of Vice-Presidents to nine and of Managers to fifteen.

Mr. E. C. Pechin gave notice that he intended to move at the next annual meeting that the name of the Institute be changed to The American Institute of Mining and Metallurgy.

The fifth session was held on Thursday afternoon.

Mr. P. H. Dudley read a paper on Railway Resistances. Great interest was manifested by the members in Mr. Dudley's methods and results, and the following resolution, offered by Dr. J. Lawrence Smith, was unanimously adopted:

Resolved, That a committee be appointed, with Prof. Thurston as chairman, to adopt efficient means to make the results of Mr. P. H. Dudley's experiments beneficial to the railroad transportation of the country. The President appointed, at a subsequent meeting, Prof. Thurston, P. H. Dudley, and W. P. Shinn.

Prof. Persifor Frazer, Jr., of the second geological survey of Pennsylvania, made a communication on the Lithology of the Palæozoic and Mesozoic Rocks of Pennsylvania, illustrated by some two hundred thin sections, which were exhibited under the microscope. Prof. Frazer referred to the researches of Messrs. E. D. Dana and G. W. Hawes, of New Haven, and the previous communication of his own on the Igneous Rocks, at the New Haven meeting, February, 1875. Pending the chemical analyses of the rocks by Dr. F. A. Genth, Prof. Frazer confined his remarks to their physical and mineralogical characters.

Prof. Thomas Archer, of the British Commission to the Centennial Exhibition, was introduced to the Institute, and made a few remarks.

President Holley exhibited a section of Woodbridge gun, showing the manner in which the iron wires are soldered by means of bronze.

Mr. T. F. Witherbee read a paper on the Cedar Point Furnace, Lake Champlain.

Dr. R. W. Raymond read a paper on the Spathic Iron Ores of the North River.

The sixth session was held on Friday morning.

Mr. P. H. Dudley read a paper on Industrial Researches on Heat and Combustion. On recommendation of Council, the status of Mr. S. Howland Russell and J. K. Rees was changed from associate to member.

President Holley reported, on behalf of the Council, the following resolution for action of the Institute:

Resolved, That Messrs. B. W. Raymond, E. B. Coxe, A. L. Holley, T. Starry Hunt, and T. M. Drown, be appointed a committee to procure the preparation of papers by the members of the Institute, with special reference to the progress and state of mining and metallurgical engineering in America, and also in foreign countries, in so far as represented at the Centennial Exhibition, said papers to be published in the *Transactions* of the Institute, and to be edited by the committee within one year after the close of the Exhibition, for publication as a Centennial memorial of engineering.

On motion, the resolution was unanimously adopted.

Mr. Martin Coryell read a paper on the Diatomaceous Sands of Richmond, Virginia, followed by Mr. John Birkinbine on Suspended Hot-Blast Pipes.

Prof. Egleston, as chairman of the committee appointed to co-operate with the United States Test Board, made the following report:

The committee appointed to co-operate with the United States Board for Testing Iron and Steel and other Metals begs to report that it has communicated with the United States board, and that its services have been accepted with thanks. It has examined the plans proposed by the United States board, and find them eminently judicious, and likely to lead to the most important results in both metallurgical and civil engineering and the science of construction, and that they are likely to be of the greatest possible advantage to the United States government itself, by furnishing results which will both lessen the expense and increase the safety of the naval, war, and civil structures, which the government has to undertake. It therefore begs to present to the Institute the following preamble and resolution as one of the means of co-operation which will be likely to aid the labors of the United States board.

WHEREAS, The committee appointed by the American Institute of Mining Engineers to co-operate with the United States Board for Testing Iron and Steel and other Metals, has inquired into the plans proposed, and informed itself of the work already done by the United States Board, and has reported that the Board is, in its opinion, judiciously organized, and that the plans show evidence of the highest professional ability, and finds that the Board has already employed a competent chemist, and equipped a chemical laboratory where important results have already been arrived at; that a very complete testing machine has been nearly completed under its direction, which is a model both in design and workmanship; that it has already made a large number of experiments with the machines for testing now in use, and collected a largo amount of information relating to tests made by different departments of the United States government and other competent bodies and persons; that it has prepared for a complete series of chemical and physical tests of iron and steel and of a number of alloys, which can but result in greater economy and durability of construction ; that the members of the Board, who are men of the greatest professional ability and command the public confidence, are contributing their services gratuitously; that the results to be attained are likely not only to benefit the world at large, but also to be of particular advantage to the United States government; therefore

Resolved, That this Institute heartily indorses the work of the United States Board.

Resolved, That it is the opinion of this body that the United States Board for Testing Iron and Steel and other Metals should be continued.

Resolved, That the Institute respectfully petitions the honorable Senate and House of Representatives to grant to the United States Board the sum of fifty thousand dollars, to be expended in carrying out its plans.

Resolved, That this Institute believes that such an appropriation would be judiciously expended, and thinks it would be a *real* economy on the part of the United States government to make the expenditure.

The report was approved.

Prof. Thurston briefly explained, as one of the members of the board, the nature of the work they had already accomplished and what they hoped to do. He thought the moral support of such bodies of scientific men as the Institute of Mining Engineers and the Society of Civil Engineers would aid them greatly in carrying out their work.

Mr. E. W. Hunt then read a paper on the New Worthington Compound-Duplex Pressure Pump at the Troy Bessemer Works.

President Holley exhibited drawings of a New Suspended Water-Cooled Furnace Roof, designed by him for the Pernot Furnace.

The following papers were then read by title:

On the Percentage of Iron in Certain Ores, by Prof. A. H. Chester, of Clinton, N. Y.

On the Origin of Mineral Veins, by Col. Charles Whittlesey, of Cleveland, Ohio.

On Brückner Cylinders, by N. H. Cone, of Nederland, Col.

Condition of the Mining and Smelting Industry of the Far West at the Close of 1875, by A. Eilers, of New York.

Assay Offices and Mints of Europe, by P. De P. Ricketts, of New York City.

Electro-Metallurgy, by N. S. Keith, of New York City.

Blast-Furnace Practice, by J. A. Church, of Tarrytown, N. Y.

The Brown Coals of Utah and Adjoining Territories, by Henry Engelmann, of La Salle, III.

Determination of Phosphorus in Iron and Steel, by Andrew A. Blair, of Wintertown Arsenal, Mass.

The Boston and Colorado Smelting Works, by Prof. Thomas Egleston, of New York City.

Mr. F. Firmstone offered the following resolution, which was unanimously adopted:

Resolved, That the thanks of the Institute are due to the officers of the Smithsonian Institution for their courtesy in the reception of its members and providing facilities for its sessions; and to the venerable Secretary for his hearty Welcoming address and his kind hospitality; to Hon. A. S. Hewitt, our follow-member, for his enjoyable reception ; and to the Local Committee, and especially Captain C. E. Dutton, for its admirable arrangements for the convenience and pleasure of the members during the meeting.

The concluding session was held Friday afternoon, Vice-President Cogswell presiding. Prof. J. C. Smock, of New Brunswick, N. J., read a paper on The Use of the Magnetic Needle, or Dip Compass, in Searches for Magnetic Iron Ore.

Dr. Henry Wurtz read a paper on Preliminary Suggestions on the Molecular Nature of Iron and Steel.

Dr. Wurtz also exhibited samples of iron and wire, which had been made with the use of petroleum as fuel.

The meeting then finally adjourned.

On Thursday evening, the Hon. A. S. Hewitt received the members of the Institute at his house on K Street, and on Friday evening, Prof. Henry received the members at his house at the Smithsonian Institution.

No excursions were formally organized, but opportunity was given members to visit the Navy Yard and the Naval Observatory, under the courteous guidance of Commander Beardslee and Prof. Holden.

PAPERS.

DOVER MEETING,

MAY, 1875.

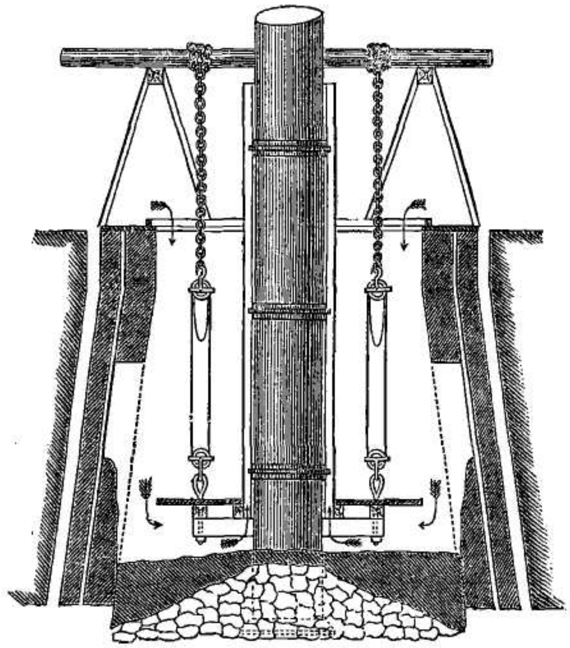
REPAIRING THE UPPER PAST OF A FURNACE LINING WITHOUT BLOWING OUT.

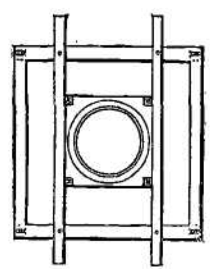
BY FRANK FIRMSTONE, GLENDON IRON WORKS, EASTON, PA,

WE found it necessary, in December, 1874, to repair the upper part of the lining in No. 5 furnace at Glendon, and, as we succeeded in doing it with comparatively little trouble, a description of the plan followed may be of service to those having a similar operation to perform.

On two opposite sides, as shown by the sketch, the lining was completely gone for a height of about four feet, below which it increased gradually in thickness, being nine inches thick about three feet lower down. On a plane at right angles to the section drawn, the brick were nowhere entirely gone, but were in some places not more than two or three inches thick, being still sufficient to sustain the upper part, where the brick, being above the level of the stock, were not at all worn.

The furnace was blown down, so that when we cast and closed the tuyeres, about 7 A.M., on December 8th, the top of the stock was about twenty-four feet below the filling-plates. The walls were quite hot, and a good deal of gas was given off for several hours after the tuyeres were closed. The hopper and bell were thrown into the furnace, and were covered by filling several charges of cold stock over them, which at once greatly cooled off the top of the furnace. A wrought-iron pipe, thirty inches in diameter, in five sections, each six feet long, was then put down, and made to stand upright, as nearly as possible in the centre of the furnace. Around this we filled a double charge of coal, taking care to heap it up next the pipe, and let it get thinner as it got to the walls. This was covered with about two feet of fine ore, leaving the lowest joint in the pipe entirely uncovered. We were now ready to put in our scaffold to get at the brickwork. The scaffold was made as shown in the sketch. It was ten feet in diameter, and was suspended from two stont poles (which reached across the top of the furnace and rested on two trestles, about six feet high), by four chains and four pair of differential





blocks, whereby it could easily be raised and lowered as might be required. The frame of the scaffold, which had been well painted and sanded, was put together around the pipe in the centre of the furnace, and was floored over with two-inch plank, leaving a hole three feet four inches square in the middle. Four pieces of 3 x 4 scantling, sixteen feet long, were nailed upright at the four corners of this opening, and, by nailing sheet iron from post to post, a square chimney surrounding the pipe was formed. By this arrangement most of the gas was drawn off through the central pipe, which got pretty hot soon after it was put in, and at the same time the strong ascending current, in the space between the square chimney and the pipe, carried off any gas which might leak through the fine ore, and brought a stream of fresh air (as shown by the arrows in annexed cut) down past the faces of the men as they worked at the brick.

These arrangements were completed about 7 P.M., when the night shift of bricklayers came on.

We at first tried to build up the holes, intending to wedge up the top brick, which were still perfect, on the new work, and then cut out and rebuild the thin places, a little at a time. We soon found that we could not get base enough for this, and determined to take out all the old work from the top down, until we had from six inches to nine inches to start on, and then rebuild, closing each course as we went.

Taking out these bricks was the hardest part of the job. They were, many of them, too hot to touch without hand-leathers, and the loam filling between the front and back lining made a very thick dust.

After the top courses were out, we had to set props to prevent the lower brick from falling in a mass. All the brick were out about 4 A.M. on the 9th, and at 6.30 A.M. the day shift of bricklayers began to rebuild, finishing about 10 P.M.

Cast-iron angle plates, one inch thick, were built in at every joint, to cover the brick and prevent rapid wear in the future.

When the masonry was done, we lowered the scaffold to the bottom, knocked off the chimney, and took the bolts out of the lower joint in the pipe. After the chimney was removed there was a slight smell of gas at the bottom, but the time spent in taking out the bolts was so short that no one got sick from it.

The scaffold and the upper part of the pipe were then hoisted out, leaving the lower section in the furnace, and the rest of the night was spent in sending down the pipe, etc., and clearing away for putting in the new bell and hopper. This was accomplished, and the blast put on by 3 P.M. of the 10th.

The furnace started without trouble, and although she slipped and worked irregularly for some weeks, she finally came to work very well, and the new part of the lining promises to last indefinitely.

ON THE USE OF NATURAL GAS FOB PUDDLING AND HEATING, AT LEECHBURG, PENNSYLVANIA.

BY A. L. HOLLEY, C. E., NEW YORK CITY.

THE occurrence of this gas, in quite appreciable quantities, has been observed for many years in its escape along the creeks of Western Pennsylvania, and more recently, in much larger quantities, from the oil wells in and near Venango County. Within about five years several gas wells have been struck, from which the gas has escaped continuously in prodigious quantities and at great pressure.

During the last year a systematic attempt has been made to utilize the flow of gas from one of these wells, and results have been reached which were quite unexpected. This well, near Leechburg, Armstrong County, is about twenty miles northeast of Pittsburgh, on one of the side tributaries of the Alleghany River. It had been drilled in search of oil to a depth of 1250 feet in 1871, but none was found. A great flow of gas was developed, however, accompanied by a slight spray of salt water, and this has continued with little or no diminution to the present time. The gas in its escape has been discharged through a 5-inch pipe, and at a pressure of from 60 to 80 lbs. per square inch, but no exact determinations, either of the pressure or quantity, have been made.

The rolling mill of Messrs. Rogers & Burchfield is on the opposite side of the river, and it has been for some years devoted to the production of fine grades of sheet iron from charcoal pig metal, by puddling and in knobbling fires. The usual weekly product of the mill has been 30 tons of No. 30 tin plates, and 50 tons of No. 24 to 28 sheets.

The well was bought by this firm for §1000, and the gas is led across the river, a distance of about 500 feet, through a 3-inch pipe. It is distributed through half-inch pipes, and at a pressure of about 45 fibs, per square inch, to several of the furnaces, but a large fraction of the total flow of gas is still wasted at the well.

No essential alteration in any of the furnaces has been found necessary in the use of the gas fuel, except to brick up the firebridge and to put in the gas and air pipes. The old grate used for coal is loosely covered with bricks and cinder, so that a slight percolation of air may take place through them. The gas is admitted through a half-inch pipe, and blows toward the fire-bridge through 18 or 20 one-eighth inch jets. The air is blown in at about 2 lbs.

pressure, through two one and one-eighth inch jets, obliquely down upon the centre of the hearth, and a very perfect combustion is obtained.

A great improvement is effected in the quality of the product of the puddling furnaces by the combined action of the gas and air blast. The air is blown in during the melting, but. it is then shut off until the boiling begins. It is then turned on full, and a violent boiling action is maintained without any rabbling. It is thus found practicable to use one-half miscellaneous cast scrap iron, and one-half "Lucy" No. 3 coke pig metal in producing the best sheets for tin plate, a better quality being thus obtained than from, charcoal pig metal as commonly puddled. Later observations, however, seem to indicate the probability of even more satisfactory results by the use, in connection with the gas flame, of a small auxiliary fire of coal.

The saving in either case in labor of firing is obviously almost total, for the flow of gas into the furnace is controlled by a simple gate or valve. It is clear, too, that many other difficulties, experienced heretofore in the use of solid fuel, are almost wholly eliminated.

A material increase in the product of the mill is effected by the use of the gaseous fuel, the amount of sheet iron made in each twenty-four hours being about 13 tons, as against 10 tons in the older way, but with the use of the same furnaces and plant. The very important saving is also effected of from 60 to 70 tons of coal in the same time, the only cost whatever in the use of the gas being the small maintenance and interest charges upon the fixtures and upon the original cost of the well.

Ten heats can be made by the two turns between 3.30 A.M. and 7 P.M., about one and a half hours per heat, and this is a clear saving of one-sixth in the time formerly occupied in the two turns' work. A common charge for each heat is 460 fibs. "Lucy" pig metal, and 50 lbs. to 80 lbs. cinder from the rolls or the hammer. The yield in the bloom is from 480 lbs. to 490 lbs. for each heat. It has been found that 500 lbs. of ore for fettling will last the five furnaces for a week with the gas fuel, while with coal, in two turns and at one furnace, 800 lbs. has been required. The waste in the rolling, and all the later working of the sheets, is greatly in favor of the iron puddled in the gas furnace, as it is softer and more uniform in quality and texture.

The reduction in the cost of the blooms thus made is very marked, those made from the scrap and pig metal mixture being credited to the gas furnace at $45 per ton, while the charcoal pig blooms, as puddled with coal, have cost $80.

The natural gas is thus far used in five furnaces for puddling, two for heating piles, three for annealing, and four for heating thin sheets, fourteen in all. In the pile-heating furnaces a half-inch pipe supplies gas enough to heat 8 or 10 tons of sheets per turn.

One new form of furnace has been designed for use with the gas fuel. This has no fire-box at all, but the gas is blown down upon a shelf, like the ordinary bridge wall of a furnace, and it is thus spread out-into a thin sheet. The air jets are directed down into and through this sheet of gas flame. Four or five air jets are also set so as to blow down into the hearth, and as many of these are used as may be needed.

The gas is also burned under seven boilers, a sufficient supply for each being delivered through a 1-inch pipe. A layer of old bricks is roughly piled on the grate, and by the discharge of the gas beneath the boiler, through a hole in the front, a sufficient flow of air is induced, and a long and effective flame is maintained, with an entire absence of smoke.

The lowest approximate estimate that has been made of the quantity of gas discharged by one of these large flowing wells is 1,000,000 cubit feet per twenty-four hours. If, for the sake of making a comparative estimate, the amount of similar gas yielded by the coal of the same region be taken at three cubic feet per pound, then one of these wells would represent, in its flow of gas, a production of about 150 tons of coal per twenty-four hours.*

* From observations made subsequent to the reading of this paper, the following results have been gathered:

Number of Heat.	No. 1.	No. 2.	No. 3.	No. 4.
"Isabella" G. F. pig,	312	294	265	241
Old car wheels,	160	184	201	230
Total iron,	472	478	466	471
Scales from rolls, etc.,	275	302	260	260
Total charged,	747	780	726	731
Product in blooms,	553	556	540	572
Gain over iron charged,	81	78	74	101
Percentage of gain,	17	16	15	21

THE SWANSEA SILVER SMELTING AND REFINING WOBKS OF CHICAGO.

BY J. L. JERNEGAN, JR., M. E., HALL VALLEY, COLORADO.

IN a former paper laid before the Institute, entitled Lead and Silver Smelting in Chicago, I endeavored to give a description of the manner in which argentiferous lead ores from the far West were treated in that city, and also described the method employed in the desilverization of the silver-lead produced from the ores. It will perhaps be remembered, that very siliceous ores, principally from the Emma mine, Utah, containing over 40 per cent. of silicic acid, were then being treated at the works of the Chicago Silver Smelting and Refining Company in the reverberatory furnace, with the use of metallic iron, in the form of borings, as a precipitating medium for the lead ; and that the extraction of the silver from the. resulting bullion was effected by the Balbacli process. The Swansea Works, also the works at Brighton, just outside of this city, and those of S. P. Lunt, were at that time treating ore of a similar character by the same method. The inadequacy of the process for the ores then under treatment was, in a manner, pointed out by me in the paper above referred to. Since the time of its writing, many and important improvements have been made in the metallurgical treatment of Western ores in Chicago. Most ores are now roasted previous to reduction, and the latter operation is conducted in the shaft-furnace instead of the reverberatory. Such is the fact at least at the Swansea Works, the largest in the city, and here it was where the first steps were taken in this direction. In selecting these works as the subject of this paper, I am in hopes that the description given of the various metallurgical operations, as they are there now conducted, will serve to give an idea of the improvements introduced

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A recent analysis (1876) of the gas from this Leechburg well, by Mr. Sadtler, of the University of Pennsylvania, gives specific gravity, .558:

Carbonic acid,	.35
" oxide,	.26
Illuminating hydrocarbons,	.56
Hydrogen,	4.79
Marsh gas CH_4,	89.65
Ethyl hydride C_2H_6,	4.39
	100.00

within the last two years. I would here acknowledge my obligations to Mr. N. A. Cook, superintendent of the works, for valuable information kindly rendered.

The works are situated on what is known as the West Side of Chicago, occupying nearly a block on South Jefferson Street. Their location in the midst of a crowded business section of the city is, for numerous reasons, very unfavorable, among the most prominent of which may be mentioned the lack of sufficient space for a slag dump, necessitating the continual carting away of the slag.

The following are the principal furnaces and apparatus: Two roasting furnaces, one of which is built in the style of the German *Fortschaufehmgsofen-;* the other is a revolving cylinder connecting with a slagging hearth ; two blast-furnaces of four tuyeres each ; four reverberatory smelting furnaces; one lead-softening furnace; two small reverberatory furnaces for the reduction of lead dross; two liquation furnaces, employed in separating the zinc-silver-lead alloy from the bullion after it has been mixed with zinc for the extraction of its silver; one lead-refining furnace; eight tilting retort furnaces for distilling the zinc from the zinc-silver-lead alloy; two English cupellation furnaces; a No. 9 Sturtevant blower, supplying blast to the shaft and cupellation furnaces ; ore-crushing machinery, consisting of an improved Blake's crusher, two grinding mills, one ore-screen, two Cornish rollers and belt elevators; a 36 horse-power horizontal steam engine, taking steam from two tubular boilers, which furnishes the motive power for running the ore-crushing machinery, the Sturtevant blower, and the revolving cylinder-roaster.

The ore treated is mostly mined in Utah and Colorado, and is shipped to the city either over the Union or Kansas Pacific Railroad ; freightage from Salt Lake City to Chicago amounting to $21 per ton. From the railroad depot the ore is carted to the works, the teamster receiving about $5 for hauling a car load, which is generally considered to be about ten tons, but is more often equal to about eleven. A good team is capable of hauling a car load from depot to works in four trips; the pay received per trip would therefore be $1.25. The low grade ores are shipped in bulk, the high grade ores are packed in canvas bags. On arriving at the works it is thrown from the carts on to the ore floor.

Ores.—The following were the principal ores treated during the months of August, September, October, and November of 1874, to which space of time my remarks will be chiefly confined:

So-called concentrated galena ore from Utah, mine unknown, consisting of almost pure galena with some iron pyrites, and yielding by fire assay from 65 to 70 per cent, lead, and from 10 to 15 oz. silver per ton. Ore from Yosemite Mine, Utah, an oxidized ore in part, often containing large and small nodules of galena. Sesquiox-ide of iron is present in the gangue in considerable quantities. Laid, from 40 to 50 per cent.; silver, from 10 to 15 oz. Ore from Spanish Mine, Utah; an oxidized ore containing about 35 per cent. silica, from 6 to 7 per cent, sesquioxide of iron and small amounts of alumina and lime. The lead is almost entirely present in the form of carbonate. From 30 to 35 per cent, lead, and about 15 oz. silver. Ore from Galena Mine, Utah; chiefly composed of argentiferous galena. Lead, from 45 to 55 per cent.; silver, about 15 *ox.* A small lot from San Juan District, Colorado; very siliceous and carrying but very little lead (about 5 per cent.), but assaying high in silver, with some gold. Also small lots of high grade silver ores from Colorado, which are sometimes added to the roasting charge in small quantities for the purpose of increasing the amount of silver in the bullion to such a degree as to make it profitable for extraction.

Ore Crushing.—When necessary, the ore passes through a Blake's crusher. From the crusher it falls into a grinding mill, resembling in many respects a coffee-mill, passing from here on to a screen, to which is imparted a jarring motion. That portion of the ore sufficiently fine to pass through is ready for roasting; the portion composed of too large pieces to admit of its passage through the screen, is shaken off and into the shovels of a belt elevator, which conveys it up to and discharges it between two Cornish rollers revolving in opposite directions. The rollers complete the crushing. The finely crushed ore from the rollers is then conveyed to another belt elevator by means of a revolving Archimedian-like screw playing within a trough, the elevator conveying it to the hopper of a revolving cylinder roasting-furnace, into which it is discharged. Two men only are required to attend the work of crushing; one to feed the crusher, the other to tend the other machinery. They receive $1.50 per shift of twelve hours.

The method of metallurgical treatment, as practiced at these works, is a combination of the *roast-reduction* and *iron-reduction* processes. The entire treatment may be divided into the following eight operations :

1. Boasting in long reverberatory or cylinder roasting-furnaces.
2. Fusion and reduction of the roasted ore in blast-furnaces.
3. Softening of the bullion resulting from the preceding operation

in reverberatory furnaces, and after tapping off the charge into an iron kettle, mixing with zinc, in order to form an alloy of zinc, silver, and lead.

4. Liquation of the bullion mixed with zinc in such a manner as to leave remaining on the hearth of the liquation furnace. the alloy of zinc, silver, and lead, the desilverized lead flowing from the furnace into a pot.

5. Treatment of the desilverized lead either in a kettle, with steam, or in a lead refining furnace, for the purpose of freeing it from zinc.

6. Distillation of the zinc-silver-lead alloy in retort furnaces, whereby the greater part of the zinc is expelled and there remains a rich silver-lead.

7. Cupellation of the rich silver-lead in English cupelling furnaces.

8. Refining of the silver obtained by cupellation of the rich silver-lead in graphite crucibles within the wind-furnaces of the assay laboratory.

Of late it has often been the practice to extract the silver from the bullion by the addition of three separate quantities of zinc and skimming after each separate addition, eliminating the zinc from the desilverized lead by steam, and draining the zinc-silver-lead alloy from excess of lead in a heated kettle, thus entirely doing away with the liquating furnaces, and also effecting a much more perfect separation of the silver than by the former method of manipulation.

Roasting. — Roasting, as conducted at these works, is classed under the head of slagging-roasting, *i. e.*, the ore, after having been subjected to an oxidizing roasting in the cooler portion of the furnace, for the purpose of desulphurization, is fused at an increased temperature to a slag before being withdrawn. The slagging of the ore effects two important objects, viz., the decomposition of any remaining sulphate salts present in the charge—the bases of the same combining with thesilioic acid in the ore to form silicates, thus setting the sulphuric acid free—and the prevention of the formation of metallic fumes in the blast-furnace, thereby avoiding the loss of much metal by volatilization. The latter point is of great importance, since the blast-furnaces are not provided with dust-chambers. When the roasting charge does not possess a sufficient amount of silica to form with the bases present an easily fusible slag, it has been customary to supply the deficiency by the addition of sand to the same after it arrives at the slagging-hearth. The sand used for this purpose is brought from the lake shore at a cost of 30 cents per cubic yard. Sometimes, when the charge is composed of ores poor in silver, a few hundred pounds of high grade silver ore arc added soon after the ore commences to fuse in the slagging-hearth. The object is to increase the amount of silver in the bullion resulting from the next following operation of reduction of the roasted product in the blast-furnace. Without this increase of silver, the bullion produced from the low grade ores would not contain a sufficient amount to make the extraction of that metal from the lead profitable.

As previously mentioned, there are two roasting furnaces, differing, however, in construction. One is a single-hearth, long reverberatory, the other is of peculiar construction, resembling in some respects the Bruckner cylinder. The interior arrangement of the cylinder, however, is quite different from that of the Brückner furnace. The roasting cylinder also connects with a slagging-hearth, into which the ore, after having passed through the former, is discharged and slagged, previous to removal from the furnace.

The single-hearth, long reverberatory roasting furnace is 2G feet long and 6 feet wide over all. It has eight working doors and a fire door, all situated on the one side. The two doors at either end of the roasting chamber are somewhat larger than the others—that at the flue end serving as a charging door, the one next the fire-bridge for drawing the charge from the furnace. All the working doors are provided with sheet-iron covers, with the exception of the slagging-hearth door, which has a cover of cast iron. The side walls of the foundation are built of common brick, the interior space filled in with broken brick and mortar. The fire-box, hearth, and sides of roasting chamber are of fire-brick, also arch spanning the roasting chamber from end of fire-box to within a short distance beyond the slagging-hearth, but from this point on it is constructed of ordinary brick. As might well be expected, that part of the arch consisting of common brick is not capable of withstanding the effects of a high temperature for any great length of time, and must, therefore, often be renewed. It would certainly be cheaper in the end to make the entire arch with fire-proof material. The furnace is anchored with eighteen cast-iron bars placed vertically at equal intervals on either side, every two opposite connecting by means of wrought-iron tie-rods passing over the arch. The erection of this roaster is said to have cost §1300.

A roasting charge for this furnace consists of from 800 to 1000 lbs. of ore. There are six charges in the furnace at a time (4800 to 6000 lbs. — 2f to 3 tons). Every three hours a charge is withdrawn, and, consequently, remains in the furnace eighteen hours.

The total amount treated in twenty-four hours would, therefore, be between 3 1/5 to 4. tons. As much as 5 tons have been roasted within the same length of time when the ore was of such a character as not to require long-continued and careful manipulation. From 1500 to 1800 lbs. of bituminous coal arc consumed in twenty-four hours. This is at the rate of from 375 to 450 lbs. per ton of ore roasted, assuming the amount of ore treated in this time to be 4 tons. Two men attend the furnace. The head roaster receives $1.75 and his helper §1.50 per shift of twelve hours.

The charge is made up on the floor in front of the furnace charging door. For a long time it was composed of about one-half concentrated galena ore, and the remainder either of Spanish or Yose-mite, or both.

Manipulation.—We will assume the furnace to be charged with its full amount of ore, then the *modus operandi* is as follows: A short time before the charge next to the fire-bridge and in the slagging-hearth of the furnace is ready to be taken out, the proper quantities of the various ores that are to compose the charge, are brought in front of the charging door in wheelbarrows, dumped on the floor and then well mixed together. After the roasted and slagged charge is drawn out, and the remaining five charges moved one place nearer the fire-bridge—thus leaving a space unoccupied at the flue end— the new charge is shovelled into the furnace, spread evenly over the surface of the hearth, and the door closed. It remains in this position for three hours, during which time it parts with its hygroscopic water and possibly suffers slight chemical change under the influence of the low temperature to which it is subjected. At short intervals, the workmen turn each charge successively by means of a long iron rabble, thereby exposing new surfaces of the ore to the influence of the heat and oxidizing effects of the atmosphere. This greatly assists in accelerating the operation. The next charge nearest the fireplace having been slagged and drawn out, all the remaining charges are advanced one place nearer the fire-bridge; this accomplished, a new charge is introduced at the flue end. Here the charge remains for another three hours and now commences to oxidize and part with its sulphur, which escapes in the form of sulphurous acid. In this manner it is moved through the furnace until it arrives at that part of the hearth next the fire-bridge, or slagging-hearth, as it is called ; by this time it has parted with the greater portion of its sulphur. Under the effects of the increased temperature it soon begins to agglomerate, and the bases to combine with the silica present in the ore, after which it soon fuses to a slag and is then drawn from the furnace with a long iron rabble. * The roasted product flows from the discharging door on to a cast-iron plate on the floor. As soon as drawn out, water is thrown upon it in order to cool it off, and after becoming sufficiently cold, it is pried from the plate with bars, broken into pieces of convenient size, and then taken to the blast-furnace charging floor.

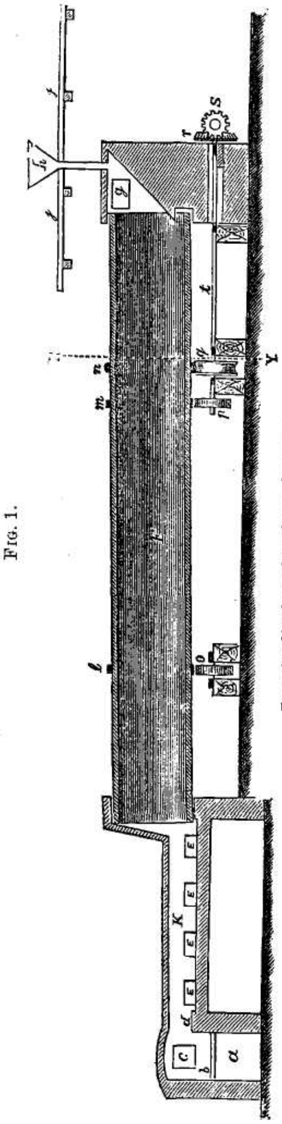
If the operation has been well conducted, the roasted product is generally deep black in appearance, of vitreous lustre, homogeneous, and showing but few, if any, particles of a bright metallic lustre. On the other hand, when not well roasted, the fused mass will present numerous spots with this metallic look, owing to the presence of un-decomposed sulphide of lead. This occasionally occurs when the ore has not become sufficiently oxidized before reaching the slagging hearth. Generally speaking, however, this furnace almost always roasted to within 3 or 4 per cent. of sulphur, and if the charges were smaller or the ore crushed finer, even better results might easily be obtained. The charges are undoubtedly too large for the size of the furnace, for when spread evenly over the surface of the hearth, they form a layer of about six inches in depth. By decreasing them to a proper limit, I do not think the capacity of the furnace would be much affected, if any, for then they would not require so long a time for roasting.

In speaking of this furnace roasting to within 3 or 4 per cent. of sulphur, it should be mentioned that the average charge before entering the furnace, when composed of one-half of the concentrated galena ore and the other half of equal parts of Yosemite and Spanish, generally contained about 22 per cent, of sulphur, more than half of which amount was due to the concentrated galena containing some iron pyrites.

I regret being unable to give any analyses of the roasted ore, none ever having been made; its average content in lead, however, is about 60 per cent., and in silver (when no high grade ores were added) from 15 to 20 ounces per ton.

The cylinder roaster (see Figs. 1, 2) has a length of 37 feet from end of fire-box to farther extremity of cylinder. The cylinder is made of boiler plate, is 26 feet long, 4 feet in diameter, and has a fall in its entire length, from flue end towards the slagging hearth, of 6 inches. It formerly served as a boiler for generating steam. The slagging hearth is 8 feet long by 6 feet wide, and has 8 working doors, 4 on either side. Distance from centre of hearth to arch spanning same, 15 inches. The fire-box is 3 feet by 6 feet; grate, 2 feet by 5 feet, equal to a surface of 10 square feet. Fig. 1 is a vertical section through the centre of this furnace, Fig. 2, a cross-section through the cylinder, showing the brick lining and position of fire-clay tiles which serve to stir the ore.

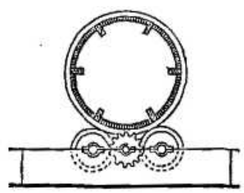
FIG. 1.



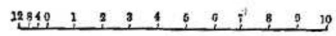
Longitudinal section through centre.
Revolving cylindrical roasting furnace with slagging-hearth.

Fig. 1, *a*, ash-pit; *b*, grate; *c*, fire-door; *d*, fire-bridge; E, E, E, E, working doors, through which the ore on the slagging-hearth is turned at short intervals with an iron rabble. The door next to the fireplace is the one through which the roasted and slagged ore is removed. K, slagging-hearth; F, cylinder, of boiler iron, lined with one layer of common brick placed on their broader sides, and having six rows of fire-clay tiles passing through its entire length (shown in Fig. 2, a cross-section through the line X, Y). The tiles keep the ore in perpetual motion when the cylinder revolves; *g*, flue opening through which the gaseous products of combustion and roasting are conducted through a long flue into a chimney; *h*, charging hopper, of sheet iron, through which the pulverized ore falls into the cylinder down the inclined surface shown in the drawing. The feeding is performed by machinery, a belt elevator conveying the finely crushed ore from the crushing machinery, situated on a level somewhat below that of the furnace, up to the hopper and discharging it into the same. Just below the funnel there is a worm screw, not shown in the figure, which regulates the discharge. The operation of feeding is thus made continuous, and the amount can be regulated at will. The flue end of the cylinder is provided with a flange to prevent the ore from escaping. *j,j,* is the charging floor. Around the periphery of the cylinder pass three iron rings, *I, m,* and *n ; I* and *n* are the surfaces upon which the cylinder revolves on the

FIG. 2.



Vertical section through x, y.



Scale 1 ft. — 0.15 in.

Scale to Figures 1 and 2.

wheels *o* and *q,* the grooved wheel *q* also serving to keep the cylinder in place. The ring *m* is furnished with teeth, into which play those of the cog *p;* motion is imparted to the latter through the shaft *t* by the level gearing *r* and s, communicating to the cylinder a slow revolving motion, making, on an average, two revolutions per minute. This roaster was the invention of Mr. Adam Smith, the proprietor of the works. It was erected at an expense of about $3000.

The capacity of this roasting furnace is from 8 to 10 tons per 24 hours, with a consumption of from 2500 to 3000 lbs. bituminous coal, or 277.7 lbs. to 333.3 lbs. per ton of ore roasted and slagged, assuming that 9 tons is the usual amount treated. It is claimed that it has roasted *as* much as 12 tons per 24 hours, but I am not informed as regards the character of the ore operated upon when treating that amount, nor the limit to which the sulphur was removed. Judging from my own experience, I do not think it is capable of treating to advantage more than 7 to 8 tons per 24 hours, of a highly sulphuretted ore. For the purpose of roasting an ore containing a large percentage of lead in the form of galena, it is not at all suited, because galena is apt to agglomerate in the cylinder, and form balls, which continually increase in size, on the same principle as a boy makes his snowball larger and larger by rolling it in the snow. I cite an instance in this connection which occurred at the works while endeavoring to roast almost pure galena, in which a ball so formed and of such large dimensions that it had knocked out several of the bricks forming the lining, before it was discovered. It was necessary to stop the cylinder, remove the hot coals from the grate, and allow the furnace to cool off sufficiently for a workman to enter and remove the ball. The only means by which ores rich in galena can be roasted in this furnace is to mix them with other ores not carrying a large amount of that mineral, and best when containing a large percentage of infusible and basic gangue, such as the sesquioxide of iron and lime. Fortunately, we were possessed of such ores in those from the Spanish and Yosemite mines, and by a proper mixing of these with the concentrated galena, were enabled to roast the latter. Without doubt, the furnace does its work well with ores not disposed to sinter at the temperature existing within the cylinder, and also when not fed too rapidly. The great mistake made in running it was, too much was always expected, *i.e.*, that it could thoroughly roast an ore—no matter how high the percentage of sulphur—as fast as it could be fed into the furnace. This of course was a great mistake, and was in part attributable to the incapacity of this and the long reverberatory roasting furnace to provide the blast-furnace with a constant supply of well roasted ore; hence the rapid feeding in order to make up for the deficiency.

In making a comparison between this furnace and the long reverberatory, it may be said of the former that it roasts about 8 tons in the time the latter requires to roast 4. The capacity of the reverberatory, however, could easily be increased by enlarging it, while the advantages to be obtained by increasing the size of the cylinder-roaster, seem to me doubtful. The reverberatory requires but few and inexpensive repairs if properly constructed; the cylinder-furnace, on the other hand, was subject to the necessity of repeated repairs during the time I was engaged at the works. It is also dependent on the engine for its efficiency, so that in reality there are two causes which may render it necessary to allow the furnace to stand idle, while the reverberatory is subject to only one, viz., the furnace itself demanding repairs. The cause of the almost constant repairs required by the cylinder-roaster might, without doubt, be remedied, since they are generally the result of the heat radiated from the exterior surface of the cylinder upon the revolving gearing, whereby it is apt to get out of place, or work with great friction between all its parts. Two men only are required to tend the reverberatory; the cylinder-furnace requires three: a head roaster, feeder, and helper. The cost of roasting seems to be nearly the same in both. The accompanying figures give the approximate cost of the process in both furnaces.

Cost of Roasting 4 Tons of Ore in Reverberatory Furnace.

1500—1800 lbs. coal @ $3.62 per ton, ...	$2.71—3.25
Head roaster, 2 shifts @ $1.75 per shift, . . .	3.50—3.50
Helper, 2 " @ $1.50 " " . . .	3.00—3.00
Total, ...	$9.21—9.75

Per ton, $2.30 to $3.43, average, $2.36.

Cost of Roasting 8 Tons of Ore in Revolving Cylinder Furnace.

2500—3000 lbs. coal @ $3.62 per ton, ...	$4.52—5.43
Head roaster, 2 shifts @ $1.75 per shift, . . .	3.50—3.50
Feeder, 2 " @ $1.50 " " . . .	3.00—3.00
Helper, 2 " @ $1.50 " " . . .	3.00—3.00
Total, ...	$14.02—14.93

Per ton, $1.75 to $1.86; average, $1.80.

Difference in favor of the cylinder-roaster, $0.55 per ton of ore treated.

But it will be perceived that, in making this comparison, nothing has been charged to either furnace for wear and tear of the same, nor to the cylinder-roaster for motive power. The expense for wear and tear on the cylinder furnace is much more than for the reverberatory, and this added to the cost of the motive power required by the former, counterbalances, I think, the 55 cents per ton shown in favor of the cylinder-roaster by the foregoing figures.

The temperature in the cylinder, when in working order, is low red. The finely crushed ore, after having passed through the hopper into the cylinder, is constantly subjected to stirring by the projecting tiles, until, reaching the opposite end, it falls on to the slagging-hearth. The time required for the ore to pass from the flue end of the cylinder to the slagging-hearth depends upon the number of revolutions per minute; when making about two, it passes through in about one to one and a half hours. When a small pile of ore has collected on the hearth, just in front of the cylinder, it is spread evenly over the surface, and allowed to remain in this position until the charge next to the fireplace has become slagged and been drawn from the furnace, then it is moved up to the fire-bridge and remains until fused. The ore as it comes from the cylinder seems to have parted with the greater portion of its sulphur, and has an ample opportunity of losing the remainder while in the slagging-hearth. A roasted and slagged charge is drawn out every 2½ to 3 hours; it averages 1800 to 2000 lbs. in weight. From 2500 to 3000 fibs. bituminous coal are consumed per twenty-four hours.

Generally speaking, the roasted product from this furnace contains from 4 to 5 per cent, sulphur, more than the average of that from the reverberatory.

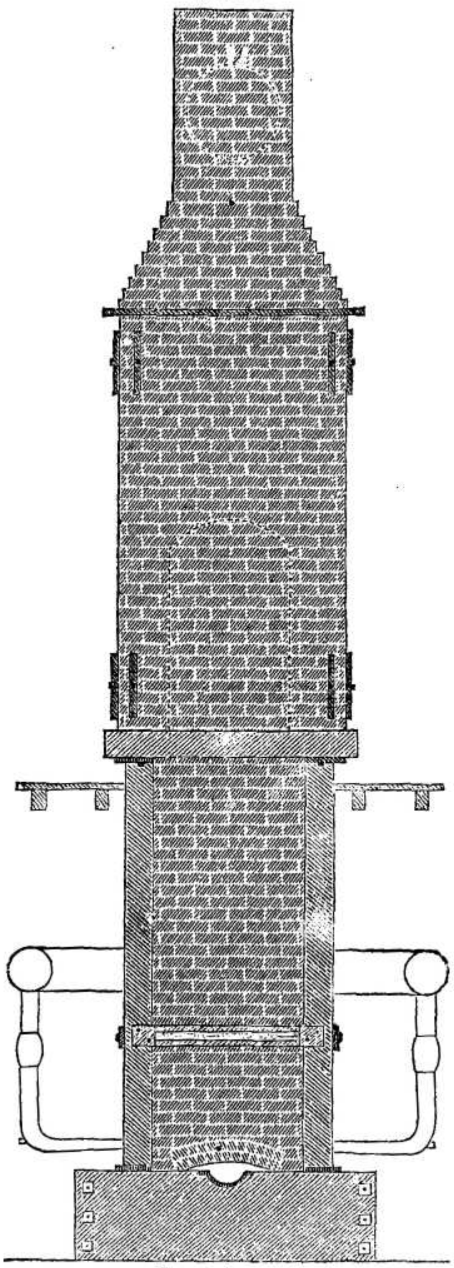
As previously mentioned, the two roasting furnaces just described are not capable of supplying one of the blast-furnaces with the required amount of well-roasted ore. In order to make up for this deficiency, the four reverberatory smelting furnaces, formerly employed in smelting all ores previous to the introduction of the blast-furnace (built September, 1873), were taken into service for roasting. For this purpose the hearths were raised to within a few inches of the top of the fire-bridge, by putting in a double row of fire-brick. Roasting, as conducted in the furnaces, is not a slagging-roasting, nor could the results be at all favorably compared with those obtained by the long reverberatory and cylinder-roasters. Roasting to within a low percentage of sulphur was a long-continued and tedious operation, consuming much fuel, and producing but a small amount of roasted ore at long intervals ; therefore, in order to increase the yield, it was customary to only partly roast the ore and send it to the blast-furnace in that condition. The results obtained are of little interest, and may well be omitted.

The coal principally used in the roasting furnaces is from the Wilmington coal fields of Illinois, though occasionally some Indiana block coal is mixed **with** it. The former cannot be classed as among the best qualities of our bituminous coals, and often contains a considerable amount of pyrites. A ton of Wilmington coal in Chicago costs from $3 to $ 4 at wholesale prices; the average price paid at the works may be placed at $3.62.

None of the roasting furnaces stand in connection with condensing chambers; consequently, a large percentage of metal contained in the ores is lost during the operation of roasting, in two ways, viz.: first, by volatilization, and, second, by particles of fine ore being carried out through the chimney by means of the strong draft passing through the furnace. The cylinder-roaster, especially, makes a good deal of fine dust, since the ore in passing through the cylinder is in constant motion. A considerable portion of the dust from the roasters settles on the roof of the building in which they stand; it is occasionally collected and mixed in with the roasting charges; but the greater part, of course, escapes into the atmosphere, and is lost forever. An assay of this product gave a result of 18 oz. silver to the ton, and 33 per cent. lead.

The method introduced at the works by me for determining the sulphur in the roasted ore, is one given by the celebrated metallurgist, Plattner, in his *Röstprozesse*, and is as follows : 1 gramme of the roasted and pulverized ore is fluxed with 2 grammes of carbonate of potassa or soda, free from sulphuric acid, and 2 grammes of nitre. This mixture is put into a wronght-iron dish of convenient size, and then placed within a red-hot muffle, where it is allowed to remain until all sulphate salts and metallic sulphides in the roasted ore have become decomposed, and the fluid mass ceases to boil, which requires from five to eight minutes, depending upon the nature of the roasted ore. After cooling, the fused mass is treated with boiling water, filtered, and the insoluble residue remaining on the filter is washed with as small a quantity of water as will suffice. The filtrate is then acidulated with hydrochloric acid and the glass placed upon a hot sand-bath, and allowed to remain until all fumes of nitrous acid have been expelled. To the concentrated solution is now

FIG. 3.



Front elevation

added from a burette, a standard solution of chloride of barium. The chloride of barium solution is so prepared that in 1 c.c. there is dissolved 0.076 grammes of pure crystallized chloride of barium, which precipitates 0.025 grammes sulphuric acid, or 0.01 gramme sulphur. Therefore, every cubic centimetre used corresponds to 1 per cent, sulphur, or 2.5 per cent, sulphuric acid, when the amount of roasted ore operated upon is 1 gramme. This method of procedure is very convenient and sufficiently accurate for metallurgical purposes, requiring but little time when the approximate amount of sulphur contained in the roasted ore is known to the operator.

Smelting of the Roasted Ore in Blast-furnaces.—The principal ingredient of the roasted ore is silicate of lead, and the object of this operation is the reduction of the lead to the metallic state, concentration of the silver in the same, and separation of the oxides, more difficult of reduction, in the form of a slag. It is desirable that the slag should approach, in chemical composition, as nearly as possible to that of a singulo-silicate. Some little matte is formed, the amount depending, of course, upon the thoroughness with which the preceding operation of roasting has been conducted. Generally speaking, it is quite poor, both in silver and lead, its chemical composition often nearing that of a pure protosulphide of iron, since metallic iron is freely employed as a precipitating agent for the lead, and the formation of an easily fusible slag. Limestone is used as a flux when deemed necessary, also slag from the same operation. Connellsville coke is the fuel.

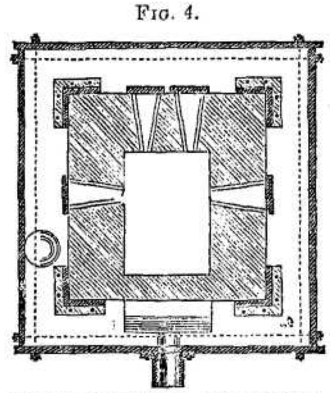
There are two blast-furnaces in which this operation is conducted; only one, however, is in blast at a time. They have four tuyeres each, cooled by Water, and are provided with the siphon tap. The blast is supplied by a No. 9 Sturtevant blower. Figures 3, 4, 5, and 6 represent the furnace in front elevation and in several sections. The following are some of the principal dimensions:

	Ft.	In.
Height of dam-plate from foundation, ...	2	0
" feed-hole " “	11	6
" from centre of tuyeres to feed-hole,............	9	0
" tuyeres from foundation, ...	2	3
" tuyere nozzles above slag-flow, ...	0	6
Diameter of tuyeres (inside measurement)	0	2½
Distance from back wall to breast at tuyeres, ...	2	8
" between side walls at tuyeres, ...	1	10
Prom centre of tuyeres to bottom of hearth,................	2	0
Hearth projects beyond hearth wall, ...	0	8
Width at throat (square), ...	2	8
" of upper portion (square), ...	4	0
Total height from foundation to top, ...	2	70

It will be seen, on inspection of the cuts, that the hearth of the furnace is well secured by four cast-iron plates, and the shaft by upright angle irons securely fastened at top and bottom with bolts passing through the flanges. There are also horizontal cross-pieces, about half-way between foundation and feeding-hole. Both furnaces connect with a chimney 105 feet high by means of long sheet-iron pipes, which collect a considerable portion of the fumes coming from the furnaces.

Before starting the furnace, it is heated for several hours by keeping up a fire with charcoal on the hearth bottom; the lead-well is then filled with hot coals and a gentle blast is forced down through one of the tuyere nozzles into it, and thence through the pipe connecting with the hearth into the furnace. The shaft is now filled to the height of five or six feet with charcoal, and, after having become well ignited, about twenty bars of bullion are put in at the feed-hole. It soon melts and flows into the hearth and rises up into the lead-well. A slight blast is put on soon after this and regular charges of coke and small quantities of roasted ore and fluxes are added, and the two latter gradually increased until the furnace is receiving its full amount and working under its normal pressure of blast. The average campaign lasts about ten days, the longest was fourteen days. The greatest difficulty experienced is the rapid burning out of the furnace lining, hence the short duration of the campaigns. Why not make up the charges so as to form a more highly silicated slag, and thus avoid this difficulty? The answer is, the furnace would not work as quickly and produce bullion as rapidly as those having the chief interest in the works desire, if the amount of the basic fluxes were reduced.

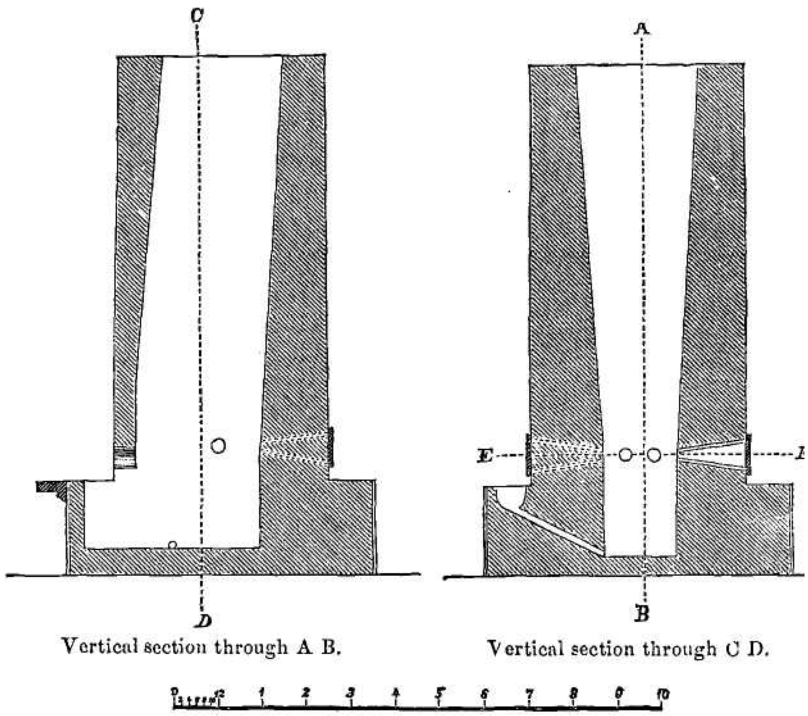
FIG. 4.



Horizontal section through E F.

The slag runs continually from the furnace into an iron slag-pot mounted on wheels, which, when full, is drawn away and another brought into requisition. It generally runs thin and cools rapidly with turgescence, and the bubbles on bursting frequently emit blue gaseous flames. After solidification, it has a feeble metallic lustre, and is black in color. What little matte is found flows out with the slag and settles to the bottom of the slag-pot, provided the latter is not of too high a specific gravity to allow of a good separation. I mention this, as a case of this kind actually occurred after having used the same slag as a flux several times in succession (not having any other on hand), which, finally, by its repeated passage through the furnace, became so saturated with iron, that its specific gravity

FIG. 5.



Vertical section through A B. Vertical section through C D.

Scale 1 ft. = 0.25 in.

was materially increased, leaving but a slight difference between it and that of the matte. As a very natural consequence, the slag assayed high both in silver and lead, owing to the imperfect separation. The average pressure of blast is equal to one half-inch mercury column, the blower making about 1800 revolutions per minute. The charges are not made up in large quantities in layers on the charging floor, but roasted ore, scrap iron, limestone, slag, and coke are all dumped in separate heaps near the feeding-hole, the feeder shovelling the different materials into the furnace in such proportions as directed by the superintendent. Neither is anything weighed, though the weight of a shovelful of the various fluxes, ore, and fuel are approximately known. Ore, fluxes, and coke arc spread as equally as possible over the entire area of the shaft, unless deviation from this rule becomes necessary from some irregularity in the working of the furnace.

The coke is from Connellsville, Pa., and costs from $6 to *$7* per ton; the scrap iron (old cans, clippings from tinsmith shops, etc.), between $4 and $5 per ton; limestone (sometimes oyster-shells are employed) from the quarries near the city costs about $1 per ton. It may be mentioned in this place that good firebrick can be procured for about §50 the thousand.

There are five workmen engaged about the furnace: the head smelter at $1.80 per shift of 12 hours, two slag runners at $1.50 each, one feeder at $1.75, and a roustabout at $1.50.

The capacity of the furnace running on the ores enumerated in the first part of this paper may be stated at from 10 to 15 tons, when previously roasted and slagged, with an average yield of from 5 to 7½ tons of bullion per 24 hours. As much as 20 tons, however, have been smelted in the same time.

I give here a single example of the composition of the charges. It was seldom that they ever varied when there was a full supply of roasted ore on hand. The roasted ore contained about 60 per cent, lead and 15 oz. silver to the ton.

BLAST-FURNACE CHARGE.

Roasted ore,	6	shovels	@ 13	lbs.	= 65	lbs.	= 51.18	per cent.
Iron scrap,	3	"	@ 3⅓	"	= 10	"	= 7.87	"
Limestone,	½	"	@ 10	"	= 5	"	= 3.93	"
Slag,	3	"	@ 11	"	= 33	"	= 25.98	"
Coke,	1	"	@ 14	"	= 14	"	= 11.02	"

Amount of fuel consumed, according to the above, is equal to 12.38 per cent, of the total amount of roasted ore and fluxes corn-posing the charge, or 21.53 per cent, of the roasted ore.

Sometimes considerable annoyance was experienced by the deposition and accumulation of metallic fumes on the walls of the furnace, from two to three feet below the throat, which, at the end of nine or ten days after blowing-in, frequently formed a complete circle, leaving only a small circular opening in the centre for the passage of the charges. This only happened to any great extent, however, when raw ores were introduced into the furnace for want of a sufficient supply of roasted ore, and since the former were mostly carbonates or oxidized ores, the formation of accretions in the upper part of the furnace is easily explained by the condensation of the volatile compounds of carbonate and oxide of lead on the cooler portion of the furnace walls. Another circumstance conducive to the formation of metallic fumes is, undoubtedly, the small vertical distance from slag-flow to tuyere-nozzles, which is only six inches, whereas it should be at least ten, otherwise lead will invariably be volatilized in large amounts. Probably the best method of getting rid of such accretions after they have once formed, is to discontinue the charges, allow the smelting column to sink down several feet, throw in several billets of dry wood, and then, with the aid of iron bars and the intense heat produced by the burning wood, the accretions are partly melted and partly pried off, after which the charging begins again.

The products of this operation are:

Slag.—Sometimes quite free from lead. The average result obtained by fire assay may be put at about 2 per cent. When not containing much more than this amount, it is thrown away, with the exception of a small portion retained for fluxing material. There has been only one complete analysis made of the slag. It is given below. The sample selected for analysis had all the appearance of being a fair type of the slag generally produced at the works. The deficiency shown is probably due to my not having determined the sulphur, which was no doubt present in the form of matte.

ANALYSIS OF BLAST-FURNACE SLAG.

				Oxygen.
SiO_2	= 33.755 per cent.,			17.79 acid.
Al_2O_3	= 13.000 "		7.60	= 19.56 bases.
FeO	= 40.665 "	9.04	= 11.96	
CaO	= 9.567 "	2.73		
MgO	= 0.226 "	0.09		
MnO	= Trace.			
PbO	= 1.468 "	0.10		
	98.301			

The oxygen of the bases of the RO type amounts to 11.96, of the bases of the R_2O_3 type it is 7.60, and that of the silicic acid, 17.79. The sum of the oxygen of both types of bases is 19.56. This gives the ratio of 19.56 : 17.79 = 1.09 : 1, or nearly as 1:1. The slag, consequently, very nearly approaches a singulo-silicate in its composition. Since the oxygen of the bases of the RO type is to that of

The R_2O_3 as 11.96 : 7.60, the composition of this slag may be approximately represented by the formula,

$$2Al_2O_3,3SiO_2 + 2RO,SiO_2.$$

Matte.—Quite often the matte is an almost pure protosulphide of iron, then again, contains lead and silver in considerable quantity, the amount produced depending entirely, of course, upon the thoroughness with which the ore has been roasted previous to smelting. Average contents in lead, from 5 to 15 per cent., and in silver, from 7 to 10 oz. to the ton. When containing much over 5 *per* cent. lead, or 2 to 3 oz. silver, it is separated from the slag, crushed, mixed with the ore roasting charges, roasted, and again put through the blast-furnace.

Speiss.—Occasionally produced in very small quantities. It is thrown away.

Wall Accretions.—They are smelted raw, in conjunction with the regular charges in the same furnace.

Fumes.—All but the small portion settling in the pipes leading from the furnaces to the chimney is lost. The small amount saved is mixed with the roasting charges and then passed through the blast-furnace after roasting.

Bullion.—Containing from 20 to 90 oz. silver per ton. Average of 25 assays of samples carefully taken from every bar produced from August 24th to October 1st, 1874, $31\frac{69}{100}$ oz. When assaying much lower than 90 oz. it is not desilverized, but sold to other works in the city where bullion of a higher grade is being produced. In order to give some idea of the rate at which bullion is produced, the following maybe cited : From August 24th to October 1st (37 days' intermittent work) there were produced 420,264 lbs. $= 210\frac{132}{2000}$ tons of lead, containing 6853 oz. of silver, with some little gold.

The bullion, when refined and parted at the works is, with the exception of a few slight modifications, treated in accordance with the Balbach process. It is not my design to describe this process here, since I have already treated of the subject in a former paper to the Institute.

From last accounts, the Swansea Works are now standing idle. It is to be hoped that operations will soon be resumed. Thus far, of the five smelting works in and near Chicago, none has had any very decided success. The causes to which this is attributable arc various, and to fully explain them would take me beyond the proposed limits of this paper.

FIRES IN MINES: THEIR CAUSES, AND THE MEANS OF EXTINGUISHING THEM.

BY RICHARD P. ROTHWELL, M. E., NEW YORK CITY.

FIRES in mines are so serious in their consequences and of such frequent occurrence, that their causes and the means of extinguishing them are certainly questions of the greatest interest to a large part of the engineering profession. We have already, in this country, many mines which have been burning for years, and though our hard anthracite is so difficult to ignite that for a quarter of a century after it was first discovered it was not known how to burn it except with the aid of an artificial blast, yet most of the fires which have occurred underground have been in anthracite mines, and in the coal itself. The injury which these fires have caused to properties in various parts of the anthracite regions, and the cost of extinguishing them, would amount to many millions of dollars, and they have also occasioned the loss of many valuable lives. It is not surprising, therefore, that the subject has already attracted much attention, and the exercise of great ingenuity; and the present communication is made less with the expectation of announcing anything new, than with the object of putting upon record the present state of our knowledge on this subject, or, in other words, of indicating how defective are the present means of combating underground conflagrations.

Causes of Mine Fires.—Even upon the surface, fire is a terrible foe to contend with, and there is probably no other which inspires such thorough and well-founded alarm. With what feelings, then, must we look upon this destructive element, when its field is in the narrow galleries of a mine, where the poisonous products of combustion, spreading in every direction, protect, in the most effectual manner, the fire itself from the attacks of extinguishers, while, if the face of attack be ventilated so as to enable them to approach the seat of the fire, the air current simply increases the extent and violence of the conflagration.

Fires underground originate in as various ways as those on the surface, and it is scarcely necessary to say that, except in the rare cases where they are the result of design, they are invariably classed as " accidents," and most generally as " unavoidable accidents." In reality, by an intelligent understanding of their causes and with due precautions, they can almost always be prevented. Ignorance and carelessness are their chief causes, and they are generally "unavoidable accidents" only in so far as ignorance is an accident, or carelessness unavoidable. Moreover, what, according to the light we possess to-day, may be styled an "accident," will, it is to be hoped, be rendered avoidable as the increase of our knowledge gives us a better insight into causes now hidden.

I will mention some of the more common immediate causes of mine fires, and then speak of the means adopted to prevent fires, and those employed to extinguish them when they have occurred.

It is now happily a rare thing that a mine is ignited through malice or design. The most ignorant and vicious of those who work about them understand too well the enormous injury that is occasioned, to all who live in the district, by a mine fire to indulge in it as a measure of revenge for real or imaginary personal injury. It is not the owner of the mine who is the only, or in most cases, the principal loser. The efforts made to extinguish it are very frequently, we may say generally, accompanied by the loss of the lives of some of those engaged in the work; and during its continuance, which, in many cases, extends through many years, the regular work of the mine is suspended, and the workmen with those dependent, directly or indirectly, on their labor for the means of living are the chief sufferers. Still, rare cases do occur where a vicious individual is so blinded by what he considers injustice or oppression as to overlook the injury he brings upon innocent parties, and to seek revenge in this manner.

In the so-called "good old days," before the rights of our neighbor were as well defined or as much respected as they are to-day, fires from this cause were not unfrequent; but as the mines wore usually small, the extent of the injury done was limited. An example of one of these ancient fires, and, we believe, the only one, in Belgium, which continues burning from the olden time to the present day, is that in the vein known as the *Grande Masse de Falzolle.* This bed, Ponson tells us, was worked in a piratical way, above water-level, in a hill near Falizolle, between Namur and Charleroi, by the inhabitants of the neighboring country. The quarrels that even in those early days sometimes existed between neighbors were not forgotten when they went below ground, so when the drifts in which they worked happened to meet it was made the occasion for a regular battle, and those that heaven helped with a favorable wind were not slow in taking advantage of the blessing to smoke out their neighbors by burning pieces of old leather on a fire built in some *safe* place in the galleries. On one occasion, about the year 1822, while indulging in this harmless, but effective, method of disposing of their enemies, the coal in the mine became ignited, and has since continued to burn, excluding both sides of the fight from the benefits of free coal. Many attempts have been made to extinguish this fire, but owing to the position of the bed, near the surface and above water-level, it has been found impossible to control it.

In this country, in the anthracite regions particularly, many fires whose origin is unknown, have been attributed to design. In the majority of cases the cause was probably carelessness, though in some rare instances the malice of men on strike, who have had, or thought they had, some grievance, has doubtless been the origin.

Among the mines that have been on fire for a great many years may be mentioned the Summit Hill Mine, near Mauch Chunk, the Greenwood Company's Mine, near Tamaqua, and some others in Scliuylkill, Carbon, and neighboring counties of Pennsylvania. Some of these fires have now been burning upwards of twenty years. The causes of most of these are shrouded in mystery, but they were probably due to carelessness or spontaneous combustion.

Carelessness is by far the most frequent cause of mine fires. A workman will leave his candle, or lamp, attached to a piece of timber in such a manner as to finally ignite it, as was the case in the great fire in the Yellow Jacket Mine of the Comstook Lode, in 1875. A fire basket will sometimes be hung so near the coal or timber as to set it on fire. Smoking in the stables underground has occasionally been the cause of conflagrations by the fire from a pipe falling among the straw and litter. It was from a lamp igniting a bundle of straw in the shaft that the West Pittston disaster occurred, by which 20 persons lost their lives. In a word, carelessness acts through about the same channels below ground that it follows above, though the field for its operation is more restricted in the mines and its effects are more disastrous. If a miner, going into a portion of the mine in which fire-damp has accumulated, with a safety lamp in his hand and *an open light on his hat*, as has been done on many occasions that are well authenticated, the resulting explosion and fire can scarcely be considered as accidental, any more than can the equally well-authenticated case of a man blowing himself up by firing the open keg of powder, from which he was filling a cartridge, by the burning oil dropping into it from the open lamp on his hat. Incredible as these cases of carelessness may seem, they are by no means isolated occurrences, but we have heard, from the very best authority, of several instances of each.

Ignorance is a scarcely less frequent cause of fires in mines than carelessness; indeed, it is difficult to say just where the one ceases and the other begins. It is frequently not altogether carelessness that causes the fire when a miner hangs his lamp so near the coal that it finally ignites it; he may not know that the heat of the lamp, not in itself sufficient to ignite the coal, may liberate and ignite highly imflammable gases, and thus communicate the fire to the solid coal. Nor is it always pure carelessness that causes a fire by throwing away among the "gob" the oil-saturated cloth, or the cotton "Waste" that has dropped from the oil-box of a mine wagon. He who threw it away among the fine coal may have been ignorant of the fact that the heating which comes from the decomposition of iron pyrites, and from the slow combustion of carbon in a comminuted state, though it may be insufficient to ignite coal alone, may be quite sufficient to ignite the oil-saturated " waste," already heated by the oxidation of the oil.

There are few of the mine superintendents, not to mention the miners, who have any knowledge of the very important influence which coal-dust has upon the explosiveness of mixtures of fire-damp and air, or of the causes of spontaneous combustion of coal and wood; and while exercising the utmost care required, as they believe, they may, in ignorance, be doing or leaving undone, tilings which result in a fire—a fire that is then said to be " purely accidental," and which it was " impossible to foresee or prevent."

Nearly every fire that occurs in a mine is said to be an " unavoidable accident," and so far as an accident is " an event that takes place without one's foresight or expectation; an event which proceeds from an unknown cause," most fires may be so designated ; but the ignorance which makes them, in this sense, "accidents," is not unavoidable, and should not exist.

I have frequently seen the fire-pot, or grate, that stands near the foot of almost every shaft in the anthracite coal regions in winter, placed so close to the solid "rib" of coal, as to heat it far beyond a safe temperature; and before leaving the mine, at the close of the day, coal would be piled upon it, in order to have it burning well in the morning. A change in the direction of the wind, or in the temperature at the surface, is sufficient to increase the draught, and fan up the fire to a furnace-heat; is it surprising, then, that-several fires in our mines have been traced to this cause?

Underground boilers is a cause of mine fires still more fruitful than that just mentioned. The number and extent of the conflagrations due to this kind of " accident," in Pennsylvania, are enormous. In the immediate vicinity of Wilkes-Barre, Pa., alone, they have cost the companies millions of dollars. One would suppose that the enormous losses inflicted by such fires would have absolutely prohibited the use of boilers or furnaces in coal mines, yet there are many of our mines still ventilated by furnaces, and not a few that have boilers underground. The fire in the Avondale Colliery, in which one hundred and ten persons lost their lives, was occasioned by a ventilating furns.ee. Wood was used in lighting up the fire, and the sparks from this were carried up into the wood-bratticed upcast shaft, igniting it and the "breaker" building which stood over the shaft. As the mine had but this one outlet, the one hundred and eight persons at work in it (and two volunteers, who subsequently entered it), were suffocated before they could be rescued. In this, as in nearly every case, the furnace was thought to be "perfectly safe;" it was at some distance from the shaft, and had been in use for some time without " accident" of this kind. The mine did not produce fire-damp, and, consequently, one source of danger was eliminated. In fiery mines when the air for the furnace is taken from the return air courses, there is introduced a source of accident of a very serious character. It is probable that even when the return air is not, in it-self, explosive, it may become so by the presence of a very small quantity of coal-dust; and it is well known that, even without the presence of fire-damp, the finely comminuted carbon, whether soot or coal-dust, is very easily ignited, and this has, probably, been the cause of more than one of the mysterious fires that have occurred in our anthracite mines. Such a case was that known as the Empire Mine fire (Lehigh and Wilkes-Barre Coal Company), near Wilkes-Barre, Pa. The fire originated in an abandoned chamber, from which the coal had been taken, and which was made to serve as a flue for the smoke from a set of underground boilers. It is supposed that the soot collected in this large chamber, and became ignited from a spark, or that pieces of wood, dried to tinder, caught fire in the same way ; in either event, the furnace was considered " perfectly safe," and yet it resulted in a fire that cost more than half a million dollars to extinguish. The great difficulty experienced in igniting anthracite coal, when it is desired to burn it, is relied on too implicitly as a safeguard against fire; and this misplaced confidence leads to the introduction of risks that would never be admitted in a bituminous coal-mine.

I have frequently seen both ventilating and boiler furnaces separated from the Solid coal by but a thin brick wall, and a few indies of space. The boilers, which are always of the plain cylinder type, fired externally, are usually covered with a thin bed of sand, and a crack in the brickwork, or a hole through which the sand can run, may allow the fire free escape to the solid rib, or to the roof, that in some instances is a carbonaceous shale.

When the roof is not very solid it is frequently supported, over the boilers, on heavy timbers ; and it is not unusual to find a mass of timber, that the heat has made as inflammable as tinder, supporting the roof only a few feet above the boilers. A single spark may ignite the mass, and the matter of surprise is, not how fires originate in such mines, but how these so often or so long escape being burnt up.

The fire which has now been burning in the Baltimore Mine, near Wilkes-Barre, for two years, and the efforts to extinguish which are said to have cost already nearly three-quarters of a million of dollars, was caused from underground boilers. These were, as usual, " perfectly safe," but the blast of air occasioned by a heavy fall of the roof in the vicinity, forced the fire from under the boilers and ignited some timber under the fall. As the cave extended over several acres of ground, and as the vein was above water-level and near the surface, to which the rock broke through, there was no means of getting at the fire, or of extinguishing it with water. That part of the mine had to be walled off by brick or earth walls, and, doubtless, the fire will continue in the portion " caved in" for many years to come.

Underground boilers and ventilating furnaces have probably occasioned more fires than any other cause, at least this is the case in the anthracite mines of Pennsylvania.

Explosions of Fire-damp.—Not many years ago, while the Pennsylvania mines were worked along the outcrops of the coal-beds, it was commonly stated that anthracite did not yield this dangerous gas, but as the mines were carried below water-level to a constantly increasing depth, it was found that not only is fire-damp met with in anthracite, but that some of the most fiery mines in the world are in this hard coal.

The hardness of the coal is so great as to require the use of explosives to break it down, and it is not an uncommon thing for a vein to yield fire-damp in such enormous quantity as to ignite at every shot in headings driven out into the solid.- At the Prospect sh.ilt, near Wilkes-Barre—probably the most fiery mine in the coal field—the make of gas has been so rapid that with a current of air from 20,000 to 30,000 cubic feet per minute, passing through the gangway (12 feet wide by 7 feet high), it was impossible to proceed more than ten feet beyond the cross-heading connecting the gangway and parallel airway, without putting in bratticing to carry the air up to the face—or with such bratticing (dividing the gangway into two parts, each 6 feet by 7 feet), the velocity of air current being from 500 to 600 feet per minute—the gas would ignite at the face when the distance from the face of the gangway to the bratticing was more than fifteen feet. With such a prodigious discharge of carburetted hydrogen almost every blast would ignite it, and if the promptest measures were not taken, the coal was quickly aflame. The heat of the burning gas always tends to draw still more gas from the coal, and the longer the fire continues the more fiercely it burns and the more difficult it becomes to extinguish it. A number of fires have occurred in this and other collieries in the same field from this cause, and that notwithstanding all the efforts that it was thought possible to make to extinguish the fire. With a sudden fall of the barometer, or the striking of an unusually strong blower, the fire would gain the mastery, and several of the mines have had to be filled with water to extinguish the conflagration.

There is still another and more mysterious cause of fires in mines, viz., spontaneous combustion. As this important cause of fires is but imperfectly understood by those in charge of our coal-mines, and as it is a matter whose interest and practical application are not confined to fires in mines, I shall enter with some detail into the subject. It may be remarked, at the outset, that what is known as "weather waste," is but a mild form of spontaneous combustion; we may, therefore, treat this part of our subject under the title of

*Spontaneous Combustion and Weather Waste of Coal,**—Coal is a very complex substance, and though one with which we have long been very familiar, and which we make use of by oxidizing (burning), the subject of the exact conditions under which its oxidation takes place has received but little attention, and is, even yet, but imperfectly understood. We all know that at a high, but variable, temperature, the carbon of coal combines with the oxygen of the air, and forms carbonic oxide, or carbonic acid, as the case may be; but there are

* Many of the data relating to this subject will be found in the last edition of Percy's Metallurgy, 1875.

few who know at what temperature this absorption of oxygen commences, or what conditions facilitate it at a low temperature.

We are principally indebted to Professor E. Richters, of the Mining. School at Waldenburg, for our knowledge, so far as it goes, of this interesting and important subject. He has determined that at the ordinary temperature coal left in contact with oxygen, either pure or mixed with nitrogen, as in atmospheric air, absorbs oxygen, of which one portion combines with carbon and hydrogen, forming carbonic acid and water respectively, while another portion enters into an unknown state of combination with the coal, and proportionately increases its weight.

Berthelot* has succeeded in demonstrating the fact that coal can be hydrogenized also, at a temperature not exceeding 527° Fahr. In absorbing hydrogen, in the experiments of M. Berthelot, as much as two-thirds of the coal was converted into liquid hydrocarbons of the petroleum class.

On the other hand, we know that all coals, when freshly mined, give off a very noticeable amount of a hydrocarbon gas. In sonic mines, even in the hard anthracites of Pennsylvania, this escape of occluded gas is so energetic as to make a hissing or singing sound, that is easily recognized. This discharge of gas continues for a very considerable time, probably several weeks in some cases, after the coal is removed from the mine. In proof of this we have the record of a great number of explosions on vessels loaded with coal, and even with anthracite, days, and sometimes weeks, after it was mined.

It has also been ascertained that all coal, or at least all bituminous coal, and above all those soft varieties that are rich in volatile matter and poor in fixed carbon, lose a large part of their volatile constituents by exposure to the action of the atmosphere, especially when the coal is in a finely comminuted state, and is exposed to a high temperature and moisture. The gas thus evolved varies, both in quantity and in composition, according to the nature of the different coals; it contains carbonic acid, oxygen, nitrogen, marsh gas, ethyl hydride (C_2H), gases absorbable by sulphuric acid, and sometimes a small amount of carbonic oxide. By far the most abundant of these gases is free nitrogen, and as this has never been certainly proved to result from any natural process of decay, it is probably derived from the atmosphere.

This view seems to be confirmed by Richters's investigations on the

* Ann. Chim. Phys., 1870, and Bulletin Soc. Chim.

weathering of coal, from which he concluded that more oxygen is absorbed from the atmosphere in weathering, than suffices to oxidize that portion of the carbon which is evolved in the state of carbonic acid. A portion of the balance, probably, combines with the hydrogen to form water, and another portion enters into an unknown state of combination with the organic substance of the coal, and still another portion is consumed in oxidizing the iron pyrites which are almost always found in coal.

M. Marsilly (see I'*Eclairage du gas* de R. d'Harcourt) found that the long flaming coals, free from fire-damp, of the Grand Hornu, Belgium, when heated to 350° Cent. (662° Fahr.) evolve nitrogen to the extent of 31.83 to 44.27 cubic inches per lb. of coal, and that 1 kilog. (2.2 lbs.) *of fat fiery caking coal at* the temperatures indicated gave off the following quantities of gas:

Degrees Cent.	Degrees Fahr.	Litres.	Cubic inches.	Gas.
70 to 150	158 to 302	0.46	28.07	Uninflammable gas.
150 " 180	302 " 356	0.2	12.21	Gas yielding a blue flame.
180 " 250	366 " 482	0.9	54.93	" a long illuminating flame.
250 " 300	482 " 572	0.51	31.12	" a longer and brighter flame.
300 " 325	572 " 617	0.5	30.51	" a still longer and brighter flame.
325 " 350	617 " 662	0.23	14.04	" a very long and brilliant flame.

Marsilly concludes that coal impregnated with fire-damp gives off from 1 to 2 per cent of uncombined hydrocarbons, below 626° Fahr., and the coal then completely loses its caking properties. These are the coals which deteriorate when exposed to the air in heaps.

The long flaming dry coals, at 572° Fahr., evolve but little nitrogen, a circumstance which distinguishes them from the fiery coals. Heated from 572 to 1013° Fahr. (545° C),they do not give off gas, and are not much affected by exposure to the air.

Freshly mined coal is acted on most energetically by the oxygen of the air, and though, according to Richters, coal never entirely loses its power of absorbing oxygen, that power constantly diminishes by exposure to the air. According to the same authority, when coal is heated from 180° C. to 200° C, it at first gains in weight, more oxygen being absorbed than the weight of carbonic acid and water evolved; but on continuing this temperature, after a time both the weight and chemical composition of the coal will remain constant, (?) and the relation in weight which then obtains between its hydrogen and oxygen is that in water, from which it is inferred that the oxygen which combines with the carbon is evolved again as carbonic acid, and that, consequently, with the disappearance of the disposable hydrogen, the permanent absorption of oxygen should cease. It has also been found that the quantity of oxygen absorbed by different coals, under the same conditions, is proportionate to the quantity of water they absorb, which last does not appear to depend on the physical structure of the coal, compact bright coals sometimes absorbing from two to three times as much water as very loose, soft, and tender schistose coals; but coal from the same seam over a wide area absorbed the same proportion of water. This characteristic may prove to be of such general application as to afford valuable assistance in the identification of coal-beds where the measures are disturbed by faults, etc.

Richters also found that coal absorbs three times as much carbonic acid as oxygen in a given time, and under the same conditions ; and even coal that has been weathered till it will scarcely take up any oxygen will quickly absorb its own volume of carbonic acid.

Numerous experiments seem to prove that sunlight always lessens or retards the absorption of oxygen by coal; a fact that may, in part, explain the generally admitted phenomenon of coal or wood not burning so well in the sunlight as in the shade.

That some coals are capable of spontaneous ignition when allowed to accumulate in the form of dust or slack, and, sometimes, when subjected to heavy pressure in the pillars of coal-mines, is a well-known fact; but to what this property is due has always been an open question, though it has usually been attributed to the decomposition of iron pyrites in the coal and shales accompanying the coal. The atmospheric oxidation of iron pyrites, by which the sulpurets are changed into sulphates, is a comparatively slow process; and, though undoubtedly capable of developing a large amount of heat in a confined area, it does not account for the majority of well-substantiated instances of spontaneous ignition of coal, both in the mines, on board ship, and in stock-yards. Richters has shown conclusively that the coals most liable to spontaneous ignition are not those which contain the largest percentage of iron pyrites, but that this property is principally due to the atmospheric oxidation of the organic substance of the coal. The following table gives his classification of eleven varieties of coal, according to the degree of their self-inflammability :

Table of Coals arranged according to Degree of Self-Inflammability,

Degree of Self-inflammability.		Iron Pyrites. Per cent.	Water. Per ct.	Character of the Coal.
CLASS I.—Difficultly self-inflammable......	1	1.13	2.54	Easily friable.
	2	1.10 to 3.04	2.75	Very compact.
	3	1.54	3.90	" "
CLASS II.—Of medium self-inflammability	4	1.20	4.50	Firm, schistose, bright.
	5	1.08	4.55	Hard, but very brittle.
	6	1.15	4.75	Moderately tender.
CLASS III.—Readily self-inflammable.........	7	1.12	4.85	Outwardly very like No. I.
	8	1.00	9.01	Mode'ly tender, schistose.
	9	0.83	5.30	Moder'aly soft, schistose.
	10	1.35	4.85	" " "
	11	0.84	5.52	Not stated. Yielded only 2.5 per ct. of ash. From the same pit as No. 10, but from a different seam, remarkable for its great self-inflammability.

From the above-mentioned facts, which express the results of the latest and most reliable observations and direct experiments, somewhat contradictory as some of them seem to be, we may deduce many valuable practical lessons.

Many varieties of coal deteriorate to a great extent when exposed to the air, and this deterioration is greatly favored by high temperature, and, in coals which contain sulphurets of iron, by moisture; in coals free from iron pyrites, this oxidation seems to be even more energetic when dry than when wet. It is always greatly increased in all kinds of coal by increase of temperature, and is more energetic when the coal is in dust or slack.

This deterioration of coal has been aptly termed " weather waste." It is, as we have seen, not dependent solely on the physical character of the coal, though the harder the coal the less it is injured, and, in some cases that have come to my own knowledge, an exposure of eight or ten years of certain Lehigh anthracites had not affected the quality to any extent that could be appreciated in its subsequent use in blast-furnaces. In the case of coking and gas coals, however, the depreciation in the heating power, and in the coking and gas producing properties is very great; indeed, a very moderate exposure to the air, in heaps, at a high temperature and when moist (for these coals, for the most part, contain more or less iron pyrites) frequently entirely unfits them for use. A recent example suggests itself, in which a large amount—several thousand tons—of Albertite (a rich gas-producing mineral quite free from sulphur) was piled on dock in Boston. So rapid was the absorption of oxygen by this so-called coal that it heated and actually fused, running together round the edges of the pile, and finally even ignited. Its value as a gas coal was almost entirely destroyed.

The spontaneous ignition of coal is, doubtless, greatly facilitated by, though not altogether due to, the presence of iron pyrites; for the oxidation of the iron pyrites is attended with a considerable development of heat, and by swelling, it splits up the coal, and renders it more pervious to oxygen. The real cause of spontaneous ignition is probably the oxidation of the organic substance of the coal; it is, in fact, a very energetic example of weather waste, and the precautions to take in each case are the same.

In mines the crushing of the pillars, where they are left too small, and their gradual spalling off, from the oxidation of the coal and pyrites in the coal, cause an accumulation of fine coal around the pillars; this and the fine coal thrown back into the "gob" along with the shales (which contain most of the iron pyrites) and other rubbish, form exceedingly favorable conditions for spontaneous combustion. There is usually enough oxygen in the air of the goaves to support this slow combustion, while the velocity of the air current is not sufficient to carry off the heat, and thus prevent the weather waste from developing into spontaneous ignition of the coal.

Spontaneous combustion is by no means confined to coal, but pieces of wood imbedded in the coal-dirt, rags or cotton waste saturated with vegetable or animal oils, are very subject to it; in fact this is the cause of a great number of fires on the surface as well as in mines.

As an instance of the facility with which cotton, saturated with oil, will ignite, I may mention a curious case that came under my observation some years ago. Two or three men were severely burned by an explosion of a powder-mill at Wilkes-Barre, Pa., and the remedy applied by the kindhearted neighbors was to envelop the patient in cotton padding, saturated with linseed oil. They were greatly astonished to find that the heat of the body, after a time, ignited the cotton and oil, and the victim of well-meaning ignorance was with difficulty saved from cremation.

Many of the unaccountable fires in the mines, both in anthracite and bituminous coal, are undoubtedly due to spontaneous combustion, either of the coal itself, in some of the bituminous coals, or, more frequently, from the more energetic spontaneous combustion of oiled "waste" or other easily inflammable substance. The fire that has now been burning since August, 1871, in the No. 6 tunnel, Summit Hill mines (Lehigh Coal and Navigation Company), is supposed to have been caused by spontaneous combustion, originating in the gob or rubbish in some abandoned works where the ventilation was very slack. It is exceedingly doubtful if our hard Pennsylvania anthracites will ignite spontaneously, even when they contain considerable quantities of iron pyrites, but it is an incontestable fact that piles of culm, or coal-dirt, on the surface, in many parts of the anthracite regions, have ignited spontaneously. I attribute the ignition to the presence of the more inflammable rags or cotton-waste saturated with oil, or simply to oil saturating the fine coal, as can readily be conceived may occur in almost every pile of coal-dirt about a colliery. Many of you have, doubtless, frequently noticed the heating of culm-banks, but it is rarely that one actually ignites, which tends to prove that the anthracite coal itself, even in the form of dust, will not ignite spontaneously, but that the accidental presence of a more inflammable substance may readily cause a fire.

Soot from anthracite coal, or indeed from any kind of coal, is less inflammable than ordinary lampblack, which ignites with such facility that even a few drops of water, oil, or other moisture falling in it, is liable to cause its ignition by the rapidity with which it absorbs oxygen, as several fires in lampblack factories in different parts of the country have proved. It is well known, also, that powdered charcoal will absorb oxygen from damp air so quickly as to ignite spontaneously; is it possible, therefore, to overestimate the danger of using chambers in the coal as flues for underground furnaces? If it be necessary, which is rarely if ever the case, to have boiler or ventilating furnaces in a coal-mine, it is no more than ordinary prudence to line the flues with brick throughout, and take even greater precautions than would be taken in houses on the surface.

Means adopted for Preventing Mine Fires.—Having thus reviewed the principal immediate causes of mine fires, it remains for me to mention the means adopted to prevent these causes from producing their natural effects, and finally to investigate the means of extinguishing fires when they do occur.

The mere mention of the causes of mine fires suggests, in most cases, the preventives to apply. Where the cause is carelessness there must he strict and judicious rules and careful inspection, this will prevent many of these and other accidents that make the miner's calling a somewhat dangerous one. Ignorance of the nature and full bearing of the immediate causes we have just mentioned is the ultimate cause of most "accidents." Carelessness is usually, though not always, the result of ignorance of the results that may spring from the careless act. For example, it is too often either not known, or if known, not fully appreciated, that though the wood over the boilers is not at first easily ignited, and the new setting of the boilers allows no undue escape of heat or sparks, yet the wood in time becomes like tinder, and the walls supporting the boilers arc liable to oracle, and the accumulation over the boilers of coal-dust, and possibly of light wood-fibres, from the timber supporting the roof, create a constantly increasing danger. The fire that results from these favorable conditions can scarcely with propriety be called accidental, though that term may satisfy the unquestioning faith of that patient and exemplary class, the stockholders of the mining company.

In fiery mines the practice of shot-firing is the cause of many explosions and fires. In anthracite coal it would seem at present as if the use of some explosive were absolutely essential for the economical getting of the coal, yet substitutes for explosives have been proposed and are actually in use for many purposes, but no effort scorns to have been made by the owners of fiery anthracite mines to investigate or test such substitutes, or to encourage the invention of others. They seem to rest satisfied with taking the precautions which experience has shown to be sufficient, in most cases, to control and extinguish fire when once ignited, but which experience has also fully demonstrated to be unequal to some emergencies, or to be subject themselves to unavoidable accidents.

Of course it is in but comparatively rare cases that underground boilers, or ventilating furnaces, or powder shots, result in fires, but the enormous loss incident to a mine fire makes the risk from these rare eases much too great to be undertaken by prudent managers; and so far at least as underground boilers and ventilating furnaces are concerned they are quite unnecessary risks. Steam can be carried to considerable distances (say 1500 to 2000 feet) through properly protected pipes, without any very great loss from condensation. Boilers on the surface are so much more economical in installation, and in running expenses, as, generally, to compensate for this loss of steam; and where steam cannot be used—and in most cases where it can—compressed air forms a perfectly safe and equally efficient means of transmitting power. Compressed air is not an economical motor as compared with the direct use of steam, but it is a safe and convenient one for mine use, and after its use in the underground engines it serves for ventilation, while the exhaust steam is exceedingly injurious to the timber, and in some cases, to the roof rock of the mine.

Wire ropes can also be employed to advantage in some cases for the transmission of power in mines. Mechanical ventilators have been shown to be almost always more economical, and in every case more efficient, reliable, and safer than furnaces for mine ventilation. There is consequently no necessity for incurring these risks of enormously costly conflagrations.

As already stated, the danger from spontaneous combustion of the coal in mines may be overcome either by a ventilation so active as to keep the temperature of all parts of the mine so low as to prevent ignition of the coal, or it may be prevented by an almost opposite course, viz., by cutting off altogether the ventilation of abandoned workings, so that, from the absence of oxygen, no combustion can take place. In mines where the coal is subject to spontaneous combustion, both plans are adopted, with more or less success. If it were possible to keep the abandoned works always open, to prevent falls, or crushing of pillars, or accumulations of fine coal in places where but little air can reach them., probably thorough ventilation would insure safety; but as these conditions cannot be secured, it has been found safer to prevent altogether the access of air to the parts of the mine where conditions favorable to spontaneous combustion exist. The method of walling off the goaves or old workings is objectionable in many respects. If the mine produces firedamp, the walling off merely creates a magazine of a most dangerons explosive gas in the mine. If a fall of roof occur in the goaves, it may force this gas out into the working parts of the mine, and cause explosions ; or, in many ways, a small but sufficient, quantity of air may be admitted to the walled-off space to sustain, in the most effective manner, the slow combustion which it is desired to prevent. In the south of France, where the beds are very large, and the coal subject to spontaneous ignition, the system of mining known as by " remblais," where the space from which the coal is taken is filled with waste material, and the roof is allowed to settle down on this packing, has been found to be the only really effective preventive of fires from spontaneous combustion. The packing effectually excludes air, and consequently no combustion can take place. No other system of mining than that of taking out all the coal, and either allowing the roof to fall as the work proceeds, or of filling the space from which the coal has been taken, is adapted to working in coals of this character. In chamber and pillar work, the crushing of the pillars, which cannot be prevented, is a constant source of danger, for it presents the most favorable condition possible for the spontaneous ignition of the coal.

The most efficient preventives of fires in mines, from whatever cause they may come, is to be found in education—in increased knowledge of the causes of fires and a better appreciation of the working of these causes. Our mine managers should be obliged to pass strict examinations, and no one should be allowed to undertake the responsible duties of this place without a certificate of competency, given by a qualified board of examiners. Nor is it sufficient that the managers alone should be better educated; the miners themselves should be taught the causes and preventives of the dangers they meet with in their work. Special, free, instruction upon these points might be furnished at every colliery, and this could doubtless be accomplished by encouraging the giving of popular lectures, by practical miners and engineers, on subjects of interest to the miners, and by the giving of small prizes to those who pass the best examinations on subjects of daily practical application in their calling. I am well aware of the difficulty of exciting any interest among the majority of our miners in anything that is not actually their "bread and butter." They care little for the dangers they encounter, and do not appreciate the importance of knowing more than how to swing a pick or use a drill, and but little even of these accomplishments. Nevertheless, I believe that the leaven of a small percentage who would profit by such instruction would finally leaven the whole mass, and the practical results of the increase in knowledge would be apparent in greater care and better mining, even by those who had not taken any part or interest in the lectures. Greater knowledge always makes better workers, and the mine-owners would find in this a good return for the small expense incurred. No startling results are expected from this suggested plan. A pretty intimate acquaintance with our mining classes, long ago dissipated the expectation of bringing about a millennium in the mining regions by means of education and instruction such as wo have here suggested, but I nevertheless believe the modest results anticipated would abundantly justify the trial of some such plan as this.

Means adopted for Extinguishing Fires.—With all the precautions that the present condition of our knowledge suggests, fires will sometimes occur, and as there is, unfortunately, no prospect of the immediate application of all the preventives that we do know, fires in mines will continue to be common accidents. We will now review the more important means proposed for extinguishing them.

When blowers of fire-damp ignite in a mine they can sometimes be beaten out with wet clothes. In some instances the sudden vibration of the air, caused by the discharge of a small cannon, has been found quite effective. This remedy is applicable only when the fire has not had time to ignite the coal, and when the discharge of explosive gas is limited to the confined space on fire. When the burn-'ing gas cannot be beaten out by the vigorous application of wet clothes, carbonic acid applied by portable fire-extinguishers, such as the Babcock, the Connolly, and others, can be used with advantage, as has been done in Pennsylvania during the past few years. The carbonic acid, in addition to excluding oxygen from the fire, tends, in expanding rapidly, to cool down the inflammable gas to a point below the temperature of ignition; the force with which it is thrown against the burning gas also exerts a powerful extinguishing influence. The portability of these extinguishers, which are easily carried like a knapsack on the back, enables the workmen to take advantage of every current of air, and to apply the extinguisher wherever it will prove most effective. When once the fire has obtained such headway as to make it impossible to approach it close enough to allow the carbonic acid gas being thrown directly on the fire, recourse must be had to water, which under a heavy head or pressure can be thrown to a much greater distance than the extinguishing gas. Moreover, the carbonic acid would quickly make the air of a narrow heading irrespirable if the ventilation were not active ; and if active, the fire would extend too rapidly. This objection does not obtain against the use of water ; it can be thrown from a considerable distance and with great effect. A single example will suffice. The Prospect shaft, near Wilkes-Barre, Pa., already mentioned in this paper as an exceedingly fiery mine, is also a very dry one, scarcely any water being made, though the depth is 600 feet, and the gangways run out very near, if not quite, under the Susque-hanna River. In order to combat successfully the fires that occur there so frequently from the ignition of fire-damp by shot-firing, the general manager, Mr. Frederic Mercur, an engineer of great experience and ability, had a pipe laid along each gangway (when the work was confined to driving gangways and their parallel airways), and strong rubber hose attached to the end, and at other points along the line of the pipe. The shaft-end of this 2½ inch pipe connected with a column-pipe, leading down the shaft from a reservoir on the surface. This gave somewhat more than 600 feet of head, or 2G0 lbs. per square inch pressure on water leaving the hose, a force sufficient to. throw it with great force to a considerable distance. When the gas became ignited the water was immediately turned on (everything being kept constantly ready for such emergencies), and a few minutes usually sufficed to extinguish a fire that with less experienced men would have been considered ample cause for the abandonment of the works.

The skill which men engaged in this work of fighting fire ae-quire with experience, is not the least important clement in the success which has generally attended Mr. Mercur's management of this trying colliery. But even experience and ability have at times been foiled by unexpected events, such as the breaking of the pipe leading down the shaft, and other less important mishaps, which caused the few minutes' delay that were all-sufficient to give the fire an irresistible and unconquerable force. In consequence, the mine, though a new one, and not yet worked upon a large scale, has twice had to be drowned out to extinguish fires occasioned in this manner.

The Pine Ridge shaft (400 feet deep), also near Wilkcs-Barre, is scarcely less fiery than the Prospect, and as it makes a large amount of water, it was found sufficient to tap the base of the column-pipe from the pumps, and to lead the water, as in the other case, along the gangways in iron pipes, with attachments for rubber hose at intervals in those parts of the mine where fires were likely to occur.

When a fire has fully ignited the coal and obtained such headway that it is impossible to overcome it promptly by these means, a more systematic method of attack is adopted. The fire must be confined by temporary bratticing or walls, so as to exclude air; the points of attack are approached in regular siege manner, a temporary batticed approach being kept open and ventilated with a special fan ; from this heading the men direct streams of water on the fire, and as they partially extinguish it, the loose coal is removed, and access given to portions still burning. The work is exceedingly arduous and dangerous, and the least interruption in it allows the fire to recover the ground that may have been gained from it. A better example of fighting a fire in this manner can scarcely be cited than that of the Empire Mine fire near Wilkes-Barre, Pa., which was fully described in the report, for 1874, of the very efficient State mine inspector for the district, Mr. T. M. Williams. In the same report is an account of the old Baltimore Mine fire, and the one in the Prospect shaft, to which reference has already been made.

In the case of the Empire fire, water was thrown upon it from no less than six underground pumps, and worked upon by a force of five or six hundred men, directed by the greatest experience and energy, for four or five months, yet one accident or another always prevented the final extinguishment of the fire. It may, therefore, be assumed as proven that, when a fire gets beyond a certain stage, in most cases, it cannot be extinguished by throwing water upon it. The difficulties can be understood by a reference to the mode of fighting a conflagration in an anthracite mine. Let us imagine a fire in the chambers in a large anthracite vein, the pillars of coal all aglow and burning fiercely. When a stream of water is played on this incandescent mass a portion of the water is decomposed into hydrogen and oxygen, and probably this latter and a portion of the oxygen of the air form with the coal CO. This hydrogen and carbonic oxide burn again on the admission of air, making explosions sometimes of considerable violence. The pillars "spall off," and the pieces accumulate around their base in a mass of burning coal, so deep as to be impenetrable by the water, and therefore impossible to extinguish, so long as it gets the very small quantity of oxygen requisite to maintain slow combustion. The roof-rock breaks down also under the action of water and heat, and covers still further the burning pillars of coal, till finally the fire is under an immense covering of broken coal and rock. In this manner the men will sometimes be quite above the coal-seam, standing on the pile of waste coal and rock that has accumulated from such falls. It is then impossible to reach the seat of the fire except by laboriously attacking by regular approaches on the foot-wall, and carrying away the entire mass of rubbish as it is cooled by the stream of water. Since the fire generally occurs in " old workings," the pillars are not much more than sufficient to support the roof, and in most cases timber props have also to bear a portion of the superincumbent load. As the wooden props quickly burn out, the strain on the pillars is increased, and the spalling off, produced by both the heat and the water, soon brings them to the limit below which they will no longer support the roof, and a general crush occurs. After this there is no possibility of overcoming the fire in this manner, and the attempt is abandoned.

If the fire has not obtained much headway, and other conditions are favorable, it is possible to extinguish it by this direct application of water, but the cases are not rare where the almost superhuman exertions of experienced men have failed. There remain but two remedies, either to close the entire mine, or to wall off the district on fire.

This latter course is usually adopted as soon as the fire has gained such headway as to satisfy those in charge that its extinction, by throwing water on it in the manner described, will be either impossible or too expensive, if successful. The simplest method is to fill the mine with water, either by allowing this to accumulate, if the mine be a wet one, or more commonly by pumping or turning sonic natural water-course into the shaft. Of course, there can be no doubt as to the result of this method. Wherever the water goes it extinguishes the fire. But it may happen that this is in portions of the mine above the foot of the shaft, where the water cannot reach, because the air cannot escape. In this case the fire may long continue, to burn, deriving its oxygen from the air compressed in the "rise workings," and when the mine is pumped out, and fresh air admitted, the conflagration may break out again.

Where the fire has occurred from spontaneous combustion, the admission of water sometimes aggravates the trouble, for, though it extinguishes the fire wherever it goes, it leaves in the wet coal-dust a condition of things very favorable to spontaneous ignition, and it not unfrequently happens that, on pumping the water out, fires occur at points where they did not previously exist.

From these and other considerations, it would seem that, in coals subject to spontaneous combustion, drowning out is not a safe or desirable manner of extinguishing a fire, but, in nearly all cases where it can be applied, it is the cheapest and most effective! moans yet adopted.

Where mines are extensive, or where there is a necessity for working the portion not on fire, or where the nature of the roof is such that the admission of water would cause it to fall, as is the case with many shales, it is evident drowning out is not a method that can be adopted.

The system in most general use for extinguishing fires in large mines consists in walling off the portion on fire, trusting to the exclusion of air to secure its gradual extinction. The products of combustion (carbonic acid gas and nitrogen), are most effectual extinguishers, and all that is necessary is to confine them, or, in other words, to exclude the supply of oxygen, when in time the fire must inevitably go out. The time necessary to effect this object depends on the intensity of the conflagration, and the extent of the area in-closed. A mass of coal in full combustion requires a long time to cool below the temperature of ignition, and, even when the fire is actually extinguished, the admission of a little fresh air on the still hot coal is often sufficient to bring about spontaneous ignition. Time must be given for the combustible material, wood or coal, to cool off, before the fenced-off portion of the mine can be opened, and this delay is one of the chief objections to this remedy. To hasten the cooling, and also to hasten the expulsion of the air from the in closed space, steam, carbonic acid, and the mixture of carbonic acid and nitrogen, known as " choke-damp," have been injected, with greater or less success. The *r6le* of steam appears to be principally as a cooler, and it is probably the most efficient agent that can readily be applied for that purpose, except, indeed, carbonic acid gas were allowed to expand from a state of very high compression (such as liquid CO_2) into the space to be cooled. At the Empire Mine, already referred to, after all efforts to extinguish the fire, by the direct application of water, had failed, a large part of the mine was walled off, and steam, from some sixty boilers, was forced in during many months. When examined some time after closing the mine, the fire was found completely extinguished in those parts where it burned most fiercely when inclosed, but it was thought that it still burned in the higher " rise workings," where the carbonic acid and nitrogen had not had time to accumulate. There was no question but that the steam had acted advantageously, but it is by no means certain that carbonic acid, allowed to expand from a liquid state into the space inclosed, would not have been quite as efficient, and economical as the steam. Where carbonic acid has been tried, as has been done in a number of cases in different countries, in Europe, and in some mines in this country, it must be confessed the results have not been very satisfactory, but this is probably due principally to the defective manner in which it was applied, and particularly to the shortness of the time allowed for the cooling of the heated coal. The district on fire should be hermetically closed. If the gas can run out, as it will like water, from the lowest part of the mine, it will of course be inefficacious. In mines it is very difficult to make perfectly tight stoppings, and where the cover rock is broken up to the surface, air obtains entrance, and carbonic acid exit, through innumerable, unnoticed fissures. Moreover, where the fire exists under an accumulation of fine coal and rock, the carbonic acid really does not come in contact with the fire, so that its failure in many cases was probably due to causes which would have prevented the success of other methods; indeed, it has generally been tried only after the failure of even-thing else. The carbonic acid is usually generated by the action of sulphuric or muriatic acid on marble-dust or limestone, and is somewhat expensive where such large quantities are required.

Mr. George Thomson, in a paper read before the British Iron and Steel Institute, gave an interesting account of the extinction of a fire in the "Wynnstay Colliery, Ruabon, "Wales, by the use of carbonic acid gas. The following is the description of the apparatus em-ployed for the production of the carbonic acid gas:

"Two strong wooden boxes, 6 feet square by 2 feet deep, were provided, and lined with sheet-lead to resist the action of the acid. Pipes with taps were fixed into the upper side of the box, and man-lids were provided, the latter for charging the box with limestone, the former for introducing the acid. Pipes with plugs were also fixed into the bottom of the box for the purpose of discharging the residuum, chloride of calcium, after the decomposition of each charge. Two cast-iron pipes, with separate valves, and also a valve common to both, were connected to the box to convey away the gas as it was produced. Small pipes, provided with taps, were inserted for allowing the air to escape, and also for attaching a mercury gauge during the operation to indicate the pressure of the gas. Whilst one box was giving off gas, the other was being charged, so that a continuous flow was kept up.

"The charge used was about 4½| cwt. of limestone, broken *vary* small, and the 'manlid' being fastened down, the hydrochloric acid was poured in, and the mercury gauge was watched so as to keep the pressure tolerably equable, usually about 3 inches of mercury. We found, generally, that 120 gallons of the acid, of 1.12 strength, decomposed the charge of limestone, which, by calculation, gave us about 12.0 cubic yards of gas. The gauge indicated when the charge was exhausted, and then the valves, etc., were shut, and the residuum withdrawn, and thus the operation was repeated alternately as long as needful. Altogether we put down about 6000 cubic yards of carbonic acid gas, and we believe that it had a very important effect. The gas collected from all the pipes through the different stoppings from time to time would not support combustion, and the temperature within the stoppings continued very moderate. It may be interesting to state here that, in analyzing the gases within the stoppings, we found that a mixture of 5 per cent. of carbonic acid, with 25 per cent. of atmospheric air, and 70 per cent. of carburctted hydrogen, extinguished flame instantaneously. On adding more air to the mixture, and applying a match, it would not explode, but when pure oxygen was added, and a match applied, the mixture exploded gently. Further, when this gas was deprived of the carbonic acid by means of caustic soda, and a match applied, it would burn when issuing into the open air."

Carbonic acid or choke-damp may also be produced by passing air through a bed of incandescent coal, mixed with limestone, of such a depth that the oxygen of the air will all be converted into carbonic acid, and not into carbonic oxide. The depth of the bed of coal to effect this purpose will be about 14 or 15 inches, and the greater the proportion of carbonic acid the better. If too little air is admitted, the gas formed may be in large part CO, but even a very small percentage of CO_2 will render this incombustible, mixed as it is with a large proportion of inert nitrogen. The application is quite similar to that of carbonic acid made from limestone and acid, with the additional drawback that it usually enters the mine hot, and therefore effects nothing as a cooling agent.

To sum up, the records of a great number of fires, and of more or loss successful efforts to extinguish them, seem to justify the conclusions that the use of the portable extinguishers is sometimes advantageous in extinguishing mine fires before they have attained much headway, that water under a heavy pressure is a much more efficient agent, and with energy and experience on the part of those using it, can be relied on to conquer, in most cases, when applied promptly and continuously. When the fire has gained such headway that, it cannot be extinguished in this way, the burning district should at once be walled off, and the admission of air exeluded. Carbonic acid or steam, or both, may then be blown into the inclosed space with advantage, steam being the most efficient cooling agent, and carbonic acid the best extinguisher. Neither the one nor the other can effect the extinguishment, except the admission of air be carefully avoided. When a mine is small, and the nature of the roof such as will not be much injured by water, and that the coal is not subject to spontaneous combustion, the quickest, cheapest, and most reliable method is to fill the mine with water, and pump it out again.

On account of the numerous modifying conditions which must be taken into account in each special case, it would be simply absurd to prescribe any one method as applicable in all. The best means to employ to extinguish a miue fire can only be determined after the most careful examination and study of the local conditions, and the object of the present paper has been simply to point out the means that have been adopted, with more or less of success, in cases where the conditions have been those common in mining regions. It is safe to say that none of the chemical nostrums that are proposed from time to time by persons not familiar with mines are of any practical value whatever.

CLEVELAND MEETING.

OCTOBER, 1875.

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*SOME PRESSING NEEDS OF OUR IRON AND STEEL MANUFACTURES.**

BY A. L. HOLLEY, C. E., NEW YORK CITY.

. IT has been customary at our opening sessions, for the presiding officer to address you on the general development of one or another of our several professions, or upon some important feature of Mining or Metallurgical Engineering. It is somewhat embarrassing to his successor that our former President, Dr. Raymond, expert as ho is in every one of these professions, has been accustomed to keep them all, in their turn, prominently before you.

In selecting for this occasion a subject necessarily connected with iron and steel, I have thought that a review of these manufactures, with reference to some of their more pressing needs for improvement, will be more timely than a general or statistical paper. I shall endeavor to confine my remarks to a few specific defects of practice and management, and to their equally specific and more or less developed remedies.

That serious defects exist; that they must be remedied ; that the manufacture is indeed already on the verge of transition, will be generally admitted. But it cannot be revolutionized all at once, however desirable the technical results might be, for that would bankrupt the business at large. We cannot afford to pull down and rebuild all our blast-furnaces that do not make a ton of pig iron with 25 cwt. of fuel; nor to replace all our hand-puddling furnaces with revolving ones, even if we could select the best revolver. Although the soft steels promise to supplant iron for most structural purposes, there are neither money nor present market to warrant all at once replacing our iron works, or half of them, with steel works.

Since, then, these manufactures can neither stand still nor be suddenly metamorphosed, their managers are saying to one another: " We must feel our way into larger development; we must work gradually into better practice; we must improve a little at a time."

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* President's address on the opening of the Cleveland meeting.

All very true—but some of us have been saying it so long and so complacently, that it is rather acquiring the flavor of a pretext for doing next to nothing at all.

Whatever economies may be made by little improvements of old tools and processes, the grand results are to come from thorough and radical changes, not necessarily in all departments at once, but sweeping when they are introduced. Putting a slightly less wiredrawing cut-off upon an old steam engine, promoting a little better combustion in a heating furnace, empirically experimenting with refractory materials and purifying compounds, are all more or less useful, but the "survival of the fittest" is to be decided on larger issues than these.

Among the more important and decided improvements demanded in this critical situation of affairs, are the following:

1. *Cheap Power.*—The cost of coal to drive the machinery of an average American Bessemer plant, when applied through engines requiring, as they generally do, 5 or 6 pounds of it per hour for one horse-power, averages about $1.50 per ton of ingots. Engine-builders are ready to guarantee a duty of 2½ pounds per hour per horse-power, and it is perfectly well known that a large number of engines, stationary and marine, are running at from *2¼* to 3 pounds. The saving of one-half the steam-coal in a Bessemer works would pay for a quarter of the total labor in the manufacture of ingots, or for all the refractory materials employed, or for all the royalties. In some works it would not be less than $50,000 per year.

The average cost of coal required to drive a rail and blooming mill is nearly $1.50 per ton of rails. Although mill engines have the advantage over blowing engines, of high speed, and are often of good type, yet it is probable that taking all our steel-rail mills together, a third of this cost could be readily saved, and this saving would be an aggregate of $175,000 per year.

The economies effected by better steam engines are not exceptional—they are of every-day occurrence. They have revolutionized the ocean service, and have completely changed the land service, especially in New England, where fuel is clear. As one of many examples, I quote the Troy steel-rail mill engine. This had a cylinder of 54 inches diameter by 3-feet stroke, and required the firing of 5 auxiliary boilers. A 44-inch Corliss cylinder was substituted, 9 per cent, of speed and 30 cent. of work were added, and yet three boilers were thrown off, and the economy in fuel was about $25,000 per year.

It will not be questioned, I think, that regenerative furnaces will gradually, but inevitably, take the place of the ordinary heating, puddling, and melting furnaces, thus preventing the application of unspent furnace-heat to steam generation. For this reason, economical boilers and engines are all the more important. When every rolling-mill and forge come to burn coal for steam, the saving of a couple of pounds per hour per horse-power will be something enormous in the aggregate. Again, while many schemes for blast-furnace improvement are speculative, almost any expense to increase the economy of blowing engines is warranted. Making uniform iron out of raw materials which cannot be uniform, requires reserve of power in the temperature and in the force and volume of blast. As coke and anthracite furnish barely gas enough under the best circumstances, combustion under boilers and the use of steam must be in the highest degree economical to meet the worst circumstances.

The blowing engines of the country are usually very wasteful of steam, by reason of wire-drawing valve gear, and especially of slow piston speed. The latter is perhaps the greatest, and the least recognized, of all steam engine defects. When steam enters the cylinder at say 75 pounds pressure and 320° temperature, a part of it is condensed into water before it can heat the walls of the cylinder to the same temperature. As the steam then expands from the point of cut-off down to the atmospheric pressure, its temperature falls from 320° to 212°, and as it falls, this water is re-evaporated by the heat in the walls of the cylinder, thus cooling them down to 212°. The steam thus formed passes off with the exhaust into the atmosphere, and is lost. At the next stroke, steam at 320°, impinging against walls at 212°, is condensed as before, and so this perpetual waste goes on. Now, we can conceive of a piston moving so fast that the walls of the cylinder would not have time to be measurably cooled ; and we can imagine a piston moving so slowly that nearly all the steam would be condensed. In practice, the indicator card, which reveals the real work of the steam in the cylinder, shows a very slight loss from condensation in the high-speed engine, but it shows in engines moving at very slow speeds, more heat wasted by condensation than there is utilized.

Many of the rolling-mill engines of the country are of good typo, but most of them will use 6 pounds of coal per horse-power, despite their comparatively high speed. What shall we say of mill engines without cut-offs or condensation, where coal is dear, and where steam is made by firing under boilers ?

Now, why does this general wastefulness of steam go on from year to year? Mill managers have a ready answer. They want "a strong, simple engine, that will stand the rough attendance it gets in a mill, and that won't break down." The first reason is ridiculous ; yet, you can find plenty of mill engines with leaky pistons, out of line, and wasting their cost every year, to save a dollar a day more pay to an engine-driver. The second reason is perfectly sound. An engine may better waste a few thousand tons of coal, if it only makes a regular business of it, than to go to pieces without notice, in the middle of a time contract. But the inference that an engine which is economical of steam is, for that reason, more likely to break down, is totally without foundation. The commerce of the Atlantic Ocean is largely done by compound engines, which are just twice as "complicated" as single cylinder engines, and which run with 2½ to 3 pounds of coal, and which are subject at every pitch of the ship, many thousands of times every voyage, to the violent strains of the screw plunging in and out of water—strains which often shake the ship from stem to stern; but we rarely hear of these engines breaking down. I have recently taken time to examine, in detail, the working of eleven specimens of one of the most economical, highly finished, and delicately adjusted engines ever built, the Porter-Allen engine, and I find them notably free from breakdowns and abnormal wear. They had been running from two and a- half to six years, and in some cases the working parts had not been readjusted at all. It is true that some of the earlier Corliss mill-engines were too light, but this had nothing whatever to do with their economical steam distribution. Probably there are more successful engines of this type than of any other.

The stability and durability of an engine is simply a question of good proportions, materials, and workmanship. Of course, a piston that takes the boiler-pressure at the first opening of the valve, re-ceives more force than one which gets only 60 or 70 per cent. of it, and that not till quarter stroke—of which there are many examples. But on the Porter-Allen demonstration, this force is required to start the very heavy reciprocating parts, which, in turn, give it out to the crank during the decrease of cylinder pressure by expansion, so that the strains on the crank-pin are not necessarily greater with good than with bad steam admission. If the sudden impact of steam is hard on machinery, what should be the result of a 10-ton hammer-head, falling 6 or 8 feet upon an 80-ton anvil? And yet, steam-hammers are made to run for years. Some of the most economical valve-gears are not complex; the complex ones a boy can work by hand, so that they are not under dangerous strains, and rarely break down. Finally, the mill engine, by means of the interposed fly-wheel, is relieved from all violent shocks, while the marine engine has no such protection.

The objection, therefore, that engines are liable to breakdowns and delays, because they are economical of steam, will not hold. If the builders of such engines do not make them strong enough, the engineer of an iron or steel works ought to know it beforehand, and to know what changes to specify. There are numerous examples of sturdy engines which he can study, I will venture the opinion that move breakdowns are caused by accepting the lowest, bids for engines, than by all other causes combined.

There is a great temptation to save the heavy cost of radical change, by patching up old engines, attaching condensers, applying cut-off valves, enlarging cylinders to get more expansion, and running faster by means of change of gearing or belts. All these things may save fuel, but do they not stand in the way of a greater economy by constantly adding cost to the old engine, and so giving it a long lease of life? No man ever throws out an engine which he has just rebuilt, however bad it may be. The way to get the greatest possible profit out of an engine of bad type, is to melt it down in a cupola. The excuse is often made that a new engine cannot be afforded. One would supose that an establishment which can afford to waste $20,000 a year in steam coal, might afford to lay up half that sum every year to invest in better engines.

The blowing engine presents a larger problem than mere perfection of valve gear. The air-piston should not run fast; the steam-piston must not run slow. Gearing a pair of small engines, making, say, 150 revolutions, to a large air-piston making 25, entirely overcomes the objectionable features of gearing, which only works harshly when the small wheel is driven. There is a possibility by this arrangement, of saving more steam than can be done even by com-pouadiug, which would cost about the same. Compound engines have certainly achieved a very great success for marine, pumping, blowing, and other large-scale uses. They, however, involve condensation, and either a large water-supply or extensive cooling ponds, both of which are often very costly, and in some cases im-practicable.

The use of the indicator—not the vile instrument made only to sell, but Elliott Bro.'s Richards indicator—should be a matter of regular practice. I will venture to say that a high degree of steam engine economy cannot be maintained without the regular application of the indicator, to show whether or not the condition and functions of the machine are normal and healthy. Beyond a few hundred dollars cost in preparation, the expense of taking cards once a week is absolutely nothing.

There are vast numbers of bad boilers, as any one will conclude, who takes pains to observe the innumerable proportions of grate, combustion-chamber and heating-surface in use for the same kind of fuel. Fortunately for mill-owners, great improvements rarely require such sweeping changes in boilers as in engines. The changes, however, should be scientifically devised. Altering the style of a grate when its surface is insufficient, or increasing draft when combustion-room is too small, will not promote much economy. The employment of a commission of experts to ascertain the real nature of the defect would be a paying investment in a great many cases. The diseases of boilers and their setting are often obscure, and the diagnosis of a cheap engine-driver is not infallible. Perfect combustion, while boilers arc being fired by hand, is probably impracticable, but bad combustion all the time is entirely unnecessary. Steam-induced air-jets sweeping over the surface of the fire, where there is heat enough to ignite the combustible mixture thus formed, is an effective and cheap arrangement. Mechanical firing, as done at Barrow and other works abroad, promotes almost continuously perfect combustion. I cannot dwell upon this subject; it would require a treatise by itself.

2. *Improved Healing Furnaces.*—The commercial importance of this subject is no less than that of the preceding. The coal-fired reverberatory furnace, however skilfully managed, must be wasteful of both fuel and metal. Much of the coal placed on the grate is lost through the grate; the very irregular volume of air passing uncon-sutned through the solid fuel is at one time insufficient to unite with the combustible gases over it, and at another time great and undistributed enough to go bodily over the bridge, and consume the metal on the hearth; combustion cannot be perfected when firing is done by hand, without an excess of air, which will waste the metal, so that the flame should always be smoky. The heat passing out of the furnace may be utilized under boilers, but not as economically as the same quantity of heat can be under coal-fired boilers, nor any better than waste heat can be utilized in regenerators.

Do iron-makers realize the enormous loss due to oxidation? An iron-rail mill making 40,000 tons of product, heating all the material twice, and oxidizing not less than 8 per cent. of it at each heat, would, at present prices, burn up more than $200,000 worth of iron in a year. Upon averaging a number of results, I find the saving in the oxidation of iron in regenerative gas-furnaces, as compared with coal-furnaces, to be over 3 per cent. In one case of first-rate practice with both furnaces, on small iron billets, it is 3.32 per cent.; in another case of good average practice on large iron piles, it is 4.45 per cent. In heating iron piles for plates, the waste in the ordinary furnace has been in some cases as high as 15 per cent., while in Siemens's furnaces, which have been substituted in the same works, it has been as low as 4 per cent. The smaller of these savings would amount, in the rail practice we are considering, to some $70,000 per year, which would pay for half the labor on rails, or it would pay above 20 per cent. on the cost of a rail-mill. The oxidation of steel is somewhat less in either furnace, because the required temperature is lower ; but the proportion of loss appears to be about the same, so that the economy of the gas-furnace is also very important in heating steel.

The amounts of fuel used in gas-furnaces are surprisingly various in different works. They run from 350 to 650 pounds per ton of rail piles and blooms, and steam coal varies similarly. These figures indicate very bad working of furnaces in some cases; and the absence of all definite data in some other cases, as to steam and gas fuel used, indicates, at least, that bad working may be going on without the knowledge of the management. The fuel for heating rail piles and blooms in ordinary coal-furnaces also varies from 700 to 1200 pounds per ton, the differences not being wholly due to plant nor management, but to quality of coal. With ordinarily bad boilers and engines, the saving of fuel, including steam coal, by the use of the gas-furnace, varies from 5 to 25 per cent. A fair comparison of the two furnaces should be based on the best practice in both cases. If coal-furnaces lose heat enough up chimney to make steam for wasteful engines, no economy of fuel is attained by using economical ones. But as regenerative gas-furnaces, which make no steam, arc necessary to the minimum oxidation of the metal heated, steam must be generated by firing under boilers, so that good engines in this case have an unlimited opportunity to save fuel. Thus the gas-furnace economizes, first, and chiefly, in oxidation; second, in fuel directly; third, in fuel indirectly, by giving economical engines a chance; and fourth, it also saves largely in quality of fuel, as cheap slack and small coal may, in most cases, be burned in gas-producers, but not in coal-furnaces. To these advantages must be added decreased loss of coal due to burning it in one concentrated nest of producers, rather than all over a rolling-mill, and the general convenience and economy of avoiding the handling and storage of coal in various parts of the works. Still another important advantage of the regenerative gas-furnace is the facility it affords for varying the chemical character of the flame, and more especially for maintaining the neutrality and perfect uniformity of the flame. This furnace seems essential to the production of the high temperatures required in the Martin steel process. The Siemens furnace has within the last few years been so highly perfected in its proportions and details, that its adaptation and working are no longer subject to any unusual risks or embarrassments.

The most imperfect feature of the gas-fuel system, at least in the English and American practice, is the gas-producer, which has not been materially improved for years. As it is simply a fire-box with a grate below, and is subject to variation in firing, in stirring, in the caking of the coal, in the holes in the fire through which carbonic acid gas and air may pass up into the chamber, and in air admission due to the irregular formation and removal of clinkers, the most careful attendance cannot insure the regular production of good gas, nor prevent the burning of some gas above the coal-bed. The Ponsard producer, on the Continent, and in some experimental practice here, promises well. It dispenses with the grate, promotes uniformity of combustion, and furnishes gas to the furnace at a higher temperature. The gasogen of M. Tessié du Motay is said to be very successful abroad; fourteen are running at the works of M. Wendel in Lorraine. The same producer is employed for the production of illuminating gas at the new works in Buffalo, Troy, and New York. There are many other schemes for the improvement of gas generation, which I cannot even refer to within the limits of this paper. It thus seems probable that a considerable economy will be shortly added to the gas-furnace through the improvement of the producer.

There are cases in which the replacement of old furnaces by regenerative gas-furnaces may not be the most economical proceeding, as in works situated but a few feet above water, and requiring costly tanks for the whole producer department, as well as for the regenerators, or else the raising of the whole floor and machinery. But it by no means follows that the old furnaces should be left as they are, in any works, whatever its circumstances. Among the various improvements which may be added to existing furnaces, or at least applied without the entire removal of the old plants, are those of Mr. Sweet, of Syracuse, New York, and of Mr. Price, of Sunderland, England. Mr. Sweet has already described his furnace and its working, in a paper before the Institute. It is certainly doing well at his own establishment. The furnace of Mr. Price and its results have been made the subject of a recent paper before the Iron and Steel Institute, by Mr. Lowthian Bell, with which our members are doubtless familiar. I will not, therefore, occupy your time with their discussion, but will very briefly state the facts about the Price furnace. Solid fuel is burned on a grate, but it is heated (its gases being thus partially distilled), and the air for combustion is also heated by the waste heat, before it enters the chimney. The inflow of the gas thus produced and of solid carbon, to the grate, and of air under the grate, is thus uniform and at high temperature, so that combustion is uniform and comparatively complete. It is thus, in some sense, a regenerative furnace. The saving of fuel is about one-third in puddling, and one-half in reheating iron, as compared with the ordinary furnace; but the cost of steam-coal, otherwise completely or partially saved by means of boilers over the common furnace, must be deducted from the abovementioned economy. In respect of fuel, the Price furnace would seem to be nearly the equal of the gas-furnace, but it cannot compete with the latter in intensity of temperature. Mr. Bell states that the character of the flame may be controlled, and that a reducing flame may be maintained. There must, therefore, be an important saving in oxidation. The pulverized fuel puddling furnace of Mr. Crampton may also be mentioned. There is no doubt as to the excellent working and economy of this furnace in respect of fuel. Mr. Crampton tells me, however, that his experiments do not, so far, warrant the belief that he can apply pulverized fuel successfully to furnaces which do not have a readily renewable oxide lining. The particles of coal blown into the furnace cut and flux brick fire-chambers.

An adequate discussion of so vast a subject as metallurgical furnaces could hardly be mapped out within the limits of a single paper. My object has been simply to draw the attention of iron and steel makers to the great waste in fuel, and the enormous waste in metal, which are constantly going on in most of our works—losses which draw a respectable dividend every year from the profits, and which may be prevented by thoroughly developed improvements. In view of such serious defects, and such ample and adequate remedies, it seems hardly worth while for our manufacturers to putter with trivial contrivances—to add a little heat to the blast, to check a little smoke, and to save a little fuel, and so to eke out the wasteful life of a furnace system which is radically bad.

3. *Refractory Materials.*—Improvements in this direction are probably the most important that can be considered, and they increase in importance as iron and steel processes become cheapened, and as products become more refined. A better blast-furnace lining would be desirable; better heating-furnace walls would be very valuable; better Bessemer vessel linings would lead to great economy; better open-hearth furnace roofs are absolutely essential to cheap Martin steel manufacture, and better refractory materials generally must be provided before the Siemens direct process, high-pressure furnaces, the cheap compounding of various metals with iron, and many other promising processes can be carried on at all with commercial success. It is not too much to say that a better and cheaper fire-brick will be the key to the situation.

The cost of maintaining refractory linings and fixtures in the Bessemer process averages nearly $1 per ton of ingots, of which the cost of vessel-bottoms is about one-third. Merely doubling the life of bottoms would save some $6000 per year, in a single works. As the life of a bottom frequently exceeds double the average life, it should not seem impossible to raise the average in this proportion. The cost of refractory materials and maintenance in the American Siemens-Martin manufacture is not far from $5 per ton of ingots, while in Wales and in France it is about $1. This difference lies largely between bricks which cost $50 to $60 per 1000, and stand 50 to 70 heats here, and those which cost $10 to $20, and endure 200 to 250 heats abroad. Merely equalling the foreign practice would of itself make a good business profit.

Our metal manufacturers seem less serious and methodical in their attempts at this, than at any other improvement. They can copy the steam-engine results of others, but the refractory material problem is all their own. That it is difficult cannot be denied; but the average attempts to solve it, which consist largely in travelling round in a circle, are wholly inadequate, and unworthy of the profession. Bricks, tuyeres, and fire-clay mixtures generally have not been notably improved for a decade, except here and there, accidentally, by the discovery of better clays, or empirically, by trying all sorts of mixtures haphazard. There have of course been some attempts at scientific improvement. Mr. Snelus gives the following facts in his late valuable paper before the Iron and Steel Institute: The presence of 2 or 3 per cent. of oxide of iron renders bricks unfit for open-hearth furnace roofs, and 1 per cent. of alkalies makes them fusible at high temperatures. There are some apparent anomalies: lime fluxes ordinary fire-bricks, but 1 per cent. of it used to bind together pure silica sand, makes the most durable furnace roofs known. Alumina by itself, and in the proportion with silica of 30 to 38 per cent., as in some of the best clays, is extremely refractory, but 3 per cent. of it in a silica brick will flux it at high temperatures. These facts explain the bewilderment and discouragement that usually attend experimenting on a limited scale; they also show the necessity of combining the results of a vast number of experiments and analyses; and they especially show that the direction of these experiments should be in accordance with chemical probabilities. Merely varying mixtures, even with a knowledge of their constituent parts, might never lead to improvement, if the laws of chemical affinity were misunderstood or ignored.

The same conclusions may be drawn from another group of facts, viz.: the very different behavior of refractory linings in contact with different metals, slags and ores, such as the cutting of sand bottoms in the pig-and-ore open-hearth process. The best furnace roof brick we know of—as nearly pure silica as possible—is the worst brick to stand the manganese reactions in a spiegel cupola. In the first case, it might endure 250 charges at an excessively high temperature ; in the second, it would hardly stand 25 heats at a low temperature.

In view of these complications and of the obvious necessity for prolonged and searching chemical work of the highest class, and for a systematic series of experiments—also, in view of the extremely limited progress which has been made by present methods, it really seems that the time has come for a new departure. No individual works can, nor should, afford the cost of such an investigation, which would be for the general benefit. A clay-bank owner, or a brick-maker, can hardly be expected to do more than develop his own products, since complete experiments might prove them inferior.

Why should not the iron and steel makers of the country unite in carrying out a series of investigations which, if properly managed, would inevitably lead to important savings in the old processes, and to revolutionary economies in the new and developing ones? It has been objected to this kind of effort, that "what is everybody's business is nobody's," and that valuable results rarely follow mixing up the interests of independent companies. If these remarks are ever true, they do not apply to this case. In general, the history of associated effort is the history of civilization ; and in particular, the association of individuals, through governmental and private organizations, to test the strength of metals, to inspect boilers, to analyze ores, to collect facts, and to do numerous things of general and of special interest, is often the foundation of success in commerce and the arts. The proposed investigation would be entirely relieved from those uncertainties which embarrass combinations to sell products under certain limitations of price and quantity. It would be simply a search after physical facts, by a corps of experts in whose ability and integrity all parties would have confidence. However difficult the problem may be, the manner of its solution is plain, and the means of experiment are numerous.

Not to anticipate the proceedings of such a commission, but merely to observe how large and hopeful is the field for investigation, let us for a moment consider the situation and probabilities.

I. The comparative failure of previous attempts to improve refractory materials has been due to the varying presence of unknown elements. Three materials each make a good fire-brick; mixing the first with the second makes a better one, but mixing the first with the third makes an inferior one—and the experimenter is all adrift. The more alumina, between 40 and 60 per cent., we mix with silica, the better the result, but the more alumina, between 3 and 10 per cent., we mix with silica, the worse the result. Repeating apparently the same mixture sometimes gives different results. But there are no anomalies in nature; apparent contradictions are merely want of knowledge. Therefore one important step in this inquiry would be to variously compound pure silica, alumina and other substances, to imitate nature in their mixing, and then to try their refractory qualities, rather than to confine experiments to variable natural mixtures. Even if we must use materials as we find them compounded in nature, it is better first to find out at any cost, exactly what we want, by means of artificial mixtures of pure materials, and then to come as near it as we can in practice.

It is not certain, however, that we shall be confined to natural mixtures just as we find them. The chief ingredients of that remarkable refractory material, bauxite (which is somewhat rare and expensive), alumina and oxide of iron, can be obtained more free from other substances than bauxite is. Why cannot artificial bauxite be made? The intimacy of mixture, indeed, has much to do with the character of the product. We know that five per cent. of alumina, incorporated by nature with siliceous sand, give more adhesiveness, both wet and glazed, than three times that amount as ordinarily mixed by hand. The artificial distribution of manganese ore with iron ore in a furnace makes iron pigs and manganiferous slag, while, if the manganese ore had been rubbed into the iron ore by nature, the result would have been spiegeleisen. More than intimacy of mixture may be necessary in some cases. Dr. Sterry Hunt has suggested that the difference in the behavior of silica in furnaces may be somewhat due to the manner of its formation—either as an animal secretion, or as found in igneous rocks, or in rocks stratified from their debris. The shape of sand-grains has also much to do with their binding qualities, angular fragments being better than rounded ones. There is, however, a strong probability that refractory materials may be artificially compounded out of pure, or nearly pure substances, more uniformly than they are compounded by nature. So that the synthetical method we are considering should be useful, not. only in showing what we want, but in enabling us to produce it.

II. Other substances than silica and alumina are extremely refractory, indeed indestructible, by mere heat, such as lime, magnesia and carbon. The great difficulty has been to form them into compact bricks without adding such binding substances as will flux them, and so impair their refractory qualities. But as pulverized silica— a rope of sand—is sufficiently held together by 1½ per cent. of lime, to make the best heat-resisting brick we know of, the other incoherent refractories should offer a promising field for experiment.

We may learn much on this subject from the experience with crucibles. The two required qualities to be chiefly considered are,—1st, resistance to softening, or to melting by contact with neutral flame—by mere heat; 2d, resistance to the chemical action of metallic oxides, slags, and free oxygen. Both these qualities are attained by lining a crucible that will resist fire well, with one that will resist chemical action well. For instance, a carbon crucible wastes more rapidly than an earthen one, in the fire; but by lining an earthen crucible with carbon, it. perfectly resists the action of manganese oxide, which would soon destroy any vessel containing much silica. Carbon mixtures, however, are affected by oxygen in a surprisingly small degree. The endurance of graphite crucibles in a fire of coke driven by a powerful blast, and graphite Bessemer tuyeres in contact with air blast and oxide under intense heat, are examples. The use of carbon, even in the form of wood, is already on trial by Mr. Siemens, and, in another form, by one of our members.

Lime is extremely refractory, never having been fused by mere heat. Crucibles cut from blocks of well-burned, slightly hydrated lime are used to melt platinum. Magnesia is also infusible at the highest attainable temperatures. M. Tessié du Motay, of Paris, has made some remarkable magnesia bricks, of which I have specimens. They are, certainly, expensive, but they are said to resist not only heat, but the dissolving effect of manganese oxide and various corroding slags. There is a prospect of this manufacture being started in this country. Dr. Percy says of this material, in his new *Metallurgy:* " Reverberatory furnaces for melting steel may be lined with a paste formed of the prepared magnesia and water, which will undergo the necessary drying and firing after the furnace is lighted, without any special precautions being required." He also gives directions for preparing magnesia for use in crucibles and bricks. This material is also used at Creusot in Bessemer vessel linings. The only difficulty is to make it sufficiently coherent.

Still another requirement of Bessemer vessel linings and revolving open-hearth linings, is hardness, to resist the mechanical erosion of the contained metal. All the foregoing considerations, indeed, point to the importance of making refractory materials hard and dense, without running into the other extreme of increasing their liability to crack and crumble on the exposed surfaces. But even this tendency may be prevented by proper treatment. Silica bricks require slow heating. In some Bessemer vassel linings made of natural siliceous stones, trimmed like bricks to make a wall, which are now in successful use, the "spalling off" was permanently stopped by glazing the wall at its first heat, by means of blowing a charge of metal within it.

III. It is probable that refractory linings must, in many cases, be made where they are used. This is already the case with the silica bricks we have mentioned, as at Landore and Terrenoire. These bricks are too tender to bear transportation, but are remarkably refractory when once set in a wall. The apparatus for making them is not very costly, nor elaborate. The quartz is crushed to fine sand, wetted down with lime-cream (1½| to 2 per cent. of lime), and moulded by hand into bricks. These are dried and burned in kilns, containing 32,000 each, for seven days. Bessemer vessel linings are also necessarily made where they are used, and it seems reasonable to believe that the use of monolithic linings will become more general in all kinds of furnaces. It is very obvious that the cost of a furnace roof and sides, rammed up like a Bessemer vessel, dried out and glazed, would be much less than that of bricks individually moulded, pressed, dried, burned, trimmed, and set. And if the material is equally good, the continuous wall should stand much longer, because it has no joints, which are always the first parts to fail. We know that such linings in Bessemer vessels will outlast a dozen linings made of any fire-bricks yet tried. The vessel-lining is, indeed, a continuous arch of small radius, while the furnace roof is nearly flat, and, consequently, more liable to fall by shrinkage, due to variation of temperature. But could not a flat arch be sustained by a lathing of water-pipes, either in tension or in compression, which would also cool it, and thus increase its endurance? This subject will be further considered under the following head :

IV. It has been a matter of surprise to me, that the cooling of refractory linings by means of water-jackets has not been developed in heating and open-hearth furnaces, when it has been so remarkably successful in blast-furnaces, puddling furnaces, and, especially, in Sellers's and in Crampton's revolving puddlers. I have seen the fettling of the Crampton furnace purposely knocked off for more than a square foot of the shell and front ring, during the boiling of the metal. The naked iron plates were thus exposed to the molten iron and slag on one side, and to water on the other; in a very few moments the lining was completely renewed by the chilling action of the jacket. Some jacketed cupolas are running with success, but where increased durability is most needed, as in Bessemer cupolas, the attempt has not been carried out, although it has been frequently planned.

If a fire-box sheet of naked iron, in immediate contact with a white-hot anthracite fire, will remain sound for years, it is probable that it would be nearly indestructible under a four-inch coating of fire-brick. Of course, the cooler the bricks are kept, the more heat will go into the water, but, as we can melt down a gas-furnace roof in an hour or two, there is, evidently, reserved power enough to furnish the necessary units of heat to the bath, while passing as many other units, at the same temperature, through the roof. Nor would water-jacketing, say, an open-hearth furnace, be comparatively wasteful. Even if a quarter more fuel were thus required, half a dollar per ton of ingots (at average rates of fuel) would pay for it, while even doubling the endurance of furnace-bricks would save four or five times this sum.

Water-jacketing should protect the bricks not only from destruction by mere heat, but from chemical dissolution, as this is generally a question of temperature.

The effects of heat are notably lessened as walls become thinner, so as to conduct heat more rapidly to the atmosphere. The thickness at which a lining will remain, in the Crampton revolving furnace, for instance, is exactly regulated by the amount of cooling. Where the lining is knocked off, the fluid slag quickly sets, up to a certain thickness, but beyond this thickness the water cannot chill it, and it cannot, therefore, accumulate. The amount of cooling by water can be perfectly regulated. The two features requiring experiment are—1st, Decreasing the water-supply in such a regular manner, when the furnace has to be stopped, that the lining shall be neither overheated nor rapidly cooled; 2d, How to sustain very thin linings. Water-jacketing a furnace roof a foot thick would not do the maximum good until the bricks were nearly burned out, and then they would fall in. As before mentioned, I believe that a roof composed of groups of wrought-iron water-pipes, either in tension for a drooping one, or in arch form for a convex one, each group having its separate water-connections, the whole to be filled in and rammed with a ganister mixture, like that of a Bessemer vessel, or with a natural or artificial bauxite, would be very durable. Certainly, there might be some very promising experimenting in this direction.

In concluding these observations on refractory linings, I must again call attention to the importance, the necessity, I believe, of putting this whole subject into the hands of a Commission of Chemists who are familiar with the requirements of metallurgical processes. It really ranks in importance with government tests of metals and boilers, but as governments can, with difficulty, be got to sustain experiments which seem to be of greater public interest, the expenses of refractory material tests would have to be borne chiefly by iron and steel makers. They can well afford to do it, and some important results can, doubtless, be determined without a very large expenditure. But such a commission should be nothing if not thorough. Immature conclusions would do more harm than good, as they have done heretofore in iron and steel tests.

4. *Enlarging the Range of Manufacture and Utilizing Waste Products.*—The wrought-iron manufacture, by reason of its long period of development, and the ease with which old and defective materials and scrap can be reworked, has adapted its products, in a remarkable degree, to every branch of construction, very largely

crowding out cast iron from such important works as large columns and long-span bridges. The following remarks will therefore apply chiefly to the steel manufacture, which has within it the elements of superseding wrought iron in a still more remarkable degree.

The rapid adaptation of steel to large structural uses other than rails, in foreign countries, should be more seriously considered by our steel-makers. For instance, three French men-of-war, built mostly out of Bessemer and Martin steels, were so successfully constructed in 1873, that three more large ships were ordered in 1874, to be built from the same materials. Notwithstanding the objections so strongly urged against steel ship-plates in England, partly from the conservatism of " practical" men, and more largely from their improper treatment of this material in heating, shaping, and applying it, the English government has recently ordered three vessels to be built wholly of steel, and many private shipbuilders are employing more or less of this better material. Several Bessemer works in England are running exclusively on a general merchant product, having a large range of grades and uses, and taking the place of both crucible steel and wrought iron. The Continental works are turning, probably, a third of their Bessemer product, and a greater proportion of their Martin product into other forms than rails. All the late locomotives, many hundreds, on the London and Northwestern Railway, are built of Bessemer steel, excepting only the wheels and necessary castings. Everywhere abroad, Bessemer and Martin steels are more and more satisfactorily employed for plates, beams, channels and angles, for ships, bridges and other structures, and for railway tyres and axles, general shafting, agricultural implements, and the multitudinous forms of machinery bars and forgings. In the railway and machine shops, the bridge works and shipyards of Europe, and of France especially, the method of treating steel, of heating and shaping it, and of building it successfully into machinery and engineering structures, has become, what it must everywhere become before this material can be employed to the best advantage, a distinct and highly developed art.

We learn the following facts from Mr. Menclaus's recent address before the Iron and Steel Institute : Krupp, after successfully making thousands of steel cannon, large and small, is now fabricating 14-inch guns of 57 tons weight, to carry 9 cwt. shot 9 miles, and is about, to build others of double this weight; Mr. Reed, late Naval Constructor, believes that there will henceforth be no obstruction to the large development of steel for shipbuilding, and that "the special arrangements required for steel shipbuilding present no real difficulties to a careful builder;" steel bridges of large span are successfully constructed in Holland and elsewhere on the Continent, and steel bridge-building in England is hampered chiefly by the Board of Trade regulation, that the material shall not be loaded above five tons in tension, and four tons in compression. The Bolton Bessemer works have produced between 9000 and 10,000 tons of steel plates, three-fourths of which have been used in boilers. Mr. Adamson, the eminent engineer, has built between 600 and 700 boilers out of Bessemer steel, and uses no other material for this purpose.

What, on the contrary, is the condition of the manufacture at home? Out of a Bessemer product of some 350,000 tons per year, probably less than 6000 tons are used for other purposes than rails. Very few Bessemer works have any machinery for producing the various constructive shapes required, or any experience in making steel of high or low grades. Bessemer manufacturers are talking about reducing product, in the fear that rail orders will fall below the capacity of their works. Martin steel is now made in American works, regularly and successfully, of all grades, from springs down to boiler-plates, thus furnishing every constructive grade required. Engineers and machinists are generally asking for just such material as steel has proved to be abroad, but are yet hesitating about the use of steel, because our Bessemer manufacturers have not got much into the way of making other grades than rail steel, and Martin manufacturers have not, until quite recently, begun to adopt those improvements in plant and practice which will make steel cheaply; and, also, because our artisans have not, in most cases, made any study of the art of working steel, and are therefore afraid of it. Experts say that the use of wood, not only in ocean vessels, but in river and lake boats and barges, must soon give way to the use of metal, as it has done abroad, and is beginning to do here; and there are thousands of wooden bridges on our railways and highways, which must soon be replaced by metal; so that for these two large uses, not to speak of general machine construction, there is growing up a vast market for a better material than iron. Excellent pig, for the production of cheap steel, is obtainable in all parts of the country, and ferro-manganese, upon which important qualities of constructive steels depend, is now cheap enough to warrant its general use. In short, with every facility for making the product so largely needed here and so largely used abroad, with the best steel-works in the world, and working organizations in them which have increased

Product and decreased cost in a remarkable degree, we are devoting more concentrated action to schemes for preventing over-production, than we are to adapting grades and shapes of product to the various ' constructive uses, and to teaching artisans how to heat, shape, and apply them.

The remedies for this state of things are various and obvious, and arc indicated in the foregoing statement of the case.

I. It is, undoubtedly, the policy of every Bessemer works, whether it as the machinery for rolling merchant steel or not, to hard and soft, so as to learn the proper ingredients and treatment make, from time to time, experimental charges of high quality steel, both. As such steel should be better than the average make, it can be disposed of for rails if it is of the right grade, and if of softer or harder grades, what little would be adeexperimentally could be sold in one place or another. There might e no immediate profit in it, but it would give the maker knowledge of his resources, facts about cost, experience in treatment, and confidence in his ability; in short, it would put him in a position to take and execute orders. Steel-makers cannot expect a very brisk demand for materials which they do not know whether they can make or not, nor what they will cost or be like when they are made. An equally great advantage of this experimental steel making would be an opportunity to test the exact value of their new products in tension, compression and elasticity. I have seen Bessemer plate made and tested at Terrenoire, out of common Bessemer pig and ferro-manganese, which stretched 19 per cent. and had but 0.16 per cent of carbon. Some Crewe Bessemer plate, that I saw made and had analyzed, stood every mechanical test and had 0.21 carbon, 0.029 silicon, and 0.054 phosphorus, which shows what may be done by selecting good materials. If our present pigs are not sufficiently siliconized to blow hot, the addition of manganese in the vessel, in the shape of good spiegel, will answer the same purpose, and help rather than harm the product.
The reason why our Bessemer men do not make soft steels and those adapted to a larger range of uses, is because they do not try. But they must try, and succeed, and know what they can guarantee, before they can get orders.

II. It is also obvious that Bessemer steel-makers should increase their facilities for turning out the various *shapes* required, and for putting rail-ends and bloom-ends into marketable forms. Probably, a stand of billeting rolls attached to the rail train, also a 14-inch train and direct engine, and a 9-inch train belted from the same engine, would best cover all up to rail sizes. Judging from what the one or two works are doing which have these facilities, one or the other of these small trains should very soon be kept busy on special steels and reworking rail-ends. Probably the best means of rerolling old steel rails and rail-ends, is the very ingenious device of Edwards & Rogers, of Cleveland,--placing the grooves at an angle with the axes of the rolls. The whole rail-end can thus be utilized, while slitting off the flange and stem makes pieces that are too short for economical use. Rerolling old steel rails and long ends into smaller rails is done successfully abroad. Even small pieces may be utilized better than by remelting, if they are of proper grade and soundness. The Troy works, for instance, are making steel cut-nails, which will drive through an oak plank and clinch.

The large use of steel for structural purposes, however, will be in bars which will require a 21 to 24-inch train, such as angles and small channels, I-beams and deck beams, and large flats, rounds and squares. To change the rolls of a rail-train to fill orders which would necessarily be small at first, for this kind of work, would be very expensive. But a couple of stands of rolls on the end of a rail-train could be changed as often as necessary, without interfering with the regular rail production. The same stands would take the billeting rolls before mentioned. It is probable that boiler plates can be made cheaper and better in the long run by the Martin process, but ship, bridge, and tank plates are successfully made by the Bessemer process. The existing blooming trains can, I believe, be changed from time to time into excellent and fast-working plate-trains, by the mere substitution of suitable rolls and fixtures. This feature was considered in the original design of the mill.

III. It will also be necessary for steel-makers to take the initiative in practicing, perfecting and disseminating the new art of working steel for structural purposes. The high degree of success which attended the treatment and use of steel in the French ships referred to, was due to an elaborate series of experiments, before and during their construction, on the injury done to plates, bars and beams by hardening, and the remedies—hardening, not by cooling only, but by pressure, as by punching, shearing and cold hammering. It has not, probably, occurred to many boiler-makers who could do nothing with these grades of steel, and so have condemned steel altogether, that shearing and locally hammering plates puts them in a condition similar to that produced by cold punching, which reduces the strength of the parts above 20 per cent. These injuries, however, are entirely local, although their effects, if not remedied, may become general. It has been demonstrated at the Barrow works (as set forth by the manager, Mr. Josiah T. Smith, in a late paper before the Institution of Civil Engineers), and most completely proved by these French experiments, that the injury done to steels of rail grade and below, by cold punching, is confined to the skin of the hole (4-100 inch thick in the French tests); and that this injury is only hardening by pressure, which may be completely removed by tempering or annealing, or by reaming out this thin ring of hardened metal. The same is true of shearing; the hardened skin may be removed by planing or restored by annealing. The Bessemer and Martin steels employed were not the softest grades; they had at least 0.25 carbon, and stood 30 tons tensile strain. They were easily hardened, and readily acquired dangerous internal strains; yet they were made so completely tractable by proper treatment, that they did not fail in manufacture as often as iron did, and gave promise of vastly longer endurance in service. With proper appliances, these necessary additions to ordinary iron working processes need add but little to the cost of construction. There are still other features of the treatment of steel, especially the effects of heat, which form an important feature of this new art. I will omit its further consideration at this time, from the fact that we are to have a valuable paper, at another session, which will present this subject in detail.

The adaptability of steel to constructive purposes was specially shown in stamped work, such as pieces shaped like a low-crowned hat, of which 700 were produced without losing one, while not one good piece could be stamped out of iron. The fact that steel crystallizes less than iron by heating without working, and that steel plates have practically the same strength with and across the "grain," were also demonstrated. The conduct and results of these experiments have been published by M. Barba, and are republished by Van Nos-trand in New York.

IV. But the advantages of steel, as a constructive material, and of its improved treatment, cannot be monopolized by the present steel-makers. There are many iron merchant and rail mills now short of work and likely to lose business every year, as steel is developed, which have nearly all the appliances for working up steel into shapes for implements and structural uses. Such works, abroad, and, to some extent, here, are insuring the utilization of all this machinery, and the permanence of their business, by working their way into the steel manufacture, by means of the open-hearth furnace.

The Siemens-Martin process has, in such cases, the advantage of working economically on a small scale. Where it is best carried out, the product is cheap enough to warrant its substitution for iron in a large number of uses, and it is particularly economical in that the raw material employed may be largely scrap iron and steel of good quality, and even of bad quality, if rich ferro-manganese is used instead of spiegeleisen. Martin steel rails, in successful service in France and Russia, contain 0.38 of phosphorus, neutralized by 0.75 to 1.00 of manganese, which replaces the usual carbon. Of carbon there is but 0.12 per cent.

V. Finally, one of the most obvious and important methods by which steel-makers can promote not only the adaptation of better materials to structural uses, but the increased use of iron and steel structures, is to aid in the government tests of metals which have recently been inaugurated. Many thousands of tons of iron are annually put into bridges and ship-frames, for instance, when bridge and shipbuilders know and admit that steel is stronger and probably better in every way, but they are afraid to use it because they do not know just what the strength, elasticity and ductility of the various grades are. In default of such knowledge they will take no risks. Now this is just the knowledge which this government commission will supply. If steel-makers will take hold of the matter heartily, and make it their business to supply specimens of various grades, and to contribute in all ways to the thoroughness of the investigations, they will benefit themselves even more than they will serve the public. This commission intends to avoid the mistake which has made similar attempts, heretofore, of partial and limited value—the mistake of ascertaining only the physical qualities of metals, the chemical constituents of which are practically unknown. They intend to determine what it is, not only in composition but in treatment, that makes iron and steel good or bad, or well or ill adapted to uses in building and in the arts. This information must be of the greatest value to both iron and steel makers. And the final result must inevitably be, not only the adaptation of better materials to current uses, but the vastly increased employment of both iron and steel for new uses.

In conclusion: While it cannot be denied that the foregoing criticisms are applicable in more than a majority of cases, it would be not only ungracious, but unfair, to put forward their objects as representative and characteristic of American practice and management. Our economies, in some departments, have been remarkable, while our general steel-works and rolling-mill practice is, on the whole, superior to that abroad. While the introduction of economical mill-engines is making slow but measurable headway here, the increasing 'use of reversing engines in England is a step to the rear. The gas-furnace and the utilization of waste heat are quite as generally employed at home, as in other countries.

In this connection, I cannot close these remarks without bearing testimony to the gallant manner in which the commercial promoters of our early Bessemer works poured out money and encouragement to us who were so long floundering in the slough of technical uncertainties. I refer especially, but by no means exclusively, to the three establishments which first resisted the upper and nether millstones of inadequate professional knowledge and popular prejudice against steel,—the works at Troy, Cleveland, and Harrisburg. And it is with a feeling equally of-pleasure and of justice, that I also refer to the remarkable production of steel, and to the notable economics in its manufacture, which have been accomplished by the technical knowledge, the workfulness, and the common sense of the superintendents of our various steel works. Let shareholders and directors, remembering the outcome of the troublous past, bear in mind what results the future should bring forth, when technical management of this quality is reinforced by that system of improvements, which this paper has but too inadequately set forth.

COKING INDIANA BLOCK COAL.

BY JOHN S. ALEXANDEB, PHILADELPHIA.

THE typical block coal of the Brazil (Indiana) District differs in chemical composition but little from the coking coals of Western Pennsylvania. The physical difference, however, is quite marked; the latter has a cuboid structure made up of bituminous particles lying against each other, so that under the action of heat fusion throughout the mass readily takes place, while block coal is formed of alternate layers of rich bituminous matter and a charcoal-like substance, which is not only very slow of combustion, but so retards the transmission of heat that agglutination is prevented, and the coal burns away layer by layer, retaining its form until consumed. This property permits the use of raw block coal in the furnace but thcoretically interferes with coking; therefore, coals of this class are usually denominated non-coking.- Contrary, however, to this popularly received theory, a very excellent coke has been produced at the Brazil Furnace in ordinary beehive ovens; so successful has been the experiment, that the proprietors of the furnace, Messrs. Yandes, Root & Garlick, have erected twenty ovens, and this coke is now employed by them to the exclusion of the heretofore used Connellsville as a mixture with the raw block coal ; the proportions being about one-fifth coke and four-fifths block coal.

The ovens are 12 feet in diameter, and 6 feet high; the usual charge is 31/2 to 41/2 tons of the raw coal, and the contents are drawn in 54 hours. The coke has a bright and silvery appearance, and retains the shape and peculiar stratification of the coal. In fact these characters are so well preserved, that the process might more properly be termed charring than coking.

An analysis of the raw coal by Prof. Cox, State Geologist of Indiana, is as follows:

Coke,	60.55	Ash, white,	2.60
		Fixed carbon,	57.95
Volatile matter,	39.45	Water,	2.10
		Gas,	37.35
	100.00		100 00
Phosphorus,			.096
Sulphur,			.073
Spec. gravity,	1.232	Weight per cubic foot,	77 lbs.

Two assays by the same analyst gave, respectively, 4 per cent. of ash in the coke made from the centre of the vein, and 6 per cent. in that made from the more richly bituminous coal of the top and bottom of the seam; thus affording, by difference, an unusually high percentage of carbon. The sulphur and phosphorus were not determined, but from the analysis of the coal just given, it may be inferred that the merest trace of these deleterious substances is present in the coke. According to an analysis in Saward's *Coal Trade Journal,* the composition of Connellsville coke is as follows : Carbon, 87.456; ash, 11.382; moisture, 0.490 ; sulphur, 0.639; phosphorus, 0.029. This large percentage of ash is probably due to the very considerable quantity of slate found in the coking material ; a trouble from which the block coal in question is entirely free. It will thus be seen that, chemically, the Brazil coke is all that could be desired, and from the following data taken from the books of the Brazil Furnace, which , were kindly placed at my disposal by Mr. E. C. Gariick, one of the proprietors, a knowledge of its behavior in the furnace will be obtained. As an average week, that ending September 4th last was selected; during this period the furnace received 410 charges of] 800 lbs. of raw block coal; 350 lbs. of Brazil coke; 700 lbs. of limestone ; 950 lbs. of Simmon's Mountain ore ; 475 lbs. of Iron Mountain ore ; 475 lbs. of Lake Superior specular ore; and 120 lbs. of furnace scrap. The product was 212 1/2 9/2 2/4 0/0 tons of pig metal graded as follows: No. 1 foundry (Bessemer), 35 per cent.; No. 2 foundry (Bessemer), 9.5 per cent. ; and No. 3 Bessemer, 55 per cent. Turning back, it was found that during the week ending November 21st, 1874, 411 charges entered the furnace, each charge consisting of 1800 lbs. of block coal; 385 lbs. of Connellsville coke; 825 lbs. of limestone; 1050 lbs. of Lake Superior specular ore; 525 lbs. of Michigammi magnetic ore; and 525 lbs. of Lake Superior (Salisbury) hematite ore. The product was 217 1/2 8/2 2/4 0/0 tons, graded as follows: No. 1 foundry, 41.4 per cent.; No. 2 foundry, 8.5 per cent.; No. 3 Bessemer, 38.6 per cent.; and No. 2 mill, 11.5 per cent. Pig metal from this furnace is in active demand for Bessemer purposes, which proves that the product is of a superior quality.

With block coal at $1.50, this coke can be produced at a cost within $3 per net ton; whereas, Connellsville coke, after being delivered at Pittsburgh, must be transported 438 miles by rail, at a cost not less than $4.50 per ton, which, added to the lowest quotation at Pittsburgh, $2.50, brings up the cost to $7 per ton, at the furnace; the importance of this new industry to the iron interest of Indiana is, therefore, easily apparent.

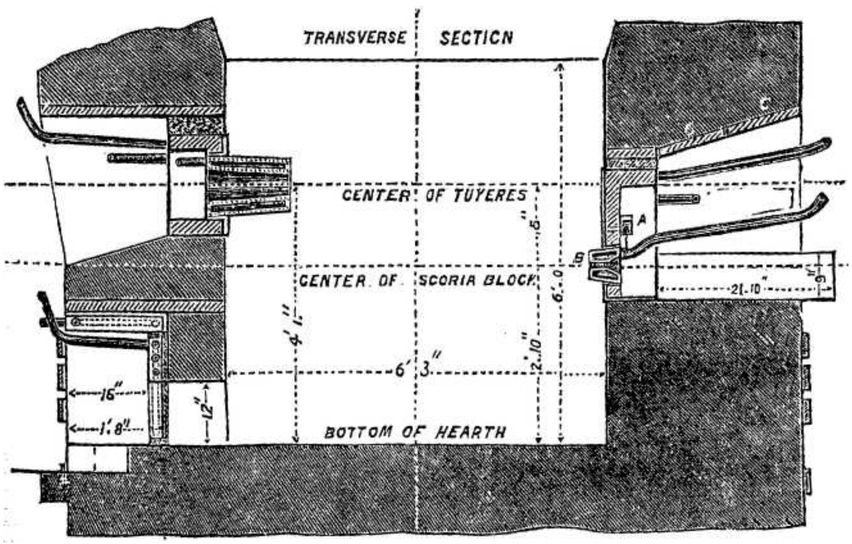
FURNACE HEARTHS.

BY GEORGE ASMUS, NEW YORK CITY.

CLOSED front, or open front for blast-furnaces, has been for a number of years a much discussed question among the furnace-men in every country where iron is made. As blast-furnaces are costly structures, and as the whole question is one of economy, I hope to be excused for entering a little into details.

The "fore-hearth " is a prolonged opening in the lowest part of the hearth, from two to three feet wide, four to six feet long, and two to three feet high. It is a more or less fire-proof box, cooler than the inside of the hearth, and is apparently made for the purpose of letting the cinder out. Its front is closed by the " dam," *over* which the cinder runs and *through* which the iron flows, when casting. As no iron is made in this part of the furnace, it being below the range of the blast, and as it forms in most cases a source of daily work and sometimes the cause of most serious troubles, it is interesting to inquire why this thing was made at all. In olden times the furnaces had no fore-hearth ; a vertical slot, a few inches wide, was cut into the front hearth-stones, reaching to the bottom, and iron and cinder were tapped through the clay which closed it. These furnaces were called *Blauöfen,* also *Blaseöfen,* Blow-furnaces; and up to the present day some of these metallurgical relics have withstood the pressure of our fast times. There are in the remote mountains of Steyermark charcoal furnaces, which make daily a few tons of excellent iron. But a time came when men were no longer satisfied with these little smelt-ing-pots, into which a gentle stream of air was blown through one nozzle, which received its scanty supply from a leather bag, squeezed by some tired water-wheel. Larger dimensions, more tuyeres, higher pressure, finer steam-engines, and hot-blast increased the production of iron and cinder. Soon the tapping-slot in front got too hot, and in taking it farther from the hearth it, the dam and fore-hearth, were formed. In this fore-hearth not only fluid iron and cinder accumulate, but coal and half-smelted ore float into it and, as the blast is intercepted, no combustion and no fusion can take place here. So this ore and coal become rubbish, and often of a dangerous kind. Cast-iron clings to it, and, after the tap is made, enough air blows upon it to effect a partial puddling, and there results a tenacious mixture of all kinds of steel and wrought-iron, which pastes the whole pile together. To prevent this, the fore-hearth has to be cleaned out, and that is what the smelters call *working the furnace.* A superstitious idea had come about, that some incomprehensible, but very bad, matter lay hidden in all smelting material, which crept slyly into the fore-hearth, where it was caught and expelled. During this purifying process, of course the blast had to be stopped ; and the more industrious and faithful the smelter the more thoroughly he did his work, and the longer the furnace stood still. So it was, up to eight years ago, everywhere, and so is it still at a great many places. The loss of time by stopping the blast amounts from two to four hours out of every twenty-four.

The honor to have broken this practice is due to Fritz Lurmann, one of the most able blast-furnace engineers in Germany; and eight years ago I commenced, in connection with him, to bring his simple innovation, the closed front, before the iron men of America. Lurmann's idea can be expressed with a few words : The fore-hearth is only made to get rid of the cinder ; it is a troublesome, additional construction, which has nothing to do with the smelting process proper at all; let us cut off this fore-hearth completely and tap the cinder through an opening just wide enough to suit the purpose, but which cannot burn out. This is effected by a water-cooled casting, which is inserted a foot or so below the range of the tuyeres, and may be put in



any part of the circumference of the hearth, where it seems most convenient. The iron tap in front is a separate matter; it may be water-cooled, as by the usual dam. Two great advantages are gained, — cinder and iron are tapped *directly* from the hearth, and all the loss of time and all the labor in cleaning the hearth are saved. Quite a number of other advantages are gained: the tuyeres can be put absolutely equidistant, as no weak place has to be protected ; and, in consequence, the smelting becomes perfectly even and the smelting column sinks vertically. As the heat is properly distributed, the quality of the iron made in the different parts of the smelting zone is uniform. The air-heating furnaces are always kept at the same temperature, because the blast is always on; no coal is wasted, and clay and tools, now quite an expense, arc done away with.

So we have a self-acting apparatus, which is actually in the hands of the manager.

The accompanying cut shows Lurmann's construction in detail, when applied to new furnaces. When applied to old furnaces the minor details may differ, but the main points remain the same, and as the whole idea is correct, its application to any furnace, running on any material, is unquestionable. If the furnace, as *such*, works, this arrangement does, and if the furnace does not work, no fore-hearth can help it. Moreover, a large opening may be made in the furnace, if desired, without touching a brick, simply by slipping out the cinder-tuyere.

The facts have shown that Lurmann was right, and in Germany the open front has become obsolete. In England, Lurmann's system has been only within a few years fully adopted and indorsed by many of the leading men—by Mr. William Whitwell, for instance—and I am not able to understand the objection of Mr. I. Lowthian Bell, that the cooling effect of the cinder-outlet might be injurious to the fur-nace. Where there are half a dozen or more water-cooled tuyeres, this little casting ought not to take all the blame.

In this country the opinions are much divided. A great many of these furnaces have run with perfect success for years in all parts of the country, and I am happy to say that the different furnaces you will see in Cleveland on your excursions are of this improved stamp.

As to the opposition, which seems to be strange, it is susceptible of explanation: first, I myself have made mistakes, by taking the matter too easily, and by making too many compromises with the old constructions I had to deal with; furnaces were altered while in blast, and, by doing this, part of the old fore-hearth was left, which filled up, and paralyzed the whole operation.

Another reason why all furnaces do not bear the stamp of Mr. Lurmann's name as yet, is to be found in the fact that most people would rather go step by step, than jump at things at once. A great many, seeing that a fore-hearth was not a necessity, have shortened it so much, that little is left, gaining by doing this some of the ad-vantages the entirely closed front gives. Others close virtually, and add some cleverly cooled casting somewhere near the cinder tap, which in some cases is done so nicely that only a very expert man is able to detect the difference. This I do not say to complain; my object *here* can only be to speak about the technical points, and the above remark was only made to show that Lurmann's sound plan has sent its roots much deeper than a superficial spectator might infer.

The increase of the furnace product over the old system, as it was eight years ago, and the closed front *in full*, has been found, by careful comparison of a number of furnaces in Germany, to be between 15 and 20 per cent.; the saving of fuel about 10 per cent.

One objection, the burning of the iron cinder-blocks, has been done away with, by using hollow cast bronze blocks. These are almost indestructible; the cinder-outlet remaining always of the original width of 1 1/4 inch, the cinder runs off quietly, and no hot air is blown out with it, though the blast is always on with full pressure.

Messrs. Taws & Hartman, at Philadelphia, have made at my request bronze cinder-blocks, and are now ready to cast tuyeres, either out of a proper bronze or of phosphor-bronze made by the Pittsburgh Phosphor-bronze Co. This latter composition is the same as is used in England for tuyeres. Toughness and rapid transmission of temperature are the two requisites wanted for a good tuyere.

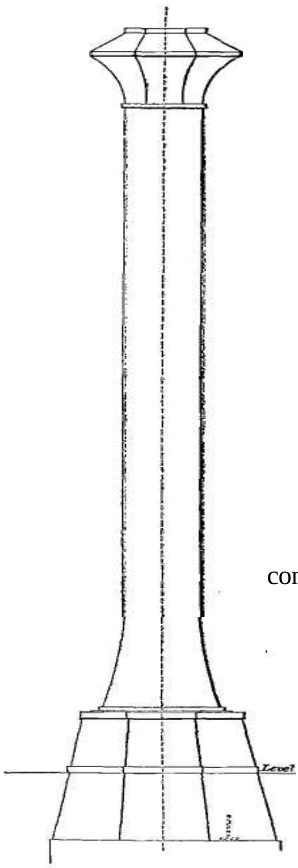
The common bronze used in Germany is composed of 94 copper, 3 zinc, and 3 tin; in other words, as rich in copper as it can be made for casting purposes, because copper is, next to silver, the best conductor of heat among the metals. If we place the conducting power of silver for heat at 1000, copper becomes 736, and iron 119. Bronze tuyeres are actually cheaper than iron ones. They arc more relia-ble, last longer, and can quickly be changed, because they keep bright even when stuck well into the furnace.

MEMORANDA RELATING TO TWO NINETY-FEET CHIMNEYS FOB SIEMENS SEATING FURNAGES AT THE EDGAR THOMSON STEEL WORKS.

BY P. BARNES, EESIDENT ENGINEER. PITTSBURGH, PA.

EXACT accounts have been kept of the cost of these chimneys, and it may he a matter of some possible interest that the plans and details of cost should be laid before the Institute. The statement of cost herewith submitted does not give minute particulars of the weights or quantities of material used, although these are noted upon the company's books.

Reference being made to the accompanying drawings, it will be seen that, each chimney has an external shell of sheet iron, which rests on an iron base plate, and is thusanchored to the masonry foundation. They are identical except in the depth of the concrete formation. One of them (north) had to be put in the bottom of a slight val-ley on the premises, while the. other (south) stood on higher and solid ground. Flues were led into the chimney base from two directions, one being large enough for two furnaces. The base was carried eight feet above the general level of the yard, partly for appearance sake, and partly to keep venturesome boys from climbing up the ladder on the outside.

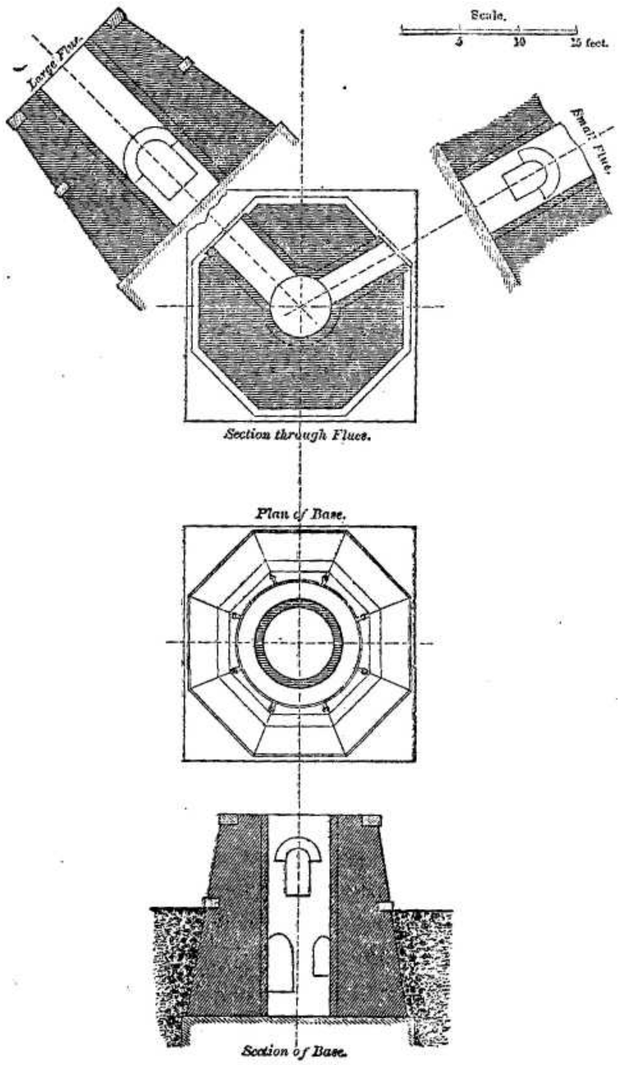


Elevation of Base and Shagt.

The whole base from the level of the flues was made of red brick grouted in cement, chiefly for the purpose of utilizing a large lot of soft brick that had accumulated at the works. The anchor-bolts were hung in place before the brickwork was commenced—the wash-ers resting upon the concrete—so that the total weight of the brick is utilized in securing the stabil-ity of the chimney shell. A belt course and coping of sandstone were laid, and upon the latter the iron base-plate, in four pieces, was bedded in cement. A side flue lined with firebrick was put in, leading, above the belt course, into the central flue, both to give access to the interior,

both to give access to the interior,

and to build a fire in when needed to secure a more perfect draft. The shell was made in 4 feet courses, the lower ones being tapered outward to give a broader base upon the plate. The first course was



made of 5/16 inch iron, the next four of 3/16 inch iron, and the remain-ing upper part of 1/8 inch iron. A light ladder was put upon the outside, and carried entirely over the top. The finish at the top was made of No. 22 galvanized iron, and painted inside and out.

The interior lining was made of common red brick, laid in lime mortar, and it is 4 inches thick, except at the bottom, where it is thicker, to suit the enlarged diameter of the shell.

The shell was put together complete, while lying on its side upon the ground, and hoisted into place in one piece. This was found, even for so light a weight, to be more troublesome than was anticipated, although no real difficulty was experienced. The cost of erection, however, was slightly greater than really need have been incurred.

All that can thus far be said of the actual performance of these chimneys is that they give a tremendous draft, and that as yet they have not been at all shaken by the wind.

Cost of South .

		Per cent, of cost.
Excavation,	$132	.032
Concrete-stone and labor,	264	.064
Cut stone " " "	267	.065
Cement, total used,	230	.056
Lime, " "	53	.013
Sand, " "	57	.014
Anchor-bolts,	57	.014
Castings,	242	.059
Red brick,	629	.153
Bricklaying foundation	242	.059
" lining,	197	.048
Sheet-iron shells,	1190	.292
Paint,	29	.007
Labor of erection, etc	444	.108
Teaming,	103	.025
	$4136	1.009

MR. WM. METCALF said that he had recently built a brick chimney containing 143,000 brick, and that the cost was less than $3000. The brickwork was 31 in. thick at the base and 13 in. at the top. Every three feet, flat iron rings, 2 in. by 1/8 in., and 18 in. larger in diameter than the interior of the flue, were inserted, set on edge. The painting of iron stacks is a serious objection to them, since the paint must be repeatedly renewed. He had found the best and cheapest paint to be common soot with the light oil from the refineries, costing about ten cents a gallon. This oil does not contain acid which, when tar is used, attacks the iron perceptibly.

ME. J. B. PEARSE said that the reason iron chimneys were first built was to avoid the cracking of brick chimneys when driven hard. The Pennsylvania Railroad had built a chimney shaped like a double star, the points acting as buttresses. He preferred the iron chimney with square base-plate, to get a leverage at the corners, and said that, having built several, the first used in this country, he had gradually reduced, with safety and success, both the thickness of metal and lining—the metal to 1/4 inch at bottom and 1/8 inch at top, and the lining to 4 inch firebrick at bottom, then red brick, and 2 1/2 inches red brick at top. The foundation could be made without cut or ashlar blocks, using bricks and cement under the bed-plate. A chimney like this was built for $3800, at Harrisburg, in 1872.

ME. F. FIRMSTONE had always thought brick chimneys were both better and cheaper than iron ones, but never supposed before that the difference in cost was so much in their favor. They had just finished the shell of a brick chimney at Glendon, 105 feet high and 6 feet in diameter, which would cost much less than the one described by Mr. Barnes.

[This chimney rests on a concrete foundation 15 feet (5 inches in diameter. The base is 13 feet in diameter, 9 feet high, and 4 bricks (3 feet) thick. At 9 feet high it is diminished by offsets to 11 feet 6 inches diameter, and 2 1/2 bricks (1 foot 10 1/2 inches) thick. Above this it is built with a batter of one-quarter inch per foot to the top, diminishing in thickness by three internal offsets, each of half a brick to one brick (9 inches) in the top section. A double row of hoop iron, in pieces about 2 feet long, was laid in the bed joints at every eighth course, one row close to the outside, and one close to the inside of the shell. It is to be lined to a height of 69 feet, with firebrick 4 1/2| inches thick. It was begun August 17th, 1875, and finished October 8th, in 44 working days, by 2 bricklayers and 5 laborers.

The cost, exclusive of scaffolding and mortar, of which no account was kept, has been as below:

68,400 bricks at $10.25 per M., ...	$598 GO
2 bricklayers, 44 days, at $3 each, ...	264 00
5 laborers, 44 days, at $1.10..	242 00
10 bundles hoop iron...	35 00
Cast-iron cap, 2280 lbs. at 4 1/2 c., ...	102 60
	$1242 20]

THE MASS COPPER OF THE LAKE SUPERIOR MINES, AND THE METHOD OF MINING IT.

BY PROF. WILLIAM P. BLAKE, NEW HAVEN, CONN.

THE occurrence of enormous masses of pure copper has given the mining district of Lake Superior worldwide reputation. The first masses brought from there excited great attention, and directed the notice of the mining world to the few particular mines from which they were taken. It may not now be generally known that nearly all the veins which are worked, and which cut across the trap ridge, contain mass copper, and that large masses are continually being raised from them.

The largest continuous mass which has been taken out was probably that from the Minnesota, in 1857, which is variously stated as weighing 420 tons and 470 tons. Its length was about 45 feet, its breadth or height 22 feet, and its greatest thickness 8 feet. All such masses are very irregular and ragged in their form and thickness, thinning out generally from a foot to a few inches, and straggling through the vein until they connect with other large masses. This was the character of a mass found in the Phoenix Mine, one of the oldest on the. lake, which mass altogether weighed some 600 tons. But this was really a series of masses more or less connected by strings of metal, yet no one large part of it weighed, singly, over 200 tons. A similar series of masses, weighing about 600 tons, was extracted from the Minnesota, Some of the Phoenix masses were four to five feet thick of solid copper. The Cliff Mine has yielded masses weighing from 100 to 150 tons in one piece. One of 40 tons was taken out this year, besides numerous blocks weighing from 1 to 8 tons. This mine and the Central are now yielding mass copper in abundance.

It is, of course, impossible to pick, or drill, or to break out such huge masses of solid metal when they are found, by drifting upon the course of the vein. The method of extraction is as follows: The miner picks out or excavates a narrow passage or chamber upon one side of the mass, laying it bare as far as possible over its whole surface. It is usually firmly held by its close union with the vein-stuff, or by its irregular projections above, below, and at the end. If it cannot then be dislodged by levers, the excavation of a chamber is commenced behind the mass, and this excavation is made large enough to receive from 5 to 20 or more kegs of powder. In one instance, the Cliff Mine, a charge of 21 kegs of powder threw down 200 tons of copper. Bags of sand are used for tamping, and the drift is closed up by a barricade of refuse and loose dirt. After such a blast the drift is, of course, charged with foul air, and it cannot safely be entered for hours afterwards. If entered too soon, men lose all strength in their limbs, and fall down.

The huge masses of copper dislodged in this way are too large to be handled and got to the surface. They have to be cut up. The copper-cutters are called in, and the mass is marked off into squares or blocks of suitable size. Copper-cutting is a distinct art, and requires considerable skill and experience. Ordinary miners, however skilful they may be, cannot cut up copper without long training.

The tools used are simply narrow chisels and striking hammers. The chisels are shaped like the parting-tool of turners. They arc made of flat bars of half-inch steel, about two inches wide, and eighteen inches long. They are chamfered each way like a cold-chisel, to form the cutting edge. This edge is made a little longer than the thickness of the bar. The cutter holds the chisel, and two men strike it. A thin slice or chip of copper is in this way cut out in a narrow channel across the mass of copper. The operation is repeated until the narrow cut, but little over half an inch wide, has been carried through the mass. The chips cut out in this way are long, narrow strips of copper, only about half as long as the groove from which they are taken, the metal being condensed and thickened by the force of the blow. This work is necessarily slow and tedious, and it costs twelve dollars ($12) per square foot by contract. At this price the cutters make $2 per day.

It is inconvenient to handle masses weighing over six tons. Such masses when hoisted are landed upon very strong platform trucks, and are then dumped in the rock-house upon a large pile of dry pine logs. When a considerable number of masses have accumulated, the logs are fired, and the whole pile is heated to redness, for the purpose of loosening the very considerable quantities of vein-stone which are inclosed in the ragged cavities. This vein-stone consists chiefly of calcite, and after cooling off it is so much softened, that the greater portion can be knocked out by pounding upon the copper.

The masses are then marked, numbered, and recorded, and are shipped to the smelting works, where they are melted down in reverberatories.

DR. KAYMOND remarked that, though some of the Lake Superior mines had been productive of mass copper, the general average of the yield of copper, calculated upon the amount of rock removed in mining, was very low. Some of the most profitable mines had worked for long periods material yielding but one or two per cent. Many persons seemed, particularly in former days, to be dazed by the idea of "pure, native copper," and to consider the Lake Superior region on that account one of unsurpassed richness, which was by no means the case.

PROF. BLAKE said that the present average at the Calumet and Hecla Mine, where 800 to 1000 tons were mined daily, was five per cent., and that Dr. Raymond's remarks might give too low an impression of the general average. The same test applied to other copper regions might show a percentage of metal, as compared with all the rock moved, equally surprising to those who judge by assays of specimens. He would refrain at present from giving a general review of the copper interests of Lake Superior, reserving for a future occasion the discussion of some interesting subjects in this connection. Of these he would mention merely the fact that, in the melting of this native copper, there was an increase of weight, owing doubtless to the absorption of oxygen. It had been a matter of surprise to him that the pure barrel-work from the stamps was not sent, at least in part, directly into the market, for the use of brass-founders, instead of melting it, and casting in large ingots, which subsequently have to be broken.

PROF. EGLESTON asked whether any attempt was made to separate the native silver from the copper?

PROF. BLAKE replied that there was no mechanical separation, nor was it removed by smelting} usually boys pick it out as it comes from the stamps, but the amount thus saved is insignificant.

NOTES ON TEE OCCURRENCE OF SIDERITE AT GAY HEAD, MASS.

BY PROF. WILLIAM *P.* BLAKE, NEW HAVEN, CONN.

THE occurrence of siderite in beds of considerable thickness in the clay formations of Martha's Vineyard, Mass., may have some economical importance, and is at least interesting in a scientific point of view.

This mineral is found in masses which have been loosened from the beds of clay forming the bluffs, and in some places have accumulated in considerable quantities in the debris along the beach. Some of these masses of carbonate of iron contain the imprints of leaves and stems of plants. There are indications that some of the beds at least are of secondary origin, derived possibly from the decomposition of ferruginous water in its passage downward through the strata from a lignitic bed in the upper series. This bed of lignite contains a large amount of iron pyrites which is constantly decomposing and yielding a solution of sulphate of iron, and this iron salt permeates a large amount of the clay deposits below the bed. Its decomposition gives the highly variegated colors which characterize the bluffs at Gay Head. Some of the clay beds are as highly variegated as Castile soap, and pieces may be cut out which closely resemble that material.

The almost universal presence of the iron salt is made evident during dry weather by its appearance in efflorescences upon the surface. Many of the masses of sitlerite dislodged from the strata are in the form of large flat slabs, varying from a few inches to a foot or more in thickness.

My examinations were not sufficiently extended to enable me to state with certainty in regard to the extent of the deposits from a technical point of view. It is not impossible that large quantities may be cheaply obtained there, and perhaps along the outcropping bluff of the same formation upon the north shore of Long Island, possibly also in New Jersey.

ON EVIDENCE OF STBEAMS B TIMING TEE DEPOSITION OF THE COAL.

BY JOHK F. BLANDY, M.B., NEW BETHLEHEM, PA.

THE map on Plate I illustrates a part of the works of the Red Bank Mining Company, on the Upper Freeport scam of coal, in Armstrong County, Pennsylvania. The contour lines give a careful representation of the conformation of the surface, showing also the line of outcrop of the seam, and the gangways of the mines arc shown by the black lines.

Upon assuming charge of the works in January last, I found that the first and greatest difficulty lay in the great uncertainty of the mine operations, as the rooms were so often being cut out by what the miners termed "horsebacks"—a roll in the roof of what appeared to be an indurated mud. These rolls would sometimes cut down to the floor of the seam, on a level with the underlying fire-clay, but most frequently they came down to within a few inches of the floor, leaving a "mining" of impure coal between them and the clay. There seemed to be so much uncertainty as to when and where they wonld occur, that I determined to map the mine carefully, so as to see whether there was not some regularity to these "horsebacks." On account of sundry places having fallen in, I was not able to map all as completely as I should have wished. The result I here give, and the conclusion came to was, that they followed the line, or rather were the "filling in" of a streamway, which existed at the time of the deposition of the coal, and a more careful examination of the material strengthened me in the opinion.

The map shows two separate mine openings on opposite sides of a narrow valley. In the one on the north side of the valley, there are what may be called two main streams, the work not having been extended far enough to the northwestward to show their junction.

Upon the area between these two main streams, the coal-bed is regular and coal good, but it is only about 2| feet thick; whether this reduction of about fifteen inches from the average thickness of the scam is due to the coal having been deposited on higher ground, or to an earlier covering with slate material than the other part of the seam, cannot be determined by any measurement. I am inclined to think the former was the case.

On account of the valley between the two mines cutting below the level of the coal-bed, no direct connection can be traced between the " horsebacks " of the two mines, but, as in working southward the main stream seems to get smaller, I judge those in the south mine to be branches from that in the north. On account t>f the frequent interruptions which had been met with, no regular plan had or could be carried out in the mining. The result of my surveys caused me to open out towards the southwest, in order to get away from the "stream," and so far I have met with no disturbances in that direction.

I might mention here, that I have learned of these same occurrences in several coal-banks of the farmers of the neighborhood, and in some of those of the Colwell Furnace, three miles to the south.

The most interesting point of this subject, is the manner of the filling in of these water urges. I give a cross-section of the branch (see Plate I) in the north mine, at the point A, which illustrates more distinctly than any other that I have met with the characteristics.

The mass of the "horseback" is of indurated raud, reaching about half way down from the roof to the floor, the coal underneath it being regularly bedded. The sides show an intersfcratification of coal and earthy material, the layers varying in thickness from that of a knife-blade to half an inch. Every cross-section shows more or less the same features, though in some this interstratification occurs only on the one side, the other side being an abrupt face of coal. The coal within two or three feet of the "horseback" is always tender and small fractured, but pure. The indurated mass at the top gradually passes into slate, showing that the stream continued to exist for a short time after the slate began to form. As we approach the ends of the branches, they gradually rise, disappearing in the roof of the coal-bed. Upon an examination of the ends of these branches, I have formed the opinion, that the earthy material has been brought up the stream by a tide, and not downward by a current. This, together with the fact that the branches are short and tortuous, shows the flat, low position of the land upon which the coal-bed was formed.

I have been particular in illustrating a cross-section, as it points to a method of deposition of the coal, not to be explained by any theory of the formation of coal-beds which I have yet met with, and further, because by the collection of such facts, we may arrive at better conclusions.

The interstratification of the coal and earthy material on the banks of the stream, points to a much more rapid deposition of coal than is generally admitted, and also to its having been in a very fine-grained or semifluid state. Furthermore, if the stream was silted up by the action of a tide, then it was formed above water, and not entirely tinder water, as some theorists have contended. I do not pretend to form any theory myself on the subject, but bring these facts forward • more as negative evidence to those which have heretofore been advanced.

In conclusion, I would state, that whilst in the anthracite district, I had the misfortnne to have charge of mines that were much troubled with what were called "dirt faults." From a careful study of them, I formed the opinion, that they were the water-courses of the era, the material with which they were filled or silted up being such a mixture of earth and powdered coal, as not to admit of a solidification of the mass. I am now still more convinced of the correctness of the idea.

However interesting these "streams" may be to the geologist, I must say, that to a miner, they are anything but desirable.

DR. R. *W.* RAYMOND said that he felt deeply indebted to Mr. Blandy for the presentation of his interesting and suggestive paper. No doubt similar careful work would connect and explain the irregularities of this character in many coal-basins, to the great benefit of owners and engineers. He was not prepared, however, on first hearing of the evidence submitted in this paper, to admit that the facts of structure and stratification set forth, were inexplicable upon accepted hypotheses of the formation of the coal deposits, though perhaps this feeling was due to the brevity of Mr. Blandy's discussion of this point.

ON THE COMPEESSION OF GASES.

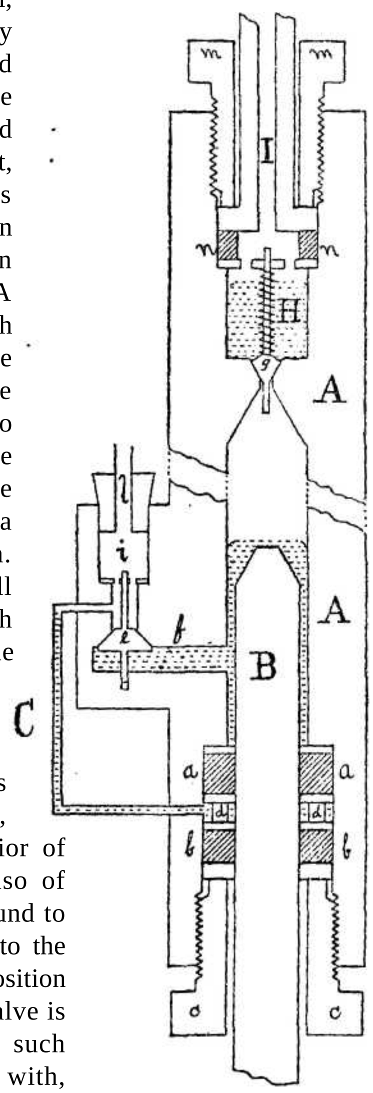
BY CHAKLES F. BKTJSH, M.E., CLEVELAND, OHIO.

THE compression of gases to a very high degree, for purposes of scientific research, has long presented serious difficulties to the physicist.

Great advances have been made of late years in the construction of ordinary air or exhaust pumps, while very little has been done towards the improvement of compression pumps. The principal difficulties encountered in the construction of such apparatus are the existence of the so-called "dead space" in the pump barrels, leakage of the piston packings under high pressure, and the trouble arising from the unequal expansion of parts caused by the development of the latent heat of the gas during compression. Of these obstacles to success, the "dead space" is far the most serious, as it fixes a limit to the performance of the pump beyond which it is impossible to carry the compression.

The writer having occasion, some time since, to make a series of investigations on gases very highly compressed, and finding no apparatus, or description of apparatus, adequate to produce the required pressure, devised the following, which appears to entirely eliminate all the difficulties above mentioned.

The accompanying diagram represents a longitudinal section of the pump through its axis. The barrel, A, which may be made of any convenient length, is of cast iron, and is made rather heavy, both for the purpose of resisting great pressure, and to absorb and dissipate, to some extent, the heat evolved during action. B is a steel plunger of less diameter than the interior of the pump, so that an annular space is formed between A and B. The plunger passes through two stuffing-boxes, *a* and 6, whose packings are supported by movable iron rings; thus both arc compressed to the requisite degree by means of the screw, c. The stuffing-boxes are separated by a ring, *d*, thus leaving a small space between them as shown. This space is connected by a small tube, C, with the chamber, *i*, which latter communicates with the reservoir of gas to be compressed, by means of the cork and tube, l. The in-let valve, e, is of steel, conical in form, and carefully ground to its seat. It opens into the passage, f, thus communicating with the interior of the pump. The exit valve, g, is also of steel, but smaller than *e*, and is ground to its seat with much care. It opens into the chamber, H, and is held firmly in position by a spiral spring of steel. This valve is prolonged at its lower extremity to such an extent that it comes in contact with, and is raised a short



distance by the plunger, B, at the completion of its upward stroke. I is a strong tube for the conveyance or storage of the compressed gas. It is firmly secured to the body of the pump by means of a flange on its lower end, and the screw, *m*, which forces the flange against the rubber washer, *n.* Such a washer will make a tight and permanent joint under any degree of pressure, provided the flange of the tube, I, fits the bore of the chamber with tolerable accuracy. The plunger, B, may be actuated either by a crank and fly-wheel, or by a lever so arranged that its short arm shall lie in a straight line with the axis of the plunger at the completion of its upward stroke. This arrangement is absolutely necessary when very high pressures are to be produced, as the resistance at, and near the completion of the stroke, is very great, and could scarcely be overcome without thus taking advantage of the "knee-lever" principle. The body of the pump is finally partially filled with mercury, as shown by the dotted spaces, to such an extent that at the completion of the upward stroke of the plunger, the annular space around it, together with the passage, f, are entirely filled, and the chamber, H, nearly so. The operation of the apparatus is then as follows: At the downward stroke of the plunger, the valve, E, is opened, both by its own weight (the mercury having receded from under it at the completion of the stroke) and by the pressure of gas above it. Gas, from the chamber *i*, then rushes through the valve and fills the vacuum above the plunger. At the beginning of the upward stroke, mercury flows into the passage f, and closes the valve e, by *floating* it into position. As the plunger proceeds upward, the compressed gas may force open the valve, g, and escape into the chamber, H, rising through the mercury there contained; or, if the compression has already advanced to a considerable extent in the chamber, the valve may not open until raised by the end of the plunger; but, at the end of the stroke, the space above the plunger will be entirely filled with mercury, leaving no dead space whatever, and *all* of the barrelful of gas will have passed up into the chamber. The valve, *g*, being still held open by the plunger, will allow a small quantity of mercury to pass from the chamber back into the pump when the plunger recedes; thus insuring sufficient mercury in the barrel to completely fill it at the end of the next stroke, after allowing for leakage through the stuffing-box *a.* The object of *two* stuffing-boxes, *a* and *b,* will now be apparent; the small quantity of mercury which must certainly be forced through the box *a* at each stroke, by the great pressure in the pump, and which, if allowed to escape, would very soon exhaust the supply inside, is conveyed by the tube, C, to the chamber, *i,* and is drawn into the pump again at the next stroke. No leakage occurs through the box *b,* as the pressure sustained by it is only that due to the height of the short column of mercury in the vertical part of the tube C. It will be noticed that the upper portion of the interior of the pump barrel contracts gradually toward the valve passage; this is to prevent small bubbles of compressed gas sticking to the walls, and allowing the advancing mercury to flow past them, as might happen if the contraction was abrupt.

A small pump of this kind, in the writer's possession, readily compresses air into the thousandth part of its normal volume; and there appears to be no reason why the operation might not be carried much further by the application of sufficient mechanical force. The limit to the action of this apparatus appears to be only a question of the strength of the receiving vessel and of the pump itself.

TEE VELOCITY OF BLAST-FURNACE GAS.

BY JOHN A. CHURCH, E. SI., TARRYTOWN, *N.* Y.

THE Lake Superior blast-furnaces probably represent the maximum economy of fuel possible in this country. They smelt an ore which is very rich and easily reducible, and as the small amount of gangue present is not all silica, but in part a silicate, the amount of limestone required is a minimum. The average yield of the ore treated at six furnaces was 63 per cent., and the average quantity of limestone 179 pounds per ton of pig. The fuel used is charcoal, so burned as to retain most of the combustible volatile part, which, before the utilization of furnace-gas, was burned away. With these conditions it is not surprising that the Lake Superior charcoal practice is extraordinary in almost every respect. In any scientific discussion of American furnace work, the establishments there will be found at the head of the list, and they work under conditions which are extremely favorable for careful study.

The Bay Furnace, near Marquette, has the honor of carrying "the broom" for the largest daily make. "With a capacity of 1908 cubic feet it has, for months together, produced 29 tons of pig, graded at about No. 1.49, with 1922 lbs. of charcoal per ton. It makes a ton of pig daily for every 73 cubic feet of capacity, and burns only 13 cwt. of pure carbon to do it.

Of the four stacks which I visited, the Morgan Furnace, on the line of the Marquette and Ontonagon Railroad, stands next in order of production. It has a capacity of 1679 cubic feet, and averages 20.46 tons per day, though its make for weeks together runs up to 27 tons, and it has made more than 30 tons for a short time. Its average gives a make of one ton to 82 cubic feet, with 1911 lbs. of charcoal. This is the greatest economy of fuel noticed, and corresponds to 12.8 ewt. of pure carbon.

The Deer Lake Company has two stacks, one of which is 45 feet high, like the two mentioned above, and has a capacity of 1566 cubic feet. It makes 18 tons a day, on the average, or one ton to 87 cubic feet. Fuel is 2457 lbs. per ton of pig, corresponding to 16.45 cwt. of pure carbon. The other stack was formerly noticeable from its extreme smallness, compared with other modern furnaces. It was only 33 feet high, with boshes of eight feet, and possessed a hot-blast oven which was one-half larger than that of any other furnace in the district. As its blowing cylinder was run by water power, it was able to keep its blast to a uniformly high temperature. This little furnace, with a capacity of 968 cubic feet, averaged 13.3 tons of pig per day, or one ton to 73 cubic feet, consuming 2404 lbs. of charcoal, or 16.1 cwt. of pure carbon per ton.

In addition to the above, I am enabled, by the kindness of the proprietors, to add two instances of charcoal and one of bituminous practice, though I did not visit the furnaces. To this list of examples are added three of anthracite practice.

The Lake Superior furnaces probably offer the simplest blast-furnace problems to be found in this country. I was not in a position to make the gas analyses necessary for accurately gauging their per formance, but it struck me that with an economy so near the maximum, the possible error in making approximate calculations would be very small, and I accordingly calculated the heat requirement and heat expenditure, and the amount of carbon burned in the hearth. The object of the calculations was to arrive at the velocity of the gas in the furnace. It is usual to look upon this velocity as enormous, but having made some calculations under less favorable conditions, I had been surprised to find the rate of ascent comparatively small. It is evident that there are two different velocities in the furnace, the velocity of the nitrogen and carbonic oxide in the lower part, and that of the gas in the upper part; this gas being composed of nitrogen, carbonic oxide, oxygen of the ore and volatile constituents of the fuel. Each part has its own average temperature, with a corresponding expansion of the gas. The section of a furnace changes so rapidly in area that it is evidently impossible to take this clement into consideration. The only method possible is to find the average velocity for a given height, and this has been done by ascertaining the interstitial space lying between the masses of " mine" and fuel, and then comparing this with the quantity of gas rising through the furnace per minute. By this method the number of times the gas fills this interstitial space per minute is found, and multiplying this by the height of the column, we have the total vertical ascent or velocity.

To obtain the interstitial space, the weight of a cubic foot of stock was determined by carefully measuring the ore- and coal-barrows. By comparing these weights with the quantities used in filling the furnace the deduction necessary for the greater compactness of the stock in the furnace, than in the barrows, was found. This was determined at 10 per cent, for charcoal, and 15 to 20 per cent, for bituminous and anthracite furnaces. By calculating the true solid contents of the materials from their specific- gravities, we have two elements, the bulk of the materials as charged and their real solid contents, the difference between which is the interstitial or vacant space.

Of course, these results are only approximate, and can be improved only by making a great number of determinations. But after checking the results in all possible ways, the error will probably not be very great. This is especially true for small charcoal furnaces.

A more difficult problem was to determine the height of the two zones for which the calculations were make. The limits of the lower zone are at bottom, the tuyere level; at top, that point in the furnace at which the evolution of carbonic acid from the limestone, oxygen from the ore, and volatile matter from the fuel ceases. With gas of a constant composition and velocity this point depends upon the temperature selected. For these calculations the temperature has been taken at 700° C, or about 1300° F., at which it is probable most of the vaporizable constituents will be driven off, in a constant current of reducing gas. In the charcoal furnaces, which are of nearly equal height, and have an effective column of about 39 feet between the tuyeres and the upper level of the stock, this line of 700° C. was assumed to lie at one-third the distance, or 13 feet, from the top of the column. In the bituminous and one anthracite furnace treating mainly Lake Superior ores, both of about the same height of column, the 700° C. line was placed at the same point. In the two large anthracite furnaces, with a larger area and a slower velocity, the line was placed at 12 feet from the top, and probably it is too low in both.

The temperature in the crucible was assumed at 1500^0 C., and the mean temperature in the lower zone is therefore $\frac{1500+700}{2}=1100°$ C. This may be thought too low, for the determinations of the fusing point of pig-iron have varied between 1050° C. and 1700° C, while those of wrought-iron vary between 1600° C, and 2100° C. But as the tendency of late investigations is to assign 2000° C. as the limit to the sun's temperature, I am justified in assuming the correctness of the lower determinations. The temperature of the blast-furnace is not sufficient to fuse wrought-iron, while the sun is hot enough to keep that metal in a state of vapor.

The average temperature of the upper region is equal to 700 C, *phis* the temperature of the exit gas divided by 2; it has varied between 450° C. and 550° C.

From these data it was found that in six Lake Superior charcoal furnaces, the

Velocity of the gas in the lower part averaged 14.7 feet per second.

Velocity of the gas in the upper part averaged 16.4 feet per second.

In the bituminous furnace, smelting Lake Superior ores, the

Velocity of gas in the lower part averaged 17.3 feet per second.
Velocity of gas in the upper part averaged 19.5 feet per second

In an anthracite furnace of about the same height, but larger section than the charcoal furnaces, but also treating Lake Superior ores, the

Velocity of gas in the lower part averaged 11 feet per second.
Velocity of gas in the upper part averaged 10.3 feet per second.

In two large anthracite furnaces, treating Lake Cliamplain ores, the

Velocity of gas in the lower part was	13.3 feet per second.	6.9 " "
Velocity " " upper " "	10.8 " "	4.6 " "

The solid materials descended at the rate of

In the charcoal furnaces, Lake Superior ores,	3.87 feet per hour.
" " bituminous " " " "	2.4 " "
" " anthracite " " " "	0.73 " "
" " " " Lake Champlain ores,	0.90 " "
" " " " " " "	0.55 " "

Thus it is evident that the velocity of gas is not so great as many furnace-men suppose. Fifteen feet per second, as in the charcoal furnaces, is two and a half times the periphery velocity of a good water-wheel. It is 10¼ miles an hour, or less than twice as fast as hoist-cages move in mines, or cars on the long " planes " found in coal regions. In fact it is not an excessive velocity for mechanical movements.

The study which has led to the preparation of this paper was undertaken to disprove an argument which has been urged against the theory that reduction of the ore takes place by the action of carbonic oxide. The objection was that the gas moved too rapidly to allow of any complete action. Of course this is absurd on its face, since the ore is continually bathed in the reducing agent, but these calculations, show that the fact of the supposed excessive velocity docs not exist.

From an inspection of the velocities found, it is apparent that a position might have been chosen for the 700° C. line (or a proper temperature for the two-thirds division), which would have given equal gas velocities in the two zones. In the Morgan furnace this line probably does lie just 12½ feet below the top, as the table shows; for the velocities above and below are 13.7 and 14 feet per second. In the Bay furnace the line is placed at 13 feet, but is not low enough to produce equal velocity in the two zones, though a difference of half a foot perhaps would do so.

Two tables are appended, in which the velocities and the data from which they have been calculated have been given for each furnace.

Economical Results.

Lake Superior Furnaces.	PER TON OF PIG. Length of blast. Weeks.	Made per day. Tons.	Total ore. Tons.	Hard ore. Tons.	Soft ore. Tons.	Limestone. Tons.	Charc'l. Tons.	Average yield of ore.	Average grade of pig.	BLAST. Cub. feet per ton pig.	Pounds pressure.	Temperature.	Tuyeres diam. and number.	Exit gas temperature.
CHARCOAL.														
Deer Lake, No. 1, . .	35.	13.3	1.608	1.126	0.482	0.060	1.073	62.19	1.46	120,000	2	662°F. 350°C.	3	482°F. 250°C.
" " No. 2, . .	63.	18.0	1.634	1.090	0.544	0.068	1.097	61.20	1.24	126,000	2	662°F. 350°C.	3	482°F. 250°C.
Morgan, ...	62.	20.46	1.615	1.292	0.323	0.091	0.853	61.85	1.85	106,900	2¾	600°F. 315°C.	5 in. 3	392°F. 200°C.
Bay, ...	52.	29.00	1.589	1.271	0.318	0.047	0.858	62.93	1.49	106,400	2¼	600°F. 315°C.	4½ in. 3	392°F. 200°C.
Fayette, ...	19.	31.25	1.514	. . . .	. . . .	0.052	1.040	66.05	1.10	117,000	...	800°F. 427°C.	4½ in. 3	482°F. 250°C.
Elk Rapids, ...	1.	29.75	1.613	1.613	. . . .	0.145	0 884	62.00	1.05	109,500	...	700°F. 370°C.	. . . .	392°F. 200°C.
BITUMINOUS.					Limestone.	Raw coal.	Coke.							
Stewart, ...	14.7	29.00	1.453	1.453	0.388	1.891	0.229	68.80	2.20	234,000	...	800°F. 427°C.	4½ in. 6	750°F. 400°C.
ANTHRACITE.						Anth.	Coke.							
Fletcher, ...	221.7	25.27	1.730	1.359*	0.617	1.399	0.028	57.8	2.11	190,200	...	700°F. 370°C.	3⅝ in. 6	750°F. 400°C.
Champlain Furnaces.			Magnetite.											
Crown Point, . . .	25.	34.00	1.830	. . . .	0.787	1.640	. . . .	54.64	1.25	197,400	6	1000°F. 537½°C	4 in. 5	750°F. 400°C.
Bay State, ...	104.	27.35	1.671	. . . .	0.444	1.330	. . . .	59.66	2.20	159,000	6	900°F. 482°C.	4 in. 5	750°F. 400°C.

* Including 0.538 ton cinder; soft ore, 0.371 ton.

Gas Velocity.

Lake Superior Furnaces.	Tons per day.	Height. Feet.	Diameter. Boshes.	Lower Zone. Cubic feet capacity.	Lower Zone. Height.	Upper Zone. Cubic feet capacity.	Upper Zone. Height.	Hearth. Diameter.	Solids. Descend feet per hour.	Gases. Lower Zone. Ft. per sec.	Gases. Upper Zone. Ft. per sec.
Deer Lake, No. 1	13.3	33	8	710	20.	235	10.	4	3.12	12.5	11.2
" " No. 2	18.0	45	9	1316	24.	304	12.	4	3.7	12.4	13.7
Morgan	20.46	45	9	1140	25.	334	12.5	4½	3.3	13.7	14.0
Bay	29.0	45	15½	1445	26.	385	13.	4½	3.87	15.0	18.0
Fayette	31.25	41.5	9½	1300	22.	327	11.	4	5.25	18.0	24.0
Elk Rapids	29.75	47	12	1495	24.5	410	12.25	3⅔	4.	15.0	16.67
Average	......	......	......	......	23.9	......	11.96	......	3.87	14.4	16.26
BITUMINOUS.											
Stewart	29.0	51	12¾	2115	26.7	636	13.3	4½	2.4	17.3	19.5
ANTHRACITE.											
Fletcher	25.27	45	14	2863	26.	1330	13.	5½	0.73	11.0	10.3
Champlain Furnaces.											
Crown Point	34.0	65	16	6160	44.5	1316	12.	6	0.90	13.3	10.8
Bay State	27.35	63⅔	16	6360	41.25	1812	12.	6	0.55	6.9	4.6

COMPARISONS OF BLAST-FURNACE RESULTS.

BY FKANK FIKMSTONE, GLENDON IKON WORKS, EASTON, PA.

IT is proposed to consider here only comparisons made between results obtained when the materials employed are precisely the same, « two furnaces at the same works for example, or the same furnace under different conditions as respects temperature of blast, method of charging, etc. With this limitation, the most important point in the comparison is the amount of fuel consumed per ton of iron. This, in fact, is the only item in the prime cost of the iron which can properly be said to vary in consequence of changes in the furnace process; for of the other principal items, the ore used per ton of iron, and also the amount *of* fluxing material, will depend on its richness, which, under the assumed conditions, will be practically invariable when taken over any considerable period; the labor cost also, from its nature, should be very nearly constant when estimated on the ton of iron. Moreover, as it consists principally in handling and moving material, it is greatly affected by circumstances quite independent of the furnace process. If the fillers have a greater distance to wheel the stock at one furnace than at another, or if the arrangements for removing the cinder or iron are defective, the labor charges on the ton of iron may be very seriously increased, but it is manifest that such an increase has nothing to do with the good or bad working of the furnace itself.

We can see from the above that the prime cost of the iron is no index to the good or bad conduct of the furnace process, and that in most cases we may judge of this by the fuel used per ton of iron. Of course, in nine cases out of ten, the furnace which uses the least fuel will make the cheapest iron, and be both technically and commercially the best furnace.

In comparing the amount of fuel used, it is necessary to take into account the grade of iron produced. *Coeteris paribus*, the grayer the iron the greater will be the consumption of fuel per ton. Of two furnaces using equal quantities of fuel to the ton of iron, one making No. 2 iron and the other mottled, the one making the No. 2 iron is practically working more economically than the other, for, under normal circumstances, we could cause it to make mottled by increasing the burden (weight of ore in the charges), *i.* e., cause the same weight of fuel to produce more iron.

We can take account of this only by finding the average grade of the iron made during the time through which the consumption of fuel is calculated. If we designate by numbers from No. 1 to No. 6, the six different grades into which iron is commonly sorted, it is easy (knowing how much of each grade is made) to calculate the average grade of the whole. Such an average is the more natural and allowable, from the fact that the various grades shade insensibly into one another.

In addition to differing in consumption of fuel, furnaces differ in *regularity*. By this we mean the greater or less tendency to vary in the grade of iron produced, without assignable cause. If the furnace process were perfect, we should be able to produce, at will, any grade of iron desired, with the minimum amount of fuel, which the special conditions of the furnace (size, temperature of blast, etc.) would permit; actually, however, this perfect control does not obtain. In practice, the grade of the iron is found to vary more or less, and independently of variations in the quality of the materials, which are but little under control, or of the temperature and quantity of blast, which should be perfectly under control; and some furnaces are much more subject to these unexplainable variations than others.

It is not easy to fix on a standard by which to judge of the working of a furnace in this respect. In most cases we can form a pretty fair opinion by calculating the average grade of the iron, and also the percentage of each grade in the whole quantity made; the greater the percentage of the grades next to the average grade, the more regular, in most instances, will be the working of the furnace. Thus if we have in one example,

No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
5 per cent.	5 per cent.	20 per cent.	40 per cent.	15 per cent.	5 per cent.

average grade No. 3.4 ;

and in another,

No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
20	10	21	14	15	20

average grade, 3.55,

we should infer, in most instances, that the working was more regular in the first case than in the second, because of the larger percentage of the grades next to the average grade (20 per cent. No. 3, 40 per cent. No. 4 in the first, against 21 per cent. No. 3,14 per cent. No. 4 in the second). This method of comparison will sometimes lead to wrong conclusions, for the regularity depends not only on the quantities of each grade made over a considerable period, but also on the daily variations in grade. Thus, if nearly all the No. 1 and No. 2 in the second example were made in consecutive weeks and the No. 3 and No. 4 and Nos. 5 and 6 in other consecutive periods, the regularity in the second case might be as great or greater than in the first.

We can do away with this source of uncertainty by calculating the average grade of the iron made each day, and writing the results in a table, noting at the same time, all known causes of variation, such as changes of burden and in temperature of blast, or better by exhibiting the table in the form of a diagram, in which the average grade for each day is shown by the length of ordinates drawn at equal distances apart. The variations in burden and temperature of blast can be shown by other lines on the same sheet.

Such diagrams give a fair idea of the daily variations in quality, when these are not exceedingly great, and in connection with the figures showing the percentage of such grade in the whole quantity of iron made during the period considered, enable us to compare the workings of furnaces in respect of regularity, independently of any bias or preconceived opinion on the subject.

COMPARISON' OF RESULTS FROM OPEN-TOPPED AND CLOSED-TOPPED FURNACES.

BY FRANK FIRMSTONE, GLENDON IRON WORKS, EASTON, PA.

IN 1871, two furnaces at the Glendon Iron Works, which had been blown out on account of the "coal strike," were altered from the open-top plan with side flues for collecting the gas, to closed tops with cup and cone.

In one furnace the suppression of the side flues permitted a considerable alteration in the profile, but in the other (No. 5) no change in this respect was made; the side flues were simply bricked up and new ones cut through the sides close to the top.

This furnace was in blast over four years, and we can, therefore, form a pretty good idea of the effect of the alterations on the furnace process.

The principal dimensions are; Height 72'; greatest diameter, 18'; diameter at tuyeres, 8'; diameter of top, 10; diameter at stock line (point at which the top of the materials is kept), 11'; cubic contents, 11,900 cubic feet.

The table below shows the average results for periods of twenty-six weeks each. 1st, of the open-topped furnace; 2d, of the furnace with the first charger used, which was an ordinary cup and cone (diameter of cone 5' 2") 3d, with the charger used ever since, a "double " cone 7' 5" diameter outside, having a central opening 3' in diameter. The diagram (Plate II) shows the daily variations in the grade of the irons for the same periods.*

	Average iron per week.	Average coal† per ton iron.		Aver'ge grade.	Percentage of each grade.				
					No. 1.	No. 2.	Gray forge. No. 4.	Mottled. No. 5.	White. No. 6.
		ton.	cwt.						
26 weeks ending Feb. 25, 1871 (open top)...........	291	1	3.8	3.9	3.9	25.7	34.5	19.5	16.4
26 weeks ending Feb. 24, 1872 (small cone)........	271	1	6.5	3.8	6.4	22.4	39.3	18.3	13.6
26 weeks ending Feb. 22, 1873 (double cone)........	291	1	4.1	3.4	10.1	25.4	24.3	15.7	15.5

* In calculating the average grade of each day's iron, each twelve hours was taken by itself whenever more than two kinds of iron were made in the 24 hours, and the diagram drawn accordingly. By counting, it will be found that there were more such days with the single cone than with the "double" cone, and more with this than with the open top.

† Anthracite.

It will be seen at once, that the results with the single bell, were in all respects inferior to those previously obtained with the open top. The consumption of coal was higher, amount of iron per week less, and the working of furnace, as shown by diagram, very irregular.

Twice in this time, the bad working went so far that we lost all the tuyeres, and were compelled, in one case, to put a tuyere in the tymp, and in the other to put tuyeres in the tymp and over the two tuyeres next to it.

Shortly after the last of these bad spells, we took out the small bell and put in the double cone. There was, at once, a marked improvement. There is little doubt that the first cone was much too small, and that, with a larger one, better work would have been done, and of course, correspondingly less advantage have resulted from the change to the double cone.

Comparing the 26 weeks of open-top working with the 26 weeks of work with double bell, we find the average weekly make, average grade of the iron and the coal per ton of iron nearly the same, but the regularity, both as shown by the diagram and by the percentage of the various grades made, decidedly less. In this respect, therefore, we are still behind what we did with the open top. The diagram shows nothing as to the average temperature of the blast, as the record is not complete enough to permit it to be done properly. As far as it goes it shows that the average temperature now is higher than it was with the open top, and that the variations from day to day are less.

Since we began to use the double bell, we have at times had the iron too thick to run into merchantable pigs, but have never been forced to raise the tuyeres or blow in the tymp. So far as we can learn, the experience at other works on the Lehigh, where the cup and cone was substituted for side flues and open-top filling with barrows, has been similar, although I do not know that such bad results as we had at the start at Glendon were met with anywhere else.

We may briefly notice some of the reasons for the changes caused by the alteration in the mode of filling and taking off the gas. These are clue principally to the different distribution* of the stock in the furnace from that which occurs when it is dumped in, directly from the barrows. ,

When the material is shot in, off the cone, or is dumped in from the barrows, there is a tendency for the coarser and heavier lumps,

* See De Vutbaire, Etudes sur les Hunt-Fourneaux, p 95 et soq.

both of ore and coal, to separate from the finer and lighter ones, owing to the greater distance to which they will roll; this causes some regions of the furnace to be more open than others, and thus affects the course of the gas, which of necessity takes the path in which it meets the least resistance. When a small cone is used, the coarse material, especially the coal, is found next the walls, the fine ore being in a heap in the middle, and the distribution is nearly like that obtained, when the materials are thrown into the centre of the furnace from a car with a drop bottom, which is probably, in most cases, the worst possible plan of filling. With a *very* large bell, the distribution will be precisely the opposite, the fine stuff lying against the walls, and the coarse rolling into the middle.

With the double cone, the effect is more complex, but in general there are two regions of fine materials, caused by the double discharge, and in any event, the separation will be much less marked than with a single bell, because the surface of the stock in the furnace is more nearly level and even, and, therefore, the distance through which the stuff can roll is much less.

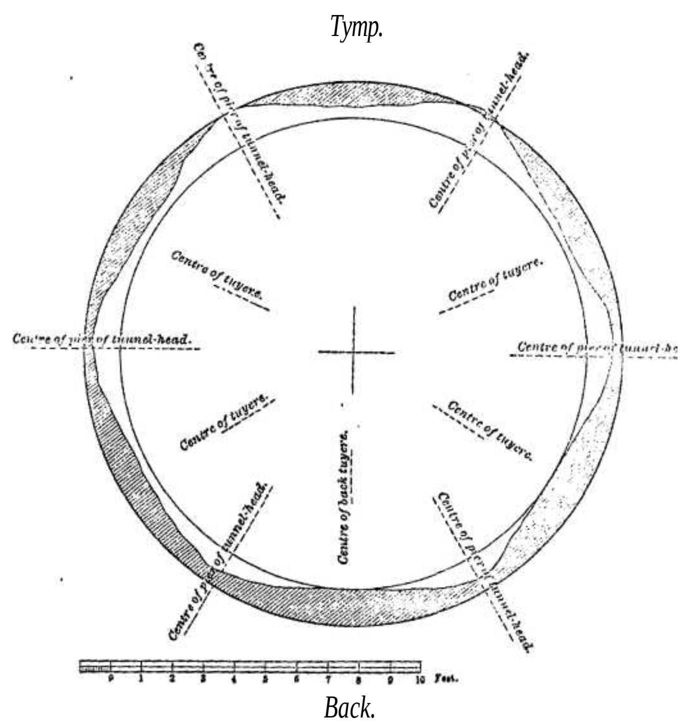
With both the double and single bell, the tendency is to distribute the stock into rings, of (approximately) equal fineness, the diameters of which are governed chiefly by the diameters of the bell and of the furnace at the stock-line.

In filling the same furnace with barrows through four or six doors, the distribution will be radically different. In the first place, the rolling of the stock, as it leaves the barrows, causes the coarser stuff to go to the centre, but in addition to this, the spaces between the doors are filled by a sidewise rolling of the large pieces. In this way the distribution is into sectors of varying coarseness, the finer stock lying opposite the doors, and the coarser in the "dead" angles between them, while at the same time, in each sector, the stock becomes coarser in passing from the walls toward the centre.

In two instances we have been able to see very plainly some of the effects of this sidewise rolling of the stock. In 1872 No. 2 furnace was allowed to go down to the top of the flues (about 12'), during a heavy snow-storm which prevented filling for several hours. It was then seen that the lining (9" thick when new) was worn through in seven places, six of which were exactly under the six piers of the tunuel-head.

The wear was stopped at the top of the flues by a ring of castings built into the lining to prevent the stock from rolling into and obstructing them. The furnace was kept in blast until this upper part of the lining and the tunnel-head fell in, so that, after blowing out, no measurements of it could be obtained.

No. 4 furnace, 10' diameter on top, was blown out in March, 1874, after a blast of over five years, when the horizontal section of the furnace was as shown in the accompanying sketch. The grooves commenced about 3 feet from the top, and grew wider and deeper as they went down, until they reached the point at which the section was taken (about half-way down), below which they gradually dis-



appeared, and were lost a short distance above the tuyeres. If this example stood entirely by itself, we might attribute the grooves to the action of the tuyeres, but, considered in connection with what was seen at No. 2, we may ascribe them, without hesitation, to the unequal distribution caused by the six doors.

At first sight, it would seem that any mode of filling, which resulted in such unequal wear, would be unfavorable to the regular action of the gas and working of the furnace. To try this, and also with a view of increasing the durability of the lining, the furnace when blown in again was filled through twelve doors, whereby the sidewise rolling was almost entirely suppressed.

The result was that the furnace worked with decidedly less regularity than before, and there was so much trouble from large lumps of spongy iron coming down over the tymp, that it was necessary to **put** a tuyere in the front and blow there constantly. It must be added, that but little benefit resulted from returning to the plan of filling through six doors, which was done after about ten weeks' trial of the new method.

The furnace was blown out in March, 1875, from want of coal, after a six months' blast, and gave signs of being badly scaffolded, among other things, making 35 tons of iron in the last 12 hours,—more than had been made in any 24 hours through the blast.

The figures given above seem to show that there has been a slight but appreciable falling off in regularity, in changing from the open to the closed top. Some closed-top furnaces, however, have done well, in respect of regularity, notably, the large furnace at the Musconctcong Iron Works (Stanhope, N. J.); but in this case, we have no comparable results, as the furnace was never worked open-topped.

For new furnaces, and especially, for new works, the great saving in first cost, and the advantageous general arrangement which it permits, should cause the adoption of the closed top.

Some furnaces on the Lehigh have been altered back again from closed to open tops, and, in one instance, a new furnace has been changed from a closed to an open top, and, it is said, with decided improvement in the results obtained.

BESSEMBR CONVERTER BOTTOMS.

BY ROBERT FORSYTH, NORTH CHICAGO ROLLING MILL, CHICAGO.

IN working the Bessemer process, the bottom of the converter has always been a source of trouble and annoyance, and the subject of more experiments, probably, than any other part of the complex mechanism called a Bessemer plant. This will not appear remark able when the duties this important piece of refractory material has to perform are taken into consideration. In the first place, by means of the tuyeres, it delivers at a high pressure the air necessary for the conversion of the bath of metal, and has then to resist the intense heat developed (the highest known in metallurgy), the chemical actions thereby induced, and the wash of five or six tons of molten iron tossed about by the violent ebullition which takes place during the process. That the bottom of the converter has some special difficulties to meet may be judged by the fact that the lining of the vessel (composed of substantially the same materials), not only docs not wear away, but actually increases in thickness, while the bottom, in close proximity to the lining, is entirely destroyed by a comparatively small number of heats, and has generally a very variable endurance. It is this irregularity of endurance which is the principal annoyance; and although the methods and arrangements for removing old and setting new bottoms, in use in this country, leave nothing to be desired for rapidity and certainty of working, still, a bottom which can be depended upon absolutely for a certain number of heats facilitates the work wonderfully. This ideally perfect bottom is perhaps unattainable, but it is none the less the constant object of the steel-makers' search. The life of a bottom (barring accidents) may be said to range from 5 or 6 up to over 20 heats; but anything above 8 heats is generally considered satisfactory.

The removable bottom used in the American Bessemer works consists of a cast-iron "tuyere-box," perforated with holes to receive the tuyeres, and provided with a suitable blast connection and a removable cover allowing access to the tuyeres for repairs. In making up the bottom the tuyeres are first placed in the holes, and around them is rammed the "bottom stuff," a mixture of refractory materials, chosen especially for their infusible qualities. This mixture is rammed in a moist state, and requires drying before the bottom is put on the vessel. In some European works so much importance is attached to careful drying that bottoms are kept in stock, in the ovens, for months ahead, with certainly excellent results, but no better than are attained in this country without this slow and expensive method.

The life of a bottom depends, in about equal proportions, upon the tuyeres and the bottom stuff. Much trouble has been encountered from bad tuyeres in American works, but at present the manufacturers are making a very good article, and that part of the bottom may be said to be generally satisfactory. The bottom stuff should of course be as infusible as possible, but it should also be solid and capable of resisting the wash of the metal as well as the chemical action of oxide of iron at a high temperature. These requirements are best met by a mixture of silicious and aluminous materials, in proper proportions, well rammed about the tuyeres and thoroughly dried. Any tolerably pure quartz rock, ground, will do for the silicious part of the mixture, and the plastic fire-clays, found in all parts of the country, answer very well. But the ramming and drying, being dependent upon the individual skill and carefulness of the workmen, are naturally the points which require the most attention and are apt to get. the least.

It was the consideration of the difficulties encountered in bottom-making, at the Bessemer Works of the North Chicago Rolling Mill Company, which led Mr. A. L. Holley to design the method of making bottoms to which I wish to call attention.

Evidently it will very much facilitate thorough drying, as well as careful and uniform ramming, if the bottom is made in separate pieces, which are, after drying, put together and connected by as small a portion as possible of fresh moist material. Accordingly, separate "bricks," as they are called, are prepared, conforming to the shape of the spaces between and around the tuyeres, leaving room enough between them, when in place, to finish the ramming, and no more. These bricks are of substantially the same material as the ordinary bottom stuff, and are made in an iron mould by ramming. When finished they are removed from the mould, which is made in pieces, and taken to the oven, where they are dried, not burned, by a gentle heat for twenty-four hours, and are then ready for use. In making up the bottom, the tuyeres are first inserted in the tuyere-box, the bricks are then put in place between and around them, and the spaces rammed up with fresh material. Each brick, in the making, gets the undivided attention of one man, and is, consequently, remarkably solid and homogeneous; and, by the slow drying, the cracks, which often follow the rapid heating of a highly plastic clay, are prevented. The vertical surfaces of the bricks are roughened, to form a more perfect joint with the other stuff and hold it in place, and the washing out of the material from this space is of very rare occurrence. In ramming up the spaces care is taken that all the spaces are carried up together, not in layers, but by the addition of small quantities of material at a time, each of which is well rammed into the preceding one. The same precaution is taken in making the brick. All the bricks and bottoms are made in the daytime, each brick is stamped with the mark of the man who made it, and a record is kept of each bottom, showing the number of heats it made, the tuyeres renewed, if any, and the particulars of its working. The time required to dry a bottom thus made is short. Ordinarily, however, a bottom is forty-eight hours in the oven, although twelve are sufficient, and bottoms have been made, using brick fresh from the oven, which were ready for use when the ramming was finished. Instead of "ganister" bricks, as those made of bottom stuff are called, ordinary firebricks, moulded to the proper shape, may evidently be used, and in some cases with advantage. Firebricks for this purpose are now made, and the comparative cost will determine, in any case, which material shall be used.

This method of bottom-making has been in use over two years at the North Chicago Rolling Mill, and the results obtained are as follows, for the seven months ending October 1st, 1875, during which time, except for experimental purposes, the tuyeres of one maker were used. The average number of heats made by each bottom was, in the month of

March,	10.76
April	13.80
May,	12.05
June,	11.44
July,	10.06
August,	11.12
September,	11.43
The average for the whole period is	11.45

The greatest number of heats made by a single bottom was 22; the least number, 7. The total number of bottoms used was 489, of which there were 327 above the average, 162 below, and only 7 of the minimum life, 7 heats. The mean pressure of the blast is twenty pounds per square inch.

The materials used in making a bottom are quartz, fire-clay, and sand; a small portion of ground firebrick is occasionally used. The quartz is crushed by a Blake crusher and passed over a 5/8 in. screen; what passes the screen, varying in size from dust to 1/2 in. cube, is used for the bottom. The clay is carefully dried and ground in a Bogardus mill. The fire-sand is used as it comes without preparation. Having been well mixed dry, the "batch" of stuff is sprinkled with water while being turned over upon the floor, and allowed to stand a couple of days before use. After ramming and drying, a cubic foot of this bottom stuff weighs 120 pounds, about the density of ordinary sandstone.

The quartz rock used is a very hard and compact quartzite, somewhat stained with oxide of iron. It is found near Marquette, in the Lake Superior region. Its analysis is :

Silica,	95.50	pr. ct.
Alumina,	1.50	"
Peroxide of Iron,	2.75	"
Lime, Magnesia,	.40	"
	100.15	"

The fire-clay is a highly plastic, mottled red and white clay, from Southern Illinois. It contains :

Silica,	50.50
Alumina,	32.80
Limo,	1.'25
Peroxide of Iron,	1.60
Water,	12.40
	98.55

The fire-sand is from Central Illinois, and is a white decomposed sandstone, having the composition :

Silica,	96.00
Alumina,	1.25
Peroxide of Iron,.	1.00
Lime,	.50
Water,	.50
	99.25

The mixture for the brick, made up of these materials, contains, neglecting small quantities of alkalies:

Silica,	7850
Alumina	13 50
Peroxide of Iron,	2 25
Water,	5.00
	99.25

The other bottom stuff contains less clay, and consists of:

Silica,	85.50
Alumina,	8.75
Peroxide of Iron,	2.00
Water,	2.85
	99.10

These refractory materials are not, it will be soon, of remarkable purity—the quantity of oxide of iron in all of them is sufficient to give the bottom stuff, while moist, a deep pink color—but the clay is unusually plastic, and the others are fairly good. The clay which is most deeply stained with oxide of iron is found to be the most plastic, and is therefore, preferred—a highly plastic clay being necessary to cement the silicious particles together, although such a clay is not very refractory, and an excess of it makes the bottom liable to crack in drying. The advantages of this method of making bottoms are:

1. The rapidity with which bottoms can be made up. Four men and a boy, working about nine hours, make up four or five bottoms, fetching and mixing their own stuff. This enables all bottoms to be made on the day turn.

2. The facility afforded for inspection of the work in all its stages, and the carefulness which this imposes on the men.

3. The ease with which a perfectly dry bottom, well rammed, can be made. The solidity of the bottoms is remarkable. On several occasions an entirely new set of tuyeres has been inserted in a bottom, and its life thus prolonged considerably, when, with a less solid bot tom, such as is made by the ordinary method, this would not have been possible.

That this bottom has merits, the average of 11 1/2 heats for seven consecutive months is pretty conclusive evidence. The regularity of the results in connection with the high number of heats averaged is particularly noticeable. A steady result of eight beats would not have been remarkable, but a continuous average of over eleven is, I think, unprecedented with the materials in use in this country.

It is noticeable that with the introduction of this bottom a great many of the mysterious events which formerly complicated the bottom question have disappeared. The metal (except in cases which can be readily accounted for) does not "work harder on the bottom " at one time than another; the unfortunate tendency of the bottom to "flux" has been very much mitigated, and the whole catalogue of terms by which the workmen were wont to describe the ills of bottoms has been put out of use.

WHAT IS STEEL?

BY A. L. HOLLEY, C. E., NEW YORK CITY.

THE general usage of engineers, manufacturers, and merchants, is gradually, but surely, fixing the answer to this question. In every country rails, boiler-plates, and machinery bars, whether hard or soft, are almost universally called steel, when they are made from *cast ingots.* Other names for the softer steels, such as " homogeneous metal," "Bessemer iron," "Martin iron," and the like, have failed to obtain general recognition.

The meaning of the term steel, before it was enlarged to cover newly developing varieties, has been traced, by a recent writer, down through Percy, Shakspeare, and the Bible, in a most interesting manner, from an archæological point of view. Undoubtedly, it did characterize hardness and other qualities imparted by carbon. It is within the memory of most of us, that all steels were tool steels, and that the soft, structural varieties were introduced—varieties which harden but little, which bend cold, and which, in many physical properties, are akin rather to wrought-iron than to tool-steel. But, since both the hard and the soft steels are made by the same processes, and have their great, distinguishing structural feature in common, viz., homogeneity resulting from fluidity, it has come to pass, despite every other proposed nomenclature, that all the compounds of iron which have been cast in malleable masses, are called steel, the term wrought-iron being still confined to malleable iron made from pasty masses, and hence laminated in structure.

No inconvenience has been found, so far, in distinguishing between the more or less carburized products, in general, by the terms " high-steel," "low-steel," "tool-steel," etc., and, in particular, by prefixing the percentage of carbon and other ingredients, to the term steel. Steels which contain distinguishing ingredients other than carbon, are called "chrome-steel," "titanium-steel," and the like, just as variously compounded bronzes are called "phosphor bronze," "aluminium bronze," etc. Thus the combination of several words or symbols, and figures, may completely disclose the characters of the metal, in terms that are subject to no misunderstanding.

But inasmuch as several high metallurgical authorities and clever writers have of late proposed to disturb this natural and somewhat settled nomenclature, it seems important to consider the claims of, the various classifications. I shall attempt, in this paper, to show that the existing classification is more scientific and more convenient than any other, and that those others which have been most prominently brought into public notice are radically defective.

1st. The most common objection to the existing enlargement of the term " steel," so as to include the soft steels, is that it " pirates " a time-honored term, and applies it to a thing which is very different in many of its qualities. People who know nothing about steel, except as they use it in cutting instruments or read about it in classic authors, say that it is brittle, hard, and resilient, and they are much shocked to hear that it may also be soft and ductile; just as any one who knows nothing about India-rubber, except in the form of springs, would be astonished to find that one change in manufacture turns it into waterproof clothing, and another into hard, crystalline instruments and jewelry. The terms "hard-rubber" and "soft-rubber," as used in technical literature and commerce, have not given rise to any serious misunderstandings. People who do not know that the great bulk of the material made by steel processes, and having every ingredient and structural arrangement of the old steels, is, nevertheless, soft and ductile, and that it would be unsuitable for rails, plates, and the like, if it were not soft and ductile, are not to be considered authorities in this discussion, any more than a decorative artist in coal tar would for that reason be an authority on aniline colors.

Where a material is gradually developed into new forms and qualities, there must be some general name to cover the various classes of metal; and whether it is better to enlarge the boundaries of the old one, or to arbitrarily make a new one, which new one must, from the nature of the case, merge into the old one, there being no natural dividing line, will be further considered throughout this paper. I venture to assert here that the charge, specially brought by the inventors of new definitions, against the existing use of the term "steel"—the charge of upsetting the recognized order of things— is wholly without foundation. Nobody *invented* the term "steel," as applied to the soft homogeneous products. There has been no natural or obvious place in the gradual gradation from hard to soft steels, to inject a new definition. As the possibilities of the crucible process were enlarged, the first soft product was hardly more than a variation from standard carburization ; the early Bessemer and Martin steels, as produced in a successful commercial way, were hard, and, in fact, it is only quite recently that refractory materials have adopted, by means of which the slowly receding standard of carbon in cheap steels, has reached a tenth of one per cent. The same general name has been thus necessarily preserved, for the products of the same process, but its boundaries have been enlarged to admit new varieties, and a gradual growth of sub-classification. So that whatever the merits of any arbitrarily devised nomenclature may be, it must bear the demerit, whatever that is, of upsetting existing order and development.

2d. A more common form of this objection is that a blacksmith would not recognize the soft metal as steel. "A blacksmith," it is said, " calls that steel which will harden and temper, and blacksmiths ought to know what steel is." There are various answers to this objection :

I. If familiarity with soft, coking coal teaches a blacksmith how to burn highly carburized anthracite in his smithy, then his knowledge of highly carburized tool-steel ought to teach him what soft steel is. Hard coal is none the less coal because it does not respond, like soft coal, to a blacksmith's coking process, nor is soft steel any the less steel, because it does not respond, like tool-steel, to his hardening process. Anthracite coal was introduced long after bituminous coal was in general use, and the "pirating" of the time-honored name " coal," to describe this material, which is so different in many of its qualities, has not led to any vast inconveniences. It may be said that the parallel is incomplete, because both hard and soft coals arc really the same thing only changed in composition and structure by natural processes, and that they both respond to the practical test,—the influences of heat and oxygen. So are hard and soft steel the same thing, only changed in composition and structure by natural laws; and so do they both respond to the influences of heat and oxygen. Coals are, in fact, more diverse than steels in their carburization, structure, and strength, and in their requirements of treatment. If old nomenclature is to be held as a final criterion, then the modern condensing steam-engine should be a "low-pressure engine." The fact is, on the contrary, that it is as often "high-pressure" as any non-condensing engine.

The determination of previously unknown intermediate forms and functions is constantly enlarging the boundaries of all general classifications, and introducing subdivisions; hence the criterion of old classifications is inadequate and worthless.

II. If hardening in water is the determining characteristic of steel, who is to define "hardening?" As a matter of fact, all products of the crucible, Bessemer vessel, and open-hearth furnace, containing about a quarter of a per cent, of carbon, will perceptibly harden in water, just in proportion to the carbon contained ; and every one of them, however little carbon it contains, will bunion in some degree, as far as existing tests can determine. " If the product will make a tool, it is steel," says the blacksmith. What kind of a tool ? Is an agricultural tool iron, and a cold-chisel steel ? or does steel begin between cold-chisels and razors, and if so, where? A water-hardened tool perfectly adapted to certain uses may be made of Bessemer steel containing half a per cent, of carbon. The same Bessemer ingot may make a good rail. If one-half the ingot is steel, why is the other half iron ? The line must be so defined that people will agree upon it. Does it lie between thirty hundredths and thirty-one hundredths of carbon, or between ninety-nine hundredths and one per cent. ?

Obviously, no two men can agree on the amount of any hardening element which may constitute steel. And if they could agree, it would only be after a quantitative analysis had been made in all close cases.

III. A recent writer in the *Engineering and Mining Journal* (Aug. 28 to September 18, 1875) makes a number of ingenious objections to the use of the word " steel" for all compounds of iron which are cast into malleable masses.

1. The term "steel" is said to be so vague that some words must be added to it to indicate the very dissimilar classes of steel, and the necessity for this explanation is deemed objectionable.

This objection, is best answered by its author, who says, in the same column, that it is desirable to discriminate between the different classes of iron, and proposes the following brief and convenient nomenclature: " Cast-steel, welded steel, homogeneous wrought-iron, homogeneous iron, welded wrought-iron, puddled steel, puddled iron, blistered steel, Bessemer steel, Bessemer wrought-iron, open-hearth wrought-iron, Uchatius steel, Uchatius wrought-iron, crucible steel, crucible homogeneous iron, etc." "This classification," he says, shows whether the metal "has the properties given by carbon." Now, every one of these metals has properties given by carbon. The percentage of carbon must be mentioned anyhow, so why not briefly say twenty-carbon steel or forty-carbon steel, and so denote both its carbon value and its homogeneity ?

The objection, in its common form, is that the one word "steel " does not, without farther explanation, define the various classes of metal referred to. Neither do the words "oil," "coal," "rook," "brass," nor great numbers of general names express the sub-classes referred to; nor can any word nor any simple sentence define them all. The objection holds equally against all possible general classifications, and the only way to avoid it here is not to have any general classification in the iron business.

2. The writer referred to objects to calling the soft homogeneous compounds "steel," because it is sometimes difficult to tell whether they were made from cast or from pasty masses. It is true that a well-worked puddled iron, rather high in carbon, and a low steel with about the same carbon, cannot be distinguished very easily by means of ordinary observation and simple tests.

I will in answer to this objection quote the same writer, who admits the impossibility of any perfectly adequate definition by saying that "classifications are based on important differences between the classes they separate, and not on the facility of distinguishing those classes sharply." Now there are important structural differences between puddled irons and cast steels which look alike—differences which will make themselves known after sufficient stress and wear; but is the difference between two steels varying only by a hundredth of a per cent, of carbon, one of these " important differences," upon which an adequate classification may be based ?

The real answer to the objection, however, is this: Admitting for the sake of argument, that a considerable range of wrought-irons and low steels cannot be distinguished by the observation of their fracture, nor by bending, nor by the usual quick mechanical tests—people do not largely purchase iron and steel by sampling individual pieces, as they would cigars; they purchase by specification *of manufacture;* for instance, the Pennsylvania Railroad Company specifies 0.35 carbon steel for its rails, meaning by "steel," that it shall be homogeneous or cast; and from 0.30 to 0.40 carbon is recognized by makers and users generally as the proper percentage for rails. I note this fact here, to correct the writer whose objection I am quoting. In trying to explain away the fact that such rails are recognized as steel, he says : " Railway managers do not care much about the degree of carburization of rails said to be steel, provided they are absolutely weldless."

The practical usefulness of a name does not, therefore, lie so much in its discrimination between metals-after they are made, as in specifying the method and quality of their manufacture. Rails, plates, bars, and iron and steel generally are ordered on the understanding that they shall be fabricated by processes and of ingredients which are known to have yielded certain endurances to long-continued stress and wean If purchasers do not themselves specify the ingredient and processes they want, they specify a name and grade of metal, such as "0.60 carbon Martin steel," which refers the manufacture to such ingredients and process; so that the name completely meets the requirements of the case.

Supposing even that it should be, not difficult, but impossible to distinguish between certain grades of steel and wrought-iron by the most searching mechanical and chemical analyses, it can probably be determined in all cases from synthesis. Lawsuits arise as to the composition of material substances about which we have no synthetical record, such as a late suit about a certain paving-stone, based on the question as to whether it was trap-rock, or a sandstone altered by the trap-rock that flowed over it. But there are almost always sufficient records of manufacture to determine whether a metal has been cast or welded. This, however, is an extreme case; perhaps it is one that could never occur. Destructive tests can, I believe, determine in every case whether a metal was cast or welded. In the. great majority of cases the most simple tests can distinguish iron from steel, as at present defined, so that practically the existing classification is entirely adequate.

3.The writer we are quoting misinterprets the current definition of steel, as calling for a production which is *better* than wrought- ron; and then he attacks the definition by saying: " Who would call cold-short Bessemer ingots, on the whole, superior to the best Swed ish iron?" Now, as cold-short ingots are altogether *nil* until they have been reconstructed, we must admit that "a living dog is better than a dead lion." The bearings of his observations do not lie in its application.

4.Another objection from the same source, that the current definition excludes certain classes of iron heretofore called steel, such as " blistered steel," "puddled steel," etc., is at first sight a valid one. But should not the same objection also be valid against the old and limited meaning of the term " steel?" Does the mere fact that " puddled steel," so called, is carburized more than the usual products of the puddling furnace, although less than tool-steels, docs this mere fact of a little more carburization really define steel, ac cording to the old restrictions of the term, despite the fact that the product, so called, has a totally different structure, which renders it unfit for tools and for most other things that steel is used for? If then the term " puddled steel " should be excluded under the old classification, surely the classification now current must not be held responsible for its exclusion.

5. Again, classing homogeneous irons high in carbon and those low in carbon, under the same name, "steel," is objected to, because the range of properties and uses due to variations in carbon, are much greater than those due to variations in homogeneity. Hence the classification, it is said, should be based on carbon and not on homogeneity. Every malleable iron, whatever it is called, contains carbon in some proportions, from a trace to the highest attainable solution, and since these combinations and the properties they impart, form a regular series of variations, running into each other, there can be no general carbon classification, except by drawing an arbitrary line at some carbon percentage. Now, 1st. As the irons for some distances on both sides of this line cannot be thus distinguished, except by minute analysis in every instance; 2d. Since synthesis, which is the practical matter, cannot be based on a carbon specification alone, because it would omit the vital feature of homogeneity, upon which depend, for instance, the advantages of steel rails over iron rails; and 3d, since a classification based on homogeneity furnishes means for distinguishing between products, while it also affords, with the addition of the carbon percentage, a perfect basis for synthesis, for these reasons, I fail to see why a carbon basis, which must be arbitrary and revolutionary, could be useful or desirable. 4th. No less prominent an authority than Whitworth has proposed to divide wrought-iron from steel, at the point of twenty-eight tons tensile strength. This classification is open to all the objections we have urged against the equally unnatural and arbitrary carbon classification. How would Mr. Whitworth like to order gun-steel by this definition? Any steel-maker can produce a metal so full of phosphorus and silicon that it will fly into pieces under a sudden blow, and yet it will stand over twenty-eight tons statical pull. A steel made with very small proportions of carbon and manganese, to the almost entire exclusion of phosphorus and silicon, would safely stand the severest blows, and stretch perhaps thirty per cent, before breaking, but still it might barely reach twenty-eight tons tensile strength. A puddled iron, totally unfit for guns, plates, and I rails, might stand twenty-eight tons statical tension, while the most pure and costly product of the crucible might fail under it. The former, according to this classification, would be steel, the latter wrought-iron. 5th. It has been stated that what is known as "mal-leable iron "will confuse the existing classification. Seeing that

iron is remanufactured into malleable iron by a subsequent process, and not cast while in a fluid state into a malleable mass, as our specification demands, this objection is absurd. Without answering the more trivial objections, let us consider what we *are* to do if we give up the existing classification.

I. The old and restricted term "steel" indicated certain properties, such as resilience, hardness, etc., in an indefinite degree, which were imparted by that indefinite amount of carbon which gave hardening and tempering qualities. Now what shall we call the structural steels? We cannot call them wrought-iron, because they have all the enumerated features, even hardening and tempering in a gradu ally lessening degree, as carbon is diminished; and the features are not characteristic of wrought-iron. Besides, Tought-iron totally differs in feature of homogeneity, and is rapidly growing out of use to make room for the homogeneous compound.

II. We may call these compounds " homogeneous iron," but we must then add the percentage of carbon, and designate them as "ten carbon homogeneous iron," up to say " fifty carbon homogeneous iron," for there is a vast range of grades and uses between these car-burizations. Now, is it not easier to say "ten carbon steel" up to "one hundred and fifty carbon steel," thus including all the varie ties of ingot metal? And is the general public likely to agree that " homogeneous iron " means metals made from ingots, up to a cer tain arbitrary point of carbon, which nobody can determine without analysis, when beyond this point, ingot metal, made in exactly the same way and by the same furnaces and processes is " steel ?" The inconvenience of such a nomenclature is illustrated by certain streets in London, which are called by one name up to a certain number, and by another name the rest of the way, a very inadequate illus tration, for one can sometimes find a label on a street without mak-ing a quantitative analysis.

6. As the author referred to, whose objections I have endeavored to answer, has offered, not dogmatically, but for discussion, a new definition of steel, and has advocated its claims with much learning and ingenuity, I think we ought to examine it in some detail. He defines steel as "a compound or alloy of iron whose modulus of re-silience can be rendered, by proper mechanical treatment, as great as that of a compound of 99.70 per cent, of iron with 0.30 of carbon can be by tempering." This is substantially an arbitrary division at the carbon point, .30 per cent., of all malleable iron compounds, whether made by wrought-iron processes or by steel processes. The

chief reasons appear to be, 1st, that this division somewhat corresponds to the distinction made between wrought-iron and steel at a time when there were no soft steels; 2d, that the carbon point, 0.30 per cent., is a "somewhat critical point in the curve representing the degrees to which differently carbonized varieties of iron possess the properties which are most affected by carbon ;" 3d, that resilience being the chief attribute of steel, it should for this reason form a basis of classification.

I. It is difficult to understand why scientific men should be will-ing to sacrifice a natural classification, which has grown out of the necessities of the case, for one that is unnatural and arbitrary, on the ground that it embraces species which are unlike the earlier species, although of the same genus. It is hardly necessary to re peat what has been said again and again in the foregoing pages on this subject.

II. If the 0.30 carbon point is a critical one, which I have not practically noticed, and which, for the purposes of this paper, need not be discussed, it is stated to be a point in a *curve*, which must be arbitrarily placed, and not the point of an angle, which might dis tinguish homogeneous from welded masses.

III. As to resilience being the most important quality of steels, and for that reason the proper basis of classification, it is unnecessary to discuss this claim for resilience here. The question is whether the importance of a quality can make existence of that quality a definite basis of classification when it exists in both classes, gradu ally increasing in one and decreasing in the other, and being practi cally the same near the dividing line.

To sum up once more, the answer to this and to all the cases of arbitrary classification : Exact definitions must be based on differences which always exist in every form and phase of the materials defined, and not on differences which, however great they may be in certain forms and phases of the materials, run together at one point, and there cease to be differences. If we divide steel from wrought-iron by an arbitrary line of percentage of any ingredient or of modification due to any ingredient, there must be some, point at which the difference between steel and wrought-iron is infinitely small. If, however, we define steel as a compound made homogeneous by fusion, while wrought-iron, although the same in composition, is heterogeneous from welding, there is always, and at every grade of the respective materials, a large and radical difference. Casting fluid steel and welding pasty iron are always distinct in their characters and results; they do not at, any point shade into each other. The latter classification is therefore exact and complete.

IV. A very serious objection to the proposed division is that it occurs at a point about midway in the range of structural steels. It would be less inconvenient, though not less unscientific, if it divided the general class of structural steels from the more ordinary grades of tool-steels. Of a pair of locomotive tires, both made by the same process, out of the same materials, and containing as nearly as practicable 0.30 of carbon, one might be steel and the other wrought-iron; or, a pair of locomotive tires might both be steel, the one having been welded up from scrap, and the other drawn from a cast ingot; or, one end of the same ingot might be steel, and the other end wrought-iron, the first having been hardened, and the other annealed. The convenience of such a nomenclature is not obvious at first sight.

The author of the proposed definition we are criticizing has so vividly portrayed the disastrous confusion which would arise from changing a settled nomenclature, that I can hardly do better than quote him in this connection. He says: "It is a complete change in the meaning of a word that is in every man's mouth—a change in which the interests of the whole civilized world are affected, and in contemplating which, the convenience of all mankind is to be considered. . . . The natural conservatism of language would prolong this painful period of change to a most unpleasant length. Moreover, the confusion would not end till the change had been well established in the other languages of the civilized world. In meeting the word ' steel,' in specifications, contracts, and, indeed, all literature, whether technical or not, whether English or foreign, it would be necessary to determine whether it had been written before or after the change had been effected."

In conclusion, it seems hardly necessary to *again* sum up what has been chiefly a reiteration, in different forms, of answers to criticisms on the present enlarged use of the term "steel," and of the one great objection to the nomenclatures, that they are fatally indefinite.

The names of new materials and processes, like the laws of trade, are not fixed by the arbitrary edicts of philosophers, but they are gradually developed to meet the general convenience.

MR. PEAESE said he objected to the definition of steel proposed in the paper on two grounds:

First. The fact that the definition of steel proposed by Mr. Holley is not an old one, nor an established one, but one of comparatively recent introduction in popular language, and which might be called a new-old one, with great propriety. The old, and generally received, classification of steel is based on the work of Karsten—a man of the exactest practical knowledge—a director of government works, and not a philosopher nor a theoretical speculator. He found that, under the same conditions and by exactly defined methods, a compound of iron and carbon with a given amount of carbon would harden, to an appreciable extent, and that, just below this point, similar compounds would not harden. He specified 0.25 per cent. carbon as the limit.

Now the point at which, under exactly similar conditions, one metal will harden and another will not harden requires no quantitative analysis to determine, and but a few minutes of time. At his anvil, an ordinary smith, at Neuberg, grades and classifies steel to correspond with the chemical and physical tests. This being the case, the distinction on which the old received definition is based must be acknowledged to be both practical and easily recognized. The steel carries its own label on its face, as easily read as the name of a street.

Second. In the paper read, the President pointed out that Sir J. Whitworth proposed 28 tons tensile strength as the dividing line between iron and steel. This is only another way of designating the point that has been in the mind of all who have recognized the dividing line, some having of course approached the truth more nearly than others. The exact truth is that besides having a metal that will harden under a given treatment, we have a metal that will soften and become more ductile under exactly similar treatment; this metal is a compound of iron and carbon with about 0.17 per cent. carbon. The fact that it softens under exactly the same conditions as the other metal hardens, proves that we have a different substance, viz., *iron*. There is no doubt about this fact, for I have in my possession bars thus treated, which show the fibrous silky fracture of wrought-iron, while the same metal containing a little more carbon shows when similarly treated the granular conchoidal fracture of steel. Here then is the point; it is fixed by no philosopher, but by the nature of things. The term "homogeneous metal" is in general use, if one is not willing, as one ought to be, to call the product iron.

So far as *true steel* was concerned, he agreed with the President that the best way to designate the steel was to prefix the carbon percentage, and he had advocated similar views in his paper on iron and carbon read at the previous sitting. He did not agree with Mr. Howe that resiliency was the characteristic property of steel, nor with the President that homogeneity was that property.

DR. R. W. RAYMOND referred to the fact mentioned by Mr. Cogswell, that tool-steels heated to a certain temperature soften in water, and said the behavior of the metal evidently depended on the initial temperature of the metal and liquid, and the rate of cooling, as well as on the contents of carbon or other "hardening" element. With regard to the able and ingenious paper of the President, he said that the real question seemed to be rather, "What is *not* steel?"—one party having denied this name to the Bessemer and Martin metals, the other retaliates by carrying the war into Africa, and giving us a definition, "any cast, malleable alloy of iron," thus excluding among other things, blister, shear, and puddled steel. The President's comparison with the case of anthracite and bituminous coal would be more complete, if the anthracite owners had denied that bituminous coal was coal at all. He had no objection to permitting the Bessemer and Martin products to be ranked as cast-steel. It was inevitable and also right. But a definition which demands that blister steel, the thing which always was steel, shall be suddenly voted iron, certainly calls for pause.

PROF. EGLESTON said that the experiment of fusing wrought-iron in crucibles was successfully carried out in St. Etienne in France about the year 1846, and castings made of this fused iron. Did this simple process of melting convert iron into steel?

IMPROVED BESSEMER PLANT.

BY JOHN B. PEARSE, PHILADELPHIA.

THE works heretofore used in carrying out the Bessemer process have been constructed substantially as follows: The whole works or plant has been divided into three parts. 1. The division in which the metals for conversion are melted. 2. The division in which the metals are converted into steel and cast into ingots, or the converting department. 3. The engine and boiler department which supplies the hydraulic power required to move the machinery, and which furnishes the blast used for converting the crude metal into stool-

These several departments have usually been so constructed as to be separate from each other, and so as to be practically in separate buildings separated by division walls extending to the roof.

The pig-iron is melted in cupolas, and is run into ladles mounted on heavy scales fitted to weigh about sixteen tons, and placed at the height of from fourteen to sixteen feet above a horizontal line drawn through the trunnions of the converting vessels. These ladles are usually placed twenty-five to thirty feet behind the converting vessels, and are connected with the latter by spouts or runners, down which the melted metal runs. The spiegeleisen used for recarburizing is melted in air furnaces or cupolas, in the cupola department; similar runners, usually connected with the ladle runners, conduct the melted spiegeleisen into the converting vessels. All these runners pass through a division wall by means of arched openings, and are usually from thirty-five to fifty feet in length. In the Cambria Bessemer Works this division wall between the cupola and converting divisions has been omitted, but the general design is otherwise the same.

In the converting department, the converting vessels, two in number, stand with their mouths toward the cupola department. They occupy, with their chimneys, a central position every way, being directly on each side of a line drawn across the cupola and converting departments and through the centre of each department, and are almost centrally between the two departments. The converting vessels are so placed that the flame, gas, smoke, and matter thrown out from the vessel during conversion are directed towards the cupolas and ladles. To protect the latter a large chimney is built for each vessel in the division wall. The matter thrown out from the vessel is thus projected against the back of the chimney, where it adheres.

The operation of converting the crude metal into steel is completed with the aid of one ladle crane, and three lifting or ingot cranes. The ladle crane has an arm sufficiently long and strong to support a ladle weighing about twelve tons, when full of steel, at a distance of fifteen to eighteen feet from the centre of the crane-post. The ladle crane carries the ladle around under the converting vessels, and then over the tops of a number of moulds, previously arranged in a circle. The lifting cranes are designed to lift from five to eight tons each, and to cover a circle of about thirty feet in diameter round the post of each crane. Two of these lifting cranes are arranged to swing just over the converters, while the third is so placed that its circle just meets the circles described by the other crane jibs. All these cranes are moved vertically by water power, but all other motions are given by hand.

The converting vessels are fitted with a tuyere-box, which carries the refractory bottom lining of the vessel, and also the tuyeres, through which the blast passes on its way up into the melted metal in the vessel. This tuyere-box is usually of large size and great weight, weighing over half a ton without the refractory bottom, or the tuyeres. A railroad track is laid under each vessel from the drying ovens, so far under the vessel that the centre of the ear may come vertically under the centre of the vessel. The tuyere-box, previously prepared with its bottom and tuyeres, is placed on this car, run under the vessel, and is lifted into position by a strong hydraulic lift, which rises beneath it, and lifts it so high that it may be keyed or bolted on to the vessel in its proper place.

The buildings containing the boilers, engine and pumps are usually placed along one side of the converting department, and most commonly on the opposite side to that on which the cupola department stands.

The cupola department must be made of great height, so that the cupolas and ladles may be sufficiently far above the converting vessels to secure a steep inclination of the runners, down which the melted pig-iron and spiegeleisen flow into the vessels. All the metal and fuel for melting must be lifted to a great height, thus necessitating heavy hoist arrangements and large expenditure of power. The cranes being fixed in regard to location, have but one set of functions; none of the lifting cranes could take the place of the ladle crane, should that break down, nor if the lifting crane that serves the steel ladles should be injured could either of the others replace it. The weight of the tuyere-box and refractory bottom is so great that it necessitates special arrangements to handle them, and each converting vessel requires a separate and distinct set of these arrangements as above described.

The plan or design of the plant usually adopted is a dual one, that is, if a line be drawn between the converting vessels and carried each way through the buildings there will be one vessel, one drying-oven, one ladle for molten iron, two cupolas for melting iron, and in most plants, one air furnace or cupola for melting spiegeleisen on each side of the line. This line also passes through the centres of the ladle crane and one lifting crane, and has one lifting crane on each side. Each of these sides is, with the exception of the ladle crane and the one lifting crane, which are common to both sides, complete in itself, and, in case of necessity, could be worked without the other side; but the two sides are designed to be worked together, and all the rest of the machinery of the plant is subservient to both in common.

The second principal feature of the designs heretofore used is, that they are constructed round a central point. The vessels are the centre, and the whole plant is so arranged that the molten iron, spiegeleisen, scrap iron, and refractory materials are all brought to them in various ways, and the steel is delivered from them by means of the ladles swung round the circular pit. Around this pit, on one side of which the vessels stand, is conducted the whole work of conversion. In melting pig-iron the product is easily carried away down runners without further trouble, but, in the case of steel, we have ingot moulds and ladles, many of which are needed immediately round the pit. We have there, further, the drying ovens for vessel bottoms, not so much needed now it is true, but the bottoms are still made up in the immediate vicinity of the vessels. But in front of one oven, as usually arranged, the steel ladles stand, and the moulds in front of the other. The steel ladles after use, discharge their slag and scull under their crane, at one side of the pit, while the hot moulds are distributed round the other two cranes. The central position of the steel converting details is thus disadvantageous, for the heat arising from the hot moulds and glowing ingots greatly inconveniences the men. Besides this, the inward movement of the material brought in to the centre interferes with the removal of the d6bris, and the d6bris itself of each operation, is also more or less in the way of the other operations.

From the above descriptions it is evident that the design of the Bessemer plant, usually employed, is of such a nature that any increase of capacity must take place by the union of two converting vessels and their necessary appurtenances. It would be far too expensive to build for one vessel the parts usually accessory to both vessels in common.

The object of my improvements is chiefly to diminish the relative cost of plant per ton of steel produced, and the amount of the original total cost of erection, to reduce the cost of repairs by simplifying the apparatus employed, and also to arrange each part of the Bessemer plant, and the combination of the several individual parts, so that each division of the operations necessary to conversion shall be carried on in an entirely separate place, so situated that each separate division may be reached from the outside of the building, or from a space equivalent to the outside. (See Plate III.)

With this object I unwind, as it were, the whole circumference of the pit, bring the cupolas down, and get the operations in a longitudinal line, instead of in a number of radial lines converging to a common centre. The iron comes in at one end, and goes out as steel at the other end. For these purposes I so arrange the converting plant, that the whole of the machinery, including blowing engines, pumps, boilers, and all other necessary parts, may be placed under a single roof of moderate span intended to be. nothing but a shed made fireproof. The only raised floors employed, are the platforms required to charge and work the cupolas, the highest of these platforms being not more than eighteen or nineteen feet above the ground, and all of them in one corner of the building. The cupolas stand on the ground, and the molten pig is tapped out of them into an ordinary foundry ladle of large size, which also rests on the ground. I employ small cupolas, also resting on the ground, for melting the spiegelcisen for recarburization, and I arrange a crane so that it commands all the machinery in the building, except the cupolas themselves, the blowing engines, and the boilers.

The crane lifts the ladles containing the molten pig-iron, spicgel-eisen, and automatically pours their contents into the converting vessels, without the intervention of runners of any kind. The Indie and contents are weighed on the crane, and the diminution of weight as the pouring goes on, is indicated so that by watching the index of the weighing apparatus, the required quantity may be readily poured out. Regular steel ladles receive the steel from the vessels direct, and arc carried away by the crane to the ingot moulds. One travelling crane, arranged as in the drawings, will perform all the operations requisite for the manufacture of a large quantity of steel; if a very large production is intended, two travelling cranes can be used, or in either case equally good arrangements can be made with a jib carne. I put the traveller in the drawing, because it is by far the handiest crane of the two.

The service of the vessels includes renewing the vessel bottoms when the refractory lining and tuyeres have been burnt away, and I arrange my plant so that the crane pulls the car out of the drying oven, and then, by means of a long peel or lever, of suitable construction, raises the fresh tuyere plate and refractory bottom, and carries them into the proper position for attachment to the converting vessel. The worn-out bottom was of course previously removed by means of the same lever or peel.

In order to make the tuyere-box and bottom very light and eon-

Venient to be thus handled, I have designed a special form of tuyere-box, which would be best designated by being called a tuyere-plate.

The converting vessels are so arranged, that they need no chimneys of any kind, the flame, smoke, gas, and matter thrown out from the converting vessel, during the process of conversion, going directly into the open air, the heavy matter falling on the ground outside of the building.

I provide, as you sec, a place for relining the ladles so situated as to be entirely accessible from the outside, and quite out of the way of all other work. The drying ovens and the engines, boilers, and pumps are disposed in a similar way, so that coal may be taken to the boilers, and refractory material to the drying ovens from the outside, either by railway, car, or on carts, without interfering in any way with other work.

The cupolas are placed as close to the converting vessels as is consistent with comfort and convenience, but, at the same time, so that they may be in free communication with the outside. The pig-iron, spiegeleisen, and fuel can thus be raised to the cupolas in any convenient way from the outside, and the slag and other débris resulting from the operation of melting go directly, in the shortest way, to the outside.

The ingots are cast in an entirely separate and distinct locality out of the vicinity of the vessels and easily accessible from the outside of the building. This is done in order that the heat resulting from the cooling off of the hot ingot moulds, after use, may be diminished as much as possible. Further, this arrangement enables us to perform the hot operation of casting the ingots away from the vessels, which are themselves rendered very hot by the process of conversion. The heat to which the workmen are exposed is thus reduced as far as possible.

The travelling crane is so arranged that it can itself, if desired, convey the hot ingots to the heating or in this case cooling furnaces, even at a long distance. Or it can pile the ingots where needed or handle them as may be convenient.

I design, as you see, the blowing engines, boilers, and pumps in such a way that they go into a small space, and into a convenient position with reference to converting vessels and cupolas, and to the track laid in the building for the removal of ingots and the facilitating of repairs.

All divisions or parts of the operations incident to the conversion of iron into steel, are so arranged that each of them, except the melting in part of the crude metal, may have a location such that no other operations are carried on opposite to it, thus securing great convenience and freedom, from the fact that the operations are all carried on in areas adjacent, but not opposite.

An incidental, though important feature of my design is, that the steel for ingots or any metal in course of handling may be weighed while being poured, without further preparation. In the ordinary plants this cannot be done. There are many directions in which this feature can be made useful.

The travelling crane may be run at any speed; when running about forty feet per minute the iron ladles can be taken from the cupolas to the vessels and emptied in from one to one and one-half minutes. But a speed of one hundred and fifty or two hundred feet per minute is perfectly admissible for travel. One hundred to one hundred and fifty feet for cross motion of crab and fifty feet for lifting ordinary weights. With these speeds a great amount of work can be done. One Brown's steam and hydraulic traveller, in the works at Landore, handles the ingots from eight to ten Siemens furnaces, doing all the work alone.

In regard to the cost of the plant above described, I have detailed estimates which show that it can be built for from sixty-five thousand to eighty thousand dollars, depending on locality, to produce an average of at least one hundred and fifty tons per day. It can be started with a single vessel, two cupolas, and the lowest basis for say sixty to seventy-five tons per day for forty-five thousand dollars, and its capacity can be enlarged, up to the capacity of the cupolas, simply by extending the building in length. The estimated savings on all items, as compared with ordinary large plants, is not less than two dollars and fifty cents per ton, in addition to the large saving in interest. All dimensions can be ascertained by measuring the plates, which are drawn to scale.

MB. A. L. HOLLEY said that there were some good details in the design of Mr. Pearse. It was certainly desirable, as far as possible, to decrease the very large cost of a Bessemer plant, now about $300,000 for a plant capable of producing 1300 tons of ingots per week. He thought, however, that Mr. Pearse's plan was defective in grouping, and that he would be disappointed in his attempt to realize from one travelling crane, the work performed by ten hydraulic machines. Mr. Holley further remarked regarding the estimated cost ($65,000 to $80,000) of the plant, that he thought that here, too, Mr. Pearse would be disappointed. In the erection of the Edgar Thomson Steel Works, they had found that over and above the cost of buildings and of all the machinery free on board at the builders works, the cost of setting up and finishing and putting the plant in running order was $80,000.

MR. ROBERT W. HUNT thought that the plan of removing the casting pit to one side would not relieve the men materially, since they do not now suffer any great inconvenience from the heat of the operation. He further objected to lifting of melted metal, when avoidable and thought to avoid this a greater height of cupolas was desirable. He agreed with Mr. Holley, in thinking that one travelling crane would be inadequate to the work of the plant. He thought moreover that the labor would be more expensive.

MR. PEARSE replied that his principal object was to cheapen the cost of erection of a Bessemer plant, which in its present state is rather apt to repel than attract investors. His plant would permit the erection of works in new districts, and would also permit experiments to be carried on at small expense. As to the travelling cranes, he thought that they would, in time, drive out jib cranes, as they are now doing, for many purposes, in England. He cited instances where, travelling cranes were doing prompt, efficient, and heavy work. If, however, one crane was not found sufficient, two could be used. Moreover, jib cranes could be used with his plant if thought desirable.

In reference to the remarks of Mr. Hunt, as to the difficulty of handling melted iron, he found not the slightest trouble in foundries, where steam cranes handle ladles containing twelve to fifteen tons of iron, with the greatest ease. It is thus a matter of every-day work, and objection on this score is not well founded. But further, in the second plant of the Pennsylvania Steel Company, a design was made for handling a movable ladle on a truck and track, laid before the cupolas, and though the building has not been finished, yet this plan can be seen in operation in the Bessemer works of the Bethlehem Iron Company. Here the cupolas are about one hundred to one hundred and fifty feet from the vessels, and the spiegel-fur-nace is still farther away, and the ladle is on a truck which is pushed the whole distance by a locomotive, and placed on the platform of a hydraulic lift, which lifts truck and ladle to the working platform around the vessels. This plan is entirely successful for heavy seven-ton heats, and any handling proposed in his design is far less in amount, and more easily directed, than that done so easily, every three-quarters of an hour, all day long, by Mr. Fritz.

As to amounts stated in estimate, they were carefully calculated at engineering works, and he had reason to believe that at present rates they can be materially reduced. An estimate of his plant was not comparable with an estimate of a plant five times its size. In a large plant the buildings and foundations and roofs alone cost about what his improved plant could be built for.

He had actual figures on all the facts, and had every reason to believe that his offers were *bond fide*, as the bids used were, many of them, made to the Pennsylvania Steel Company two or three years ago. The amount may seem very small, but a comparison of the specifications of the two plants (ordinary and improved), and a view of the number and design of parts used in his plans, would convince any one that his total was not underestimated.

As to cost of steel per ton, the cost of the plant submitted was so much less, that its product need not be nearly as large as is necessary in ordinary plants, in order to make steel cheaply. Hence with an ordinary product, the new plant will, it was believed, make cheaper steel.

IRON AND CARBON, MECHANICALLY AND CHEMICALLY CONSIDERED.

BY JOHN B. PEAESB, PHILADELPHIA.

IN view of the great importance of accurate knowledge respecting the chemistry of iron and steel, as related to their physical properties, I come before you with a paper showing the great mass of work. Which has been heretofore done on the subject. I have tabulated the more important data I bring at this time, so as to draw out the results clearly. This information is accessible to all who will seek for it. I have made it the basis of my own practice throughout, and such knowledge is undoubtedly the only foundation for the successful practice of metallurgy.

As is well known the ordnance corps of our army, after 1841, made exhaustive experiments on the properties of cast-iron. The investigations were undertaken in order to obtain necessary information on the reorganization of the corps. I wish to call your attention to the results obtained by a comparison of the chemical and physical properties of cast-iron for guns, to describe certain characteristic peculiarities of steel, and to give a brief history of the chemical work relating to carbon in iron.

The *Reports on Experiments on the Strength and other Properties of Metals for Cannon*, published by H. Carey Baird, Philadelphia, 1855, consists of reports by Major Wade, Lieut. Hagner, Lieut. Rodman, Captain Walbach, Major Ramsay, and of Messrs. Morfit and James C. Booth. The cast-iron guns in use up to 1840 were highly unreliable, many bursting in the proof or after a few rounds of service-charges. But others endured 2000 rounds or more, so that it became evident the fault lay not in the metal wholly, but also with the iron-founders. The guns in service were classified and a stringent system of inspection instituted during manufacture. This work occupied the thirteen years between 1840 and 1853. The results, direct and indirect, were more than commensurate with the cost of the work. The change of form now adopted universally in our service was then suggested, and the methods of manufacture of cast-iron put on a rational, practical basis. Lieut. Rodman invented his admirable system of cooling guns, and Captain Walbach, in a classification of 2808 guns made prior to 1841, showed that the improved system of manufacture was thoroughly well founded. The density and tenacity of the cast-iron in guns was raised far above the standard previous to 1841. as follows :

	Density	Tenacity
Guns east prior to 1841,	7.148	23638 lbs.
Guns east in 1851,	7.289	37,774 lbs.

To Captain Walbaeh is due, so far as I know, the credit of first bringing chemical research to the aid of the engineer. He foresaw the importance of a field of investigation more extended than the mechanical one, and it became the cherished object of his life to procure the invaluable knowledge flowing from an inquiry into the chemical constitution of all elements entering into gun manufacture, from the raw material to the finished product.

Owing to the metallurgical skill attained by Major Wade, who afterwards connected himself with the Fort Pitt foundry, our guns were long regarded as superior to any in the world, and have only recently yielded the palm to Krupp's steel, and to the Woolwich 35-and 81-ton guns with steel tubes.

In the manufacture of cast-iron guns particular attention was paid to tensile strength, hardness, and density, especially in the raw material. I collect the following information of general interest:

Charcoal Pigs of No. 1 Iron, made at the Amenia Furnace.

		Density	Tenacity.
Blast	250º,…………………………	6.948	1,420lbs.
“	200º,…………………………	6.978	12,970 “
“	150º,…………………………	6.967	12,243 ”
“	Cold,…………………………	7.071	14,140 “

Kent Furnace, No. 2 Pigs.

	Density	Tenacity.
Cold-blast,……………………………	7.315	24,349 lbs.

The specific gravity of the different grades of cold-blast charcoal iron *pigs,* usually employed, was determined as follows:

Greenwood Pigs: Foundry Iron.

	Density	Tenacity
No. 1,…………………………………	7.004	14,486 lbs.
No. 2,…………………………………	7153	27,153 "
No. 3,…………………………………	7.245	34,424 "

These figures show the striking difference in the density of different grades of the same pig-iron. At some future time I hope to have the opportunity of presenting a reliable method of determining the grade in disputed cases, partially based on this property. A variation of 2.8 per cent in the density is quite as indicative of change and is far more easily determined than one of 2.8 per cent. in the carbon.

In the Amenia and Greenwood No. 1 pig-irons, the following effect was produced by remelting :

	Fusion.							
	1st.		2d.		3d.		4th.	
	Density.	Tenacity.	Density.	Tenacity.	Density.	Tenacity.	Density.	Tenacity.
Amenia, No. 1……	6.948	11,420	7.172	26,310	7.322	34,728	……	……
Greenwood, No. 1..	7.032	15,129	7.086	21,344	7.198	30,107	7.301	35,786

The transverse strength of bars of No. 1 iron was similarly increased by four remeltings from 5290 to 9448 pounds per square inch. But repeated fusion finally brings the density to a point at which the iron loses strength rapidly. Thus, in the case of Greenwood iron this point was determined as 7.27, and the iron possessed at 7.272 a tenacity of 40,897 pounds per square inch.

Observation of these points and a combination of different grades with each other, or with different fusions, enable the founder to produce cast-iron of any desired density and strength. For instance, at Fort Pitt, the iron had a density of 7.290, and a tenacity of 39,934, and at West Point, a density of 7.260, with a tenacity of 38,093. The pig-irons of course were different.

The first attempts to measure accurately the comparative hardness of metals were those of Major Wade. A blunt pyramid, the sides and opposite angles of the base of which were equal, were used to determine the hardness. The hardness being inversely as the bulk of the indentation, and the indentation made by the whole body of the pyramid being taken as 0, an accurate comparison was instituted between different metals and grades of pig-iron. In Greenwood pig-iron the different, grades showed the following scale of hardness :

Pigs of No.1,..8.48
" " No. 2,..13.86
" " No. 3,..21.40

No. 3 being about 2½ times as hard as No. 1. The extremes of hardness noted were No. 1 pig-iron or soft bronze, with a hardness of 4.57, and hard cast-iron with one of 33.51.

The tenacity, transverse, torsional, and compressive strengths, all vary directly as the density except the tenacity, when the density has passed a given highest point. The range of density in metal available for guns seemed to lie between 7.051 and 7.272, with a respective tenacity of 18,922 and 40,897, though at Fort Pitt, iron of a density of 7.306 possessed a tenacity of 42,425, rising to 44,917 and 45,970 in different parts of the same gun.

The result of all the experiments was, that while some kinds of pig-iron were susceptible of very great improvement by different methods of treatment at the foundry, other kinds were at their maximum strength in the crude pigs. And although, in general, a very close relation existed between the density and tenacity, yet there were exceptions, either when a medium tenacity accompanied a high density, or a low density was coupled with fair strength. In the first case the limit of density had been passed, and in the second an unusual chemical or physical state of the metal existed. But cast-irons of the same density did not possess the same tensile strength, nor was the cause of the limit of density understood. With a view to determining the cause of these obscure relations between the properties of cast-iron, a laboratory was established at Pikesville Arsenal in 1849, in charge of Messrs. Morfit and Booth, under general direction of Captain Walbach. Their chemical work continued, with some interruptions, for nearly six years, covering a field which, though not untrodden, had never been explored with critical accuracy. After making some thousand determinations to compare processes and insure accuracy, Messrs. Morfit and Booth embodied their results in their final report in 1855, which contained the complete analyses of the cast-iron of 32 guns, fully described by Captain Walbach. This report embodied a complete system of iron analysis, perfect for the time, and is still an authority on many elements.

These guns were cast before 1841, at different foundries, of different irons and mixtures. Consequently, any agreement of results is much more worthy of credence than it would be, were the experiments made at a single foundry where an effort was made to insure uniform results. I append a table containing extracts from the analysis of 27 guns, cast between 1827 and 1841, and arranged in the order of their density. The elements mentioned are the only important ones.

Analysis by Booth and Morfit.

Name and Number.	Specific Gravity.	Tensile strength.	Graphite, per cent.	Combined carbon, per ct.	Silicon, per cent.	Sulphur, per cent.	Phosphorus, per cent.	Manganese, per cent.
18 W. P. F.,	7.020	18,758	2.80	0.30	1.17	0.07	1.01	. . .
54 C. F., . .	7.040	18,335	3.20	0.70	1.13	0.01	0.80	1.44
225 F. P. F.,	7.060	13,399	3.25	0.45	0.82	. . .	0.71	1.81
56 C. F., . .	7.080	18,335	3.20	0.80	1.08	0.03	0.75	1.30
364 B. F., . .	7.080	20,874	2.45	0.85	0.65	0.01	0.48	2.97
21 F. P. F.,	7.080	22,425	2.65	. . .	1.02	0.06	0.88	1.30
46 "	7.080	21,579	2.70	0.70	0.98	0.03	0 04	2.17
301 W. P. F.,	7.085	20,875	3.00	1.20	1.79	. . .	0.62	2.24
42 F. P. F.,	7.090	22,425	2.90	0.90	0.90	0.05	1.29	1.81
322 W. P. F.,	7.090	24,823	2.65	1.20	1.74	. . .	0.81	3.54
366 B. F., . .	7.110	20,028	2.80	0.15	0.73	. . .	0.73	2.31
325 W. P. F.,	7.124	19,464	2.80	0.20	2.00	. . .	0.66	5.21
9 F. P. F.,	7.130	22,284	2.30	0.40	1.43	. . .	0.80	2.24
7 "	7.140	23,131	2.40	2.10	0.52	. . .	0.80	1.95
6 C. F., . .	7.150	19,605	2.75	1.35	0.70	Trace.	0.57	2.89
20 F. P. F.,	7.170	26,939	2.15	0.95	1.00	0.03	0.72	2.02
307 W. P. F.,	7.185	25,105	2.40	1.70	0.75	0.01	0.53	2.46
248 C. F., . .	7.190	26,516	2.10	1.40	0.58	. . .	0.80	2.31
344 B. F., . .	7.200	29,619	2.50	1.60	0.52	. . .	0.97	3.77
27 C. F., . .	7.210	31,311	1.45	2.55	0.32	. . .	0.44	2.82
28 " . .	7.220	31,734	2.20	1.70	0.32	. . .	0.43	3.54
119 W. P. F.,	7.220	26,799	2.30	1.95	0.65	0.02	0.51	1.44
12 F. P. F ,	7 220	31,029	1.80	1.50	1.41	. . .	0.48	3.25
131 C. F., . .	7.220	26,657	2.10	2.30	0.67	0.03	0.48	0.72
17 W. P. F.,	7.227	28,631	2.20	2.40	0.72	. . .	0.48	2.31
10 F. P. F.,	7.230	29,196	1.85	1.35	1.43	0.09	0.66	1.52
10 W. P. F.,	7.245	31,734	2.00	2.20	0.77	. . .	0.03	2.10

W. P. F. denotes West Point Foundry; F. P. F. denotes Fort Pitt Foundry; C. F. denotes Columbia Foundry in Georgetown, D. C.; and B. F. denotes Bellona Foundry, near Richmond.

All the samples below a density of 7.124, inclusive of No. 6 C. F., were graded as third class guns of poor metal; Nos. 9 and 7 F. P. F. and 131 C. F. were second class, and all the rest first-class metal. The iron in all approaches comparative uniformity as to general properties, being cold-blast charcoal-iron cast to undergo a certain proof. Let us classify the samples by their speaific gravity into divisions at intervals of a specific gravity of 0.05.

Averages of Preceding Table: Taken in Classes at Intervals of 0.05 *Specific Gravity.*

No.	Specific gravity.	Tensile strength.	Average graphite, per cent.	Average combined carbon, per cent.	Average silicon. per cent.	Average sulphur, per cent.	Average phosphorus, per cent.	Average manganese, per cent.
1	7 030	18,546	3.10	0.50	1.15	. . . .	0.90	. . . .
2	7.080	20,592	2.85	0.87	1.12	. . . .	0.70	2.14
3	7.126	21,227	2.57	0.71	1.17	. . . .	0.75	2.93
4	7.173	24,541	2.35	1.35	0.76	. . . .	0.65	2.42
5	7.215	29,525	2.06	1.93	0.65	. . . .	0.55	2.59
6	7.234	29,854	2.01	1.98	0.97	. . . .	0.39	1.98

We now see two facts clearly proved; first, that the tenacity, and second, that the density of east-iron increase directly as the amount of combined carbon present. The amount of silicon is small, as might be expected from the character of the metal and its mode of manufacture. It is evident from the analyses of the samples with density 7.220, that silicon, in this amount, has small effect on the tenacity. The phosphorus also diminishes, as the tenacity rises, while the manganese remains nearly constant; other things being equal, the less phosphorus the stronger the iron, but here the diminution is too small to affect the qualities of cast-iron in any marked way. Hence it is evident, that the carbon alone causes the change in quality, though, without doubt, the elimination of silicon and phosphorus is an advantage. The total amount of carbon remains nearly constant, but the combined carbon increases fourfold, the graphite diminishing correspondingly and regularly. The use of white grades of iron sufficiently explains the increase of 0.39 per cent, in the total carbon, since these grades contain somewhat more carbon than others.

Messrs. Booth and Morfit are entitled to the credit of first estimating *slag* in cast-iron. Its presence is of scientific interest, but it

May become an important element in reducing tenacity, as is shown by the behaviors of No. 225 F. P. F., which contains 1.15 per cent., and has a tenacity of 13,399, or the lowest on the list. The original silicon of the iron was, doubtless, converted into slag, during the remelting or refining of the iron.

The samples, Nos. 322, 325, 301, and 225, are hot-blast iron, containing, as above, an average of 2.92 per cent, graphite, 0.76 per cent. combined carbon, 1.59 per cent silicon, and 0.49 per cent, slag; their average tensile strength is but 19,640 with a density of 7.065. These facts, and the results of the trials of the guns, were, doubtless, the causes of the prejudice so long prevalent against hot-blast iron, for many purposes. Our earlier furnacemen, however, followed a blind rule of thumb. But now, by using brains, the charge can be so mixed, and the shape of the furnace so controlled, that hot-blast iron can be made identical in composition with cold-blast iron, and superior in the tenacity of the pigs themselves to the excellent cast-iron described above. Commander L. A. Beardslee, of the Washington Navy Yard, states* that tests made under his direction on pigs, produced by the Muirkirk Iron Company, gave the following results:

Muirkirk Furnace Pig.

Grade.	1st Test.	2d Test.	3d Test.	4th Test.	5th Test.	6th Test.	Average.
No. 2, . .	20,817	22,178	21,113	22,297	. . . .	. . . .	21,601
" 3, . .	22,454	25,493	22,316	25,572	. . . .	. . . .	23,959
" 4, . .	47,756	40,193	42,166	40,311	39,712	37,840	41,329

The density of No. 4 iron was, in sample 1, 7 3251, and in sample 2, 7.3467.

The test-bars were turned direct from the pigs. The iron was made with hot-blast and charcoal out of the Tertiary carbonate ores, on the western shore of Maryland.

This iron is fully equal to the Kent and Greenwood cold-blast irons described above, and I believe that a tenacity of 47,756 is the highest ever recorded of pig or cast-iron. The grades are peculiar, No. 4 being close-grained, light gray iron, not mottled, and with a slight white rim on the outside.

The preceding facts have shown the great influence of carbon in

* Bull. Am. I. and S. Assoc., 1875, p. 205.

modifying the physical properties of pig-iron. But a still more re-markable proof of the influence of carbon is given by the effects of its combinations in steel. I append an original table of the classification used for Bessemer steel at Neuberg, in Styria. The scale of grades was established by Prof. Tunner, on the basis of the Swedish; but he added, for greater accuracy, two subgrades to each number. In the last two columns I add the carbon percentage and specific gravities of the grades, into which Bessemer steel made at Turrach, in Carinthia, is divided.*

Classification of Bessemer Steel.

No.	Grade.	Per cent. Carbon.	Tenacity, lb. per sq. inch.	Tenacity of grade.	Carbon, by S. A. Ford.		Turrach Steel. Buchan.	
					Eggertz.	Ammoni'm, Double Chloride.	Sp. Gr.	Carbon. Per cent.
18	7 soft.	0.05	57,500	57,500	0.14			
17	7	.12	62,000	to	.16	. . . . . .	7.8718	0.11
16	7 hard.	.16	65,500	69,000	.19			
15	6 soft.	.22	69,000	69,000	.31			
14	6	.28	73,500	to	.17	. . . . . .	7.8358	0.53
13	6 hard	.36	78,000	80,000	.35			
12	5 soft.	.42	82.500	80,000	.32			
11	5	.50	92,000	to	.42	. . . . . .	7.8562	0.72
10	5 hard.	.58	100,000	103,000	.47			
9	4 soft.	.67	105,500	103,000				
8	4	.75	113,500	to	.56	. . . . . .	7.8476	0.85
7	4 hard.	.83	123,000	126,000				
6	3 soft.	.92	131,000	126,000				
5	3	1.00	137,500	to	8.12	0.82	7 8279	1.15
4	3 hard.	1.08	147,000	149,000				
3	2 soft.	1.17	155,000					
2	2	1.25	not de-		1.20	1.24	7.7913	1.35
1	1	1.50	term'd					

It seems to me that Buchan's determinations of sp. gr. are not entirely accurate; they were made on rolled bars. The Neuberg scale was, of course, fixed on rolled steel.

Here, in seven grades, we have eighteen varieties. But it is said that such an enormous number is of no use, and again that, even if advisable to sort so accurately, the character of the different grades would vary so little that they would not be easy to distinguish by practical tests.

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* Max Bachner. Erg- u. Hüttenmännische Zeitung.

Now, supposing you were a cast-steel maker, and got an order (an ordinary one) for a "bar of steel;" you heard, on inquiry, it was "for a railroad," but nothing more. On sending the bar you heard it did not do as well as it ought. I am telling you what has actually taken place. By this education one soon learns that a "bar of steel" is an expression no more definite than the "size of a piece of chalk." A railroad, for instance, uses crowbars, spiking hammers, tires, tap and die steel, machinery steel and tool steel, say seven kinds of steel in ordinary use in the shops, and an eighth as rails in the track. Each one of these kinds is unfit for the purposes to which the others are applied, and the harder kinds would be injured by the treatment to which the softer ones are subjected.

This injury is a matter of ordinary occurrence and of great loss and annoyance. But so long as the cast-steel maker divides his steel *by name* only into ungraded classes, the smith will be at liberty to experiment, and will certainly not have the opportunity of deciding exactly what steel he wants. I believe, from experience, that cast-steel graded by names varies far more than the makers believe, and I think it correct to assert that there is money, safety, and reputation for cast-steel makers in the Eggertz test. This test is most thoroughly applied in Bessemer works, and by recent improvements in apparatus it is easy to make 150 tests a day.

The chemical test is a decisive one of course, but a good smith can readily learn to sort steel even into these eighteen grades. He has strength, hardness (both natural and produced by hardening) and temper to judge by, three qualities which vary greatly in the different grades of steel. That a smith does readily learn I shall show you in two ways. At Neuberg, in 1866, a smith, who had been working on carriages for field guns, was selected to test the steel in regular course of manufacture, and at that time no Eggertz test was used, except in special instances. I got from the smith a series of bars representing all grades soft and all grades hardened. I have had the carbon estimated in the soft bars by Mr. S. Alfred Ford, with the results appearing in the sixth and seventh columns of the table Now these bars were graded at the anvil from a lot of small bars an inch square, previously drawn out in a merchant train from small test ingots. You see he has erred seriously only in Nos. 14 and 15, and this may be a transposition when he numbered his bars, and has graded the rest, at least, in the proper order. No especial care was observed by the smith, it being a matter of ordinary grading. But

I can also show you how the strength of the bars graded by the same smith in regular work agreed with the limits previously fixed.

Mechanical Tests of Neuberg Steel.

No.	Grade given by smith.	Tenacity, lbs. per square inch.	Extension, per cent.	Tenacity of subgrade previously determined.	Tenacity of grade.
18	7 soft.	62,669	29.7	57,500	57,500 to 69,000
		61,292	30.0		
17	7	59,111	30.0	62,000	
		64,162	29.4		
		64,276	29.0		
		59,915	30.5		
16	7 hard.	69,442	27 0	65,500	
		64,619	29.4		
		64,162	31.4		
		64 850	30.8		
		67,719	28.0		
15	6 soft.	63,817	31.0	69,000	69,000 to 80,000
		64,619	35 6		
		71,852	28.0		
		64,390	20 0		
		74,147	23.8		
14	6	64,276	29 8	73.500	
		69,556	23 7		
		75,525	24 0		
		66,572	24.5		
		78,500	26.0		
		80,920	26.7		
		79,372	21.8		
		80,920	26.7		
13	6 hard.	69,097	25.5	78,000	
		74,607	26.5		
		88,036	24.5		
		77,132	25.7		
		85,740	16.8		
		74,607	23 0		
		88,839	19.0		
12	5 soft.	78,509	24.5	82,500	80,000 to 100,000
		85,261	24 0		
		90,676	21.2		
11	5	75,869	20.0	92,000	
		92,627	23.2		
		99,399	15.0		
8	4	99,514	4.0	113,500	
2	2	130,963	3.0	. . . . .	

You see from these tests that the smith usually kept within the limits of the subgrade and did not go outside the number, except in two cases, in subgrade 13. In the harder numbers, seldom made, you see the grading is almost equally reliable. All these experiments were made without reference to the smith, and, so far as I know, he was never made acquainted with the results. The fact that a man can distinguish and sort steel so closely at his anvil, shows that the characteristics exhibited by the various grades are actual and tangible. This being so, the fact that the above statements are exact, is sufficient to show the great importance of accurate knowledge of this kind, both to maker and user.

It is most strange that this knowledge is so little disseminated in this country. From what I have heard in public from intelligent steelmakers, one, not knowing otherwise, might suppose such knowledge did not exist at all. Bat it does exist in rich store, wrought out in detail with care. I can assure all parties that by securing the services of a competent chemist familiar with the subject, and then experimenting on a definite basis, they can, in a short time, refer to these details of their business with greater certainty than they now refer to their books.

The Neuberg steel is of a very high grade, and the then small product was mostly worked into tires and boiler plate. The latter has been exclusively used by Haswell, of Vienna, for his locomotives, boilers and all, for many years. The tests show great regularity in the steel, since they agree well in their grades, though made somewhat at random as to date. But I believe our Bessemer works i?- ?lls country now turn out a product much more regular than the one we have been discussing. The steel commonly used in this country would come under the subgrades 13, 12, and 11, being usually made between 0.36 and 0.45 per cent, of carbon. In regular work with us, there is no need of varying more than 0.05 per cent. carbon, even when blowing by the eye. I have kept the averages for weeks between 0.39 and 0.42 per cent., without trouble. I may be allowed to state here, that so far as my experience goes, I believe Bessemer steel as now made, is the most regular product in the whole metallurgy of iron. I have, for instance, examined good iron merchant bars and rails by the Eggertz process, and find the variation in the same lot is often 0.25 per cent. carbon, and the parts richest in carbon are often distributed, at intervals, through the bars.

Seeing, then, that carbon is such an important element in iron, it is needless to say that the history of its determination has been a most interesting one. It began practically with Berkelium, who laid a wonderfully good foundation in this matter, as he did in so many others in chemistry. But Karsten was the first to apply the processes, suggested previous to his time, systematically to the analysis of iron, discovering, among other things, the true nature of graphite.

He did wonderful work with a process (*chloride of silver)* that required ten to twenty days for a single estimation. Imagine, if you please, the despair of a modern chemist under such circumstances at a works temporarily making bad steel!

In this case before us, hydrogen and oxygen are Scylla and Charybdis for the carbon. If acids, acting by substitution, are used, the hydrogen evolved carries off carbon as a volatile oil or as gas, while if oxidizing acids are used, the carbon is oxidized as completely as the iron. To avoid these fatalities Berzelius originated the chloride of silver process, in which a lump of iron, laid on a lump of fused chloride of silver, reduces the silver, and a mass of carbon, silica, etc., is left on the partly reduced silver chloride. The contact of air was injurious, and the operation required ten to twenty days. It was, however, the best process in his time and long afterward. He also recommended chloride of copper, which attacked energetically, but deposited copper, and had a tendency to form a difficultly soluble subsalt. To avoid this difficulty, Fuchs proposed the use of perchloride of iron, which leaves an iron subsalt easily handled. Berzelius tried dry and pure chlorine gas, which forms a volatile chloride, which can be separated from the carbon by sublimation; he used also bromine instead of chlorine. Berzelius further recommended the combustion of carburetted iron, heated to redness, in **a** current of oxygen, and also a fifth method, based on slowly dissolving the iron by a dilute solution of absolutely pure nitric acid; also the use of sulphate of copper with common salt.

Berthier determined that the dilute nitric acid process was entirely unreliable, owing to the partial conversion of the carbon into humus He found that the methods based on determining the carbonic acid resulting from the carbon, viz.: (a) by fusion with saltpetre; (b) by burning in oxygen; (c) and by heating with metallic oxides (as litharge, oxides of quicksilver, and copper) were all unreliable, since they required the iron to be *powdered,* thus affording both an irregular average and a mass difficult to act upon. A method based on the use of a solution of chloride of lime as a solvent was condemned by the strong evolution of hydrogen, though it was somewhat rapid. Berthier found the chlorine process open to loss by the presence either of air or moisture, and protested against the use of chloride of ammonium as a solvent, because it evolved hydrogen and acted slowly. Berthier considered the chloride of silver process inaccurate in presence of much silicon in the iron, since silicon, during its oxidation, frees hydrogen. He proposed the use of bromine and iodine in water, but found the results uncertain in presence of much silicon, though very convenient. Berthier gave, as the best process known to him, one based on the slow oxidizing action of air. Fincly powdered iron was well wet in a porcelain mortar and exposed to the air, being thoroughly stirred daily, the oxides and carbon being then poured off and collected. By adding salt the operation could be completed in 8 or 10 days. The iron oxide was then dissolved, and the residue weighed and burnt off, the carbon being determined by the loss.

Regnault* originated the use of chromate of lead (80 grammes) and chlorate of potash (5 grammes) in a combustion tube. He depended on the chromate to oxidize the iron (5 grammes), using the chlorate in a separate part of the tube to evolve a large excess of oxygen to complete the operation.

Karsten found Regnault's process reliable for total carbon, but preferred the chloride of silver process, by which all his determinations were made, and which, as he himself afterwards said, have been confirmed by later analysis. Karsten found the chlorine process liable to great error from the tendency of the chloride to condense and fill the tube. He experimented with corrosive sublimate as a solvent, but found its action slow, and the formation of calomel embarrassing. He found Berzelius's chloride of copper method the best of all similar methods, but inaccurate when the solution was heated above 5° to 8° Reaumur, but stated that at that temperature the loss of carbon by evolution of hydrogen was inconsiderable. After the complete solution of the iron the precipitated copper was redissolved with muriatic acid. Karsten, as you know, discovered that graphite was pure carbon, and not, as previously supposed, a compound of carbon and hydrogen. Influenced by this new idea, he condemned all processes for total carbon which operated in a watery solution, because, in his opinion, the carbon liberated was a compound with hydrogen and not pure. Graphite, he determined, by dissolving in *aqua regia*, and treating the insoluble residue with a strong caustic potash solution.

Karsten† remarks that none of these processes are absolutely accurate, because the changes which the carbon undergoes on liberation are unknown, and thus one cannot select that method as the most accurate, which yields most carbon, since no method defined the state of combination of carbon and iron.

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* Ann. d. Chem. u. Pharm., xxx, p. 352.

† Eisenbüttenkunde, I, p. 395.

On comparing* the accuracy of the respective methods he found, in a Spiegel iron from Sagnerhütte:

1. Oxide of copper combustion,	4.2855	per cent. combined carbon.
2. Regnault's method,	5.7016	" " "
3. Chloride of copper,	5.6250	" " "
4. Perchloride of iron,	5.3549	" " "
5. Chloride of silver,	5.6645	" " "

He did not agree with Berthier in finding fault with the chloride of silver process.

Wöhler† modified Berzelius's chlorine process by using a boat in which the iron is placed, and, after thorough decomposition by chlorine the boat is transferred to another tube when the residue is burnt in a current of oxygen.

Bromeis‡ modified Regnault's method by mixing the iron with equal parts of chromate of lead and chlorate of potash, thus insuring thorough action. But on the other hand this modification was thought by Erdmann and Marchand§ to be open to the objection of developing free chlorine at the high temperature of combustion, while Marignac observed that oxygen derived from chlorate of potash is not free from chlorine.

Mulder|| found that the mixture of chromate of lead and chlorate of potash, as advised by Renault, would not develop the least chlorine, but that chlorine *is* disengaged as soon as the chlorate of potash predominates over the chromate of lead. He found chromate of lead alone insufficient to burn off the graphite, nor would oxide of copper do so without the aid of a current of oxygen. Mulder preferred direct combustion in the oxygen current. He found in cast-iron:

1. Direct combustion in oxygen,	5.3 to 5.13	per cent. total carbon.
2. Regnault's method,	3.77	" " "

Booth and Morfit¶ disapprove of Regnault's (Bromeis's) process with fused chromate of lead and chlorate of potash, as somewhat doubtful, and requiring *pulverization,* an operation they regard as destructive to the accuracy of the sample. They found the chloride of silver process highly accurate, but so slow as to require 10 to 20 days to dissolve 5 grammes, and liable to be greatly retarded by the

* Archiv. f. Min., Geog., Bergb. u. Hüttenkunde, xxi, p. 500.
† Chem. News, 1867, p. 94. ‡ Ann. d. Chem. u. Pharm., xliii, p. 241.
§ Journal fur praktische Chemie, xxxi, p. 275. || Chem. News, 1862, p. 5.
¶ Experiments on Metals for Cannon, pp. 400-404.

formation of a hydrated peroxide on the entrance of air into the digesting vessel. They considered the chloride of copper method objectionable on account of the loss of carbon as a carbo-hydrogen gas. After repeated trials they found that the use of iodine (5 grammes to 1 gramme of iron) with little water *in the cold* was the most accurate and expeditious process at their command. The residue was washed and weighed on a counterpoised filter with subsequent ignition to determine impurities. Great precaution is requisite to temper the action of the iodine; if a sand-bath heat were used the carbon found would be 20 to 60 per cent, too low. The process, too, required at least a clay.

Binks* originated the idea of removing the hydrogen altogether from the metal by dissolving in dilute *pure* hydrochloric acid, by electrolysis, in a single voltaic arrangement with platinum. Practically, however, some evolution of hydrogen sakes place on the metal. Weyl† used this method and specified the precaution of using a weak current. He stated that in this way 5 to 6 grammes of iron could be dissolved *in a few hours*, the carbon retaining the original form of the iron.

Richter, ‡ of Leoben, preferred the chloride of copper process, and found that the difficulty caused by the re-solution of the precipitated copper and subsalt could be largely avoided by using either salt or chloride of potassium, in connection with chloride of copper. This addition greatly facilitated solution.

Ullgren discovered the fact that the carbon obtained by sulphate of copper could be readily burnt off without heat in strong sulphuric acid, to which *chromic acid* was gradually added, the carbonic acid being absorbed by potash in the usual way. He found it increased the accuracy of the determination to avoid handling the carbon, and washed by decantation, removing the whole precipitate; with very little water, direct into a flask.

With the work of our ordnance Corps as a basis, the British Government instituted experiments the reference to the manufacture of cast-iron ordnance. Mr. Abel§ made an exhaustive report on the subject. Greatly to my surprise I found he had chosen an *acid solution of chloride of copper* as solvent, burning the residue

* Society of Arts, 1857. Chemical News, 1862, p. 252.
† Zeitschrift d. V. Deutseher Ingenieure, 1861, p. 224.
‡ Leoben. Jahrbuch.
§ Cast-iron Experiments, 1858.

With oxide of copper in a current of oxygen. He thus needlessly intensified the inaccuracy of the process.

The experiments developed the interesting fact that, while the average of attainable metal was of too low grade for ordnance, the limits of English iron were as follows:

Cast-iron.	Specific Gravity.	Tenacity.
From sandy brown hematites and coke (Minimum), ...	6.886	4.85 tons.
From hematites, or argillaceous carbo. nates, with cold blast (minimum),	7.289	14.05 "

Buckner* states that he found that *with care* Berzelius's chloride of copper method, Weyl's (Binks's) by electrolysis, and Wöhler's with chlorine and oxygen gave quite concordant results. But he does not deny Hahn's statement that, even with neutral chloride of copper, an evolution of hydrogen, containing carburetted compounds, takes place. He finds the error due to this cause small, when *absolutely neutral chloride of copper* is employed, and found, in a spiegel-iron, by the chloride of copper process, only 0.04 per cent, less carbon than the amount given by Wöhler's process.

Kerl states† that, in the laboratory at Clausthal, Wöhler's process was found both the most convenient and the quickest.

Fresenius‡ suggested a method of determining carbon by solution in dilute sulphuric acid, passing the resulting gases over red-hot oxide of copper, collecting the insoluble residue and burning it off in oxygen, adding the weights of the two portions of carbonic acid to obtain the total. This is a double process when a single one should suffice, and it is inapplicable to iron containing much carbon.

Schnitzler§ estimated carbon in the same *steel,* by Weyl's (Binks's), Berzelius's chloride of copper, and Fresenius's method with the following results. He found the first method too low, through evolution of hydrogen:

1. Weyl's (Binks's) method, ...	0.75
2. " " "	0.74
3. " " "	0.68
4. Berzelius's chloride of copper method, ...	0.93
5. " " " "	0.96
6. Fresenius's method, ...	0.92
7. " "	0.92

* Berg. u. Hüttenmann. Zeitung, 24, p. 84. † Ibid., p. 85.
‡ Zeitsehrift Analytische Chem. IV, p. 69. § Ibid., p. 78.

Tosh* compared the accuracy of different methods in Wöhler's laboratory. He confirmed Booth and Morfit's opinion of Regnault's (Bromeis's) process with fused chiorate, and stated Fresenius's process was defective in requiring complicated apparatus, unusually great care and too much time. Proving Weyl's (Binks's) process inaccurate, through evolution of hydrogen, he selected Wöhler's process as the best, because, while affording results of equal reliability with any, it required much less time. In the same sample of cast-iron Tosh found;

1. Regnault's (Bromeis) method,	3.886	"	"
2. " " "	3.996	"	"
3. Weyl's (Binks's) method,	4.235	"	"
4. " " "	4.086	"	"
5. Fresenius's method,	4.244	"	"
6. " "	4.166	"	"
7. Wöhler's "	4.348	"	"
8. " "	4.367	"	"
9. " "	4.327	"	"

Eggertz† ascertained that the residue left, by the action of iodine, on cast-iron and steel, consisted mainly of silica and a compound of carbon, iodine, and water, unaltered by heat, under 110° Centigrade. After deducting silica, the compound was found to have a uniform composition, containing, on an average, 60 per cent, carbon. Booth and Morfit's process is followed, but the 60 per cent of the loss on ignition, instead of the whole, is reckoned as carbon. An estimation required 1½ days.

But, though we have in our list the names of many distinguished chemists, it is clear that, notwithstanding the labor expended on the subject, no reliable process has been developed entirely convenient and quick enough for practical use. The chloride of silver process is far too slow, the iodine slow, and does not permit the use of large amounts of the iron, and Wöhler's chlorine process highly disagreeable to execute.

There are two necessities in a steel-works laboratory; first, entire accuracy; and second, great speed of processes.

As to accuracy, it may, in one sense, be said to be a comparatively small matter in 4 per cent., to be, 0.1, in error; but, when one must work between the narrow limits of 0.30 and 0.50 per cent., even 0.02

* Chem. News, 1867, pp. 67, 94, 169.

† Percy, Iron and Steel, p. 891. Translated by Sandberg.

per cent becomes a considerable error. We have seen there is no substantial agreement among our authorities as to the best process, and that 0.04 per cent is an ordinary variation for the same sample by the same process. The fact that the processes reputed best varied, on the same sample, 0.5 to 0.6 per cent. among each other in less than 5 per cent., does not present such an agreement as to induce confidence.

The carbon, in standard steel I had in use, had been determined by Regnault's (Bromeis's) process, of which I was not perfectly sure, and I felt it necessary to have the carbon determined by a process giving results varying less than 0.02 per cent. With this view I suggested to Mr. Andrew S. McCreath, then chemist of the Pennsylvania Steel Works, whose business I managed, that he should try the most favorable of the above processes as he found leisure, and select the most accurate one. I also suggested that the use of a double chloride of ammonium and copper would probably be best adapted to our wants, both as to accuracy and facility.

In the course of a year or more, Mr. McCreath made 36 determinations of carbon, in the same sample of steel, by seven different processes, each being on a redetermination modified to avoid objections.

Regnault's (Bromeis's) Process.

Fused chromate of lead and fused chlorate of potash.
Determination made at a *high heat:*

1. Per cent carbon, ... 0.567
2. " " 0.600

Determination made at a *medium heat:*

3. Per cent, carbon, ... 0.524
4. " " 0.520
5. " " 0.524

Determination made at a medium heat, and nitrate of silver interposed on pumice, before potash bulbs, to retain chloride:

6. Per cent. carbon, ... 0.534

Wöhler's Process.

Determination by chlorine and combustion in oxygen:

7. Per cent carbon, ... 0.567

Iodine Process.

Eggertz's modification. Sixty per cent of carbon residue taken as carbon:

8. Per cent, carbon, ... 0.468
9. " " 0.468
10. " " 0.468

Combustion of *residue* in *oxygen:*

11. Per cent, carbon, ... 0.532

Combustion of *residue* in *chromic acid* (Ullgren):

12. Per cent carbon, ... 0 513
13. " " 0.508

Combustion of residue in *oxygen,* but *sulphuric acid interposed* before potash bulbs:

14. Per cent, carbon 0.508

Sulphate of Copper Process.

With chloride of copper, and muriatic acid to assist in re-solution of copper. Ullgren's combustion of residue in *chromic acid,* but with soda-lime to absorb carbonic acid:

15. Per cent carbon, ... 0 080

Combustion in *chromic acid,* but *potash* bulbs used as usual:

16. Per cent carbon 0.373
17. " " 1.316
18. " " 0.368
19. " " 0.376

Combustion of residue in *oxygen:*

20. Per cent, carbon, ... 0.414

Chloride of Copper Process.

With addition of *salt* and use of counterpoised filters for ascertaining weight direct:

21. Per cent, carbon, ... 0.520

With *hydrochloric acid,* to redissolve copper in ordinary way:

22 Per cent carbon, ... 0.430

Combustion of residue in *chromic acid,* but with chloride of calcium tube, instead of sulphuric acid wash-bottle:

23. Per cent. carbon, ... 0.472
24. " " 0.442

Absolutely Neutral Chloride of Copper.

Muriatic acid, used carefully, after solution of iron:

25. Per cent, carbon, ... 0.496

Double Chloride of Copper and Potassium.

This was rather a mixture of the two salts than a double chloride, as the two salts seemed to have little tendency to form a double salt. Requires acid to redissolve copper.

Combustion of residue in *chromic acid,* but *soda-lime* used as absorbent:

26. Per cent carbon 0.401

Combustion in *chromic acid,* but *potash* as absorbent as usual:

27. Per cent carbon, ... 0.510
28. " " 0.519

Combustion of residue in *oxygen:*

29. Per cent carbon, ... 0.494
30. " " 0.504
31. " " 0.502

Double Chloride of Copper and Ammonium.

There is no trouble in forming a perfect double salt, *neutral* on recrystallization. *No acid required* to redissolve copper. Combustion in *chromic acid:*

32. Per cent carbon 0.490
33. " " 0.502

Residue weighed on *counterpoised filters :*

3i. Per cent carbon, ... 0.500
35. " " 0.510

It is evident that Regnault's method gives discordant results, as do also Wöhler's, Ullgren's, Eggertz's, and the chloride of copper process, as ordinarily used. It is also clear that *soda-lime* is a very defective absorbent. On comparing the other reliable results we have

			Per Cent. Carbon.
No.	12.	Iodine,	0.513
"	13.	"	0.508
"	14.	"	0.508
"	25.	Absolutely neutral chloride of copper,	0.496
"	27.	Double salt (?) copper and potassium,	0.510
"	28	" " "	0.519
"	28.	" " "	0.494
"	30.	" " "	0.504
"	31.	" " "	0.502
"	32.	Double chloride ammonium and copper.,	0.490
"	33.	" " "	0.502
"	34.	" " "	0.500
"	35.	" " "	0.510

You see the average of the absolutely neutral chloride of copper solution with combustion in chromic acid is 0.496 per cent.; the average result of the ammonium double chloride is 0.500 per cent.; that of the chloride of copper and chloride of potassium is 0.50C per cent.; while the average of the iodine determinations with combustion in chromic acid and one in oxygen is 0.509 per cent of carbon.

As to *accuracy,* the ammonium double chloride and the potassium salt are nearest the general average, and of the two the double chloride of copper and ammonium exhibits the least variation.

As to *speed* and *facility,* however, the results arc decisively in favor of the ammonium double chloride method.

A determination by Regnault's process takes at least two hours.

Solution in iodine and combustion in oxygen takes six hours, as it is necessary to dry the residue on asbestos, before burning off. Combustion in chromic acid shortens the process to about four hours. This is with a small amount of metal, say 1 gramme; if 5 grammes were to be used, the solution would require at least three hours.

Solution in chloride of copper is tedious, must be made in the cold, and the action of muriatic acid on the precipitated copper is slow, as strong acid or warmth would cause loss of carbon. The sulphate of copper method is also tedious. Either of these methods requires five to six hours under the most favorable circumstances.

With the mixture of potassium chloride, with chloride of copper, action is not very rapid, and a slight precipitation of copper takes place, so that acid is required for its re-solution. A solution requires two hours.

With the ammonium double chloride, the action is extremely rapid; 3 to 5 grammes of metal are completely dissolved in the cold in ten to fifteen minutes. Heat does no harm. The solution is so neutral that on heating, a slight precipitation of peroxide of iron takes place, which is taken up by a drop or two of muriatic acid. In twenty-five minutes the carbon is filtered and ready for combustion in chromic acid, which can be completed in three-quarters of an hour. By using counterpoised filters, three to four determinations can be made in 1½ hours, since they can be made together; while a chromic acid combustion requires closer attention. Where little silicon is present, as in Bessemer steel, the counterpoised filters answer admirably; when more silicon is present, the chromic acid determination is preferable. When the ammonium double chloride is used in excess, 520 grains double salt to 75 grains metal, the

Process leaves nothing to be desired for entire accuracy, easy working, and rapidity, and I am happy to say that, in my opinion, the long struggle over accurate determination of combined carbon in iron is thus brought to an end.

The carbon, in the sample treated above by Mr. McCreath, was also determined by the following analysts:

Prof. Oscar D. Allen, by the chloride of copper method, with combustion in oxygen:

1.	per cent.	Carbon,…………………..0.43
2.	”	”………………………….0.45
3.	“	“………………………….0.45

Dr. T. M. Drown, by the chloride of copper method and combustion in oxygen:

Per cent. Carbond,……………………………………0.470

Messrs. Booth and Garrett, by Regnault's process:

Per Cent. Carbon,…………………………………….0.513

These results show that the chloride of copper process gives uncertain determinations, and corroborate Mr. McCreath's work. The extreme difficulty of procuring neutral chloride of copper is a decisive objection to its use.

I have requested Mr. McCreath, now chemist to the Second Geological Survey of Pennsylvania, to write out a detailed description of the precautions used to insure accuracy, and of the double chloride of copper and ammonium process.

BLAST-FURNACE HEARTES AND IN-WALLS.

BY E. C. PECHIN, DUNBAR, FAYETTE COUNTY, PA.

AT the September meeting of the Iron and Steel Institute of Great Britain, Mr. Charles Wood, of the Tees Iron-works, read an interesting paper on "Further Improvements in Blast-Furnace Hearths," which was followed by an animated and instructive discussion.

If the durability of hearths and in-walls is a matter of interest in England, where furnaces stay in blast from eight to twenty years, it

Certainly becomes us, in this country, where furnaces are blowing out every few years for repairs, to ascertain, if possible, the cause of such rapid deterioration, and whether it cannot be avoided.

As Mr. Bell, in the discussion above referred to, observes, the difficulty lies in comparing the durability of a blast-furnace in one district, with one even of the same construction in another district. Here, where we have every variety of fuels and ores, compelling modification in both furnace construction and the working of them, it is almost hazardous for one to express an opinion outside of his own particular district.

The subject, however, is an interesting one, and its introduction may result in discussion and further consideration, which may prove of general value. In this paper, the writer only proposes to give his own experience, making a few observations generally applicable, excepting in those cases where, owing to certain peculiarities in the materials used, special considerations must apply.

The two particularly v???able points in the interior of a furnace, are, first, immediately "under the tunnel-head, where the constant abrasion of the stock wears away the brick, and second, the crucible, where the intense heat tends to destroy both the floor of the hearth, and the hearth and bosh walls. The former is not of much moment, as the upper half of the furnace walls can be readily rebuilt, by a stoppage of a few days, and the simple precaution, adopted in the Lehigh Valley, and probably elsewhere, of inserting east angle-iron between the layers of brick, which receive the shock of the falling stock, will render this portion of the in-wall as durable as any other part of the furnace. The destruction of the hearth (and by this term is included, for present purposes, the floor and the side walls above the zone of fusion) is a far more serious matter, for when a certain point is reached, the furnace must be blown out.

Mr. Wood, in his paper, exhibited a diagram of a Cleveland furnace after it had been at work eight years. He stated that he had proof, however, that it had attained its then dimensions, after it had been blowing between five and six years.

" The original diameter of the well or crucible was nine foot, while the thickness of the walls was five feet, making the outside diameter Of the well nineteen feet ....the walls or brickwork are reduced to about two feet six inches in thickness, and in places where the brickwork was very liable to get very hot from contact or from non-radiation, it is thinner than this, particularly close to the hearth line, where the thickness is reduced to about eighteen inches. The original well had, therefore, extended from nine to sixteen feet in diameter. Nor was this a solitary case. In eight furnaces which had blown out at the Tees Iron-works, although of very different dimensions, the walls and hearths were found to be in a similar condition." He goes on to state, what every furnace-man will appreciate: " When the furnace linings are burned out to dimensions approaching these, they are best blown out. It is utterly impossible to regulate the quality of the iron, and the blast cannot be either directed or concentrated, which is so necessary to proper fusion. One day it will be found that the furnace is working hot on one side, or that the slag will quickly turn black, or is difficult to run, or the furnace will scaffold, and large lumps will come down, and these lumps being difficult to fuse, will lie for hours in front of the tuyeres, turning the current of the blast in another direction .... Now these are conditions rarely found or combined in a new furnace, where the hearth and well-walls will be in proper shape, but common enough when they are burned out."

Mr. Wood then criticizes various points of practice, proposes a peculiar arrangement of his own, operating as a closed front, and avoiding the dangerous (as he considers them) points in Lürmann's front, and concludes as follows: " With tuyeres equally divided round the furnace, a closed front, boshes and crucible walls protected from the heat, and with a good hearth bottom, we may hope to insure, not only regularity in the quantity and quality of the iron, but also durability of the furnace, combined with economy in working."

In the discussion following, Mr. Thompson, of the Clarence Works, condemned the Lürmann front, and believed it a good plan to have a road into the furnace, after standing two or three days. Mr. Williams, of Middlesborough, was going to thicken his walls instead of thinning them, as Mr. Wood proposed; and as to the wearing away of the crucible walls, and its size increasing, he believed that the remedy was in pushing the tuyeres further in.

Mr. Lowthian Bell considered that it was a matter of very great importance that they should preserve, as far as possible, the shape of a blast-furnace, and that, although heat would undoubtedly be lost from the use of thin walls and water-jackets, yet they must choose the lesser of two evils. Mr. Snelus and Mr. William Whitwell strongly indorsed the Lürmann closed front.

Thus, it will be seen, how varied are the experiences and opinions of men regarded among the foremost in their profession, and many of them working under similar conditions. With this introduction, your kind attention is asked to a brief statement of the workings of the furnace which, for several years past, has been under the writer's management at Dunbar, Pa.

The materials used have been of a uniform character. The large proportion of the burden is of native ores, mixed with mill cinder and Lake Superior ore. These native ores are very silicious, containing from 11 to 16 per cent of silica, requiring the use of a large amount of limestone, about 1 4/10 tons to the iron of iron. The furnace is 15 feet 6 inches in the bosh, and 58 feet high. When blown in, the diameter of the hearth was 5 feet 10 inches, and the extreme width of the bosh is reached at a distance of 28 feet from the floor. It was blown-in October, 1870, and has been running continuously since, producing over 52,000 tons. The average richness of the ores charged is about 50 per cent., and the product for the last twelve months has been over 13,000 tons, of which 94 per cent was foundry and No. 1 mill iron.

Attention is simply drawn to these details, as evidence that the hearth and in-walls must have been in good condition, and have been free from any very great enlargement, or irregularity in shape, otherwise these favorable results would not have been obtained.

The floor of the hearth is of blocks from the Mahoning sandstone, which caps the neighboring hills, and has been in use for eight years, in the present and the preceding blast. The walls of the crucible, for 10 feet up, are of Mount Savage brick of the ordinary size, and the balance of the in-walls are of the common hard 9-ineh brick, made at New Cumberland, on the Ohio River. There is not a shaped brick in the furnace, and the boshes and in-walls are carried up continuously from the floor of the hearth.

Various inquiries have been made, from time to time, regarding the use of the 9-inch brick for in-walls. With our present experience, we would continue using them. Their use is quite common in Pittsbugh, and with satisfactory results.

A more uniform degree of hardness can be had in these small brick. In large lumps or shaped brick, oftentimes it will be found that although the outside is well-burnt and hard, the inside is soft and friable. By laying the small brick as headers and stretchers in alternate courses, the whole mass is thoroughly tied together. The objection has been urged, that, if cutting began, the small brick would rapidly give away; this, however, does not appear to be the case, but the surface of the bricks wears off uniformly. Apart from the low cost of this class of brick, much more rapid work can be made in laying them--there is no assorting of different sizes and shapes, and after the crucible is in, and the tuyere arches in, any intelligent laborer can lay the brick quite as fast, and as well, as a skilled bricklayer, the principal point being to get them close together, and as firmly bedded as possible.*

A very grave mistake is frequently made in the use of fire-clay. The writer knows of a large, fine furnace, whose in-walls tumbled in a mass, a short time after blowing-in, simply by reason of the contraction of the fire-clay mortar used in excessive quantities between the bricks. He knows of another, now building, where he anticipates the same result from a similar cause.

This mistake is made by one man, so experienced, that he cannot be wrong, or by another, so fresh, that he thinks he can do with impunity what other people cannot, but the result in either case is equally disastrous to the owners. The thinnest possible film of well-boiled fire-clay that will set the brick is all that is needed, and in proportion as this is attended to will be the excellence of the work. Another most material point is to have the furnace thoroughly dried but before blowing-in, and too much care cannot be exercised in this direction.

The interior lines of a furnace would seem to have a vast deal to do with the durability of in-walls. Common sense and good practice teaches that the lines should admit of the easy and regular descent of the stock, so that the ascending gases perform their duty with uniformity and precision.

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* Since the above was written the furnace has been blown out for enlargement, after a blast of five years and six and a half months, during which time she has made over 65,000 net tons of iron, as follows: 6 per cent. No. 1 foundry; 7 per cent. No. 2 foundry; 79 per cent. No. 1 gray forge ; 4 per cent. No 2 gray forge; 2 per cent mottled, and 2 per cent, white iron.

It is much enlarged in the bosh, say for eight feet above the tuyeres. Over the front tuyere, a groove had been cut out of the wall, completely back to the backing, some six feet wide running to the top. On the edges of this gap the walls bent outwardly, leaving as much as a foot between the wall and the backing. The remainder of the in-wall is practically as good as the day it was put in, and so tightly bound together that every attempt to throw it down in sections has failed, notwithstanding heavy wedges were used to try to force them out, commencing at the loose ends, and the walls have to be taken down layer by layer, from the top. There is undoubted evidence that the furnace has been running for some time with this vertical section cut out of it, both from the apperance of the back wall, and from the fact that during the shovelling out there were not found five hundred bricks all told. We shall reline our new furnace, which is to be 75 x 19, in the same way, and strongly recommend the plan to all furnacemen.

Some years since the writer examined a large, modern, and splendidly equipped furnace, just as it was completed. Instead of following the approved lines of the best English and American furnaces, the originator (an English constructionist then in repute) had carried up the well-shaped crucible some four or five feet above the tuyeres without any batter, and from the top of this hole had battered off the boshes. In reply to an inquiry, as to why this peculiar shape was adopted, he said that he had no particular reason, excepting that he had once lined a furnace in this way and that it had worked well, so he was trying it again. The furnace blew in, and shortly began making very bad iron, so bad that it was rejected by the mills as worthless. The stock was excellent, but the furnace worked very irregularly, improving somewhat, however, when, losing bell and hopper, she was shovelled out after a six weeks' run. The writer at once went to see her, as the opportunity of examining what a first-class furnace can do in the first six weeks of a blast is not often presented. The secret of the bad iron was readily explained; the furnace had been running Mt. Savage brick at $50 per thousand into the pig-iron, and had been doing her best to get rid of the obstructions which a stupid man had interposed. In the main, she had cut away the brickwork, and had worked back into a somewhat reasonable shape, but leaving lumps and ridges, which prevented any regularity in working. In repairing, an easy and gradual slope was given from the tuyeres to the boshes, and she has since worked very well indeed, both as to quantity and quality.

We have always considered that the large and regular yield of the Dunbar furnace was largely clue to her lines, which were copied after English furnaces of reputation, and after obtaining the results of similar lines at the Crane Iron-works in the anthracite region, and at the charcoal furnace of the Jackson Iron Company at Lake Superior.

There is, probably, no furnace contrivance of late years which has been received with such a difference of opinion as the Lürmann closed front. Of those who have tried it, some as heartily praise as others strongly condemn, but it will be found an almost invariable rule, that the latter class have attempted to introduce it while the furnace is in blast. There is no good reason why, with its proper application, it should not be entirely successful. That great economy in fuel results from a closed front is undoubted, but there is a great force in Mr. Thompson's position that it is a good thing to be able at times to get easily and quickly into the furnace.

The writer's experience with a Lürmann front was an unfortunate

One. He never recollects days of greater toil and anxiety than in his attempt to introduce it in 1871, and it was only when the tuyeres were nearly reached by the chilled iron that it was taken out. It is only just to Mr. Asmus to say, that he then said that he would never again attempt to put it in while the furnace was in blast, as it seemed impossible to make a good job. Since this attempt we have been running with a closed front of our own construction, and which can be readily applied to any furnace; it is simply letting the crust alone. We run for six months at a time without ever disturbing it, and if at any time it is necessary to open up it is easily done, and as easily closed. Opening at every cast, and poking away with bars, destroying tools, losing valuable time and cooling the furnace, is a relic of a barbarous past, and no good furnaceman will practice or permit it. But all appliances and contrivances avail little if the hearth cannot be saved. If it be badly cut, the use of a titaniferous ore will soon make it up. In fact, if one chooses to use enough of it, he can make it up so effectually that he will soon be casting over the dam, and if he keeps on long enough he can soon be not casting at all. Even if no such means are available, any cutting below the tuyeres can be gotten at and remedied, but cutting at and above the tuyeres is a more serious matter, and where the real danger lies. From the experience of his own and that of valued friends, the writer can confidently recommend the tuyere cooler of Mr. Thomas McCune, formerly in charge of the Eliza Furnaces near Pittsburgh, and now manager of the Charlotte Furnace at Scottdale, Pa., as a certain preventive against cutting. It was introduced at Dunbar some three yearn and more since, at a time when the furnace was cutting badly; the tuyere breasts were red hot, compelling the constant use of water upon them, and at intervals both cinder and iron breaking out.

Since the coolers were put in, not the slightest trouble has been met with. The original cooler is in one arch, and one replacement has taken place in the other arches. As an indication of the positive effect of this cooler, on one occasion, a cooler was burnt out, and not replaced for several months. Cutting commenced and worked back, behind the front face of the cooler, until the cinder broke out. A new cooler was inserted--the cutting was at once checked, and the walls began making up.

Some six weeks since, the Charlotte Furnace, which was in blast when Mr. McCune took charge, and only provided with the common form of a semicircle around the tuyere, was so badly cut away, that it was deemed impossible to save her, as the walls were reduced to a mere shell. Five of these coolers were put in, and a personal inspection a few days ago, showed the furnace in as good condition as ever, and doing larger and better work.

The advantages of this cooler are, the large cooling surfaces pre sented, and the impossibility of the tuyeres changing position. As they are placed, so they remain. A minor consideration is the ease with which a tuyere can be withdrawn and replaced. Where no lump had formed on the nose of the tuyere, we have drawn and replaced one in ten minutes.

It will be generally conceded, that the giving way of the in-walls begins at or near the tuyeres. Being hollowed out there, the descending stock carries away layer after layer of brick, until the in-walls are so furrowed and scarred, as to prevent further successful working, and compelling a blowing-out. Is it not reasonable to suppose that if the start is prevented, the ending is undoubtedly postponed? If a furnaceman is convinced in his own mind, that his difficulty commences at this point, he may rest assured that with the use of this form of cooler, he can overcome or avoid it.

In this desultory paper, the writer can scarcely claim that he has given anything novel or instructive, but he has done what he started out to do, given his own experience, and if in so doing he can induce others to do likewise, or has been of the most immaterial service to any one, he will be satisfied with having made the attempt.

In the present condition of the iron business, to tell a man how he can keep his furnace in blast, would seem to be the suggestion of bitterest enmity--to compel him to go out, whether he wanted to or not, might be an act of the highest and most disinterested friendship.

MR. FRANK FIRMSTONE agreed with Mr. Pechin as to the importance of having the joints in the firebrick as thin as possible, but there was a limit to this in the varying thickness of the bricks. The joints must be thick enough to take up the irregularities of the bricks, and leave the top of each course level and even. This could be done by mixing clean powdered firebrick with the clay, to make a suffibiently thick mortar. By this means there was no danger from shrinkage. He had no doubt hearths might be rammed up entirely of powdered brick and clay, but for the trouble of drying them properly.

MR. HOLLEY inquired if much progress had been made in monolithic linings.

MR. PECHIN replied that they had been used, and had proved both successes and failures; the difficulty in the latter cases seeming to be, that they were not sufficiently dried.

PROP. EGLESTON said that throughout the Continent of Europe, each brick was dressed with the greatest care, and each layer carefully levelled, in order to secure a perfect lining. Monolithic hearths were almost universal in Silesia, where they were inclosed with sheet-iron and cooled with water.

MR. FIRMSTONE said while the practice of carefully chipping the bricks down in every course, no doubt, made excellent work, he never permitted it to be done, as it was an entirely needless expense. The same end was attained by the use of properly mixed clay and pounded brick.

MR. ASMUS said that the practice of making hearths of large brick —ten inches thick, and two to three feet long—was quite common in Europe, the bricks being accurately fitted together outside the furnace before putting them in. Joints of powdered brick and clay had been found to shrink as much as 25 per cent.

MR. BIRKINBINE said that the furnaces of the Meier Iron-works at St. Louis were built of chisel-dressed brick. He had heard of one furnace at Stockton-on-Tees, in which a hearth of fire-clay and ground brick had been put in.

MR. BOYER gave an instance of a furnace in which the hearth bottom had been cut out eighteen inches. This was replaced by broken firebrick and clay, stamped down, and had stood three years of working, and was then in a better condition than the original sandstone. He had also put a monolithic breast in a furnace, and had blown twenty months.

THE WORLD'S PRODUCT OF SILVER.

BY R. W. RAYMOND, PH. D., NEW YORK CITY.

RECENT literary labors have led me to the compilation of the following tables and estimates, which may possess interest for my colleagues in the Institute, and which are here submitted without comment.

Various Estimates of the World's Product of Silver.

COUNTRIES.	Estimate of J. Arthur Phillips for 1800.	Estimate of Birkmyre for 1846.	Estimate of J. Arthur Phillips for 1850.	Estimate of Birkmyre for 1850.	Estimate of J. D. Whitney, for 1854.	Estimate of J. Arthur Phillips for 1865.	Estimate of W. P. Blake for 1867.
	Weight, lbs. Troy.	Value, £ sterling.	Weight, lbs. Troy.	Value, £ sterling.	Value, U. S. coin.	Weight, lbs. Troy.	Value U. S. coin.
Russian Empire	58,150	£167,831	60,000	£171,817	$928,000	58,000	$700,000
Scandinavia		32,346	20,400	35,607	328,000	15,000	
Great Britain		109,989	48,500	160,000	1,120,000	60,500	
Hartz		138,022	31,500	138,022	480,000	28,000	
Prussia			21,200		480,000	68,000	
Saxony		198,200	63,600	....	960,000	80,000	
Other German States	141,060	....	2,500	198,200	48,000	2,500	8,600,000
Austria		282,654	87,000	286,971	1,440,000	92,000	
France		....	5,000	....	80,000	18,000	
Italy		7,444	....	7,444	....	25,000	
Spain		227,499	125,000	440,210	2,000,000	110,000	
Australia, British America	....	....	10,000	....	128,000	9,500	20,000
Chili	183,000	297,029	238,500	297,029	4,000,000	299,000	
Bolivia	271,300	460,191	130,000	460,191	2,080,000	136,000	
Peru	401,850	1,000,583	302,150	1,000,583	4,800,000	299,000	10,000,000
New Granada	5,000	42,929	13,000	42,929	208,000	15,000	
Brazil	1,200	2,003	675	2,227	11,200	1,500	
Mexico	1,440,500	3,457,020	1,650,000	5,383,333	28,000,000	1,700,000	19,000,000
United States	....	1,864	17,400	73,532	852,000	1,000,000	15,500,000
East Indies	....	56,265	....	56,265	....	....	....
Africa	....	1,056	....	1,056	....	....	....
Various other countries	....	33,000	....	33,000	....	....	....
Total	2,337,300	£6,515,925	2,827,425	£8,788,416	$47,443,200	4,017,000	$53,820,000
Approximate value in U. S. coin	$36,250,000	$31,537,000	$43,853,000	$42,536,000	$47,443,300	$62,303,000	$53,820,000

The following estimate of the world's product of silver in 1873 is based upon returns from Germany, Austria, France, Great Britain, Spain, and the United States, and for other countries upon the most recent available accounts: Great Britain and colonies, $1,000,000; Sweden and Norway, $250,000; Russia, $500,000; Austro-Hungarian monarchy, $1,600,000; German empire, $3,000,000; France, $2,000,000; Spain, $2,000,000; Italy (Sardinia), $500,000; Mexico, $20,000,000; Central and South America, $8,000,000; Canada, $900,000; United States, $36,500,000; total, $76,250,000. According to Humboldt and Danson, the value of silver produced in Mexico and Peru from 1492 to 1803 was $4,152,650,000. The production in Europe during the same period was about $200,000,000. For the period from 1804 to 1848 Danson gives §1,244,380,794 as the production of Mexico and South America, that of Europe and Asiatic Russia for the same period having been about $325,000,000.

For the period from 1848 to 1868 Prof. W. P. Blake in his *Report on the Production of the Precious Metals*, gives the following estimates of the silver product: United States, $73,000,000; Mexico, $380,000,000; South America, $200,000,000; Australia, $20,000,-000 ; Europe and Asiatic Russia, $160,380,000; total, $813,400,000. From 1868 to 1875 the product of silver may be approximately estimated at $163,000,000 for the United States, $140,000,000 for Mexico, $56,000,000 for South America, and $63,000,000 for the rest of the world. (None of these estimates include the product of Japan, China, *and* Central Asia, of which nothing is known.) We have then, as the grand total of the silver product from the discovery of America to the present time, $7,150,000,000.

THE MAHONING VALLEY COAL REGION.

BY ANDREW EOT, INSPECTOR OF MINES, COLUMBUS, OHIO.

THE Mahoning Valley coal region lies on the extreme northern outcrop of the Ohio coal-field, and all the mines, with one exception, are opened on the lower coal of the series, No. 1 of the Ohio Geological Survey. The coal ranges from an inch to five, six, and sometimes seven feet thickness, the workable height being between two and a half and six feet.

There are two varieties of coal, known in market as "Briar Hill coal" and " Mineral Ridge coal;" both varieties are drawn from the same seam. The Briar Hill coal is generally called block coal, and is the kind so largely used in a raw state in smelting iron. It possesses a laminated structure, easily splitting into horizontal sheets, but is very difficult to break in the opposite direction. The faces of the layers are often covered with a soft, dead, carbonaceous material, like charcoal, and the whole seam throughout is marked by alternate layers of dead and bright-looking coal. In the act of combustion the coal neither swells nor changes form, the masses retaining their shapes until they fall to ashes in the furnace.

The Mineral Ridge variety is much softer, and is also shorter in the grain than the Briar Hill kind, and it contains a good deal of

Sulphur in the form of pyrites, which forbids its use in the furnace. It makes, however, an excellent fuel for household purposes, for rolling-mill purposes, and for the generation of steam.

The Briar Hill coal is invariably found in a solid bench, while the Mineral Ridge variety is almost always found in two layers, forming a double seam. Between the two layers there arc, generally, a layer of black band ore from 3 to 10 inches thick, and a stratum of gray shale, called "wide-awake" by the miners. The black band is mined and sent to the surface, and after being calcined at the pit's mouth, is used in connection with the rich ores of Lake Superior, the resulting product being a very superior brand of pig metal, known in the market as "American Scotch."

Unlike other coal-seams, where the strata have not been subjected to upheaval and erosion by mechanical agencies, this bed, instead of extending in a continuous, unbroken sheet, in a level plane, or with a natural dip, lies in a series of hollows and ridges, and the coal is frequently wanting altogether where the mining engineer, unacquainted with the peculiar structure of the troughs in which it reposes, would confidently pronounce its existence.

The upper surface of the Waverly sandstone, upon which the coal rests (for the foundation-stone of the coal-measures, the Conglomerate, is wanting in this part of the coal-field) is very wavy and uneven, forming long, narrow, and serpentine troughs, which the miners call "swamps." These troughs are of varying widths, and in one part of their line of direction may not be more than 50 or GO yards wide, while in another part they may widen out to 200 and 300 yards. Sometimes a number of them lie alongside of each other. In such cases the basin, in an unbroken chain, may be a mile in width, the coal stretching across in a series of hills and hollows, like synclinal and anticlinal curves. The coal is always thickest in the bottom of the trough, growing gradually thinner as it ascends the hillsides, till it disappears altogether, or is suddenly cut out by a fault, a "horseback," as the miners term it. The approach of a horseback is first indicated by a change in the roof, the gray slate being supplanted by a stratum of fire-clay or sandstone; then the place of the coal itself is usurped by this foreign matter.

These faults very frequently occur on the sides of the hills in mines where there is but a single swamp, suddenly cutting away the coal while it is yet of good workable height. Such faults are also found in the bottom of the troughs, as well as on the hills. They appear to have been formed, during the subsidence of the land, by currents of water in rapid motion flowing over the coal-marsh and cutting away the coal, the mud and sand finally settling down in its place.

The synclinals and anticlinals on which the coal reposes do not appear to have been formed by internal disturbing forces, upheaving and eroding the coal strata, after the close of the Carboniferous age, as in the case of the anthracite basins of Pennsylvania, but have been caused by erosive agencies, by a scooping of the coal-floor anterior to the deposition of the coal vegetation. The coal and its incumbent strata may pitch at an angle of 20° or 25°, but the material underlying the coal does not partake of the inclination; on the contrary it occupies a horizontal plane.

The lines of direction of these swamps is generally southwest, but they are very serpentine in their courses, and they sometimes cross each other. How far they extend, is matter of much conjecture among practical men. Mines are now opened along their lines of direction for ten or twelve miles. Southward towards the Ohio River, along the dip of the coal-measures, the increasing thickness of the overlying strata has, till this time, forbidden any vigorous exploration for coal.

Wherever the lower coal of the Ohio series has been opened in the State, the coal has been found resting on an irregular floor, and the coal itself partakes, in a greater or less degree, of the qualities which characterize it in the Mahoning Valley. At Massillon, in Stark County, the mines are opened in No. 1, and the coal, though softer in nature and shorter in the grain than the Briar Hill coal of the Mahoning Valley, is used in the furnace from several of the mines, as it comes from the workman's pick. In Jackson County, also, where No. 1 is in course of vigorous development, it maks a good furnace-coal in a raw condition. In both of these districts, as in the Mahoning Valley, the floor of the coal is wavy and irregular, though in Jackson County the troughs, instead of being long and serpentine, are generally round like a bowl.

WASHINGTON MEETING.

FEBRUARY, 1876.

*THE INADEQUATE UNION OF ENGINEERING SCIENCE AND AST**

BY A. L. HOLLEY, C. E., NEW YORK CITY.

THE application of scientific methods to the investigation of natural laws and to the conduct of the useful arts which are founded upon them, is year by year mitigating the asperity and enlarging the outcome of human endeavor. More notably, perhaps, are these the facts in that system of productive and constructive arts of which engineering is the general name. In metallurgical engineering especially, within the period of our own recollection, how rapid has been the rate and how wide the scope of progress: the scientific discovery and mining of metalliferous veins; the economical separation and reduction of ores of every grade; the production and regulation of high temperatures; the varied improvements in the manufacture of iron, in saved heat and work, in uniformity and range of products; and, most important of all, the creation and the utilization, to be counted by the million tons a year, of the cheap constructive steels.

Wonderful as this range and degree of development may appear to the public eye, the close and thoughtful observer must, nevertheless, conclude that neither the profession nor the craft of engineering ' may congratulate themselves too complaisantly, but that they should rather acknowledge to each other the embarrassing incompleteness of the union between engineering science and art.

There is a small school of philosophers whom we may designate as original investigators, men who come close to nature, who search into first principles, and who follow that scientific and therefore fruitful method by which the relations of matter and force are discovered, classified, and brought within the reach of practice. These wonderful men do not indeed create the laws of nature, as they sometimes almost seem to, but they go up into the trembling mountain and the thick darkness and bring down the tables upon which they are written.

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* President's Opening Address. The discussion following this paper, and also the Joint Discussion of the Institute and the American Society of Civil Engineers, on the subject of Technical Education, are published in a separate volume.

There is a larger class of men whom we may designate as the schoolmen; they are learned in the researches and conclusions of others, and skilled in reasoning or speculating from these or from abstract data upon the certain or probable results of physical and chemical combinations.

And there is the great army of practicians, almost infinite in its degrees of quality, ranging from the mere human mechanism by which mind lays hold of matter and force, through all the grades of practical judgment and power.

Let us first consider the matter from the "practical" man's standpoint. Every day's experience teaches him that the men who speculate, from secondhand data, upon the probable results of combinations of forces and materials, are not the men who can best make these combinations in practice, who intuitively know all the concealed pitfalls, such as friction, that trick of nature which like the thousandth part of phosphorus, alters all the conditions of use in iron; nor are they the men who can determine the completeness of these combinations, or read the record of their results, as in the character of a flame, in the feeling of a refractory mixture, in the behavior of a metal under treatment; nor are they the men who, by familiarity with objects and phenomena, are best fitted to pursue that original investigation which is the foundation of even theoretical progress. The expert who delights to call himself " practical," is honestly amazed at the attempts of experts by school graduation, who have not been graduated in works, to solve the engineering problems of the day. And from his standpoint there are numerous and conspicuous illustrations. While metallurgists are still disputing over the nature and sequence of reactions in combustion and reduction, the practioal ironsmelter has felt his way from the barbarous practice of a century ago, to the vast and economical production of to-day. The attainment of powerful and sufficiently hot blast by means of waste heat, the adaptation of shape and proportion of stack to different fuels and ores, labor-saving appliances and arrangements, — all these have grown out of the constant handling, not of books, but of furnaces.

Proceeding upon a chemical knowledge little superior to that of the average schoolboy, Bessemer developed his revolutionary process. Not knowing for years that the combustion of silicon or of manganese are the chief sources of the necessary heat; ignoring the fact that not alone the reaction but the presence of manganese is a cause of soundness and malleability in steel; magnifying the hypothesis that silicon should promote soundness; instructing his licensees to avoid all irons containing above 0.02 per cent of phosphorus; and sharing the ignorance of the whole metallurgical profession as to the sequence of reactions in the converter and the probability of changing their character, Bessemer and his followers, during the first fifteen years of their practice, nevertheless brought this difficult art, which the metallurgical schools call a chemical art, to a high degree of commercial success, and this in the absence of any metallurgical change or chemical improvement whatever, in the treatment of the metal. During all this time, there was almost no literature of the Bessemer manufacture, and no instructor save that grim sphinx the converter and the well-nigh inscrutable process. It was a hand-to-hand fight, involving mechanical details, refractory linings, celerity of operations, regularity of melting and conversion and economy of labor. With every fact written in his book, the closeted scientist could no more adequately prescribe the practical conditions of improvement, than could the student in optics specify in words and formulæ the glory of an Italian sunset.

Here is a cupola-furnace, an old and exceedingly simple device; but one may know all the laws of combustion and fluxing that arc written in the cyclopedias, and yet fail to change its working at will, or fail to detect the coming change, until by long familiarity, the phenomena reveal themselves as it were instinctively. One may have learned every law of the reactions of oxides and fluxes upon a refractory material, yet until his practiced hand and eye and car can nicely detect its physical qualities and measure the results of new ingredients and temperatures, he may wander for years in a maze of uncertainties. Notwithstanding all our previous knowledge about the inevitable combustion of carbon and oxygen in the presence of heat enough to ignite them, the Siemens-Martin process, both in its calorific and in its metallurgical aspects, was as purely unpractical as the direct utilization of sun-heat is to-day, until after years of patient observation, not chiefly by scientists but by men unacquainted with books and knowing nothing at second-hand, innumerable small increments of improvement at last produced a sufficient temperature in a durable furnace.

In the development of machinery, the same history is repeated. The proportions of parts, in fact, the modern formulas themselves, are derived from the study of innumerable experiments. The adaptation of machinery can only be perfected by him who, as it were, enters into it, making it an incarnation of himself. This enlargement of a man's organism is most strikingly illustrated in the locomotive. Oliver Wendell Holmes has happily described this putting of his life into his "shell" boat, his every volition extending as perfectly into his oars as if his spinal cord ran down the centre of its keel, and the nerves of his arms tingling in the oar-blades. The thoughtful locomotive-driver is clothed upon, not with the mere machinery of a larger organism, but with all the attributes of a *power* superior to his own, except volition. Every faculty is stimulated and every sense exalted. An unusual sound amid the roaring exhaust and the clattering wheels tells him instantly the place and degree of danger, as would a pain in his own flesh. The consciousness of a certain jarring of the foot-plate, a chattering of a valve-stem, a halt in the exhaust, a peculiar smell of burning, a sudden pounding of the piston, an ominous wheeze of the blast, a hissing of a water-gauge—warning him respectively of a broken spring-hanger, a cutting valve, a slipped eccentric, a hot journal, the priming of the boiler, high water, low water, or failing steam—these sensations, as it were, of his outer body, become so intermingled with the sensations of his inner body, that this wheeled and fire-feeding man feels rather than perceives the varying stresses upon his mighty organism.

Mere familiarity with steam-engines is not, indeed, a *cause* of improved steam-engineering, but it is a *condition.* The mechanical laws of heat were not developed in an engine-house, yet without the mechanism which the knowledge derived *through this familiarity* has created and adapted, the study of heat would have been an ornamental rather than a useful pursuit. So in other departments. When one can feel the completion of a Bessemer "blow" without looking at the flame, or number the remaining minutes of a Martin steel charge from the bubbling of the bath, or foretell the changes in the working of a blast-furnace by watching the colors and structure of the slag, or note the carburization of steel by examining its fracture, or say what an ore will yield from its appearance and weight in the hand, or predict the lifetime of a machine by feeling its pulse; when one in any art can make a diagnosis by looking the patient in the face rather than by reading about similar cases in a book, then only may he hope to practically apply such improvements as theory may suggest, or to lead in those original investigations upon which successful theories shall be founded.

These are the conclusions of the "practical" man, and they are none the less true because they are not the whole truth. That they are too little considered by the schoolmen and the graduates of schools is also true, but happily, less conspicuously so as the years advance.

The evil consequences of this mistake develop themselves in various ways. The recent graduates of schools do not, indeed, expect immediate positions of responsibility and authority, but they often demand them after too short a term of object-teaching. Perhaps the greatest advantage of their scientific training is that they can learn from objects and phenomena faster than can the mere workman, who, although full of the elements of new and useful conclusions, lacks, if I may so say, the scientific reagent which precipitates the rubbish and leaves a clear solution of the problem. It is however true--in the iron manufacture, perhaps, especially true--that men of wide learning and of great mental dexterity, unless they have studied at least as many years in the works as they have in the school, do not successfully compete for the desirable places with the men who have come up from the ranks. Narrow, unsystematic, and fruitless of new results as his knowledge may be, he who has grown up steadily from the position even of puddler's helper, will be selected to take the manager's post in preference to him whose reputation is founded solely on the school.

Nor does this prove, as the schoolmen too often believe, that the owners and directors of metallurgical enterprises are generally unappreciative of scientific culture. It rather proves that the lowest functions, as in the case of poor humanity, must first be considered; that the conditions of maintenance and regular working, which constant familiarity with objects and phenomena alone can provide, are earliest in order. Conservation first and improvement afterwards.

Another consideration in this connection is that scientific aid appears to be more readily provided for the "practical" man than practical aid for the "scientific" man. The trained scholar can the more readily adapt himself to the situation. He should suggest many more improvements than would ever crystallize in an equally good but undisciplined mind. Yet his attempt, with mere scholastic aids, to carry these improvements out, might disorganize a whole establishment. As there must be one final authority, judgment founded on experience almost universally ranks the wider and more fruitful culture of the school. And if we ask those great masters whose experimental knowledge is as wide as their scientific culture, they will tell us, that as the inert and clumsy flywheel, that typical conservator, is more helpful to a steam-engine in the long run, than a valve-gear so highly organized that it seems to know what it ought to do, so in their own undertakings, plodding, practical economics must sit in judgment upon theory and limit the reaches of imagination.

Another evil growing out of the inadequate regard of mere schoolmen for practice, is the frequent failure of their works or their inability to complete them. Inventions and constructions, designed after a scientific method and under the light of organized facts and detailed history as laid down in books, may fail simply in default of a practical knowledge of how far the capital at hand will reach, or what the means at hand will do, or what the materials at hand will stand, or what the labor and assistance at hand can be relied on to accomplish. A vast number of facts about the operation of forces in materials are so subtle, or so incompletely disentangled from groups of phenomena, that they cannot be defined in words, nor understood if they could be formulated. But after long familiarity with the general behavior of materials under stress, a practical expert can, by a process more like instinct than reason, judge how far and in what directions he may safely push his new combinations. Thus while the unschooled practician so usually wastes his energies in unscientific methods and on impossible combinations, but generally carries into successful use his comparatively few well-founded attempts, the student merely of principles and abstract facts so usually originates the ideas upon which progress is founded, and so rarely clothes them with practical bodies. In this chasm between science and art, how much effort and treasure, and even life, are swallowed up year by year.

These are not theoretical considerations. The blast-furnace, the converter, and the open-hearth have already been referred to; let us observe some other illustrations. A bridge-builder will tell us that few structures in his department of engineering fail by reason of mistakes in calculating the strain-sheet, but that the majority of failures arise from vibrations, buckling, rapid wear of important parts, shapes that weaken the material, inequalities in the material, and similar causes which are not stated in books, which assume different aspects under every change of proportions and dimensions, and which can only be inferred by means of a long familiarity with the behavior of similar structures during varying periods of service, and with the processes by which materials and members are fabricated. The builder of a machine like a marine engine, or a locomotive, or a roll-train, or a steam-hammer, will tell us that, in designing new adaptations, after every stress that can be distinctly analyzed is provided for, mass to resist vibration, changes of shape to insure sound casting, and various modifications which cannot be formulated for the want of even approximately complete knowledge of their conditions, must still be supplied, simply by judgment founded on long observation of phenomena under similar conditions. And he will thus explain nine-tenths of the failures. Who can imagine the volume of a book, or of an author, which should adequately teach the principles of construction as affected by the chiefest of all practical considerations--the economics of the foundry, the forge, and the machine-shop? With the tools and facilities at hand, what divisions of a particular structure, what shapes and sizes and methods of joining can be made cheaply as well as strong and efficient, in all the infinite forms of mechanism? Obtaining such facts from any other source than personal practice, would be like an oarsman studying a book to know when and how in the race he must husband his power, or like a wrestler looking out in a cyclopedia the probable feints of his antagonist. The successful constructor will assure us that no possible training in the school, nor any genius in invention can build economically without such knowledge of the shop as the athlete has of the possibilities of muscular strength and agility.

These arts have been selected as examples, not because they chiefly depend on skill, but because they so largely involve the highest formulated mathematical knowledge. How much more important, then, is practical training in those departments where physical laws are very incompletely understood and formulated. How far short of practical success will abstract science stop in sinking pncumatic piles through wrecks and boulders, in tunnelling rocks traversed by subterranean streams and beds of quicksand, in cheaply applying hoisting, ventilating and draining machinery to mines where the scene and conditions of operation are constantly shifting, in firmly founding heavy and vibrating machinery on treacherous ground, in handling and casting melted steel, in constructing refractory metallurgical vessels, in delivering bars red-hot and crooked in infinite directions to a roll train, in fabricating durable breech-loading cannon, in building boilers that shall provide for vaporization, circulation, separation, cleaning and durability, in designing enginery like the horseshoe machine to shape metals, in proportioning gas-furnaces, in submarine warfare, in aerial navigation, in machine tools, in traction engines, in scaffolding and erection, in railway running-gear, in forming artificial stone under water, in permanent way, in coal-cutting, in dredging machinery, in moulding and casting, In brick machinery, in tube-drawing, in coal-burning, in pavements? Limited or impossible as would be the progress of engineering arts in the absence of that knowledge and those methods which are imparted in schools, delay and failure would hardly be less conspicuous if the schoolmen should stay in the schools and thence attempt the application of abstract science, or expect mere workmen to apply it by hearkening to their directions.

I hope it may not seem that the dignity of abstract scientific investigation is undervalued by the utilizers of nature's powers and materials, or that any considerations of profit obscure, even in the average commercial mind, the splendor of those achievements made in the mere love of truth, with thought of neither commercial application nor pecuniary reward--achievements which distinguish such names as Faraday, Bunsen, Leverrier, Mayer, Joule, Henry, Darwin, and Tyndall. Do not their successes rather encourage us, in our lower sphere, to more persistently pursue the method of these great discoverers--the original investigation of Nature's truths? Not less literally than in the poet's fancy,

> "To him who in the love of Nature holds
> Communion with her visible forms, she speaks
> A various language,"

To the skilled artisan she reveals herself as truly though not as widely as to the philosopher. In the aphorism of Goethe, "Mankind dwell in her and she in them. "With all men she plays a game for love, and rejoices the more they win,"

But the undervaluation of the study of objects and phenomena by schoolmen, is not the principal hindrance to the complete union of science and art. A greater obstacle is the combined misapprehension and ignorance on the part of a large class of "practical" men, of what they are pleased to call " theory," meaning by theory, something which is likely to be discordant with fact--or possibly with the interests of the craft. We can hardly complain that their objection is ill-grounded, as far as it is grounded upon the practice of theoretical men; but the world has a right to complain of their narrowness of observation, of their stolid incomprehension of the results of science, of that pride of ignorance, of that bigotry, of that positive fear of the diffusion of knowledge, which is the normal condition of those who range only within the sphere of their own practice, and to whom analysis and generalization, in their business affairs, as well as in morals and politics, are an unknown thing. It is unfortunately true that a large number of managers in metallur-

Gical enterprises--men who are deemed indispensable, and who probably, are indispensable, in the average state of practical science, are thus not incorrectly characterized. Conscious of their power as conservators, ignorant of the elements of improvement, and not unfrequently jealous and blindly fearful for the interests of their craft, they sit triumphant on an eminence (the steady undermining of which they cannot observe), and sneer at the too frequently eondescending magniloquence of recent graduates and book men. The best of this class are the workful and painstaking men who come up from the ranks--men who are plucky in emergencies and regulative of labor--men whose unconscious reasoning or intuition covers the ordinary exigencies, and who, perhaps for this very reason, never inform themselves outside of their own range of observation, nor observe in a methodical or fruitful manner.

There is also a class of practicians who do secretly and abstractly respect the labors of the scientific investigator, and are unwillingly governed, more or less, by his conclusions; but their minds arc so barren of general facts and so untrained in the scientific methods of utilizing facts, and hence so distrustful of any ideas which reach beyond their own practice, that they also are impediments rather than helpers in the union of science and art.

It is often said, I am aware, that there is never any real antagonism between science and art, and that all men respect, even if they do not promote, the efforts of both scientists and practicians to forward the useful arts. What then shall we say of that phase of trades-unionism, which not only tends to repress improvement, but which often violently defeats the works of progressive thinkers and sometimes destroys their authors? Let us also observe an extreme, but not isolated case of the executive treatment of science. Long before the professional career of most of us began, the Erie Railway Company commenced a series of experiments in civil and mechanical engineering, sometimes elaborate, like those of Zcrah Colburn on traction, and always useful; many of them incorporated with and improving the practice of the road for a quarter of a century. The voluminous drawings and records of this experimental practice, always preserved by the engineers of the road, were just beginning to be remembered by young and inquiring engineers, as a mine of professional information, when it was discovered--you will hardly believe me--that the engineer of the Erie road having been turned out, the whole of this priceless accumulation of reports and drawings was dragged off by the cartload to a paper mill, and destroyed.

by James Fisk, Jr. In reviewing the railway history of the country, many of you will remember that this act of vandalism has been by no means the worst blow which engineering has received from so-called "practical" men.

I have referred to these exceptional cases, merely to correct a modern idea that engineering progress, especially by scientific methods, is as yet, the creature of popular favor. It is refreshing to turn from such considerations to the Still exceptional but happily growing appreciation and helpful respect of practitioners and scientists for each other, as sometimes exemplified in the various departments of mining engineering. When we see recent graduates patiently leading the untrained, confused, but determined mind of the workman, painfully wrestling with hard names and occult processes, into methodical habits of thought and the rudiments of organized knowledge; when we see the grimy workman, not standing aloof for fear of his craft or of his trades-master, but dragging the recent graduate into mines and furnaces, and patiently teaching him how to recognize that matter, in mass and under mighty forces, which he had heretofore contemplated in cabinet specimens, and chiefly in ideas; when we see the commercial manager of metallurgical enterprises opening his works to the gradnates of schools, and giving them a chance, not only to complete their education, but, by judicious application of their efforts, to earn a living meanwhile; when we see such things, as happily we may, here and there in metallurgical works, we may assure ourselves that *one* way has been discovered to promote the union of science and art.

In the enlargement of this method of mutual respect and instruction, to a certain extent lies the solution of the problem under consideration; but it is a complex method, only actively operative under several important conditions, such as:

1. A *public opinion* among schoolmen that a course of object and phenomena study in works is to be reckoned, not as a matter of mere business sequence, but as a large and equal feature of that curriculum which is essential to a degree of professional graduation.

2. A diffusion, among the class which we have termed the "practical" class, of a real appreciation of an organized system of information and of the scientific method of making this information useful.to all classes of men and noxious or unimportant to none; such a general explanation to that vast, preponderating class of workmen and of foremen and managers, who are foremen and managers simply because they have been efficient workmen, as will

ever prevent their indiscriminate and contemptuous application of the term "theory" to whatever a schoolman proposes.

3. An understanding among the owners, directors and commercial managers of engineering enterprises, that it is not a mutter of favor, but a matter of as much interest to themselves as to any class, that young men of suitable ability and of suitable preliminary culture, however acquired, should have opportunity and encouragement to master the practical features of technical education in works, not as mere apprentices, but under reasonable facilities for economy of time and completeness of research.

But these conditions do not largely exist, and are only growing with general civilization. They must be hastened and magnified by some better means than merely stating the case again and again, as some of us, I confess, are too fond of doing ; than perpetually repeating, in a manner more sentimental than efficient, that scientists should appreciate practice, and practicians should appreciate science, and capital should join the hands of science and practice, saying: "Bless you, my children," in the expectation that this will prove a fruitful union. Let us rather inquire if some now order of procedure in *technical education,* some revolutionary innovation, if need be, will not put the coming race of engineers on a plane which is lifted above the embarrassments from which we are slowly emerging.

1st. In order that the technical school should be in the highest degree useful, fruitful, and economical, it must instruct, not *men* of good general education, but *artisans* of good general education. The art must precede the science. The man must first feel the • necessity, and know the directions of a larger knowledge, and then he will master it through and through. Mark how rapidly the more capable and ambitious of practical men advance in knowledge derivable from books, as compared with the progress of bookmen, either in books or in practice. Many men have acquired a more useful knowledge of chemistry, in the spare evenings of a year, than the average graduate has compassed during his whole course. These men realized that success was hanging on their better knowledge. Familiar with every changing look of objects and phenomena, they detected the constant play of the unknown forces which underlie them, and longed for a guide to their operation, as a mariner longs for a beacon light. This practical familiarity and judgment at once revealed the importance of scientific facts and methods, promoted their acquisition, and guided their application. Under what comparative facilities does the mere recitation-room student, or even the mere analyst of the hundred bottles, study applied chemistry? It is to these a matter of routine duty, without a soul; they are neither stimulated nor directed by a previously created want. Beginning with theoretical and abstract knowledge, is no less an inverted process in the useful arts than in the fine arts; as it would be to take a course of Ruskin within brick walls, as preparatory to opening a studio, and then climbing the mountains to square nature with the book.

Undoubtedly there may be extremes in any form of educational method. For a youth to begin the special business of technical education by any method, practical or otherwise, before he has acquired not only a common school education, but, at least such a knowledge of polite literature and general science, including of course mathematics, as would fit him to enter one of the classical colleges, should be strongly discouraged, for various reasons. It is useless to disguise the fact that the want, not of high scholarship, but of liberal and general education, is to-day the greatest of all the embarrassments which the majority of engineering experts and managers encounter. This statement cannot be deemed uncomplimentary to the class, seeing that they have risen to power despite the embarrassment. At the present day, the high-school systems founded by States and by private enterprise, bring such an education within the reach of every one; and it seems of the first importance to promote, if not almost to create, a public opinion, that liberal and general culture is as high an element of success in engineering as it is in any profession or calling.

But this is not all. Professional and business success are not, even in America, the chief end of life. All the social and political relations, and even personal happiness, are governed, not by the specialties, but by the balance of mental culture. What, then, shall we say of the policy of wealthy parents--not indeed general, but too frequent--of placing an uncultured boy in a technical school and then in works and business, without giving him one chance to acquire a general and polite culture?

Many young men display a liking, and others a marked talent, in some special direction. There is no danger that these will be crowded out of existence by the culture necessary to make a well-balanced mind ; and the nearer the talent approaches genius, the less imminent will be any such danger.

The proposition then is, not that mere common school-boys shall go into works and then into technical schools, but that young men of more advanced general culture, when they do begin the business of technical education, shall apply to Nature first and to the schoolmaster afterwards.

It may be urged in favor of beginning in the technical school, rather than in the works, that mental capacity for the after acquisition and application of facts and principles is thus developed. But mental training is not the product of the technical school alone. Habits of logical thinking and power of analysis and generalization may be acquired in any school. And a positive objection to beginning with the technical school is, that it cannot atop at logical methods and sciences which are essentially abstract. It also attempts to teach about objects and phenomena, the first knowledge of which, if it is to be broad and genuine, must come from the fountain-head.

These considerations may be farther illustrated by the course of the inexpert graduate when he enters works as a matter of business or of study. We have seen that the practical man can, at least, keep the wheels running and the fires burning, and that when he is of a certain grade of ability and ambition, he will most rapidly acquire the scientific knowledge and culture which, joined to his practical judgment, make him a master. The unpracticed graduate, however, can keep neither wheels turning nor fires burning; he has not even the capacity of a conservator. Nor can he for a long time recognize, in the whirl and heat of full-sized practice, the course and movement of those forces about which his abstract knowledge may be profound. The youngest apprentices are more useful in an emergency. He must begin with the lowest manual processes, not indeed to become simply dexterous, but, as it were, to learn the alphabet of a new language. He has started in the middle of his course instead of at the beginning. He must go back before he can advance, while the practician goes straight on. The knowledge of the schoolman about physical science, however often he may have visited works and mines and engines during school excursions, is essentially abstract; it no more stimulates desire and power of practical research than the calculus creates a passion or a capacity for studying the actual work of steam in an engine, or the actual endurance of a truss in a bridge.

The disappointment of inexpert graduates at finding themselves so far from being experts, their inability ofttimes to pay for further schooling, the necessity that they should now begin to earn money, as they had persuaded themselves they could so readily do upon graduation, discourage many from pursning engineering, and, what is worse, send many out into practice who never do complete their technical education, but who, by the character of their work, lower the professional standard.

It can hardly be urged against the precedence of practical culture, that the student will get "out of practice" while he is in the school. He may, indeed, lose dexterity, but not the better fruits of experience. In fact, those who begin as practicians, almost instinctively keep up their intimacy with the current practice.

A most signal advantage of beginning technical education in the works is, that the mind is brought into early and intimate consideration of those great elements of success which cannot be imparted in any other way,--the management of labor and the general principles of economy in construction, maintenance, and working. *An early knowledge of these subjects moulds the whole character of subsequent education and practice.* There seems to be no corresponding advantage in beginning with the technical school. The fundamental mathematics and general information on physical science may be acquired in the preliminary school.

There is little doubt that the managers of technical schools will favor this order of study. They want to graduate, not half-educated men, but experts. They desire, of all qualifications in the student, that enthusiasm which can only spring from a well-defined want of specific knowledge.

2d. But the *order* of education is not the only desirable change. Whether before or after their course in the school, the hundreds of young men who are every year entering engineering pursuits, are wasting their time in bad methods of practical study, or, if after the school course, they are more frequently doing bad work as engineers, when they should still be only students. Hardly two engineers acquire any part of their practical knowledge in the same curriculum. They pick it up *as* best they may, usually in a manner that is wasteful of time or damaging to the public. While the teaching of general facts and principles and of scientific method is highly, developed, there is no organized system for guiding students to direct knowledge of objects and phenomena. This statement requires two explanations: I. Apprenticeship is a school of skill in a specialty rather than a school of liberal art. It is intended for a class of men who propose to remain mere workmen, and not for the class who intend to improve and direct engineering enterprises. It imparts a degree of dexterity far beyond the requirements of the general expert, while it would hardly impart in a lifetinie his required range of practical knowledge. II. A school of engineering practice, such as that of research in zoology which was established by Agassiz, would be wholly impracticable, because it could be nothing less than a vast and successful establishment for construction and operation in nearly all the departments of engineering. If such a school were not commercially successful, and if its range were not comprehensive, it would be unsuitable and inadequate.

Now, if there can be a *system* of instruction in the one school, there can be in the other. The same discipline and responsibility, the same guidance as to precedence of study, quality of evidence, and correctness of conclusion, should hold good in both cases. To say otherwise would be to say that *all* knowledge should come from unaided original research, and that every investigator should begin, not. where a former investigator left off, but where he began. It therefore appears that there can be a school of practical engineering, but that it cannot be mere apprenticeship in engineering practice, nor a system of engineering construction and operation, maintained merely for the purposes of a school.

The only alternative is to establish organized schools in the various existing engineering works. At first, this idea would seem subversive of all discipline and economy, but I am assured by experts in several branches of engineering, that such would not be the case. Let us take, for example, a Bessemer works. A score of students under the discipline, as well as under the technical guidance of a master, could be distributed among its various departments, not only without detriment, but with some immediate advantage to the owner, for while receiving no pay, they would become skilful, at least as soon as the common laborers who form the usual reinforcements. Students should, of course, be expected, not to work when and in what manner they might choose, but to do good and full work during specific hours. This responsibility as workmen, would rapidly impart not only the knowledge sought in the works, but a desire for higher knowledge and culture.

These considerations are not merely theoretical. Several students at a time, subjected to no discipline, sometimes working hard, and sometimes not at all, may often be found in a Bessemer works, and I have yet to hear of their embarrassing the management in any way. The laborer has no cause for interference, as the students are not under pay, and whatever they accomplish is clear gain to the three parties concerned,--the owner, the student, and the operative. A large number of young men may be found studying in machine shops, and sometimes earning small pay, besides having opportunity to work in all departments.

The proposition is to enlarge and systematize the existing desultory study in works--to increase its usefulness to the student, and, at the same time, to make the granting of such facilities to students an object, immediately, as well as remotely, to the owners of works. To this end, the schoolmaster should be not only well read in the professional literature, but a practical expert who could take charge of the works himself, so that whilst best aiding the students, he could prevent their interference with the regular and economical operations. His functions would be, not those of an instructor, nor, to any great extent, of a clinical lecturer, but those of a disciplinarian. The students should acquire skill, in order that they might acquire judgment of skill and original knowledge of materials and forces, and the master should see that they did acquire them all. He might do some service by stated examination and current criticism and suggestion, but his chief office would be to promote honest work, and to provide opportunity for work in all departments with reference to the economy of the student's time and to the owner's interests.

It should thus appear that these somewhat radical changes in the curriculum of engineering study--first, a hand-to-hand knowledge, acquired not desultorily, but by an organized system, and afterwards the investigation of abstract and general facts and their relations, would largely economize the student's time and better the quality of his knowledge. The novice is nearly as valuable a student in works as the graduate, but he is a vastly less apt scholar in the school. My own belief, founded on the study of many typical cases, is, that this order of procedure would produce a better class of experts in little more than half the time required by the reverse order; that it would always make *experts;* that it would discourage none from finishing an engineering education which would be complete in its parts, even if insufficient time were taken to fully develop it. A well-balanced culture will naturally grow in scope and in fruitfulness,

In this connection it seems proper to say a word about the royal road to learning, which a few ill-advised students attempt to pursue I do not refer to their availing themselves of professional data and drawings on file in engineering offices, but I do refer to their asking engineers and managers to furnish them special reports on subjects regarding which their own observation would be vastly more useful to the applicants, and quite as convenient to the respondents--reports on the number and duties of workmen in each department, and the particulars of operation and relative cost, which can only be profitably investigated by a student, when not only the facts but the reasons are ferretted out by himself, rather than transmitted to the academic grove through the post office.

In conclusion, if it should appear upon larger observation, to the profession in general, as it does appear to many of its members, that this want of coalescence, ranging from indifference to antagonism between its scientific and practical branches, is a real and substantial fact, a larger effort would undoubtedly be made to change a condition so damaging to the profession and to the public. This inappreciation of one department by the other is not unnatural--neither side has taken sufficient pains to observe what the other side has done. The mere scientist instinctively believes that the achievements of the profession are so far due to the deductions of scientists that all other causes fade into insignificance; and the practician knows that just as far as animal life is from the disembodied spirit, so far is utilization of nature from the formulæ of heat, chemical affinity and mathematics itself.

The first step is to recognize the fact, and I beg engincers, especially those who from their scholastic habits, see least of the everyday embarrassments which are encountered by the executive departments of the profession, to take into account, not only the pride of class power, which the artisan feels as keenly as the scientist, but those baser elements of disunion, ranging from trades-unionism to counting-room dictation in technical affairs.

Having recognized the grave and comprehensive character of the evil, the next step should be, not I think, to attempt any violent alteration in the existing conduct of engineering by the men who are now in active service, but to change, if I may so say, the environment of the young men who are so soon to take our places, in order that their development may be larger, higher and in better balance. Two co-operative methods have been suggested--reversing the order of study, and organizing the practical school.

Whatever the course of improvement may be, it becomes us to leave some heritage of unity to the coming race. How shall we more fitly crown a century of engineering--a century in which our noble profession has risen from comparative potentiality to living energy? And as its force is multiplied by the general advance of science, it becomes the momentum which evermore shall actuate the enginery of civilization.

SUSPENDED HOT-BLAST STOVES.

BY JOHN BIRKINBINE, PHILADELPHIA.

A RETROSPECT of the growth of the production of pig-iron for the past half century would be the history of the invention and introduction of heated blast as applied to the smelting of iron ores. As the apparatus employed was improved in conception and construction, the economical operation of the furnaces to which it was attached was the more marked, and the production correspondingly increased.

To compare the original iron box placed over a coal fire with the modern hot-blast stove, with its combustion-chamber, gas-burners, and air-regulators, would be as unfavorable to the former as to contrast the product of the little *Blauöfen* with the yield of the improved furnaces of to-day. But, as these little *Blauöfen* were the germs from which the larger plants have grown, so from the crude apparatus invented and applied by Neilson has grown, in the face of great opposition, the more economical hot-blast stoves now in use.

It is not surprising that an innovation like heated blast should have received a large amount of attention from metallurgists, nor that men of recognized ability should formerly have been found both among its champions and opponents, but it is remarkable that, at the present day, with the results of careful research and thorough experiment compiled in convenient shape for perusal, there are iron-masters who still consider it economy to allow the products of combustion to escape into the atmosphere, rather than utilize them in heating the blast, because of a supposed injury to the quality of the product.

In the present state of knowledge and practice, it is proper to express as an axiom, that a well-constructed hot-blast apparatus is essential to the economic operation of an iron-producing plant.

Of the interpretation *of proper construction* there is of necessity a variety of opinions, and, with the view of solving the problem, the apparatus for heating blast has from time to time assumed various forms. Boxes, cylinders, and pipes, placed horizontally, vertically, inclined, or in circles and spirals, have been tried; there have been pistol-shaped pipes, double pipes, divided or diaphragm pipes, siphon pipes, and as much variety in the mains, connections, flues, and setting.

It is probable that, to the introduction of the bell and hopper in furnace tunnel-heads, and the combustion-chamber and gas-jets in hot-blast ovens, the present acknowledged economy of heated blast is largely attributable, the former for the facility afforded for diverting and collecting the gaseous products of the furnace, the two latter by promoting thorough combustion of the gases, which, to a large extent, prevents injury to the iron pipes.

The apparatus at present most prominently before metallurgists, in connection with heated blast, is the Whitwell stove, and it is fully entitled to the credit given to it, but, unless the increased temperature attainable with the firebrick stoves be practically demonstrated to be of sufficient value to compensate for the additional first cost, the expense of construction will prevent their general adoption. The erection of Whitwell stoves, sufficient to maintain a uniform temperature of a hot blast, will, at the present time, cost about two and a half times as much as well-constructed pipe-ovens for the same furnace.*

Much of the trouble with pipe hot-blast stoves originates in defective construction and want of care in operating them. During a visit made last year to a prominent Western furnace plant, the writer observed a siphon-pipe hot-blast oven being torn down after a short blast. The pipes were, to use the founder's expression, "very drunk," and the oven was in very bad condition. An investigation left little room for surprise. The gases were discharged from the downcomer into a small masonry channel as an apology for a combustion-chamber, which was not supplied with any air-regulating apparatus, and the flame, in some instances, impinged directly upon the pipes. An examination of some of the broken pipes demonstrated that they were imperfectly cast of inferior metal, the shell in one instance being two inches thick on one side, and about half an inch thick on the opposite side. It is in the comparison with such constructions that the permanency of the firebrick stoves appears to great advantage. Where the pipes are made of good metal, cast in dry sand, with core and mould concentric, and set in ovens well built and stayed, provided with a proper combustion-chamber, and

* Excepting where the behavior of certain materials in individual furnaces under what may be termed "heated" and "superheated" blast is to be considered, the value of firebrick and iron-pipe stoves must be compared according to the interest upon their first cost, plus the annual expense of maintenance. Much of the condemnation which the iron-pipe stoves receive from some furnace managers is unjust, and would be of more weight had they bestowed upon the construction and operation of the iron-pipe stoves an equal amount of care and attention given to the firebrick stoves.

Gas-burners under perfect control, so as to obtain a thorough combustion and fill the pipe-chamber with a highly heated atmosphere, the apparatus is by no means a temporary one, and may be run for years without renewals or repairs. As an instance, the oven at one of the furnaces of Grove Brothers, at Danville, to which the combustion-chamber was first applied in 1850 (fifteen years before it was patented in England), is still in use and in fair condition. Unless some means are found of greatly reducing the first cost of the fire-brick stoves, our furnaces will continue to depend upon pipe-ovens; and it is my privilege to invite your attention to an improvement which, I believe, will do much towards cheapening the cost of construction and maintenance of iron-pipe hot-blast stoves. In its presentation I desire to say that, believing the subject would interest the Institute, I asked of the inventor (my former partner) the privilege of presenting it here, and thus subjecting it, in its infancy, to the candid criticism of many of our best ironworkers.

Mr. Weimer's oven contains eighteen U pipes, twenty feet long. (See Plate IV.) The cross-section of the pipe is an ellipse, twelve by four inches inside measurement, and the heating surface of each pipe one hundred and nine square feet. The usual bed-pipes are dispensed with, and the U pipes are suspended from the top of the oven by means of suspension bolts and beams.

To overcome the difficulty of maintaining a uniform heat in the combustion-chamber, two chambers are used, each seven feet high, three feet wide, and ten feet long--shortening the chamber and increasing its height having proved efficacious in equalizing the temperature. Besides the usual gas-jets a series of one-inch air-pipes are walled into the sides of the gas-chambers, so that the air may be thoroughly diffused throughout the mass of gas supplied to the chamber.

There being no bed-pipes to interfere with the arrangement of the flues connecting the combustion- and pipe-chambers, they can be arranged so as to give a uniform distribution of heat in the pipe-chamber. These openings are made six inches square. The pipe-chamber is also divided into two compartments, each of which is four feet wide, twelve feet long, and twenty-four feet high, placed above and communicating with its own combustion-chamber, entirely independent of its neighbor.

This arrangement obviates the difficulty of the hot and cold sides of the stove, and prevents the heat from becoming excessive on either side. There are no doors to the pipe-chamber, a few explosion-valves and sight-holes, the latter acting also as cleaning-holes for removing dust by steam-jets, alone breaking the continuity of the walls, which are made twenty-two inches thick, to prevent radiation and to support the weight of the pipes and mains.

On the top of the front end wall a short main 12 inches X 14 inches X 36 inches is placer], having on one side a connection for the cold-blast pipe, and on the opposite side three branches corresponding in cross-section with U pipes. To these branches three rows, each of three U pipes, are connected, and extend across the oven to a longer main placed on the rear end wall. This main has six branches, three in each chamber, the blast passing into it from the three rows of pipes in one chamber, and out of it into the three rows of pipes in the adjoining chamber, and through them into a short three-branch main connected with the hot-blast pipe. The branches of the mains and the ends of the U pipes have flanges which are planed to a true surface and connected by means of key bolts. Lugs are cast on the top of each arm of the U pipes to which suspension-bolts are secured; these bolts pass through saddles or washers, resting upon short, fifteen inch I beams, supported upon the side walls of the oven. The entire masonry of the oven can therefore be constructed before the pipes are placed in position.

Just below the connecting flanges of the U pipes, small projecting collars are cast, upon which (after the pipes are placed) five bricks are laid, forming a roof and protecting the joints from the action of the heat. On the top of the side walls an iron wall-plate is laid, which can be continued from one stove to the other when they arc in a row. This plate is cast with a projecting rib, so as to form a rail, upon which wheels of a truck carrying a crane or derrick may run. By this means a pipe which may have become damaged can be readily removed and another put in its place in a short time.

But, from the construction of the stoves, the necessity of frequent renewals is not probable, for the pipes are placed to sustain the greatest amount of heat with the least possible fatigue on the metal; their pendent positions and swelled bottoms have a tendency to keep them straight and prevent warping, the swelling also placing a surplus of metal where oxidation is the most destructive, thereby aiding in equalizing the life of the entire pipe.

In these ovens there is no metal in the lower oxidizing atmosphere in the pipe-chamber, the bottom of the pipes being four feet above the floor of the chamber; but on the contrary, the heating surfaces of the pipes are thrown into the upper and more uniformly heated

Of the pipe-chamber, which, in the ordinary standing pipe-stoves, is necessarily left vacant.

Among the additional economic features of these stoves are the following:

There being no bed-pipes there is a corresponding decrease in the weight of castings required.

The absence of door openings simplifies the masonry and lessens the castings required.

There being no other duty upon the arch over the combustion-chamber, than that of a dividing wall, considerable staying can be dispensed with.

The convenience of removal, by merely removing a section of the brick or tile roof (which rests upon the collars cast on the U pipes), and driving out the keys of the desired pipe, will materially lessen the cost of necessary repairs.

.*DETERMINATION OF PHOSPHORUS IN IRON AND STEEL.*

BY ANDREW A. BLAIR, WATERTOWN ARSENAL, MASS.

THE increased importance and value of chemical analysis in connection with metallurgical operations is largely, if not entirely, due to the increased accuracy of the analytical methods used for the quantitative determination of the foreign elements always associated with the metal operated upon. This applies especially in the working of iron and steel, and to the determination of the amounts of such elements as phosphorus, carbon, and silicon. The influence of greater or smaller amounts of these elements upon the physical properties of iron and steel will be better understood when the proper experiments shall have been made upon samples whose chemical composition is known with almost absolute certainty. From the present standpoint of analytical chemistry, it is easy to see that at least one reason for the failure of many attempts to solve this problem, is the inaccuracy of the analytical methods used. Even at the present time the frequent want of agreement (over and above the unavoidable error clue to manipulation) between chemists working on the same sample, leads one to think that there is still at least a choice in the methods, used. It is true that very frequently a faulty method in the hands of a skilful analyst may be made to give corroborative results.

from the mere identity of manipulation; but the crucial test of any method is the agreement of the results it gives on absolutely identical samples in the hands of different chemists. I desire to apply these remarks to one of the methods now in use for the determination of phosphorus in iron and steel-the acetate method. To do so, I shall state the method in all its details, as I have used it for several years, hoping that the importance of the subject will lead others to give the results of their experience, which may lead to the general adoption of this or some other method capable of giving exact results. The method is an old one, but some of the details are my own, and the experiments that I heave made on its accuracy will, I think, be of interest.

Five or ten grammes of the borings or drillings are treated with strong nitric acid, adding, from time to time, a few drops of hydrochloric acid, and applying heat as necessary until solution is complete. The solution is evaporated to syrupy consistency on the water-bath, 20 c.c. to 40 c.c. of hydrochloric acid added, the beaker covered and heated until all action has ceased, the cover washed off, and the solution evaporated to dry ness; this operation is repeated, and when the residue is dry, it is redissolved in hydrochloric acid, and when solution is apparently complete an equal volume of water is added, and the solution boiled for a few minutes to convert any basic or pyrophosphate of iron that may have been formed by too high a temperature, into the orthophosphate. The solution is then diluted and filtered, the filter washed with dilute hydrochloric acid, and then with hot water and the filtrate diluted to about 750 c.c. To this solution a sufficient quantity of acid ammonium sulphite is added to reduce all the ferric to ferrous salt. The reduction is facilitated by rendering the solution as neutral as possible with ammonia, even adding enough ammonia after the sulphite has been added, to render the solution turbid. This slight precipitate may be redissolved by the addition of a few drops of hydrochloric acid, and when the reduction is complete and the solution has been heated to boiling, an excess of hydrochloric acid is added to decompose any excess of the sulphite, and the solution boiled until every trace of sulphurous acid has been driven off. : While the excess of acid in the first place interferes with the perfect reduction of the ferric salt, when the reduction is complete, the excess of acid tends to prevent any subsequent oxidation, and facilitates driving off the excess of sulphurous acid. The solution should |be kept at a hard boil, and the beaker containing it should be

Covered with a large watch glass and stirred frequently, but the stirring must be done cautiously to avoid the tendency the solution has to boil over when agitated too suddenly. When all smell of sulphurous acid has disappeared the beaker is plunged at once into cold water and the water renewed until the solution is cold. Dilute ammonia is then added until a slight precipitate of the green ferrous oxide remains undissolved after stirring, and then a decided excess of acetic acid is added, which redissolves the ferrous oxide, while the ferric phosphate remains insoluble; a few drops of a dilute solution of ferric chloride are added and the solution heated to boiling. The precipitate should then have a decided reddish color, due to an excess of ferric oxide thrown down with the phosphate, which indicates that all the phosphoric acid has been precipitated as ferric phosphate. The cooling of the solution before the precipitation of the ferric phosphate seems to prevent the formation of a hard scaly oxide of iron during the subsequent boiling. This hint I received from Mr. Garrett, of the firm of Booth & Garrett. When the solution has been heated to boiling it is filtered as rapidly as possible on a close filter, the solution being kept boiling all the time, the beaker is washed out and the precipitate on the filter washed several times with boiling water. The filtrate should be perfectly clear, which will always be the case when a sufficient excess of acetic acid has been used. I have carefully tested this filtrate and find:

1. When it remains clear and the subsequent washing of the precipitate does not cause any cloudiness, no trace of phosphoric acid can be found in it.

2. When it becomes cloudy during the filtration, owing to an insufficient amount of acetic acid being used, or so much ammonia having been added that a large amount of ammonium acetate is subsequently formed, it always contains phosphoric acid.

3. I have never been able to find any trace of phosphoric acid in the washings alone, whether pure water, or water containing sodium or ammonium acetate, has been used.

The presence of phosphoric acid in the filtrate is owing to the fact that while the ferric phosphate is insoluble in acetic acid, it is very soluble in ferric acetate, and also in sulphurous acid, should all trace of this latter not have been boiled off. The more nearly neutral the solution is, the greater is its tendency to oxidation, which accounts for the favorable action when an excess of acetic acid has been added. The precipitate on the filter and adhering to the sides of the beaker is dissolved in strong hydrochloric acid, the filter carefully washed with hot water, and if the solution exceeds in bulk 40 or 50 c.c., it is evaporated down, sufficient citric acid added to prevent the precipitation of the ferric oxide upon the subsequent addition of ammonia, then magnesia mixture, and finally, an excess of ammonia. This entire solution should not exceed 75 c.c. in bulk. It is then cooled in ice-water, and when perfectly cold it is stirred carefully until the precipitate of ammonium-magnesium-phosphate begins to come down. After standing in ice-water for some time longer, it is stirred vigorously several times, and allowed to settle for at least eighteen to twenty-four hours before filtering. It is then filtered, and, without washing, the precipitate remaining in the beaker and on the filter is redissolved in dilute hot hydrochloric acid, a little citric acid added, and the ammonium-magnesium-phosphate reprecipitated by an excess of ammonia, using the same precautions as before. It is filtered after standing twelve to twenty-four hours, washed with very dilute ammonia-water, dried, ignited, and weighed as magnesium pyrophosphate. To test the solubility of the ammonium-magnesium-phosphate in the solution containing citric acid, ferric oxide, ammonium chloride, etc., I made a number of experiments in the following way: The filtrate from the first precipitation of the ammonium-magnesium-phosphate was evaporated to dryness in a large platinum capsule and heated over a Bunsen burner, until the volatile salts were driven off, and the separated carbon partly burned away, the residue transferred to a platinum crucible, the carbon burned off, and the residue fused with a small amount of sodium carbonate. It was then boiled with water, and the soluble sodium carbonate and phosphate separated by filtration. To the clear filtrate a slight excess of hydrochloric acid was added, and the solution boiled, a single drop of solution of ferric chloride added, and the ferric oxide and phosphate precipitated by ammonia, and excess of acetic acid; the precipitate filtered, washed, redissolved in hydrochloric acid, and any phosphoric acid present precipated as ammonium-magnesium-phosphate.

The results of these experiments, between twenty and thirty in number, and on samples containing from .015 per cent. to .314 per cent. phosphorus, showed that when the amount of ferric oxide thrown down was so large that it required from six to eight grammes of citric acid to keep it in solution, upon the addition of ammonia, and when the solution measured 150 c.c., about 25 c.c. being strong hydrochloric acid, the maximum amount of magnesium pyrophosphiitc found was 1.5 milligrammes, equivalent, when 5 grammes of steel was used, to .008 per cent. phosphorus. When the amount of ferric oxide precipitated was kept within proper bounds, requiring from two to three grammes of citric acid to keep it in solution, and the bulk of the solution was about 75 c.c., an unweighable trace only in some cases and usually no ammonium-magnesium-phosphate was found.

In regard to the results obtained by this method, I will state in general terms, that of a large number of determinations made on portions of the same sample by Messrs. Booth & Garrett, of Philadelphia, Mr. R. Chauvenet, of St. Louis, and myself, all of us using essentially this method, the greater number of determinations having been made by Mr. Chauvenet and myself, the maximum difference has been only .006 per cent. phosphorus. I have also redetermined the amount of phosphorus in samples untouched for over a year with a maximum variation of .005 per cent. phosphorus. The method, of course, requires some practice to get the details under proper control, but a little experience will soon enable the analyst to work with great ease.

NOTE UPON THE MANUFACTURE OF FERRO-MANGANESE IN AUSTBIA.

BY PROF. WILLIAM P. BLAKE, NEW HAVEN, CONN.

THE importance to the growing steel industry *of* the United States of a domestic supply of ferro-manganese or " Spiegel" of a high grade, induces me to bring to your notice some details of the method by which a superior article is produced in the Austro-Hungarian Empire.

At Reschitza, Hungary, and probably at Laibach also (the *Krainische Industrie Gesellschaft),* ferro-manganese is made in a blast-furnace, with charcoal as fuel, and limestone as the flux. The ore is a ferruginous mixture, containing about 37 per cent. of sesquioxide of manganese. It is silicious, and somewhat resembles, in its appearance, the manganese ore from Red Island, in the Bay of San Francisco, California. It contains about 29 per cent. of silica and some alumina, shown by the subjoined analysis :

Analysis of Ore used at Reschitza for Ferro-manganese.

Silica,	28.613
Alumina,	8.073
Protoxide of iron,	0.367
Sesquioxide of iron,	19.031
Sesquioxide of manganese,	37.224
Lime,	2.430
Magnesia,	0.261
Water,	3.691

This ore in the furnace requires a large amount of limestone to be added as flux. The larger the quantity of limestone, or the more highly basic the charge is made, the larger is the percentage of manganese in the product. Thus, by using 15 per cent. of limestone, and 85 per cent. of ore, the product contains about 25 per cent, of manganese. Doubling the amount of limestone about 5 per cent. is added to the product, giving, say, 30 per cent. of manganese; trebling the quantity of limestone, the metal contains 35 per cent. of manganese. To recapitulate results obtained, we have

15	Limestone,	give 25 per cent. manganese.
85	Manganese ore,	
28.6	Limestone,	gives 29 per cent. manganese.
71.4	Manganese ore,	
42	Limestone,	gives 35 per cent manganese.
57	Manganese ore,	

In a trial with the ore of which an analysis is given, 43 per cent. of limestone was added, so that the oxygen ratio of the bases to that of the acids was as 15.88 to 10.68 = 1.48 : 1, or nearly as 1.50 : 1. This is a highly basic charge, but upon this depends the success of the operation and the percentage of manganese attained.

The blast must also be under high pressure, and be very hot. In making the ferro-manganese at Reschitza, the pressure equalled from 90 to 100 mm. of quicksilver, and the heat was carried to 250° Celsius, equal to 482° Fahrenheit, the highest point attainable with the heating apparatus in use there. With a hotter blast, and still more limestone, an alloy containing at least 50 per cent. of manganese could be produced.

The quantity of ore, fuel, and flux required to produce 50 kilogrammes (100 lbs.) of ferro-manganese, and the cost of this product at Reschitza, were approximately :

	Florins.
1400 kilogrammes of ore,	2.94
5 hectolitres of charcoal,	2.00
600 Kilogrammes of limestone,	0.21
Labor, etc.,	1.00
Total,	fl .6.15

This is about equivalent to three cents a pound, or say $60 per ton.

Possessing a great variety and considerable abundance of manganiferous ores in the United States, we may expect, at no distant day, to produce within our borders a sufficient supply for the home demand. At present the inducement to enter upon the manufacture, is somewhat lessened by the influx of German spiegel, at a constantly diminishing price. The imports, at present, must be from 20,000 to 30,000 tons per annum, mostly from Germany, and the price is about $35, gold, per ton for a quality guaranteed to contain 10 per cent. of manganese. It is entered as ordinary pig-iron.

The domestic production does not exced, probably, 7000 tons per annum, but it is increasing. The Secretary of the American Iron and Steel Association, in his report presented February, 1875, gives the total annual consumption of spiegeleisen, by the eight Bessemer establishments in this country, when fully employed, as not exceeding 25,000 gross tons.

The New Jersey Zinc Company has three furnaces, each 20 x 7 feet, with a combined annual capacity of 5000 gross tons. This company produced 4072 gross tons in 1872, 3930 tons in 1873, and 4070 tons in 1874, which is about the present product. This spiegel is made from the residuum left after the extraction of the zinc oxide of the Franklinite and the associated silicate of zinc-willemite. It is a highly manganiferous mixture, and is favorable for the production of superior spiegel of a high percentage of manganese. Its composition is about as follows, two analyses:

Iron,	82.250	83.28
Mangances,	11.586	11.67
Phosphorus,	0.196	0.19
Silicon,	0.367	0.99
Carbon,	4.632	4.02

The Woodstock Iron Company of Anniston, Calhoun County, Alabama, commenced making spiegel in December, 1875, and have run out about a thousand tons to this date, varying in content of manganese from eight to twenty per cent.

The ore used contains a little over twenty per cent. of metallic manganese, and no phosphorus. It is mixed with "lamp ore" containing 58.25 of iron, 8.56 of manganese, and 1.042 of phosphorus, but these percentages are variable. The nature of the product is shown by the subjoined four analyses:

	Dec. 10.	Jan. 6.	Feb. 1.	Feb. 3.
Iron,……………	85.11	85.98	80.37	73.86
Carbon,…………	3.66	4.83	4.94	4.32
Silicon,………….	0.95	0.88	0.38	0.93
Phosphorus……..	0.10	0.17	0.18	0.197
Manganese,…….	10.18	8.14	14.13	20.69

ON THE PERCENTAGE OF IRON IN CERTAIN ORES.

BY PROF. ALBERT H. CHESTER, HAMILTON COLLEGE, CLINTON, N. T.

DURING the summer of 1875 I visited some of the iron mines of Houghton County, Mich., and was quite interested to observe the progress made there within a few years. Working in open pits is gradually giving place to underground work in most of the mines where this system is practicable. In some cases, as in the Lake Superior Mine, the body of ore is so irregular, and the deposit so liable at any time to be pinched out, or nearly so, that it has been found impractical, if not impossible, to lay out any plan for systematic underground work. But in many other mines the deposit is so regular in character, that the work can be laid out in shafts at regular intervals, and a series of 60 feet levels. The Michigainmi Mine, opened in 1872, and first worked in 1873, is arranged on this plan, though some quarrying is still done. But the men are being put at overhead stoping as fast as it can be got ready for them, and before long it will all be worked in this way. The New York Mine is undergoing a similar change to the pillar system, and several others have either been changed, or it is about to be done.

My principal object in visiting this region was to obtain samples from some of the important mines, so as to be able to answer the question: "What is the average percentage of iron in the Lake Superior ores *1"*

Most iron furnaces work on mixtures of ore, so that it is impossible to tell, from their records, just the percentage in each one.

For instance, *I* have before me the copy of one of the monthly returns of a blast-furnace near Buffalo, N. Y. As many as five ores are used, besides rolling-mill cinder. The percentage credited to each is as follows :

Lake Superior, specular,…62.5	Rossie, N. Y.,…………….54.5
“ “ hematite,..49.5	Wayne County, N. N.,……40.0
Champion, ………………63.0	Rolling-mill cinder,……….60.0

It is evident, if any one of these is placed too high or too low, that it affects the rest. The total average is stated in the return as 54.30 per cent., which is the only settled point; the details are mere guesses, depending on each other.

A prominent iron-maker of Pittsburgh, when asked what he considered the average amount of iron in Republic ore, replied that he was not quite certain, though he used a great deal of it, but he supposed it to be from 68 to 70 per cent.

As reliable information could not be obtained, the parties interested not being willing to trust the published reports, average samples were procured from several mines, and the percentage of iron in each was carefully determined. In two cases samples of ore that had been shipped for sale were taken from the company's cars at some distance from the mines, and in the other cases, ore no better than the average was taken from the stock-piles at the mines. The results obtained are as follows :

Champion Mine, 65.47 per cent. of iron. New York Mine, 61.01 percent, of iron.
Republic “ 6683 “ “ Lake Superior Mine, 64.62 " "

An average sample of Iron Mountain ore gave 64.87 per cent. of iron as the result of analysis.

My impression is that the Lake Chaimplain magnetites will not show as large a percentage of iron as these hematites. Two lots that I have analyzed show, respectively, 62.68 and 56.01 per cent. of iron. Undoubtedly there are richer ores than these to be found in that region, but these samples were taken from the stock-piles of blast-furnaces, and the ore, in the first case, was called number one.

The average amount of iron in our Clinton ore, as shown by repeated analysis, is 44.57 per cent., while in the furnace it gives about 43 per cent. A sample taken from a pile of about three hundred tons of Staten Island limonite, showed 41.19 per cent. of iron.

I give these figures with considerable confidence, as I am sure that the samples were selected with the utmost care, and fairly represent the ores mentioned.

BLAST-FURNACE STATISTICS.

BY JOHN A. CHURCH, E. M., TARRYTOWN, N. Y.

IN the year 1874, when the price of pig-iron was still high, that staple product became the subject of discussion in the newspapers and among those philosophers who are determined to know the "reason why" for all things. The object of the inquiry was to find out why iron did not fall in price as much as some other things had fallen. Indeed, there seemed to be an impression that iron and gold ought to move on nearly parallel lines, for the fact was constantly brought forward that iron then cost twice as much as it did before the war, though gold had returned to within twelve or fifteen per cent. of its former value. After some time the papers, by what seemed to be nearly unanimous consent, reached the conclusion that the maintenance of high prices was the work of the furnace proprietors, who, as the result of their shrewdness, were pocketing enormous profits. No proof was given to support this opinion, and the figures of cost and sale that were produced were of the most general kind, and used in the most vague manner.

Visiting the president of the Thomas Iron Company, whose great works at Hokendaqua and Catasauqua, in Pennsylvania, arc so well known as the largest and among the best conducted in America, I found him quite willing to meet the vague suspicions of the newspaper wiseacres, by a publication of the figures contained in the furnace-books of his company. These were accordingly given to the world through the *Engineering and Mining Journal,* and attracted the general attention they so well deserve. Though my own name became connected with these statistics, from the fact that I used them as the basis for the first attempt ever made to calculate the furnace economy of an American works, I can, without the suspicion of egotism, say that the statistics referred to arc the most valuable contribution the literature of American blast-furnace work has yet received, for their interest is independent of personal considerations, and due entirely to the fact that they represent faithfully the details of practice in one of the most prominent American works. They are an exact transcript of the furnace-books, and form a body of accurate information of the greatest value to the metullurgical student. Their importance is shown by the fact that though the theoretical conclusions which I based upon them have been several times attacked, not one of my critics has made the slightest contribution to statistics of blast-furnace practice. My table was unique, and unless the managers of other works are equally spirited, it is likely to remain so.

Believing that statistics of such value should be formally laid before this Institute, and embodied in its transactions, I obtained from the president of the company a transcript of his books for the two years which have elapsed since my publication, and the whole is now presented to you in the table on p. 223.

The geographical distribution of ore and coal in this country has produced a number of well-marked classes of iron-works. We have those which are placed close to the ore mines, but obtain anthracite coal by a long carriage, usually by land and water combined; others that have both ore and anthracite close to the furnace; others that are placed at great distances (often 200 or 300 miles) from both of these main supplies. The makers of soft-coal iron are in precisely the same positions, and railroad transportation of fuel has its greatest extension in supplying the large furnaces on the Mississippi, which obtain ore from Iron Mountain, 100 and more miles distant, and coke from Connellsville, 500 miles and more away. The conditions are further complicated by the fact that sometimes the ore, sometimes both ore and fuel, and sometimes neither one is mined on land belonging to the furnace owners. The Thomas Iron-works stand in the second of the classes first spoken of. 1. It mines its own ores. 2. Works low grade ores (average of 5 years, 41.6 per cent.). 3. Has short transportation (average, say, 30 to 35 miles) for fuel and ores. 4. Smelts with anthracite coal. 5. Uses large furnaces "with all the modern improvements," a very hot blast (900° F.), and high pressure. 6. Has produced on a long average, 33 per cent. of No. 1 X, 28 per cent. No. 2 X, 31 per cent. No. 2, and 8 per cent. No. 3; or, if we count these as Nos. *1*, 2, 3, and 4, the general average would be 2.07. (This average is for the period ending December, 1873.)

The cost of the ore includes not only the mining expenses, but also a royalty of 25 cents a ton for brown hematite, and 50 cents a ton for magnetite. The item of labor includes also repairs and the cost of blowing in and out, to which are due the very great fluctuations in this item. The "running time" includes the total number of weeks run by all the furnaces in each half year. As the furnaces are not all of one size, the average which can be calculated from the running time and the total make, would not be correct for any one of the stacks. But as the performance of the separate furnaces is not

Six Months, ending	Cost per Ton.			Amount used per Ton Pig.						Cost per Ton Pig.				Total cost per ton pig.	Tons pig made in 6 mos.	Running time.		Quality. Average number.
	Coal.	Ore.	Limestone.	Coal.		Ore.		Limestone.		Coal.	Ore.	Limestone.	Labor and Repairs.			Weeks.	Days.	
				Tons.	lbs.	Tons.	lbs.	Tons.	lbs.									
December, 1855...	$3 10	$3 59	$0 63	2	968	2	1,252	1	1,357	$7 55	$9 50	$0 98	$2 54	$20 57	6,445	39	5	1.61
June, 1856..........	2 95	3 75	0 57	2	835	2	1,353	1	834	7 00	9 61	0 78	3 08	20 47	10,605	52	5	1.67
December, 1856...	2 89	3 65	0 54	2	560	2	892	1	976	6 50	8 75	0 78	5 94	21 97	6,833	40	0	1.77
June, 1857..........	2 84	3 69	0 52	2	465	2	858	1	630	6 27	8 34	0 67	4 08	19 37	10,534	51	5	1.53
December, 1857...	2 80	3 30	0 52	2	336	2	804	1	537	6 02	7 72	0 65	4 23	18 61	7,564	39	5	1.66
June, 1858..........	2 54	2 88	0 43	2	11	2	813	1	544	5 09	6 68	0 54	3 49	15 80	7,732	32	4	1.93
December, 1858...	2 43	2 81	0 37	1	2,175	2	566	1	699	4 80	6 33	0 48	2 55	14 16	12,253	52	2	1.79
June, 1859..........	2 42	2 62	0 34	2	161	2	701	1	733	2 02	6 06	0 46	2 85	14 39	11,767	49	2	1.86
December, 1859...	2 39	2 61	0 34	2	170	2	870	1	500	4 97	6 23	0 41	4 29	15 91	10,429	52	0	1.86
June, 1860..........	2 44	2 60	0 35	1	2,056	2	885	1	778	4 68	6 23	0 47	4 13	15 50	11,155	46	0	1.96
December, 1860...	2 45	2 86	0 36	1	1,949	2	633	1	655	4 58	4 58	0 46	2 46	14 02	13,699	52	1	1.98
June, 1861..........	2 37	2 70	0 34	1	2,218	2	685	1	854	4 72	4 72	0 47	2 58	14 00	13,219	51	5	2.05
December, 1861...	2 36	2 62	0 33	2	85	2	627	1	789	4 82	4 82	0 44	2 34	13 58	13,777	52	2	2.06
June, 1862..........	2 37	2 39	0 34	2	56	2	531	1	824	4 79	4 79	0 47	2 45	13 05	12,784	52	0	2.01
December, 1862...	2 70	2 63	0 32	2	323	2	368	1	567	5 80	5 80	0 41	2 11	14 01	17,902	77	5	1.61
June, 1863..........	3 80	2 60	0 45	2	224	2	676	1	737	7 99	6 00	0 60	4 45	19 03	16,968	72	1	2.09
December, 1863...	4 92	3 03	0 49	2	579	2	909	1	978	11 11	7 29	0 71	4 94	24 05	18,724	78	5	2.07
June, 1864..........	5 66	3 59	0 55	2	435	2	871	1	1,112	12 42	8 59	0 82	4 65	26 48	23,317	102	0	2.25
December, 1864...	7 03	4 79	0 73	2	777	2	949	1	1,427	16 51	11 60	1 16	6 80	36 07	21,162	95	4	1.99
June, 1865..........	6 13	4 68	0 80	2	907	2	1,166	1	1,416	14 75	11 78	1 30	6 64	34 48	14,320	68	0	2.25
December, 1865...	5 69	4 72	0 69	2	448	2	75	1	1,128	12 66	10 87	1 04	5 73	29 70	17,189	72	0	1.96
June, 1866..........	4 85	4 34	0 76	2	262	2	758	1	1,078	10 27	10 11	1 13	5 67	27 18	23,496	101	1	2.08
December, 1866...	4 44	4 94	0 74	2	605	2	523	1	1,116	10 07	11 02	1 11	5 16	27 36	23,556	96	5	1.69
June, 1867..........	4 00	4 90	0 72	2	903	2	687	1	1,065	9 61	11 30	1 07	5 98	27 97	22,153	96	4	1.94
December, 1867...	3 54	4 56	0 75	2	890	2	642	1	1,207	8 57	10 43	1 16	4 99	25 14	24,987	104	0	1.74
June, 1868..........	3 41	4 60	0 76	2	466	2	875	1	1,140	7 53	11 00	1 14	6 54	26 21	26,214	100	6	2.21
December, 1868...	4 14	4 53	0 78	2	436	2	787	1	1,011	9 00	10 64	1 17	6 52	27 33	27,448	124	5	2.15
June, 1869..........	4 16	4 66	0 79	2	132	2	554	1	1,366	8 57	10 47	1 27	5 24	25 56	28,868	130	0	2.04
December, 1869...	4 95	4 98	0 82	2	80	2	375	1	1,345	10 07	10 79	1 30	6 11	28 27	33,352	155	0	1.90
June, 1870..........	3 98	4 89	0 81	1	2,001	2	489	1	1,059	7 53	10 85	1 20	5 05	24 62	33,357	156	0	2.15
December, 1870...	3 78	4 72	0 81	2	32	2	579	1	1,067	7 61	10 66	1 20	4 93	24 41	33,507	156	0	2.19
June, 1871..........	4 23	4 86	0 79	2	61	2	814	1	1,161	8 59	11 48	1 20	8 06	29 33	16,318	86	3	2.69
December, 1871...	3 77	4 98	0 73	1	2,032	2	493	1	916	7 18	11 06	1 03	3 84	23 12	36,301	156	0	2.23
June, 1872..........	3 69	5 24	0 74	1	1,921	2	252	1	944	6 84	11 59	1 05	4 60	24 08	36,311	156	0	2.27
December, 1872...	3 75	6 22	0 75	2	116	2	749	1	1,361	7 69	14 51	1 20	5 79	29 20	32,107	156	0	2.28
June, 1873..........	3 85	5 95	0 75	1	2,039	2	471	1	1,410	7 36	13 15	1 20	7 40	29 11	32,676	156	0	2.30
December, 1873...	3 85	6 02	0 73	2	60	2	796	1	1,412	7 82	14 21	1 20	6 50	29 72	26,420	131	0	2.30
June, 1874..........	3 86	5 88	0 66	1	2,138	2	799	1	1,140	7 39	13 64	1 00	5 44	27 49	19,521	109	3	1.84
December, 1874...	3 86	5 75	0 61	1	1,856	2	183	1	771	7 06	11 98	0 83	5 27	25 14	21,592	100	0	1.95
June, 1875..........	4 28	5 30	0 57	1	1,904	2	178	1	737	8 12	11 03	0 76	3 82	23 74	21,326	104	0	1.92
December, 1875...	3 41	5 19	0 55	1	1,678	1	2,124	1	352	5 99	10 12	0 64	3 56	20 32	21,952	92	2	1.80
Total	......	......	......	......	......	......	......	......	......	......	......	......	......	......	820,865	3,698	3	......
Aver. per six mos..	$3 71	$4 16	$0 60	2	206	2	667	1	969	$7 74	$9 42	$0 87	$4 70	$22 94	20,000	90	1	1.99

given, no other mode of representing the running time than to credit all to one furnace was possible. The "average quality" is calculated by the ordinary mode to a uniform figure, as it would be of no advantage to represent the exact amounts of each number made in detail. As given in the table, the general average number permits a direct comparison with the calculations of foreign metallurgists.

It will be noticed that the cost diminishes pretty steadily from the beginning down to the war. This was partly due to an increasing economy in the use of coal, ore, and limestone, which indicates improvement in making up the charges; and partly to the abandonment of the system formerly in vogue, of blowing out frequently. The two furnaces with which the establishment began, blew out twice in the first 30 months, giving average runs of 35 weeks, but then we find runs of 97 weeks, 183 weeks, 196 weeks, and the like. This accounts for the low amount charged to labor in the years 1860-63. In fact, the average in this period, $2.37, indicates very closely the cost of furnace labor without repairs, in former times.

From 1863 to the end of the period included in the table, much greater fluctuations in the "labor" item will noticed. This is partly due to the numerous alterations in the rate of wages, and partly to the fact that several furnaces were built and blown in. During this part of the time covered by the table, the average charge for labor seems to have been about $5.50, except when several furnaces stopped together, when it rose in one case to $8.06. The true charge for furnace work without repairs, would probably not much exceed $5.00; the average in 1869 and 1870, when there was no blowing out and only one furnace blown in, being $5.33.

At first the ore used was New Jersey magnetites, the amount being 51.18 cwt. ore, and 32.11 cwt. limestone, to the ton of pig. In the second half year brown hematite from Pennsylvania was added. From 1868 to 1873, or in five years, the charge did not vary much from 70 per cent., or 31.48 cwt. hematite, and 30 per cent., or 13.49 cwt. magnetite. The amount of limestone in the same five years averaged 30.76 cwt. This is a decrease of 7.56 cwt. of ore and flux, which, if we assume the chemical phenomena to have remained unchanged, corresponds to a saving of very close upon 9 per cent. of the fuel.

The fuel column is perhaps the most instructive of all. From an expenditure of 48.64 cwt. of coal in 1855, the amount used sank to an average of 39.56 cwt. in the 5 years, 1869-73. This saving of 9.08 cwt., or 18.66 per cent., must be accounted for in several ways.

1st. Better ores. 2cl. Increased make of lower grades of iron. 3d. Higher temperature of blast.

Comparing the first half year with the last, we find that with a reduction of 0.19 or about one-fifth of a number in the grade of iron, and 1368 pounds of ore, there has been a saving of 1530 pounds of coal, and 1005 pounds of limestone in making a ton of pig. This economy is not, perhaps, so striking as the iron manufacture in the other parts of the world, with other fuels, has shown in the same period. The business of making iron with anthracite coal seems to be handicapped with what would be an excessive expenditure of fuel in a coke furnace. The strenuous efforts of men who are acknowledged to be experienced and able, has so far failed to place this natural natural fuel on a par with its artificial rival. The difference is not in quality, for when both fuels are calculated at 85 per cent, carbon, the expenditure of carbon in the best anthracite furnaces, in this country, working with a blast as hot as it is used on this side of the Atlantic, is from 25 to 30 per cent. above corresponding practice abroad with coke.

The most experienced men in the anthracite iron manufacture look upon this large requirement of fuel, when that coal is used, as a necessity inherent in its peculiar character. I have never been able to share that opinion. Good anthracite may fairly be estimated at 85 per cent. carbon, and at this valuation it should, but for one fact, be as good a fuel as coke or charcoal, both of which arc usually valued at the same percentage of carbon, in careful calculations. That exceptional fact is that fuels of the same composition give different quantities of heat, the difference being probably due to a dissimilar construction of the molecules that compose them. The subject is obscure, and a multitude of careful experiments will be necessary before we can hope to understand it. But it does not seem probable that the difference in the value of fuels, due to this cause, can amount to as much as twenty-five or thirty per cent. Part of the excess must be attributable to the methods of smelting with anthracite. We know, from the experience of the Lake Superior furnaces, what apparatus will smelt the easily reduced ores of that region with a remarkably low minimum of charcoal fuel. Foreign works (and some American ones too) show us how ores like the Cleveland carbonate and brown hematite or fossil ore can be smelted with a minimum of coke. But it seems to me that the secret of working the Eastern magnetites with anthracite coal has not yet been found. The minimum of fuel expenditure has not been reached, if we except some isolated cases of remarkably good work. The "reason why" for this greater consumption of anthracite appears to me to be one of the great questions of metallurgical practice in America.

Returning to the table, it will be noticed that it covers the period of greatest depression, and also that of greatest excitement our iron trade has ever known. Iron cost in the first half of 1862, $13.05, and in the last half of 1864 its cost was §36.07, the highest point it has reached. It is worthy of notice that the only one of the subordinate items of cost which rose to its maximum in that year was coal, which stood at the enormous price, to a furnace, of $7.03. Ore, limestone, and labor, were each higher at a later period, when the total cost was, however, less. Another fact is that the advance in the cost of ore has been maintained while coal has returned toward, though not to, its old point.

Coal has advanced from $2.45 in December, 1860, to $3.41 in December, 1875. Ore in the same time has increased in cost from $2.86 to $5.19. The item of labor and repairs standing at $2.46 in 1860, was $3.56 in 1875. But the former price was exceptionally low. It had averaged §4.21 all through 1859. The saving in this item has been produced probably by improvement in management and increased make.

BRÜCKNER CYLINDERS.

BY N. H. CONE, M. E., NEDERLAND, COLORADO.

IT is somewhat surprising that among the many mechanical devices that were brought into the State of Colorado, that the Brückner cylinders alone have stood the test for roasting ores. The brick walls of the Arey and Stetefeld furnaces have been remodelled into reverberatories and compound reverberatories, their binding and anchor irons have been forged into hoes and shovels, while the Crosby and Thompson cylinders have been rent by the ruthless hand of the foundry man searching for a tough piece of boiler plate. Two only of these furnaces remain in operation, of the large stock that came into Colorado by car-loads several years ago, and they occupy only a subordinate position to some reverberatories on the North Boulder Creek.

But to-day there are in Colorado, in active operation, ten Brückner cylinders, and two or three more running part of the time. During the past year they have handled nearly one-half of the number of tons of silver ore that has been mined.

Four of the cylinders I have been using in the Nederland mill, in which I have roasted nearly four thousand tons of silver-ore during the past year, with results more favorable than have hitherto been attained.

The Nederland mill is similiar to many others in Colorado and Nevada. The plant consists of a Blake crusher, three batteries of five stamps each, four Brückner cylinders, and fourteen amalgamating pans, with settlers, agitators, etc. The ore, after being dried on the drying kiln, which is heated by the waste gases of the furnaces and an auxiliary fire, is weighed and fed into the batteries, which are dry crushing (size of screens 40 meshes to lineal inch), and thence carried by conveyors and an elevator to sheet-iron hoppers over the cylinders. The size of the cylinders is twelve feet long by five feet six inches in diameter. Mr. J. M. Locke has given an excellent description of them in a paper read before the Institute (vol. ii, *Transactions)*, and as during the coming year sonic very material changes will be made in their construction by reducing the weight, thereby reducing the cost of freight, and in the driving-gear, I will not go over the same ground.

After several trials I found that 3700 lbs. was the limit that could be handled in the cylinders for a charge of ores from Caribou Hill, and with several small lots of custom ore I reduced it to 3500 lbs. From these trials I very soon saw that to handle the cylinders not only to their utmost capacity, but to do thorough work, it was necessary to charge an amount of ore that when it reached its largest volume in swelling it would barely run out of the back nozzle of the cylinder. I have sometimes been delayed by small charges that it seemed almost impossible to finish.

The addition of salt *I* varied according to the value and quality of the ore; usually it was 175 lbs. to a charge, occasionally 200 lbs. The time of roasting ranged all the way from 8 hours to 12 hours, I gave my men strict orders never to draw a charge till it was thoroughly *done,* if it took a week; fortunately this circumstance never happened.

When I first took charge of the mill the diaphragms to the cylinder were entirely eaten away. For some reason " basic scale " would not form on those pipes and plates, nor on the new diaphragms that I. put in last September. The stumps of the pipes that remained gave me a great deal of trouble by working loose in their sockets, and allowing the half-roasted ore to leak out, so that I finally removed every vestige of the diaphragms, and ran the cylinders for over six months with nothing but a lining of common red brick. Having never enjoyed the benefits of a new set of diaphragms, I was very anxious to try them, so last September I put in a complete set all around and re lined the cylinders, and during the next 60 days saw them rapidly disappear, and I was obliged to clean out the dust-chambers twice as often, and take out three times as much as ever before, and since November, 1875, I have been running on the good old plan.

The class of ore that I have been treating contains about 11 per cent. of mineral matter on the average for the year.

Galena,	5 per cent.	= 11 per cent.
Blende,	4 "	
Copper pyrites,	2 "	

I have occasionally had custom ore that would reach up to 30 or 40 per cent. of mineral matter, and have been very successful in roasting it, the only difference being that it required a little longer time.

Part of the year I have had 8-hour shifts on, and the rest of the time 12-hour shifts. The advantage of 8-hour shifts is that the men watch the charges closer, and in case one is sick, or it becomes necessary to discharge one, the two can be put on 12 hours, and the work will go along more surely than if a new man from some other part of the mill was put on.

I have adopted the following plan for taking samples, after trying different methods. The roaster opens the first door that approaches him, and as it passes around and commences to clump the ore into the car the second time, a sample is taken with a long-handled shovel, allowed to cool, and then wrapped up in paper and the number of the charge marked on it. A regular list is kept of all charges, giving date, quantity, time charged, time discharged, quantity of salt used, workman's name that charged and discharged the ore, with remarks whether Caribou or custom ore had been used. Assays for chlorinations are made of each man's work, and the average recorded on the office book.

I changed the diameter of the nozzles several times. The flue to the dry kiln leads off from the dust-chambers near No. 4 cylinder so that the gases from No. 1 cylinder have the greatest distance to travel.

No. 1	cylinder,	fire-box	nozzle,	16	inches—back	nozzle,	17	inches.
No. 2	"	"	"	16	"	"	12	"
No. 3	"	"	"	16	"	"	18	"
No. 4	"	"	"	15	"	"	17	"

I have arranged the year's work under the following table, so that the work of different months can be easily compared, I also give the maximum and minimum of chlorinations, and fineness of bullion, as well as the monthly averages.

			Weight in tons.	Assay.	Fineness of bullion.	Time of roasting, hours.	bbls. of salt used.
January, . .	Max. of Chl.,	92.5	9.031	147	828		
	Min. of "	87.8	5.093	30	713		
	Averages,	90.	396.8	52	744	8½	137
February, .	Max. of Chl.,	95.4	11.231	152	831		
	Min. of "	89.7	10.344	50	788		
	Averages,	91.0	318.2	70	812	8¾	108
March, . . .	Max. of Chl.,	91.2	12.595	74	821		
	Min. of "	87.1	11.102	37	740		
	Averages,	88.	371.2	46	790	9	137
April, ...	Max. of Chl.,	93.2	8.505	92	847		
	Min. of "	89.8	12.027	34	766		
	Averages,	91.0	353.4	58	807	9	136
May, ...	Max. of Chl.,	94.5	10.214	168	842		
	Min. of "	86.8	7.361	26	763		
	Averages,	89.4	329.8	54	825	9½	140
June, ...	Max. of Chl.,	90.8	5.980	42	815		
	Min. of "	85.9	10.580	32	773		
	Averages,	88.3	393 9	37	794	10¼	138
July, ...	Averages,	88.8	362.7	42	820	9½	136
August, . . .	Max. of Chl.,	92.	10.000	41	866		
	Min. of "	87.6	12.148	27	836		
	Averages,	89.1	319.9	36	854	10½	100
September,	Max. of Chl.,	91.4	12.540	56	928		
	Min. of "	85.5	14.605	26	858		
	Averages,	89.1	246.2	51	893	11	93
October, . .	Max. of Chl.,	92.	11.880	65	946		
	Min. of "	87.5	8.580	56	868		
	Averages,	89.1	300.8	43	902	10½	96
November,	Max. of Chl.,	95.9	12.600	31	878		
	Min. of "	89.	6.930	21	814		
	Averages,	92.8	305.3	41	853	11	106
December, .	Max. of Chl.,	92.4	14.800	48	822		
	Min. of "	89.3	14.520	56	777		
	Averages,	91.5	120.9	53	804	10	42

The consumption of wood is about a cord and one-half to five tons of ore; this, of course, depends on how constantly the cylinders are kept running.

The expenses for treating ore has been, per ton:

Labor, ...	$6 18	Oil, candles, etc., . . .	$0 37
Quicksilver, ...	0 76	Repairs, ...	1 68
Salt, ...	2 09		
Wood, ...	3 43	Per ton,	$14 51

By wetting the ash-pit I have been enabled, sometimes, to get a current of steam to pass into the cylinders, and have found it a very good way to regulate the fires.

I have had no difficulty in teaching men how to roast; they very soon take hold of it, and there seems to be a general desire among the workmen to learn.

DIATOMACEOUS SANDS OF RICHMOND, VIRGINIA.

BY MARTIN CORYELL, RICHMOND, VIRGINIA.

EHRENBERG was the first to publish and direct attention to the peculiarities of the diatomaceous deposit of Richmond; but how and by whom he was supplied with the material for his microscopical investigations, is not generally known; but we may presume *W.* B. Rogers, formerly State Geologist of Virginia, furnished the material, and may have given the geological position or horizon. Of these facts we have no available evidence, nor have we any estimate of the thickness of this stratum of diatomaceous or infusorial earth.

At the request of a member of this Institute, I have investigated the subject, and offer the following facts as the result, derived principally from information supplied by Mr. John Ott, of the Southern Fertilizing Company, Dr. William Taylor, State Chemist, C. Peticolas, microscopist, Captain Robert H. Temple, civil engineer, Major C. M. Bolton and Mr. C. M. Smith, civil engineers, and formerly engaged in constructing the tunnel under Church Hill, in Richmond.

The city of Richmond is generally described as being built on seven hills. This is not the fact, geologically speaking. Originally, there was an immense plateau of land, about two hundred feet above tide, in which a deep excavation was made from the west to east by the James River cutting down to the granite. Opening southward and meeting the valley of the James are various ravines and gullies, in the principal of which are Shockoe and Gillies Creeks. The formation is tertiary, subdivided into all the classified divisions, but at the present moment no one has been found to make this section a special study. Rogers's early classifications and diagrams, with all their imperfections, are the only published records, and the printed editions are long since exhausted. The city of Richmond is really situated in these ravines of the James, Shockoe, Gillies, and their connections. The profile marked A, Plate V, represents the section of the plateau as exposed in making the tunnels and railroad cuttings through the city of Richmond, and it will be observed that thirty feet of the top stratum, as found further inland, is denuded. The tide flows up to the granite ridge which makes the rapids, not only of the James River, but also of the Delaware, Schuylkill, Potomac, and many other rivers emptying into the Atlantic.

At Rocketts, near the terminus of the Chesapeake and Ohio Railroad, the tide covers the granite some thirteen feet; near the mouth of Shockoe Creek the rock comes to the surface and forms the bed of the river, and thence rises rapidly to the west, about one hundred and twenty feet above tide in the distance of ten miles. It has a descent of about eighty feet within, or adjoining, the city limits, and is capable of furnishing power to an enormous extent. On the sides and bed of the river are the valuable granite quarries furnishing stone used in the public buildings of Washington and other cities, and the theory of deeper and greater disintegration of rocks in the Southern States, as compared with the Northern, as set forth by Dr. T. Sterry Hunt, is fully exemplified in this section along the James River. Upon this granite bed is a sandy clay some fifty feet thick, of various colors and composition, then a ferruginous sand, so compact in places as to resist the pick and crowbar, and which, when struck, produces sparks of fire, and is classed with the rocks. Upon this stratum is the blue deposit through which the tunnel was made. The thickness of the stratum in the tunnel was found to be eighty feet; and the color, when first exposed, a dark blue, but on long exposure becoming nearly white. Upon this is a yellow clay, very distinct in color, and filled with water-worn silicious boulders, nearly the size of hens' eggs. This stratum is thirty feet in thickness, and upon it are various strata of clays which make the soil of the upland country, and under present cultivation do not indicate much fertility. In excavating the tunnel, large quantities of bones and teeth were found, not interspersed through the material, but generally in pockets. The workmen, observing the interest manifested at the finding of the deposit and the anxiety to secure every relic, conceived them to have a money value, and did not fail to appropriate all the fine specimens. Subsequently, not realizing pecuniarily as expected, they neglected and permitted to go to waste what would have been highly prized cabinet specimens.

(A number of specimens, obtained by Mr. C. M. Smith, were then exhibited, consisting of fish remains, vertebræ and teeth, coprolites, etc).

The microscopic slides were prepared by Mr. C. L. Peticolas, from materials obtained from different localities, such as Church Hill, French Garden, the Capitol Grounds, etc. These localities yielded the most satisfactory and interesting specimens for the microscope, but failed to give the geological horizon or thickness of the strata containing the diatoms.

Mr. Peticolas, recognizing the importance and value of the true position and thickness of the strata from a known base-line, very kindly devoted his time to establish these facts for this paper, and, with the knowledge and assistance of Major Channing M. Bolton, he was furnished with material from well-established points in the tunnel and the railroad excavations, marked on the profile A, B, C, D.

To the eye, there is a uniform stratum eighty-five feet in thickness, blue in color when first exposed, and becoming nearly white after long exposure; this was generally denominated the diatomaceous stratum. Material from the bottom of the tunnel and lower portion of the blue stratum (A and B), was nearly barren, and the remains of an inferior type; at the point C diatoms were found in great abundance, and at D, near the top, the clay was quite barren.

These results were not entirely unsatisfactory, but time did not permit us to extend the observations further; investigations will be continued, however, in a systematic manner, and will doubtless prove instructive and useful.

This diatomaceous sand, or infusorial earth, has been known a long time, and its extent is, undoubtedly, large; yet it has not been utilized, or made profitable, although there is no reason to doubt that a proper preparation by washing will make it of commercial value as a polishing powder, or for the manufacture of dynamite explosives.

RAILWAY RESISTANCES.

BY P. II. DUDLEY, C.E., CLEVELAND, OHIO.

IN giving a brief account of the experiments in progress to inquire into some of the facts in regard to "railway resistances," recently commenced upon the Lake Shore and Michigan Southern Railway, with the dynagraph (which is essentially an instrument recording upon paper the force required to draw a train, at all speeds, marking the time in short intervals, so that the force absorbed due to any change of speed can be readily computed), I am well aware that but few of the members are directly engaged in railway construction; yet as all are interested in efforts to reduce the cost of transportation between the mines, manufacturing and agricultural industries of the country, I trust that the account will be of interest and importance to us all. We commenced using the dynagraph last November, and, while it may seem a simple thing, it has taken a long time to properly understand and interpret the record as made upon the paper.

Although only connected to the locomotive by the ordinary link and pin, every movement of the lever of the throttle-valve and of the reversing lever are at once indicated and recorded; and upon heavy freight trains the opening of cylinder cocks is generally shown. Each locomotive and engineer gives the record a distinct individuality ; the former depending upon its condition and the latter upon his ability to run even and steady. To eliminate the latter irregularities we now have the same engine and engineer in making experiments with single cars and short trains. It took time to find out all this, and as soon as the track became soft from the excessive wet weather we had in the vicinity of Cleveland, during the winter, it gave us new indications to study and interpret. Now, by passing over a track we can tell whether it is in good condition, or whether the engines are working properly or not, as to the admission and release of steam in the cylinders. The latter indication is much more difficult to determine than any other, as it makes a record similar to that of a rough track.

The Lake Shore and Michigan Southern Railway has a double track of steel rails, well ballasted and in fine condition. From Cleveland to Erie it is nearly all tangent, the grades not exceeding 16 feet per mile. The radius of curvature is very large, ranging from 2000 to 20,000 feet, with but one or two short curves of the shorter radius. With a stock train of 709 tons (of 2000 lbs. each) at a speed of 16 to 18 miles per hour, the resistance upon a straight line was from 6.5 lbs. to 7.1 lbs. per ton. Box cars of same weight of train did not differ much as to resistance per ton. The cars were mostly of the Lake Shore and Michigan Southern Railway construction. Chilled iron wheels, 33 inches diameter, broad tread, coning about 1/8 of an inch in 4 inches; weight, 550 lbs. Journals ranging from 2 7/8| to 3¼ inches in diameter, and 5½ inches long. For oiling they use petroleum nearly in a crude state. Two styles of brasses are used, both when new (and designed to do so when worn), bear on the journal their entire length ; but one brass only bears in the centre about two inches against the upper part of the box, and as the brass becomes thin by wear, it springs off the journal at the ends, and a short bearing is left in the centre, and without great care is liable to heat and get to cutting. It is not uncommon to find a journal worn a quarter of an inch smaller in the centre than at the shoulder and collar. The other style of brass has a good bearing upon the top of the box, the entire length of the journal, and seems to wear better, do more service, and run more easily when old than the kind first mentioned. In all of the experiments with single cars we found, when light, that those which had a six-inch brass, with same size of journal (3¼ inches), ran more easily than those with shorter journals. The system of lubrication seems to be somewhat deficient. The waste catches the brass which is ground off, mixes it with the oil, and is used over and over again, keeping the journal simply in an unctuous state, and not in good condition of lubrication. We took cars which were said by the carman at the yards to be in good condition (but the oil and worn brass were all mixed together, like a thin paste), and had some fresh oil turned into the boxes, decreasing the power required to draw the oars, from 10 to 20 per cent. One great object we had in view when we constructed the dynagraph, was to test the friction of various kinds of coal equipment in use in the Eastern coal districts, as well as that used West, where the car is 28 feet long over all, with 18-inch sides, and weighs from 80 to 95 per cent. of the coal carried. Very few of them have dumper bottoms, and those which have only permit a small quantity to run out without shovelling. In the Eastern States, many varieties are in use having dumper bottoms, and only weigh from 50 to 55 per cent. of the coal carried. A car in which the dead weight is reduced 30 to 40 per cent., other conditions being equal, would materially reduce the cost of transportation on Western coal, and be of ad vantage to the producer as well as to the consumer. Our Western coal cars, for some unexplained reason, do not seem to draw with more ease than box or stock cars, at speeds of from 12 to 15 miles per hour. Our coal roads are very crooked, and in curving, the longer cars offer more resistance than the shorter ones. The construction of the trucks, and the manner of bearing upon the transoms, have much to do with the ease in curving. After we had made some experiments upon the movement of trains upon the Lake Shore and Michigan Southern Railway, we came to the conclusion that those long and heavy trains of 700 to 750 tons could be run with less fuel at the rate of 18 to 20 miles per hour, than they could at 12 miles, the regular time-table rate. On December

3d, 1875, a stock train of 709 tons was run through, at the rate of 20 miles per hour, and on December 13th, 1875, a train of same weight, with same kind of journals, was run at the rate of 12 miles per hour. It was, however, 17° Cent. colder. The difference in coal used by the same engine was 1485 lbs. The colder day required some of the additional coal, but not the difference made. Subsequent experiments have all corroborated the first conclusions.

After the inertia of the train is overcome, which, in the long trains, seems to be at a speed of about 12 miles per hour, the cut-off is moved back, the steam used more expansively, and the light gradients, at the increased velocity, are overcome much more easily than at the slower rates, which, to use an engineer's expression, "becomes a drag to pull the train," when running too slow. To what extent this will be found true upon other roads, using steam in a different manner, hauling shorter and lighter trains, must be determined by future experiments. The increased damage to machinery, caused by running at the increased speed, must also be taken into consideration. It is a subject worthy of much careful investigation, as it would add largely to the capacity of the road, a much more rapid transit of freight, more service with the same number of cars, and less time on the road for the men on trains.

We do not find it true that the power to move trains increases with the square of the Velocity. On some single cars it only increased to that due to the square of the velocity of the wind acting on the frontage of the cars, the friction of the car remaining almost a constant quantity. I do not think the above will be true, for all the various kinds of car construction, as some are decidedly faulty in all respects as to a minimum amount of friction. The amount of power used to draw the stock train from Cleveland to Erie, 95½ miles, was 2,498,396,320 foot-lbs., beside that required to move the locomotive itself. 8425 tbs. of coal were used, each pound giving 296,545 foot-lbs. of power, 3 per cent. of the chemical value of the coal. The extra power required to overcome the inertiæ of the train on a level was in one instance 35,696,950 foot-lbs., which may be considered a fair average of the power lost each time this train was stopped. Dividing this by 296,545, the amount of power developed by 1 lb. of coal, and it will give the number of pounds of coal used to start the train, which in this case was 120.4. The same amount of power on a level would run the train two miles, and it required from two to two and one-half miles to get the train under motion. I introduce (his here to show the great loss suffered in stopping heavy freight trains, more particularly at grade railway crossings, which upon the line under consideration, taking the expense of fuel, water, and watchmen for 50 trains per day, amounts to 45 cents for each stop, without taking into consideration the extra wear of rolling stock, track, detention of trains, and the constant danger of accident.

The most notable increase of resistance of trains was found in passing over the Cleveland and Pittsburgh Railway, having an iron rail with the joints from ½ to 1¼ inches lower than the centre of the rail. Most of the joints were opposite.

Besides the power which would on a good steel rail be required to draw the train, the increase due to the shocks ranged from nothing to 4000 tbs. In computing the cost of moving freight over such lines, the extra wear of machinery and track must be added to the expense of the augmented power required by the rough track. The iron rail docs not have sufficient elasticity to return to a normal position at the ends, but takes a permanent set to some extent from each wheel as it passes over it. The ordinary fish-plate is entirely inadequate to make a good joint, or to sustain the ends of rails as they should be, to make a good track, on many of our shallow-ballasted roads. Passenger coaches are made to ride so easily that the principal officers of the rough lines do not get sufficient jostling and jolting to remind them of the shocking condition of many of the iron tracks. We have not worked up many of the results, as we find every detail of car construction, track and locomotive construction, will have to be taken into consideration, also many of the features of management. I do not expect that we can make formulæ which will be applicable to all roads, as nearly every road has its distinct features. We do not expect to revolutionize everything connected with railways, but when facilities are afforded and attention paid to the facts developed, many things connected with transportation may be cheapened. I am trying to find out facts, and not to support any system or plan of moving freights upon railways. I will very briefly explain some of the features of the diagrams. (See Plate VI.)

The dynagraph is an instrument designed to measure and record upon paper the resistance due to the movement of trains; it also shows by the kind of line made, the general condition of the track and motive power. It is fitted into a car which is attached next to the locomotive, and is of the following general construction : Underneath the car is a steel cylinder filled with oil, having four pistons, two four inches and the others one and three-fourths inches in diameter; so arranged that either size can be used at pleasure either in drawing or pushing a train. The drawbar of the car is extended back and draws or pushes directly on the pistons, which forces the oil in the cylinder through a pipe to a small cylinder, in which is fitted a piston, acting against springs of known tension. The cross-head of the small piston moves the levers carrying the pencil, which records upon the moving paper the amount of force exerted. The paper used is ten and three-fourths inches wide and is in lengths ranging from one hundred and fifty feet to four hundred feet.

The paper is moved by direct motion from the car axle. It is wound upon a drum upon one side of the instrument, and passes between two steel rollers, over a little table about one foot square, through another set of steel rollers, and thence to another drum, which winds up the paper as it passes through the rollers. Usually one-fourth of an inch of paper is made to represent one hundred feet on the track passed over. An electrical chronograph records the time every seven and one-half seconds, consequently the speed for any given instant can be calculated.

The force-line and chronograph-line are full size as to length, but in order to get so many diagrams on one sheet the vertical distance between the zero-line, force-line, and chronograph-line are reduced to suit the engraving.

No. 1, No. 2, and No. 3 were taken with the large piston on heavy freight trains. No. 1 was taken upon the Lake Shore and Michigan Southern Railway, and shows the force required to start a train of thirty-five loaded cars, one caboose, and the dynagraph car. Total weight, seven hundred and nine tons. About three thousand feet in length are represented.

The zero-line of force for this diagram is the broken line extending partly through Diagram No. 4.

The chronograph-line for this diagram is the upper one on the sheet, and the one immediately under it the record of force required to start the train from the Union Depot at Cleveland, Ohio. It had a Mogul engine, with forty-nine thousand six hundred pounds upon the drivers, which would pull from one thousand to one thousand five hundred pounds more than that shown upon the diagram before slipping her drivers, upon a good rail.

The slightly irregular line at first is due to a slight movement of the throttle valve by the engineer, while the downward movement of the force-line in the last one thousand feet is due to the speed of the train and cutting back the reversing lever.

The figures upon the force-line show the pounds of force exerted upon the drawbar to draw the train, per instant.

No. 2 represents four thousand feet in length, run by an ore train upon the iron rail of the Cleveland and Pittsburgh Railway. Weight of train, three hundred and thirteen tons. The zero-line is the same as that of No. 3, which is also the chronograph-line of No. 4. The speed of the train is shown by the upper chronograph-line.

The vibrations of the force-line were caused by a rough iron track, the joints being very much depressed. These vibrations are very much below the average; many of them were so great that they could not be easily distinguished, much less engraved; to check them we were obliged to use a spring drawbar.

No. 3 is the same train upon the Lake Shore and Michigan Southern Railway as No. 1, when running along at its usual speed, which is shown by the chronograph-line drawn through No. 1 and No. 2. It will be noticed the force-line is quite uniform, which we found to be so when the track (steel rail) was in good condition, well ballasted, and the engine in good order; but when otherwise the force-line assumes the character of that shown in No. 2.

Diagrams No. 4 and No. 5 are some of a series of experiments with two or three cars, and represent the start and a run of about one and one-half miles. The cars were two loaded Empire cars, and with the dynagraph car weighed fifty-two and fifty-five one-thousandths tons, of two thousand pounds each. The engine used to draw them was a small one, having a single pair of drivers, and the tender was rigidly attached to the engine, and when running was constantly oscillating from side to side, which gave the force-line a vibratory motion. No. 4 was run at twenty and nine-tenths miles per hour, and No. 5 (same train) was run at eight and seven-tenths miles per hour.

The chronograph-line of No. 4 is the record of a train running fast, though somewhat exaggerated in this.

After the diagrams are taken they are all studied, and the number of foot-pounds calculated which are required to move the train for the run or any given distance.

*REPORT OF THE COMMITTEE ON RAILWAY RESISTANCES**

TO THE AMERICAN INSTITUTE OF MINING ENGINEERS:

The committee appointed at the February meeting upon Railway Resistances would respectfully report:

That one person has been constantly employed in calculating the results of the data taken prior to March 1st, 1876. Also to complete the data taken upon the Lake Shore and Michigan Southern Railway, a diagram was taken upon a through freight train from Cleveland to Chicago, and one from Chicago to Cleveland. So that now we have diagrams from Buffalo to Chicago and return, which, when fully worked up, will give results of the utmost importance in determining the cost of transportation of freight. These data will be of much importance in determining the proper methods of equating grades and curves, which is so essential in the location of new lines.

The calculations show that instead of our attempting to formulate results from data obtained on one road, it will be best for the interests of transportation to enlarge the scope of our inquiries, and to extend the experiments so as to include all of the more probable causes which affect the cost of transportation. Were the details of railway equipment constructed alike, much work, which is now necessary, would be saved.

It is not uncommon to find upon the same road 10 to 30 different patterns of something in construction to subserve the same purpose, which more or less modifies the friction of the cars. Take the majority of our trunk lines, with this diversity of construction, together with the varying conditions of track and manner of operating, and it will be at once seen that the labor and time to do the work and arrive at correct conclusions will occupy from two to three years. The results already attained in the short time in which they have been carried on, wholly by private enterprise, simply show what may be expected when the aid necessary is given to render them of the highest value to the great industries of the country. That the information may be general and of the greatest importance to our railway interests, the committee deem it advisable to secure, so

* The following report, made at the Juno meeting of the Institute, is inserted in this place as appropriately supplementing the original communication of Mr. Dudley.

far as may be, the co-operation of all the leading railways of the country, and have them assist in carrying on the work now inaugurated, as in this way the cost to each road would be reduced to a minimum and still give them all the full benefits of the work done upon other roads as well as their own. Some of the leading Eastern and Western railways have been solicited to aid, and we think we can without doubt secure their co-operation as soon as they fully understand its importance and value to their own interests. " Large bodies move slowly," especially towards scientific investigation. There will appear for publication with this paper several sheets of data and calculations embracing nearly all of the experiments made with single cars, conducted at the Collinwood Yards of the Lake Shore and Michigan Southern Railway, eight miles east of Cleveland, Ohio.

The track is all tangent and ballasted with gravel. It is about 1¾ miles long between the switches and laid with steel rail.

All calculations were made from the diagrams as shown between the 8th and 9th mile-post. The line has two gradients requiring 3.6 lbs of force to overcome them, in addition to that given in the calculations.

In each experiment we endeavored to run each car or cars first at a speed of 10 miles per hour, then at 20, and then at 30, but from the short distance to run before acquiring speed to pass the 8th mile-post it was found impossible to run the cars exactly as desired. We did not allow the engineer to change his throttle valve, or reversing gear, after passing the 8th mile-post, so that there would be no changes of force due to increase or decrease of steam-pressure, as such changes are at once recorded upon the paper, and would be liable to be ascribed to some other cause.

The locomotives used for these experiments were quite small ones, having a single pair of drivers, the tender and boiler rigidly connected, and they did not run steadily but were in constant oscillation, making the diagram somewhat uneven. As the runs could not be made of a uniform velocity, we had to make allowance for retardation or acceleration. It will be noticed in the tables that there is a column of initial velocity, which is that of passing the 8th mile-post, and one of final velocity, which is that of passing the 9th mile-post. The chonograph, which registers the time every 7½ seconds, shows whether the velocity is being accelerated or retarded, and at what points. The cars experimented upon were such as we found in daily use at the yards. In the final resistance given in the sheets that due to the air is included. As yet we have not been able to use anything which gives uniform results as to the effect of the wind, though we have used the most sensitive anemometers and vanes.

It is thought the difference is largely due to the eddies which are formed by whatever we attempt to use in connection with the motion of the car. We cannot explain many anomalies which occur in the results of single cars. Some of them are doubtless due to difference in the engineers who ran the engines, and to sudden changes of wind. The diagrams in which they occur do not indicate that anything was wrong with the working of the instrument, yet it is possible that such was the case. The service upon the instrument with single cars is much more severe than when drawing a heavy train, as the piston is so much smaller for that work. The strain upon the pipes and joints often exceeding, in steady work, 2000 lbs. per square inch, and adding that due to shocks, makes it very difficult to keep the instrument in proper order, without constant care.

We find, in all our experiments, when the weight of the cars is partially carried upon the ends of the truck frames, that after passing curves or switches they oftentimes run long distances before they will straighten up and properly track, and not bind upon the flanges of the wheels, thereby causing increased friction, which often shows in the results of our experiments. It is seldom that we find journals upon the same cars of the same size; the wear is not uniform, ranging from 1/16 to 5/16 of an inch on the different journals of the same car. Flanges of wheels are often badly worn upon opposite wheels and the axles arc not parallel. There does not seem to be any uniformity as to the width and length given to bearings; some will have two inches and two and one half in width, the length varying from five to eight inches. As a rule we have found that a bearing of six inches in length runs easier than one of five, and is not so liable to heat.

In loaded cars, especially after standing some time, the lubricant seems to be forced from between the journal and brass, so that the car needs to be run a short distance, or newly oiled, before it will run at the usual friction. The friction seems to be higher per ton in loaded cars than in empty ones. We have not as yet attempted to formulate any of the information we have obtained, deeming it of importance to gain more before reaching definite conclusions. It will doubtless be necessary to have constants to apply to a general formula for the variously constructed cars, or to have distinct formulæ for them. In all of the experiments detailed upon the sheets or tables, petroleum was used as the lubricant, excepting that of the Baltimore and Ohio car, which was a kind of grease used by that company. This car had 30-inch wheels, all the others 33-inch wheels. In making further experiments with single cars, every detail of construction which can affect the resistance of the car will be taken into consideration, for the purpose of finding out what is best, and to point out a system of uniform construction for cars intended for the same purpose. The expense to the great trunk lines in keeping so much stock on hand to repair cars of different construction is a very large tax upon transportation.

The experiments upon heavy trains furnish the most accurate means of determining the cost of moving freight over the railways. In all instances where it can be done, we take the weight of coal consumed, and by that means have found how much power each pound of coal developed in moving the train. From these data, it will be easy to calculate the cost in fuel of moving freight upon portions of the line having different gradients, and, what is equally of importance, the cost of making stops. This was mentioned in a previous paper, yet, possibly, some will hear this now who did not then, therefore we will repeat it briefly.

Engine 485 of the Lake Shore and Michigan Southern Railway, developed to move the train, for each pound of coal consumed 296,545 foot-lbs. of power, or less than 3 per cent. of the theoretical power of the coal. To start the train, weight 709 tons, and get it under full motion, it took from 20,000,000 to 40,000,000 foot-lbs., depending upon the place and circumstances. In one place it was 35,696,950 foot-lbs.; dividing this by 296,545, the power developed by 1 lb. of coal, and it gives 120.4 as number of pounds of coal consumed after the stopping of the train to again get it into motion. Take into further consideration the loss of time, and delays to business, and it will be seen that stops are expensive; therefore the timetable should be so arranged, as far as practicable, that through trains should only stop for water and at terminal division stations and railway crossings. In through lines more attention should be given to the avoidance of grade-crossings, not only as a measure of safety, but one of economy. In a short time we fully believe that it will be found cheaper in great trunk lines to arrange the freight engines so that they will take water while in motion, or by condensing a portion of the exhaust steam, to require but a small part of the water now used. On the Cleveland and Pittsburgh Railway (in an ore train run), from Cleveland to Wellsville, 1 lb. of coal developed 398,763 foot-lbs. to move the train, utilizing in moving the train about 4½ per cent. of the theoretical power of the coal, showing a great gain over that developed on the Lake Shore and Michigan

Southern Railway. We consider the results of the different engines given by these experiments to be of the greatest value in determining which are the most economical for freight purposes. It affords a comparison as to the value of the number and different-sized drivers used on the engines; by taking the amount of coal used, and knowing its general characteristics, we are able to judge of the engine in an economical point of view. To show how erroneous it is to compare the work performed upon one road with that of another by the tonnage moved in miles by 1 lb. of coal, we will state one example of comparison of the Cleveland and Pittsburgh Railway and the Lake Shore and Michigan Southern Railway. The run upon the Cleveland and Pittsburg Railway was made with an ore train, from Cleveland to Wellsville, upon which are many long 40-feet grades to reach the table lands of the country through which it passes. On the table lands there are many short 40-feet grades, also sharp curves. The track was iron, joints very much depressed. On the Lake Shore and Michigan Southern Railway the run was a stock train, steel-track, and in good condition, the line mostly tangent, the grades not exceeding 17 feet per mile. The average friction per ton of the train on the Cleveland and Pittsburgh Railway was 10.72 lbs., and on the Lake Shore and Michigan Southern Railway 6.85 lbs., the former some 57 per cent. greater than the latter. When we compared the tonnage moved per mile per pound of coal, they were almost identical, leading one to conclude perhaps that the motive power of one road was operated as economically as the other, whereas, in fact, as above stated, the work done upon the Cleveland and Pittsburgh Railway per pound of coal was 50 per cent, greater than upon the Lake Shore and Michigan Southern Railway. The fine effect of steel track in this case is offset by the better adaptation of the motive power upon the other, so that each road would be improved by simply adapting the better practice of the other. It does not afford any accurate test of the economical movement of freight of two roads by comparison of the tonnage moved in miles per pound of coal any more than it does to compare the cost of operating a road with the total receipts. In running trains there are many things which the careful and considerate engineer must do to pull his train over the road to the best advantage for his company's interest, which if rigidly interpreted would be a disobedience of orders. The reason for this is largely owing to the manner of making up the time-tables, in not allowing sufficient time in difficult places, and too much where it is comparatively easy. It seems to us that more attention should be made to the development, within certain limits, of a more uniform adaptation of power. This idea is new, but is very forcibly brought out by a study of the diagrams. In ascending a grade you very soon come to a limit in the power which the engineer can develop on a given strain. In many instances we have found that upon a grade the engine could not draw the load it had without backing up and acquiring a little momentum to assist it in passing the difficult place. The judicious engineer, instead of running slowly over such places, takes advantage and stores up a little momentum on the train to help in a difficult place. We do not approve of any reckless running, but engineers should be allowed to take advantage of those little things, which oftentimes determine whether he can get over a grade or not. Having ridden several thousands of miles upon heavy freight trains, we must say that we do not believe it possible to make a uniform time-table on our undulating road productive of the greatest economy.

In a general statement we give the average friction per ton of 29 loaded and 2 empty cars from Toledo to Cleveland, total weight of 590 tons, at 20 miles per hour, at 7.45 lbs. From Cleveland to Erie, of 37 loaded cars, weight 709 tons, speed 20 miles per hour, 6.85 lbs., and from Erie to Buffalo, of 25 loaded and 2 empty cars, weight 512.4 tons, the friction was 7.94 lbs. per ton. These were upon the Lake Shore and Michigan Southern Railway, and include all the resistance due to gravity and air. On the Cleveland and Pittsburgh Railway, from Cleveland to Wellsville, the average friction per ton was for an ore train of 313 tons 10.72 lbs per ton.

Although stated in the previous paper, we will repeat that with the same engine upon the Lake Shore and Michigan Southern Railway to run a train at 10 to 12 miles per hour from Cleveland to Erie, it required 1.485 lbs. more of coal than it did with the same number of cars at 18 miles per hour. Weight of train about 100 tons. Upon further investigation of this question, we have found that the drivers are generally worn more unevenly upon slow-running locomotives than fast ones.

We also find the statement that it requires less fuel to run trains at 18 miles per hour than at 12 is corroborated by many leading railway men. The American Society of Civil Engineers has appointed a committee upon this subject, which will co-operate with your committee.

R. H. THURSTON.
WM. P. SHINN.
P. H. DUDLEY.

PHILADELPHIA, June 20th, 1876.

Experiments made with the Dynagraph, at Collingwood, Ohio, by P. H. Dudley, upon Lake Shore and Michigan Southern Railway.

WITH SINGLE EMPTY CARS.

Car, kind.	Number.	To what Railway belongs.	Date of experiment.	Size of Journals.	Weight of load in tons 2000 lbs, including Dynagraph car.	Velocity in feet per second. Initial.	Final.	Difference.	Average speed in miles per hour.	Resistance in lbs. per ton. Observation corrected for Level track.	Uniform velocity.	State of weather.	Temperature.	Height of barometer.	Wind. Direction.	Velocity in miles per hour.	REMARKS.
				in. in.													
Box D.....	9,109	L. S. & M. S.	Jan. 31.	3¼×6	18.225	16.5	19.6	3.1	11.7	5.44	4.74	Fair.	22°	30.17	S. S. E.	12	Journals badly worn, from
"	"	" "	"	" "	"	37.6	40.1	2.5	21.1	10.84	9.61	"	"	"	"	12	1-16th to 3-16th of an inch.
"	"	" "	"	" "	"	28.7	28.3	0.4	19.6	6.97	7.12	"	"	"	"	12	Worn from the various ones;
Box.......	7,866	N. T. C.	"	3¼×6¼	20.205	18.31	14.00	4.31	14.3	0.38	0.51	"	"	"	"	12	oiled with petroleum.
"	"	"	"	" "	"	27.65	28.08	0.43	19.2	3.79	3.64	"	.....	....	....	12	From some unexplained
"	"	"	"	" "	"	32.96	42.57	9.61	26.5	12.57	7.93	"	.....	....	....	12	cause the resistance appears
Box D.....	9,812	L. S. & M. S.	Feb. 1.	3⅜×5½	2.029	18.95	18.17	0.78	12.5	3.93	4.11	"	38°	29.71	S. S. E.	11	to be very low on this car,
"	"	" "	"	" "	"	27.34	31.51	4.17	20.4	9.31	7.64	"	"	"	"	11	though everything seemed
"	"	" "	"	" "	"	35.22	47.7	12.29	29.1	17.39	11.40	"	"	"	"	11	to be in perfect order about
Stock D...	5,298	" "	Feb. 2.	2⅞×5½	2.02	15.0	14.33	0.67	9.4	4.45	4.58	"	10°	30.15	West.	29	the instrument. Brasses
" ...	"	" "	"	" "	"	28.83	32.64	3.81	20.8	11.45	9.95	"	"	"	"	29	worn somewhat, the journals
" ...	"	" "	"	" "	"	36.72	46.50	9.82	29.4	22.94	17.51	"	"	"	"	29	varying in size from wear.
" ...	"	" "	"	" "	"	20.0	17.00	3.00	11.9	3.07	3.77	"	"	"	"	29	Newly oiled.
" ...	"	" "	"	" "	"	28.0	30.33	3.33	20.4	10.77	9.90	"	"	"	"	29	
" ...	"	" "	"	" "	"	38.42	47.87	9.45	30.0	24.2	18.96	"	"	"	"	29	
Box D.....	13,226	" "	Feb. 3.	....	2.000	14.00	14.42	0.42	9.2	7.6	7.53	Cloudy.	"	30.23	S. E.	13	
"	"	" "	"	....	....	27.73	34.00	6.27	22.3	13.6	11.13	"	"	"	"	13	
"	"	" "	"	....	....	36.31	47.06	10.75	29.5	22.69	17.02	"	"	"	"	13	
Box.......	25,684	B. & O.	Feb. 10	2 13-16×5½ to 3 1-16×5½	19.895	17.75	15.66	2.09	10.4	4.79	5.23	"	"	"	"	13	
"	581	M. D. T. Co.	"	....	....	28.27	32.56	4.29	20.9	7.82	6.16	"	"	"	"	13	
"	....	....	....	....	2.016	16.75	14.28	2.47	9.7	5.78	6.27	"	"	"	"	13	
"	....	....	....	....	....	28.27	32.00	3.73	21.3	11.99	10.55	....	.....	....	"	13	
"	....	....	....	....	....	34.75	46.77	12.02	28.2	20.9	14.64	....	.....	....	....	.....	

Experiments made with the Dynagraph, at Collingwood, Ohio, by P. H. Dudley, upon Lake Shore and Michigan Southern Railway—Continued.

WITH TWO EMPTY CARS.

Car, kind.	Number.	To what Railway belongs.	Date of experiment.	Size of Journals.	Weight of load in tons 2000 lbs., including Dynagraph car.	Velocity in feet per second.			Average speed in miles per hour.	Resistance in lbs. per ton. Observation corrected for		State of weather.	Temperature.	Height of barometer.	Wind.		Remarks.
						Initial.	Final.	Difference.		Level track.	Uniform velocity.				Direction.	Velocity in miles per hour.	
				inches.													
Box......	9,109 9,312	L. S. & M. S.	Jan 31.	....	28.715	17.73	20.94	[illegible]	11.6	3.58	2.79	Fair.	22°	30.17	S. S. E.	12	
"	"	" "	"	....	"	29.57	32.50	2.93	21.1	7.38	6.71	"	"	"	"	12	
"	"	" "	"	....	"	24.39	25.84	1.45	17.0	4.41	3.95	"	"	......	......	...	
"	"	" "	"	....	"	35.81	46.92	11.11	28.9	17.38	11.44	"	"	"	"	12	
Box D...	9,312 3,706	" "	Feb. 1.	....	28.655	10.00	9.40	0.6	6.0	3.68	3.82	....	38°	29.75	"	11	
"	"	" "	"	....	....	21.08	19.11	1.97	18.1	4.48	4.98	....	"	"	"	11	
"	"	" "	"	....	....	26.45	33.23	6.73	20.6	11.66	9.08	....	"	"	"	11	
"	"	" "	"	....	....	36.7	47.2	10.5	29.3	18.43	12.78	....	"	"	"	11	
Box......	3,278 7,866	N. T. C.	"	....	29.9	16.10	13.27	3.83	8.6	3.69	4.39	....	"	"	"	11	
"	"	"	"	....	"	26.20	30.60	4.40	19.6	12.05	10.46	....	"	"	"	11	
"	"	"	"	....	"	22.00	20.30	1.70	14.1	3.40	3.85	....	"	"	"	11	
"	"	"	"	....	"	36.21	45.66	9.45	28.2	17.26	12.32	....	"	"	"	11	
Box D...	13,226 14,031	L. S. & M. S.	"	....	30.2	16.62	15.66	0.96	10.9	5.9	6.1	....	"	"	"	11	
"	"	" "	"	....	"	25.47	29.33	3.86	19.2	10.51	9.16	....	"	"	"	11	
"	"	" "	"	....	"	35.87	48.07	12.20	30.00	23.37	16.83	....	"	"	"	11	
"	5,298 6,689	" "	....	....	30.315	16.86	17.00	0.14	10.8	5.53	5.50	....	"	"	"	11	
"	"	" "	....	....	"	22.66	26.40	3.36	16.66	10.32	9.15	....	"	"	"	11	
"	"	" "	....	....	"	35.00	45.50	10.50	28.2	23.48	18.08	....	10°	30.15	West.	29	

WITH THREE AND FOUR EMPTY CARS.

Box......	9,107 9,312 3,706	L. S. & M. S.	Jan. 31.	....	37.08	18.88	20.37	1.49	12.6	3.82	3.44	Fair.	22°	30.17	S. S. E.	12	
"	"	" "	"	....	"	27.79	30.21	2.42	20.3	7.50	6.60	"	"	"	"	12	
"	"	" "	"	....	"	35.09	44.36	9.27	27.7	17.17	12.43	....	....	....	....	....	
"	"	" "	Feb. 1.	....	"	17.0	15.7	1.3	10.8	4.15	4.42	Wet rail	38°	29.75	S. S. E.	11	
"	"	" "	"	....	"	33.78	38.18	4.40	25.3	12.65	10.62	"	"	"	"	11	
"	"	" "	"	....	"	36.45	46.50	10.05	30.0	20.30	14.94	"	"	"	"	11	
"	3,278 7,866 2,912	N. T. C.	"	....	39.675	24.55	20.32	4.23	15.0	3.37	4.58	"	"	"	"	11	Axles much worn, varying from $2\frac{7}{8} \times 6\frac{1}{2}$ to 3 1-16 $\times 6\frac{1}{2}$ inches, brass 6 inches long.
"	"	"	"	....	"	25.94	30.78	4.84	19.5	9.2	7.45	"	"	"	"	11	
"	"	"	"	....	"	32.67	47.33	14.66	27.9	21.97	14.48	"	"	"	"	11	
"	"	"	"	....	....	34.41	42.07	7.66	26.66	16.38	12.64	"	"	"	"	11	
"	5,288 6,689 7,813	L. S. & M. S.	Feb. 2.	....	3.951	18.8	18.5	.03	13.3	6.80	6.87	Fair.	10°	30.15	West.	29	Axles and wheels much worn, axles varying from $2\frac{7}{8} \times 5\frac{1}{2}$ to 3 1-16 $\times 5\frac{1}{2}$ inches.
"	"	" "	....	....	"	28.0	31.3	3.3	20.9	12.65	11.40	"	"	"	"	29	
"	"	" "	....	....	"	36.10	46.50	10.4	29.5	23.43	17.93	"	"	"	"	29	
"	5,298 6,689	" "	Feb. 2.	....	49.585	20.1	15.3	4.8	11.2	4.87	5.95	....	....	....	....	....	Axles much worn. See above.
"	7,813	" "	"	....	"	30.3	34.7	4.4	22.6	19.86	18.03	....	....	....	....	....	
"	9,198	N. T. C.	"	....	"	35.6	48.2	12.6	29.3	24.57	17.82	....	....	....	....	....	

ONE AND TWO LOADED CARS.

Box......	1,475	B. & A.	Feb. 25.	....	27.61	16.61	15.24	1.37	9.5	3.79	4.06	Clear.	17°	30.11	S. S. W.	12	
"	"	"	"	....	"	20.87	16.17	4.70	13.2	1.98	3.06	"	"	"	"	12	
"	"	"	"	....	"	24.91	26.17	1.26	18.0	4.2	3.80	"	"	"	"	12	
....	....	....	....	....	"	26.00	27.12	1.12	18.5	3.62	3.25	"	"	"	"	12	
....	....	....	....	....	"	17.64	17.19	0.45	11.6	2.76	2.86	"	"	"	"	12	
....	....	....	....	....	....	24.89	30.60	5.71	18.6	5.98	4.01	"	"	"	"	12	Newly oiled.
Coal D...	13,226 14,031	L. S. & M. S.	Feb. 3.	....	45.35	18.41	16.1	2.3	10.8	4.75	5.24	Cloudy.	10°	30.33	S. E.	13	" "
"	"	" "	"	....	"	27.6	34.4	6.8	21.8	14.62	12.00	"	"	"	"	13	
....	....	....	....	....	....	35.53	49.30	13.77	28.6	22.11	14.83	"	"	"	"	13	
Box....	3,277 3,744	Empire.	Feb. 4.	....	52.55	15.5	17.0	1.5	8.7	5.94	5.64	Fair.	17°	30.28	West.	20	
....	....	....	....	....	....	27.12	32.82	5.70	20.9	9.79	7.69	"	"	"	"	20	
Box......	5,635	S. & I. R. E.	....	....	....	33.78	46.00	12.22	28.2	19.12	13.10	"	"	"	"	20	
....	8,293	L. S. & M. S.	Feb. 23.	2 13-16 $\times$ 6 3 1-8 $\times$ 6	48.06	23.69	27.46	3.77	17.8	11.77	10.57	Clear.	5°	30.39	N. N. W.	20	

INDUSTRIAL RESEARCHES UPON HEAT AND COMBUSTION.

BY P. H. DUDLEY, C.E., CLEVELAND, OHIO.

I HAVE taken the liberty of calling the researches herein mentioned industrial, to distinguish them from those strictly scientific, where every known appliance is used to insure accuracy in determining principles. The industrial researches are made to ascertain wherein we have failed to embody, in practice, the principles which have been fully demonstrated by the more purely scientific investigations. So far the researches have been mostly confined to the conditions of combustion as used in locomotive furnaces, although we have examined, to some extent, furnaces under marine and stationary boilers. The products of complete combustion are gases, and, knowing what we should have, it is at once shown by analyzing the products whether the desired reactions are taking place.

In spite of imperfect furnaces, lack of system in the arrangement of grate-bars and exhaust nozzles, the results are not altogether vitiated, because the analyses are not closer than one-tenth of one per cent., as under the present conditions it is hardly possible to collect gas exactly under the same conditions at different times.

All of our industrial operations have developed in the past few years so rapidly, nearly all of them paying, that, until within the past three years, comparatively little attention has been given to their economy outside of the profession.

Great corporations have not asked and considered the question in earnest, can we utilize our heat so as to produce the same effect at less cost? The applications of heat are so extensive, entering into every branch of industry, the principal power used to carry ou metallurgical processes, to conduct transportation, that its economical generation becomes of universal importance; in fact, its economical generation and application is the leading industrial question of the day. It is stated by those who have given the subject much attention, that in our best steam-engines not over 10 per cent of the theoretical value of the fuel is utilized, and upon locomotives it is far less, probably not exceeding under the most favorable circumstances 5 or 6 per cent. In recent experiments made with the dynagraph, in drawing trains upon the Lake Shore and Michigan Southern Railway from Cleveland to Erie, 95½ miles, we found the force required to draw a stock train of 709 tons to be 2,498,396,320 foot-pounds, exclusive of the force to move the locomotive itself. We measured the amount of coal consumed, and only 3 per cent. of the theoretical value of the coal was utilized in moving the train. From a few experiments upon the resistance of locomotives having six drivers, the same as the one used, I think it would take one-third as much to propel the motor as to draw the train, which, added to that required to move the train, makes 4 per cent. as the theoretical value of the fuel utilized. It is hardly necessary for one to say that a great loss of heat occurs in some manner.

In this case the result depends upon the perfectness of several combined functions of action, and we cannot trace the effect of distinct ones, without taking up each separately. In this paper, we only wish to call particular attention to the first fundamental function, viz., that of generation of heat by the combustion of fuels, used to propel our motors, or to carry on metallurgical processes. The products of complete combustion, industrially speaking, would be carbonic acid, water, and the associated nitrogen of the air, which supplied the oxygen. The amount of water or steam formed would depend upon the amount of hydrogen in the fuel, and would be condensed before the gas could be analyzed, so that if the air was all consumed, we should get about 20 per cent. of carbonic acid in 100 volumes of the products. The air consists by volume, in 100 parts, of 21 of oxygen and 79 of nitrogen. When carbonic acid is formed by the carbon and oxygen, the volume is not increased over that occupied by the oxygen, but when carbonic oxide is formed, the volume is doubled.

In burning 1 pound of carbon to carbonic acid, there would be developed 8080 Centigrade units of heat; if carbonic oxide were formed only, 5600 units of heat would be developed, showing a loss of 2480 units of heat. If the combustion is complete, it does not matter how fuels are burned, the value remains the same, but the calorific intensity is raised. Carbon burnt in pure oxygen would give the 8080 units of heat, and have a calorific intensity of 10,178° Cent., while burnt in air the intensity would be 2719° Cent., and if double the amount of air required was admitted, the intensity would be reduced to 1341° Cent., from the fact that the heat would be distributed through the unconsumed air as well as the products of combustion, all of which absorb heat, consequently the intensity is lowered. Before commencing these researches, I was under the impression, from reading upon the subject, that we did not admit sufficient air into our fire-boxes to properly combine with the products of the coal, and as a consequence, carbonic oxide was formed, resulting in a great loss of heat, as the carbon was not fully consumed. I was surprised at the results obtained; for it is only under very exceptional circumstances, that we obtained a trace of carbonie oxide. That we may better understand the results of the analyses, I will give the dimensions of the fire-box and plan of grate used upon the Cleveland and Pittsburgh Railroad. Length of fire-box, 60 inches, width 35½, and 56 inches from the top of grates to the crown sheet, making a space of 69 cubic feet for the fire and combustion-chamber, which has 85 square feet of heating surface, exclusive of door and flue openings. There are 128 flues, 2 inches external diameter, 11 feet and 10 inches long, leading from the combustion-chamber to the smoke-box. The internal surface of the flues is 681 square feet. Area of flues per foot 2.1 cubic feet, or simply the opening 2.1 square feet. The size of the exhaust nozzle is 4¼ inches, and is single. The effect of the blast was sufficient to throw out small pieces of coal one-eighth of an inch in diameter, through the netting of the smoke-stack. The grate is composed of five rocking-bars, each being 29½ inches long by 10 3/8 inches wide, with 28 air-spaces one-half inch wide by 6 inches long. The air-space between each bar is one-half to three-quarters , of an inch wide, and the same at the ends. There is a dead-plate 3¼ inches wide by 29½ long. The samples first mentioned were taken from a freight engine upon the road while drawing a train of 16 loaded cars. In the table, CO_2 represents carbonic acid ; CO, carbonic oxide; O, oxygen, and N, nitrogen.

Yorkville Coal.

	CO_2	CO	O	N	
1	11.3		7.2	81.5	
2	13.3		4.7	82.	
3	14.		4.	82.	
4	12.5		6.	81.5	
1	10.5		8.	81.5	Black smoke.
2	12.5				No smoke visible.
4	10.5	.5	5.5	83.5	Damper closed.
5	9.9		9.6	81.5	Black smoke.
6	12.3		5.2	82.5	White smoke.
7	12.	1.5	3.5	83.0	Damper closed.

Salineville Coal.

1	9.6		9.7	80.7	
2	12.9		6.5	81.6	No smoke visible.
3	13.8	2.5	2.5	81.6	" " "
4	13.4	1.	5.2	80.4	" " "
5	14.		3.8	82.2	" " "
6	12.5		5.8	81.7	
7	14.2		3.6	82.2	

Some hydrocarbons were present in most eases, so that the. final reading seldom was down to 79, and sometimes carbonic oxide was found, in which case the reading would be above 79. The gas was all taken from the top of the smoke-stack by a gas pump, although at first we took it directly from the fire-box, but the intense heat would destroy the valves of the pump while taking the sample.

These analyses show the comparative reactions which were taking place. If the oxygen had been all consumed, and no carbonic oxide produced, we should. have at least 20 per cent. of carbonic acid. The greatest percentage found is 14.2, showing that there was still an excess of oxygen in the fire-box, or, we should say, an excess of air, which does not furnish, but takes away, a definite amount of heat, decreasing the calorific intensity of the fire.

The air to supply the fire was all drawn in through the grate-bars from below. Another very important fact to which I wish to particularly call attention, was developed by the analysis upon the Cleveland and Pittsburgh Railroad, viz., that when the smoke was ' the blackest, in every instance, there was found the greatest percentage of unconsumed air or oxygen among the products, showing that something besides the mere presence of oxygen is required to effect the combustion of the volatile carbon of the fuels. Its manner of admission also makes a great difference, as will be shown more fully, after giving more analyses from locomotives of other railways terminating or passing through Cleveland, Ohio.

Analyses of Gases from the Locomotives in the Freight Yards of the City.

SPECIMEN 1. — Pony engine No. 12, C. & P. R. R.	CO_2 O N	11.5 6 82.5	Old fire; escaping gas white; engine working hard.
SPECIMEN 2. — Same pony.	CO_2 O N	8.5 8 83	Fresh fire; much black gas escaping; engine working hard.
SPECIMEN 3. — Same pony.	CO_2 O N	13.5 4 82.5	Old fire; escaping gas light-colored; engine working moderately.
SPECIMEN 4. — Wood burner, L. S. & M. S. Railway.	CO_2 O N	7.5 12.5 79	Engine standing still, with blower on.
SPECIMEN 5.—Engine 197, L. S. & M. S. Railway.	CO_2 O N	2.3 17.2 80.5	Engine standing still; old fire; damper closed; supposed to be Masillon coal. At this time the fire-box had in a brick smoke-arch, and the gas was taken from under it.

SPECIMEN 6. — Same engine.	CO_2 O HC N	7.4 12.6 1 79	This specimen was taken from the top of the smoke-stack; engine not working hard.
SPECIMEN 7. — Same engine.	CO_2 O N	1.5 18.9 70.6	Engine working hard; gas taken from the fire-box under the brick smoke-arch. The striking contrast in the amount of carbonic acid gas between the engines of the two roads led me to repeat the experiments upon Engine 197 the following day, while it was hauling trains out to Collingwood. The gas was collected from the fire-box. I think the small percentage of carbonic acid gas, and large percentage of oxygen, was owing to the fact of collecting the gas from under the smoke-arch, as subsequent experiments, with smoke-arch taken out, show different results.
SPECIMEN 8.—Engine 197.	CO_2 O N	3.4 16.9 79.7	Engine working hard; escaping gas white.
SPECIMEN 9. — Same engine.	CO_2 O N	3.6 16.7 79.7	Engine working hard; escaping gas white.
SPECIMEN 10.—Same engine.	CO_2 O N	1.5 19.2 79.3	Engine working hard; escaping gas very black; new fire. These three specimens were taken under quite similar circumstances, except as to fresh coal being put on the fire. The brick smoke-arch was in, and the gas taken near it, and perhaps under it.
SPECIMEN 11. — Engine No. 140, C., C., C. & I. Railway.	CO_2 O N	7.5 11.8 80.7	August 6th.—Fire-door wide open; old fire; just starting from Union Depot with train.
SPECIMEN 12.—Same engine.	CO_2 O N	3 17.2 79.8	Engine moving slowly; new fire; smoke black.
SPECIMEN 13.—Same engine.	CO_2 O N	6.6 13 80.6	Engine moving slowly; old fire. In all of these specimens the gas was taken from the fire-box.
SPECIMEN 14.—Pony Engine No. 12, C. & P. R. R.	CO_2 O N	14 4 82	Engine working hard; hauling 20 loaded cars up a 40-foot grade; old fire; escaping gas white.
SPECIMEN 15.—Same engine.	CO_2 O N	8.6 10.3 81.1	Engine working hard, with same load as above, but a new fire.

The above is sufficient to show the average results of analyses of gases obtained from locomotives in the yards. The results from Enginc No. 197 of the Lake Shore and Michigan Southern Railway were so different from the others that I have recently taken them again, with the following result. The brick smoke-arch was out:

SPECIMEN 16.	CO_2 O N	5.7 14.7 79.6	Engine working hard; old fire; smoke white.
SPECIMEN 17.	CO_2 O CO N	8.4 8.4 1.2 82	Same engine; new fire; not working hard.
SPECIMEN 18.	CO_2 O CO N	12 4.4 1 82.6	Same engine; smoke black; not working hard.
SPECIMEN 19. — Engine No. 148, L. S. & M. S.	CO_2 O N	3.4 16.8 76.8	Engine standing still; blower on; smoke dark.
SPECIMEN 20. — Engine 197.	CO_2 O N	6 13.5 81.5	Engine working hard; smoke white.

Locomotives mentioned above have nearly the same dimensions of fire-box as the one fully described, except Pony Engine No. 12 of the Cleveland and Pittsburgh Railroad, which is smaller in dimensions, but same style of grate. On the Lake Shore and Michigan Southern Railway, rocking grate-bars are used, as upon the Cleveland and Pittsburgh Railroad, but the air-spaces are 1¼ inches round, and 46 in number, in each bar. The exhaust is composed of two separate nozzles, each 2¾ inches in diameter. The contrast will be noticed as to the decreased amount of carbonic acid found, which is generally present in largest quantity when the smoke is the blackest, as on the Cleveland and Pittsburgh Railroad, which was the effect of the increased blast, and the shape of the air-spaces in the grate.

Since so much has been said about the need of air to burn the volatile portion of our fuels, the practice has been to fire light and often, never exceeding 6 inches in depth of coal upon the grates, in order to prevent the formation of carbonic oxide. The consequence is, when the locomotive is working hard, small pieces of coal, of one inch cube, and smaller, are lifted from over the large air-spaces by the air, as it comes up in large streams, and little except the outer portions come in contact with the burning coal; in fact, the internal portion does not come in contact with the coal, and, entering in such large quantities, cools down the flame, so that much of the volatile carbon is below an igniting temperature, and, consequently, does not burn. In the burning of a candle or lamp, we notice an internal portion of gas, which does not burn until it comes in contact with air, and then if the flame is cooled very much the carbon escapes as black smoke. The burning of a piece of bituminous coal is, to a certain extent, like the burning candle and lamp. As soon as a piece of bituminous coal is thrown into a fire of incandescent fuel, the gas is expelled from the under sides, which, upon ignition, envelops the coal in flame, preventing the access of air to the gas, which is soon expelled from the upper portions of the coal, and by the time it comes in contact with air its temperature is reduced so much, that ignition does not take place, and volatile carbon passes off as black smoke. As I said before, the analyses show, in all cases so far examined, that there is a large excess of oxygen in the combustion-chamber, but it cannot come in contact with the escaping gas at the right time, therefore ignition does not take place. In proportion to the amount of volatile matter in the coal, we must not simply admit over, but eject down on to the tops of the pieces of coal, sufficient air to ignite with the escaping gases. The cones of flame must be broken up, and air of a proper temperature supplied to the escaping gases. The loss of heat which is carried away by an excess of air is enormous, it *is* mere waste. We have much to learn about combustion. Besides the air required to properly burn the coal, another portion is believed to be necessary to dilute the products so that they will escape. I examined the combustion in some Cornish boilers in the Cleveland City Water Works, and found the carbonic acid to range from 9 to 10 per cent., and the unconsumed oxygen from 10 to 11 per cent. The draught was induced by a chimney, in which the temperature of the escaping gases was above the melting-point of lead. I did not have any facilities for testing its actual temperature. Under marine boilers, in which the draft was produced by chimneys, I found the percentage of carbonic acid even less. In these cases the grate-bars were wide apart, so the air entered in large streams.

If we take up the analyses of gases from the freight locomotives in the yards at Cleveland, except those of the Cleveland and Pittsburgh Railroad, we find the harder the engine worked, the more unconsumed air was drawn into the fire-box, and as the escaping gas was white, or in popular language “smokeless,” it was supposed no loss in fuel was occurring. To see what effect upon combustion it would have to decrease the width of air-spaces, causing the air to pass into the fire-box in more minute streams, I asked Mr. Chapman, Master Mechanic of the Cleveland and Pittsburgh Railroad, to have the air-spaces in one of his grate-bars narrowed from one-half inch by 6, to three-eighths by 6 inches, and put into Engine No. 84, of his construction, which has run 80,000 miles without receiving general repairs ; consequently her flues were somewhat incrusted. The grates were put in December 9th, 1875, and she hauled 686.4 loaded cars one mile, for each ton of fuel burnt, exceeding any other engine by 10 to 50 cars for one mile. In September previous, with old grates, same average train, she only hauled 599 cars one mile per ton of fuel. In January, 1876, she hauled 694.2 cars one mile per ton of fuel. The expense of change of grate was §10.50, while the saving in fuel was nearly equal to it the first month. A much greater saving could be still made, by proper admission of air over the door, but I concluded when so much objection exists in regard to innovations, the better policy would be to proceed slowly but surely.

To learn the actual conditions as far as could be judged from au open fire and in stoves, we collected gas from a clipper stove burning bituminous coal, also from a parlor grate. First we collected the gas from the stovepipe, and in a number of specimens the amount of carbonic acid ranged from 1.5 to 2 per cent., while by inserting the end of the gas-pump pipe two or three inches into the burning coal, we could, without difficulty, collect gas having from 14 to 16 per cent, of carbonic acid gas. In the parlor grate, with the end of the pipe surrounded with three to four inches of burning coal, at a white heat, nearly every specimen contained 18 per cent, of carbonic acid. Four inches in depth was, under the circumstances, the greatest we could obtain, on account of the small size of grate we were using. In an anthracite base-burner, using Lehigh nut coal, the pipe covered with two inches of burning coal, the greatest depth we could obtain, the samples averaged from 15 to 17 per cent, of carbonic acid. We collected the gas rapidly and slowly, but could not detect any difference in results. I am well aware that it is quite a general opinion that a certain amount of air must be admitted to dilute the products of combustion beside that required to make them, arising from the fact that its presence is generally found to exist. From all of the investigations I have made I believe that if the air is properly admitted, which should be in small streams surrounding (lie fuel as much as possible, an excess is unnecessary. In the examples given above of the burning coals, the air-spaces were- small and tortuous, causing eddies in the streams of air, breaking them up, allowing the oxygen of the air to come in contact with the carbon of the coal, and thus utilizing the greater portion of the oxygen of the air. The benefit conferred by steam-jets playing over a bed of burning fuel is largely owing to the more thorough admixture of the air and gases breaking up the cones of gas surrounded by flame, and permitting the air to come in contact with the upper surfaces of the coal. I am fully aware, in practice, of the great difficulty of following theory, *i. e.*, just admit sufficient air for combustion, no more or less ; but we can come more nearly up to theory, or we ought to say more nearly up to the conditions of sound practice, than at the present time, when but little attention is paid to proper admission of air to our furnaces, or its manner of introduction, regardless of the proper conditions of so seemingly a trifling matter as combustion. It is expected that just as good results will be obtained from one kind of coal as another in the same furnace, but it is never realized. The furnace must be adapted for the work it is to do. All of the analyses show a portion of unconsumed oxygen, and we may conclude, if properly admitted, less air would be sufficient for combustion. Our Western bituminous coal generally requires 12 fibs, of air to burn it, which at ordinary temperatures would occupy 150 cubic feet; therefore, to burn one ton of coal of 2000 tbs. would require 300,000 cubic feet of air, which, when heated to the ordinary temperature of locomotive furnaces, would increase to twice its original volume, and all of this must pass through the small flues with great velocity and friction, requiring a strong blast to draw it through. Suppose, now, that you double the quantity of air required for complete combustion, you cool clown the furnace by the amount of heat carried away by the excess of air, increase the difficulty of making the products pass through the flues, requiring the steam to be released from the cylinders at a much higher pressure to produce the necessary blast. Time and opportunity are not given for the oxygen to combine with the carbon. The fact is overlooked that you can make only two pounds of oxygen unite with one of carbon, and it is worse than useless to present three pounds of oxygen. I will only mention three ways in which a loss of heat ocours by admission of an excess of air.

First. The loss of heat carried away by the increased volume of the products of combustion and unconsumed gases.

Second. The loss of heat transmitted through the boiler plate clue to the decreased temperature.

Third. The loss of heat by the release of steam at high pressure.

The same economy is expected from a boiler of the same construction, whether 20 tbs., 60 tbs.. or 120 tbs. of coal are burnt upon each square foot of grate-surface per hour, but little provision is made for the circulation of the water so that it can absorb the heat as fast as it is generated by the fire. The water-space around the fire-box is too narrow in many cases to take up the heat as fast as it is given out by the coal. I consider that we should give some attention to the generation of the heat as well as its economical application. The principles as to the admission of an excess of air apply with equal force to metallurgical processes when a neutral flame is required, as in locomotive furnaces. All these researches, as well as those with the dynagraph, and some upon steel rails, were made by private enterprise. I desire to acknowledge the important services of a former assistant, H. P. Hinsman, C.E., who has gratuitously devoted nearly one year of his services; also, Edwin Squire, C.E., who has given four months of his services in calculating and making investigations with the dynagraph.

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*BEFRACTOBY MATERIALS**

BY T. EGLE'STON, PH.D., SCHOOL OF MINES, NEW YOHK CITY.

ALTHOUGH the success of metallurgical operations depends so largely on the possibility of finding proper refractory materials, which enter so prominently into the cost of their operations, it can hardly be said that our knowledge of them is in a very satisfactory condition, or even that we know very much about them, beyond a few facts which have been gathered through their use. Experience, as a general thing, is an excellent master, but the requirements of

* This article was written at the suggestion of the Committee of the Institute on Refractory Materials, with a view of calling attention to the anomalies anil difficulties of the subject. It was hoped that its discussion would eventually lend to the appointment of a Commission, by the great metallurgical interests of the United States, to investigate the whole subject, since it is believed that u better and cheaper artificial product can be made than any now in use, and that many other important incidental results would be accomplished by such an investigation.

modern metallurgy increase so quickly that the acquirements of experience become rapidly useless, because the exactions of temperature are so continually increased, that the material depended on yesterday is of little value to-day.

The conditions which the refractory materials of to-day are called upon to fulfil, are very different from those demanded a few years ago, and unless a better, and, at the same time, a cheaper material than we now have, can be found, there are some industries which must die out altogether, and others, which, if they survive at all, can never take the commercial place which their metallurgical value would otherwise command for them. Mr. Holley has shown that the cost of the refractory materials of the Bessemer process is one dollar per ton of ingots, that in this country for the Siemens-Martin process it is five dollars per ton of ingots, while in Wales it is only one; a difference in cost, other things being equal, sufficient to almost prevent competition in times like these.

In the use of a given refractory material it will often be found that the same substance is called upon to fulfil conditions, which arc not only different, but exactly the reverse the one of the other. At one time it must resist an oxidizing, and immediately after withstand more or less of a reducing action. Now the action is neutral, followed by the corrosive action of chlorine or sulphuric acid, or again the action is that of basic scoria, and immediately afterward that of metals in fusion. The same substance must resist destructive mechanical action as well as the chemical action of melted oxides, sulphides, and silicates, and at the same time be proof against any amount of heat. We seem to be astonished, and often complain, that a brick which resists the influence of oxide of iron, should fail entirely under a gas-flame, and that one should slag under the influence of oxide of iron, but resist any amount of clear heat, and yet, when the nature of the material is considered, we see that it could not very well be otherwise. In many cases, and in certain portions of a furnace, the brick may be called upon only to support a very high temperature, coming in contact with the flame only, and this is the most trying condition of all our modern requirements, for the material must resist the temperature, and remain infusible without decomposition, cracking, or alteration of any kind, and still retain strength sufficient to, resist the pressure of the furnace. No materials are required to withstand so many and so varied conditions as crucibles, retorts, and furnace-linings, yet the success of most metallurgical operations depends on their resistance under ail the varying circumstances.

We must fairly regard the condition of our knowledge of this subject as one of the weakest sides of modern metallurgy. A review of it at this time, when we are called upon to economize in every direction, may not be out of place, for there are few departments in which there is so much scope for economy as here.

The substances with which we have to deal as refractory materials are silica, alumina, lime, magnesia; clays, which are silicates of alumina, more or less pure; the hydrated aluminate of iron, known as bauxite, and some silicates of magnesia, as talc, steatite, and the minerals which are allied to them, all of which substances are fusible in the strict sense of the word, but are generally infusible at commercial temperatures. To these substances two others must be added, as powerful agents to render infusible, under certain conditions, substances which would otherwise be fusible, and these are water, and carbon in the shape of coke or graphite.

Some few rocks are used as refractory materials, without undergoing change. These rocks are quartzites, granites, some sandstones, conglomerates, serpentines, steatites, and, in certain rare cases, as in Styria, carbonate of lime. Quartzite and sandstones were, for a long time, used almost exclusively for blast-furnace hearths. They arc very refractory, but very treacherous, as they are not homogeneous. Some aluminous shales are also used, and will, generally, stand if they do not contain more than from 4 to 6 per cent, of iron, the alkalies and the alkaline earths together, but it is not easy to use them. They are not easily cut, must be laid in their quarry-bed, and are liable to crack. Other rocks of the soapstone and serpentine varieties, which contain 60 to 65 per cent, silica, and 20 to 25 per cent, magnesia, are infusible, easily cut, and, if they do not crack;. can be used; but, in general, natural substances are not homogeneous, are difficult to get in sufficient quantities, and so little to be depended upon that artificial materials arc preferred.

Silica is found in nature anhydrous and hydrated. The anhydrous, which is quartz and jasper, cannot be used alone, as it cracks and splinters. If it is to be used, therefore, it must be reduced to powder. The hydrated varieties gelatinize with acids, and arc found as powders and soft stones, which pass under different names in different countries. They contain from 30 to 87 per cent, of gelatinizing silica, from 2 to 10 per cent, of water, and from 0 to 42 per cent, of insoluble silica, with from 2 to 10 per cent, of iron,, alkalies, and.

alkaline earths. These impurities are generally in too small quantities to affect its refractory qualities. Some varieties of this rock are so tender, that M. Deville has had crucibles made of them in a lathe; but, as the composition is never regular, vessels made of a mixture are always better. Though silica is infusible, it cannot, generally, be used without being ground, and as it has no binding property like alumina, a small portion of binding material must be added to it to make it hold together. For the Dinas brick, which is the best substance to resist heat alone, this binding material is lime. This brick is made of quartzose sandstone, which is first heated in a furnace, and thrown into water, to break it up, and is then ground. It is composed of

Silica, 98.31 to 96.73	Ferric Oxide,.81 to 48	Alkalies,.14 to .20
Alumina, . 72 to 1.39	Lime, .22 to .19	Water, .35 to 50

The amount of lime required to bind it together is 1½ per cent. The joints between the bricks are filled with the same material. At a temperature of 2200° C., about 4000° Fahr., these bricks will last four weeks in the roof of an ordinary furnace, and in that time will be reduced--by abrasion of the flame, and dust, and slightly from chipping--from nine to two inches. The bricks conduct the heat so badly, that at this temperature, which is a bright white heat on the inside of the furnace, it is only just warm on the outside. Ordinarily, the bricks seem to be fluxed away by the dust, which circulates with the gases. In the Siemens furnace, where there is no dust, they give out from weakness. They cannot be applied to any part of the furnace where there is any wear. The principal cause of their deterioration seems to be, the lowering of temperature due to stoppages on Sunday, when the bricks flake, either as the furnace cools, or when it is again heated. It was at first supposed that these bricks could only be made from the Dinas stone, but it is now known that they may be made from any pure silicious rock which has been ground and mixed with the proper quantity of lime-
In ganisters, used for the Bessemer converters, the binding material is alumina, chemically combined with silica, in the shape of clay. It is generally used unburned, and it is very important that the mixture should be so made, that it will expand a little, but not shrink at all. For this purpose, quartz, as pure as it can be had, is mixed with aluminous clay.

Silica is generally a very cheap material, and preferable to any other substance, if it is used only to resist heat, but cannot be used if any considerable quantity of scorias are to be formed. In such cases bauxite, or other aluminous material, will be found to be preferable.

Lime, or lime rocks, cannot generally be used in commercial operations, because the carbonate, the only form in which we have it, becomes caustic under heat, and this, when left to itself, absorbs water and falls to powder. It can be used when an operation is continuous, but in no other case. In Styria the hearths and sides of blast-furnaces are sometimes made of it, but they are generally quickly abraded, and make but short campaigns. Lime is infusible ; bricks of it are used for the fusion of platinum. It is, however, very easily acted upon by silica, but when this is absent, it is one of the most refractory substances known.

Magnesia made from the carbonate by driving off the carbonic acid is very refractory, if pure. It is made into any shape that is required, and is one of the most refractory of substances. It was formerly very difficult to get the carbonate of magnesia, but largc quantities of it have been found on the Island of Eubea, so that it can now be had for $15 to $25 the ton, instead of $60 to $70 as formerly. It can be calcined at a less cost than ordinary limn, losing half of its weight, so that if calcined before it is transported the cost may be still further reduced. It contains a little lime, silicates of iron, and some serpentine and silica. After calcination, the serpentine and silica can be separated, as it is easily crushed, but the most of the work can bedone by hand-picking beforehand. Before moulding, it must be submitted to about the temperature it is to undergo in the furnace, otherwise it would contract. It is then mixed with a certain portion of less calcined material, which is one-sixth for steel fusion, and 10 to 15 per cent water by weight, and pressed in iron moulds. If for any reason--either because there was too much or too little water, or because the material was not properly mixed, or contains silica--the crucible is not strong enough, it has only to be dipped in water, which has been saturated with boracic acid, and then heated.

Bauxite is one of the natural substances which has been recently applied as a refractory material. It is a compound of silica, alumina, oxide of iron, and water. Like all aluminous substances, it has the advantage of tending to form aluminates, which are less fusible than silicates, and are generally completely infusible at commercial temperatures. It does not have a very constant composition, as silica is sometimes not even present at all, as is shown by Berthier's analysis given below:

	Berthier	Deville.	School of Mines.
Alumina,	52.0	58.1	60.00
Ferric oxide,	27.6	3.0	070
Silica,		21.7	23.00
Water,	20.4	14.0	15.00
Titanic acid,		3.2	
	100.0	100.	98.80

Almost all the aluminates of iron are infusible. Siemens has taken advantage of this, to make bauxite bricks, which have the composition : alumina 50 per cent.; sesquioxide of iron, 35 per cent.; silica, 3 to 5 per cent. They last five or six times as long as the best Stourbridgc bricks. Nothing has yet been found which resists the corrosive action of basic slags so well.

The materials of which firebricks are generally made, however, are fireclays, which are hydrated silicates of alumina, containing from 50 to 65 per cent of silica, 30 to 75 per cent, of alumina, and 11 to 15 per cent of water. The relation between the silica and alumina is exceedingly variable, owing to the fact that a part of the silica, which is not always the same, is combined and a part uncombined. The quantity of water is also variable, as part of it is hygroscopic and can be driven off without injury to the clay. The plasticity generally depends on the water of combination, which, when driven off at a red heat, cannot be made to combine again, so that this property is then entirely lost. It contains, beside, a small quantity of other elements, such as potash, soda, lime, magnesia, and iron, and is generally less refractory the more it contains of them. "When it contains from 6 to 10 per cent, it will generally melt. When the clay is silicious, 3 to 4 per cent of other substances make it fusible. When it is aluminous, 6 to 7 per cent of oxide of iron does not make it lose its refractory qualities, owing to the very refractory nature of most aluminates. When, therefore, the corrosive effects of basic slags are to be feared, aluminous clays must be used.

Almost all clays contain organic matter; if present alone it makes the clay more refractory, since the presence of even a small amount of carbon tends to increase its resistance to heat, as seen in graphite crucibles. Pure material, composed exclusively of silica and alumina, would be completely infusible. Such material is, however, exceedingly rare. The property of infusibility is always more or less compromised by the presence of foreign substances, which tend to reduce it or take it away altogether. The clay which, according to Brogniard, is the most refractory, when deprived of its hygrometric water, has the composition : Silica, 57.42 ; alumina, 42.58.

While the refractory nature of clay is due, to a very great extent, to its chemical composition, it is not due to it alone. There are, probably, no two beds of clay, in the world, or even distant parts of the same bed, that have exactly the same composition, and yet they may be very nearly of the same quality. The power to resist heat is, undoubtedly, owing in part to the. molecular condition of the particles, a subject which has been but little studied, and is but little understood. Many clays, which would be rejected from chemical analysis alone, are sometimes found in practice to be excellent refractory materials. It has been found that the refractory nature of the clay depends also to a great extent on the mechanical arrangement of the particles, for of two materials having exactly the same chemical composition, one being coarse and the other fine, the coarse may be practically infusible, while the fine may be more or less easily fusible. The more porous the same substance is, the more infusible it will be. It may be said in general terms that the value of a given refractory clay will be inversely as its coarseness and as the amount of iron contained. When the amount of iron reaches 5 per cent., the material becomes worthless. This is true, however, only in general, for Pettigand cites an excellent clay from Spain, in which there is 25 per cent, of iron. This is, however, an exception.

In order to be useful, clays should be, or should be made to be, more or less plastic, as this property is necessary to their being moulded into the shapes required. This plasticity is owing, first, to the fineness of the particles, to the presence of alumina, and to the water of combination. It is diminished by the presence of iron, 'lime, and magnesia. The refractory nature of the clays, then, is due to the presence of alumina, or silica in excess, and to the absence of potash, soda, lime, magnesia, and iron.

The characteristics of all fine clays may be said to be that they do not effervesce with acids, that they make a paste with water, which is absorbed so rapidly as to make a slight noise. This paste can be drawn out without breaking, and is very plastic. Dry, they arc solid, and break into scales when struck. They have a soapy feel, are scratched or polished by the nail; can be cut into long ribbons with a, knife, and appear somewhat like horn. When fresh from the quarry they have a more or less fetid odor, owing to the presence of some partially decomposed organic substances. In composition they contain, as we have seen, either silica or alumina in excess. Silica in excess makes them rough, and takes away most of their plasticity and tenacity. Alumina makes them very plastic; magnesia makes them very unctuous, and almost soapy, but does not make them fusible; lime makes them dry and fusible; iron and other substances change the color, and, beyond certain very restricted limits, makes them fusible. The gray and brown colors, up to black, are owing to a small percentage of bituminous material. White clays are generally considered the best, but there is no certainty about it, as they often crack, or even melt. It is generally an excellent sign when they leave unbroken lines when scratched by the nail. It is, however, never safe to judge by the eye or touch, as some of their chief characteristics apply equally well to materials not in the least refractory, and even those that are peculiar to them may be taken away by improperly drying them, by carelessness in storing or handling them, or by allowing them to become mixed with other substances. A preliminary analysis gives only a general idea of their nature, but it is not always a safe guide to the manufacturer, who needs first an analysis and then an assay, for some of the most inferior clays, if we should judge by their analyses, give excellent results when used as mixtures. Analysis is necessary both before and after the assay, but there is a molecular force which seems to have more to do with the value of the material than the chemical composition. The greater this force, the less likely is the heat to overcome it, either to cause disintegration or chemical union. If possible to do so, all clays should undergo some process of preparation, with a view of purifying them.

Every person using clays should endeavor to get a certain knowledge of their properties by assay. There have been a number of these assays published, most of which, though they give accurate results, are too complicated for ordinary use. The two simplest and best are the one proposed by Bischoff, and the foil assay.

Bischoff 's assay is based on the comparison of every clay with one from Garnkirk, in Scotland, which is taken as a type. For this purpose the clay to be examined is mixed with one, two, three to ten parts of quartz, as the case may be. It is then raised to a known temperature and compared with a piece of the type clay of the same size and shape, which has been submitted to the same temperature. If the clay, with three parts silica, acts like the Scotch clay with one, it is called three, and so on. The best and simplest assay seems to be the one made by the blowpipe, which consists in mixing a small quantity of clay with water, and then spreading it out carefully on a piece of platinum-foil in a very thin sheet, which when completely dried is submitted to the flame and compared with clay of known fusibility prepared in the same way.

Very few clays can be used as found. They must be, as it were, suspended in some infusible material, which will prevent, as far as possible, the mechanical effects of the heat, and allow at the same time of a certain amount of expansion and contraction, while preventing both in too great a degree. These materials are generally called “lean,” that is, they do not make a paste with water, and require some binding material to keep them together. They are usually quartz-sand or pulverized quartz, burnt clay, old bricks, serpentine, talc, graphite in powder, and not' infrequently small coke, when the ash is not to be feared, and when graphite either cannot be had or cannot be used on account of its high price. Some fire-clays from Spain contain this "lean" material, which comes from the decomposition of talc-shale in which they have been suspended by nature, but this is a rare exception. The mixture must generally be made artificially. Of all these substances quartz-sand is the cheapest, but it has been found by experience that round grains of sand arc less liable to become thoroughly incorporated with the binding material than the angular pieces of crushed quartz, so that when a very refractory material is required crushed quartz is always used. As the clay contracts and quartz expands a mixture may be made which will not change its form ; but in a given case this may not be the best mixture for a special use. If the material has only to resist great heat, an excess of quartz is preferable; but if it must also resist the corrosive action of basic slags, clays burnt at a high heat, graphite or coke can be used. When the mixture is made in the place where it is to be used, without previous burning, it is generally made of one-fifth plastic clay and four-fifths burned clay or quartz, or one-fourth lean clay and three-fourths burnt clay or quartz. This is done to avoid contraction. It is a most economical construction, even in blast-furnaces, and is coming more and more into use.

The clay when mined is left exposed to the air under sheds, and is cleaned and carefully dried, and is afterwards mixed with the substances with which it is to be incorporated, which are classified by numbers, varying according to the size of the sieve-holes through which they will pass. The quantity and quality of the mixture will determine the refractory nature of the material to be produced. A friable paste with large grains, and quite porous, resists a great heat. One with fine grains, close and compact, splits at a high heat, especially if it is not homogeneous. The manner in which the mixture is made also influences the quality of the brick quite as much as the material. In some works in Belgium, after taking all the ordinary precautions to make the mixture perfect, it is submitted to a succession of shocks continued for some time, until it is found by experiment that the materials are perfectly mixed. It has been found by long experience that the bricks so made keep their form perfectly, while others made of exactly the same mixture in the ordinary way contract. The quantity and size of the mixture depend upon the size of the article to be manufactured. When coarse grains are used, greater thickness must be given to the sides of the articles if they are hollow, and they must be made larger if they are solid, thus giving a mechanical cohesion where a chemical one is wanting. The usual quantities of the mixture for bricks are three-fifths to two-thirds of the substances added to two-fifths to one-third of the clay, these quantities being determined by volume and not by weight. "When coke-dust is used it does not seem to have any decided effect beyond one-tenth. The action of coke or graphite is to decompose the metallic oxides as they form, and thus prevent their union with the material of the crucible. Coke may be profitably used in the place of graphite when the ash is in small quantity, free from iron and highly aluminous. Beyond two to three per cent of graphite cannot be profitably used, as it weakens the article and renders it liable to break. The mixture which gives the very best results for small objects is, however, worthless for large. It will generally be found that the pieces which crack up and down in drying have had too much material mixed with the clay, and those which crack laterally have had too much clay.

The very greatest importance is attached in some industries to not having a mixture made by a machine. In most places even to this day the inhuman method of heel-treading is used, because more care is then exercised, or because smaller quantities being mixed at once, better results are obtained. The more the operations of mixing are repeated, the better the material, and it is undoubtedly true that with mechanical means such a homogeneous paste is not produced as can be made by human labor, because the whole object of the machine is to operate on large quantities at a time.

The paste made, and the article completed, it must be dried or "tempered." This is commenced in the open air, and if possible out of the draft. If the draft cannot be excluded, the place where the drying takes place is slightly heated, commencing at a temperatare from 60° to 70° Fahr., and keeping it up from 25 to 30 days, then increasing it from 80° to 100°, leaving the article as long as possible, with an active ventilation, but the same temperature being kept up. The article should remain in a temperature of from 150° to 180° for at least six weeks. Bricks do not generally require so much care; but crucibles and retorts do. Long experience has proved that there is a great economy in conducting this process of tempering as slowly as possible, and that it influences materially the refractory nature of the article. It is found by actual experiment in crucible works, that those crucibles made from the same mixture, tempered during six to eight months, last more than three times as long as those which had been tempered only two; so that in general the older the article before being burned the bettor. This desiccation, while perhaps it is the most important part of this manufacture, is undoubtedly the one most neglected. A poor article well tempered, is often better than the best which has been hastily dried. By working rapidly, and filling up cracks as they form in a too rapidly heated drying-house, with a very liquid material, in order to secure complete penetration, both time and money are lost. The material never lasts nearly so long as when slowly dried. In the works at Andenne, in Belgium, large pieces, like glass-house pots, are kept six months in the drying-house before they arc burned, and during this time the greatest care is taken to prevent drafts, so that no air colder than the drying-room shall strike them. Leaving **the** door of the drying-furnace open has been known to crack the pieces, which had been up to this point most carefully prepared and tempered.

In reviewing the effects which the different elements which constitute refractory materials have, we find that the same clement often produces exactly contrary effects, according to the proportion in which it is present, and that there is nothing anomalous in effects being so produced. Silica causes expansion when highly heated, so that the moulds in which the bricks are made must be smaller than the brick is to be. Every mixture has its own peculiar rate of expansion and contraction. This expansion not only takes place when the bricks are made, but if when used they are submitted to a higher degree of heat, they expand still further, and contract again on cooling to such an extent, that at Dowlais the tie rods of the steel furnace are slackened when the furnace is getting into heat, and are tightened again as it cools. At Crewc, this is made self-acting by means of springs. At Creusot the furnace casing is made so strong as to resist the pressure, so that the centre of the roof-arch must rise and fall, to allow for the expansion and contraction. When neutral brick must be had for any reason, it is mixed with just enough clay and burned brick to make it keep its form, and such a brick is generally less fusible the less silica it contains.

Alumina alone, or with silica in the proportion of 30 to 38 per cent., is very refractory; but three per cent, of it in a silica brick makes it fusible. In clay, or pure, it tends to contract, and this tendency is greater as the alumina is in greater quantity, and the heat of manufacture has been low, but when it has been very highly heated at first, it afterwards undergoes but little change. Though both silica and alumina affect each other so unfavorably, Bischoff found that four of alumina to one of silica or two to one, or one to one, only sintered before the oxyhydrogen blowpipe, making masses with a granular fracture. One of alumina to two of silica was fusible like porcelain, but still somewhat granular. One of alumina to four of silica and one of alumina to six of silica melted like a thick enamel, which shows that the acid silicates of alumina are much more fusible than the basic. He also found, that a mechanical mixture of alumina and silica was less fusible than the same amount in a natural combination, and that, in general, silicates already formed are more fusible than a mixture of their constituents. The general property of alumina, when mixed with other substances, is to bind them together. When combined with iron or other bases alone, it makes infusible aluminates; but if silica is present, it fuses more or less easily. It is generally conceded that the proportion of alumina in a brick should be between 10.20 and 25 per cent.

The alkalies in small quantity make a brick fusible. There is a great difference of opinion among those who have studied this subject with regard to the quantity. Mr. Snelus states positively that 1 per cent, of alkalies in an otherwise good material makes it too fusible to withstand high temperatures. Mr. Riley states, with equal positiveness, that he has found brick containing 2.73 per cent of potash to resist the greatest heat of a Siemens-Martin furnace. It is probable that both are right, and that in the special cases alluded to, the peculiarities were owing to the association of elements. In any case, a material with a very small percentage of alkalies cannot be used.

Lime alone is completely infusible; but in very small quantities in a clay, it makes a brick fusible at high temperatures. Two per cent, of it with silica makes the most infusible brick known.

Magnesia in small quantities makes the clay fusible. In very large quantities it is very refractory. Alone, it is entirely infusible.

Oxide of iron in the absence of alkalies, may be present in small quantities without seriously affecting a clay, unless it is to be used for melting steel. If alkalies are present, any proportion of iron would make such a clay worthless. If no silica at all is present, five or six per cent, may not damage it. In a silica brick 2 to 3 per cent, of iron makes the brick worthless. If the iron was always certain to remain in the state of a sesquioxide, its compounds would be much more infusible, and a large percentage would do no injury; but some of the sesquioxide is certain to become reduced to protoxide in the presence of reducing gases, and the result is a very fusible compound in the presence of silica. There is a still more deleterious and dangerous effect of iron in firebrick, because its effects are produced, not at a high heat, but at a comparatively low temperature. It is well known, from the researches of Bell and others, that when a brick, containing iron, is exposed even at a low temperature to gases containing carbon, that part of this carbon is deposited near the iron ; this has often not only caused the brick to lose its cohesion, but has even burst it, so as to throw down the in-walls of furnaces, and the linings of flues. The presence of iron is, therefore, doubly to be dreaded, as in the presence of reducing gases it is quite as deleterious at low temperatures as at high.

As much as one per cent, of titanium has been found in some clays. Little is known about it, hut it appears to act like silica.

Bischoff found that 20 per cent of magnesia, 28 of lime, 47.1 of potash, or 40 per cent of iron, had exactly the same effect in making the clays fusible, and that when 4 and 2 of the different bases were used, the relation was striking, and in about the same order. The quantity of other substances necessary to make a compound fusible, depends upon the quantity of silica present--the more silica the less of the other substances. It will thus be seen that while the predominance of any one element will materially affect the nature of the materials, it is more the way in which the different ingredients are grouped together than their individual percentages, which affects the nature of the brick, and frequently, above all these, the mechanical and molecular arrangement of the particles which determines its commercial value.

The essential qualities of a good brick may be stated as follows :

first, infusibility ; second, regularity of shape, and the power to retain it under all circumstances, which involves perfect uniformity of composition ; third, strength to resist the different pressures required under different circumstances; and, fourth, its cheap price. No material yet manufactured fulfils all these conditions; but there seems to be no reason why, with the proper investigation, a material should not be made which will fulfil most of them. The metallurgical world is nearly agreed that the refractory material of the future must be made artificially, and that it is hopeless to look for it among natural products. No brick can come up to the modern standard of infusibility, which contains five per cent of iron, or three per cent of combined alkalies or alkaline earths, yet the most infusible brick that is known, which in the roof of a Siemens-Martin furnace will resist 250 charges, and then wear out by abrasion, when required to come in contact with metals, oxides, and alkalies in a spiegel cupola, will hardly stand twenty-five heats, while an iron pipe coil, which is easily destroyed by heat, will last almost indefinitely in the same cupola, provided only a sufficient stream of water is run through it. Different furnaces, and different parts of the same furnace should, therefore, be treated differently, instead of being treated by the same procrustean methods, as is frequently the case. If silica makes the best roof, it makes the worst hearth. Alumina, when present in very large quantities, even in the presence of a small amount of silica, makes compounds which are almost infusible, so that it should be used for the fire-bridges and hearths, and not put into the roof, where its tendency to contract would endanger the structure of the furnace.

Far too little attention has been given to the abrasive and corrosive power of coal-dust and ashes carried by the draft, in gradually cutting and fluxing away the parts of the furnace exposed to its action, and many qualities of brick which are infusible in the assay, owe their small power of resistance to its effect. A briek to be used where it is to be exposed to such action, should always be tested by placing it for a considerable time on the bridge of the furnace where it is to be used, for the destructive effects of this almost unobserved agency seems to be greater than those of long-continued heat.

A good brick should not only resist high temperatures, but sudden changes of temperature, without alteration of any kind, such as crushing, splitting, etc, and at a high temperature should undergo the least possible change of form. In general, it may be said, that bricks which have undergone a very high temperature in the manufacture are less likely to contract afterwards. Shrinkage is generally due to insufficient burning, or to a too small proportion of old material in the mixture, and generally occurs in aluminous bricks. Its . chief evil is in allowing the flame to penetrate the open joints and give the dust an opportunity to cut between the bricks, for any cause which produces eddies in the flames, such as hollows or projecting surfaces, is certain to effect the destruction of that part of the furnace. Silicious bricks have, on the contrary, a tendency to expand under the influence of intense heat. This is true to such an extent that in the steel furnace where they are used provision must be made for slackening the tie rods when the fire is being raised, and tightening them when it is being cooled.

The crushing weight of an ordinary firebrick, cold, is from 600 to 1000 pounds, but some of the best have been known to resist as high as 3000 pounds to the square inch. To insure the safety of the structure, and the success of the process, it should not only retain its power of resistance, but should not undergo any change of form nor soften materially under long-continued heat, and at the highest possible temperature should support more than double the strain required without alteration. In the walls of the fireplace those bricks will be best which are dense, and contain an excess of silica. In the hearth they should contain an excess of alumina. In the arch they should be nearly pure silica, alumina, or magnesia. Bricks in a roof give out from shrinkage, cracking, or splintering. Splintering may take place when silicate bricks are made of impure mixtures, but it is usually caused from too much fine material and from imperfect burning. Bricks which are liable to splinter are generally cross-grained and dense, with a smooth conchoidal fracture, when made from improper mixtures, and when from bad burning they generally ring like a cracked vessel. All good bricks wear off evenly.

No matter how good a material may be, if its price is so high as to prevent healthful competition, it might as well not exist. Hence any effort to furnish a good material should have for its aim to produce it at the least possible cost.

In discussing the manufacture of a refractory material which is to be used in a given locality, there is to be taken into account, first, the clay and other materials to be had; second, the ore or metal to be treated; third, the fuel to be used; and fourth, the foreign substances in the gangue of the ore or metal. Whether to use a given clay, or a mixture of calcined or raw clay, must be determined by direct experiment, and then the size of the grains of the mixture for the special use must be determined, for each substance is more or less refractory, according as it is coarse or fine. Thus in Belgium, a porous material with a large grain is used for blast-furnace brick, but a fine material with a close grain for coke furnaces, the chemical composition being the same in both cases. It must then be ascertained whether the mixture contracts or expands, for there are clays that contract and expand between one-thirty-second and one-eighth. The way in which the material tempers must then be carefully studied. It is not sufficient to have a good material, for almost as much depends on its manipulation as on the material itself. To temper properly, the clay and the manufactured article should both be dried gradually and uniformly. It must be fired evenly, and the temperature slowly raised to the proper point. If it is to be used in the raw state as ganister, it must be equally moist throughout, so as to dry uniformly, and not so wet as to cause it to crack in drying, or so dry as to prevent its binding. The bricks, or other materials, once made, should be kept from dampness; as they are porous, and likely to absorb moisture, they should be heated before being used in the furnace, and put in as hot as it is possible to handle them. If the furnace is in blast, this requires a special furnace, and a high heat. If it is to be put in blast at once, especially with silica bricks, the temperature should be as high as the hand can bear. If the furnace is to be a long time standing, this precaution is not necessary, but in the two last cases the furnace must be dried very carefully and slowly. No brick which has been dressed should ever have the dressed face exposed to the flame. Without the observation of these precautions, a really good brick may give a very bad result. It is too much the habit of this age to be in a hurry to get results, and this has led some blast-furnace managers to boast, that steam was issuing from the top of their furnace, while cast-iron was being tapped from the bottom; but under such management we never hear of long campaigns; but very frequently hear of disasters.

It is thus seen that a brick which is good for the cupola would be worthless for the reverberatory furnace; that which answers well for iron, would generally be worthless for zinc, and a crucible which is excellent for steel cannot be used for brass. It is not the way to realize progress to keep analyzing natural substances until we find the right one, or make repeated trials and depend upon them alone All investigations go to show that we should look for artificial, and not for natural compounds; and that when we have made a mixture which has stood well, we are then to analyze and examine it in order to reproduce it. Failure in this, as in many other cases, is very often owing to wrong application of good materials, rather than fault in the materials themselves.

It seems probable that the use of water for cooling the refractory substances, and thus preventing them from attaining the heat necessary to destroy them, will in the future be used to a very large extent. Its application deserves the most serious attention.

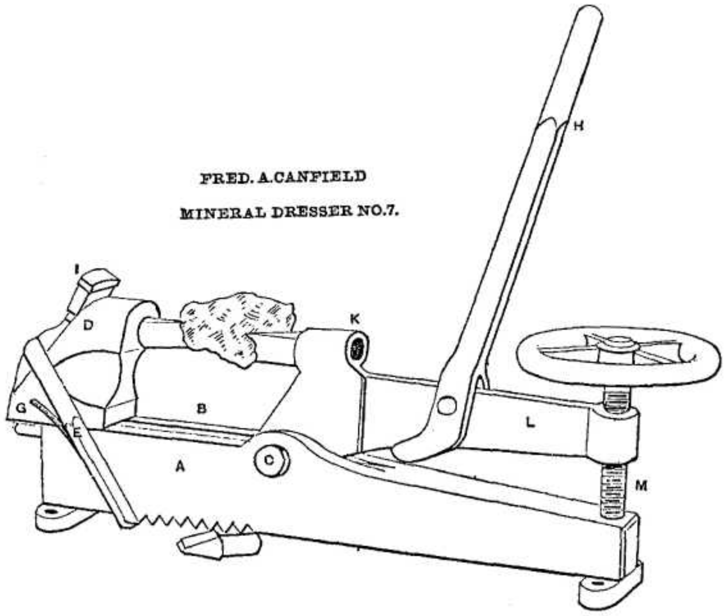
It is evident that no real progress can ever be made by any haphazard investigation. Chemical examination is, to a certain extent, a guide; but taken alone, it does not lead to any certain conclusion, for materials which on mere chemical analysis have been theoretically declared worthless, have, in actual practice, on account of some physical peculiarity which escaped observation, been shown to be of great value. Besides, a substance of no value alone may, in a mixture, be an almost indispensable article. To the analysis must be added the assay, and when these have both been carefully made, the commercial trial. After this has been done, there should be a complete chemical, microscopical, and physical examination of the substance, to determine what physical or mechanical changes have taken place, or whether it has, or has not, undergone deterioration. Only the general outline of such an investigation could be traced beforehand. Almost all of the investigations on refractory materials which have up to this time been made, have been undertaken by private parties in their own interests, and the results either good or bad have generally been carefully kept secret, so that when the same information is required it must be repeated, and the expense incurred over and over again. A thorough investigation would take a long time, probably no one company would be justified in bearing the whole expense of it, since to be really useful, the results as they arc ascertained should be published, but there is no doubt that if wisely planned and carried out, it would save millions of dollars every year to the iron and steel industries alone.

CANFIELD'S MINERAL DRESSER.

BY T. EGLESTON, PH.D., SCHOOL OF MINES, NEW YORK CITY,

AT the Dover meeting of the Institute, Mr. F. A. Can field showed some of the members a machine which he had invented for dressing mineralogical and geological specimens, which he has since modified and brought to such a high state of perfection, that after having used it for several months in preparing specimens for the cabinet of the

School of Mines, I have thought it well worth the attention of the Institute, as it is destined to render important service in the preparation of specimens of minerals and fossils for exhibition.



The machine is composed of a cast-iron bed-plate A, nearly square at one end, and slightly inclined at the other, which is fitted at the bottom with projections through which holes are bored to receive screws for fastening it. The surface, B, is planed and slotted with a V groove to receive a sliding cast-iron head, D, which is held in the position to which it has been adjusted by means of a wrought-iron clamp, E, which fits into a series of notches in the under side of the bed-plate. In the back of the head the clamp fits into a semi-circular slot, made in projections on both sides of the head. It is kept in position by a brass spring, G, and when once adjusted is held firmly in position by means of the steel wedge, I, which is driven in so as to force the clamp up against the bottom *of* the bed-plate. The head, D, is provided with a slightly tapering hole to receive the tempered steel chisels, of whatever shapes, that are to be used in dressing. Opposite the sliding head there is another head, K, of wrought-iron, which has a long arm, L, attached to it. This head rotates on a pivot, C, which runs through the bed-plate, and is fastened with a nut on the opposite side. The end of the long arm, L, is enlarged to receive the steel screw, M, which raises the arm or lowers it, according to circumstances. This head has also a conical hole for the reception of various kinds of chisels which are to be used. The end of the chisel in the head, K, is almost directly over the axis of rotation, C, so that any short movement of the screw, M, will cause it to move in a nearly horizontal direction.

To use the instrument, the screw is run up so that the long arm of the head, K, almost touches the bed-plate; the wedge, I, is taken out, the hand is pressed upon the lower part of the clamp, E, so as to free the head, D. The specimen is then placed between the two chisels, and the head, D, shoved up against it to the exact point where it is intended to cut. When the chisels are in contact with the stone, the wedge, I, is replaced and driven up; the screw, M, is then slowly turned by means of the wheel. A few turns of the screw will cut off the hardest rock very nearly square. The length of the cutting surfaces of the chisels may be made to suit the work to be done; they are usually about an inch and a quarter long.

The action of the pressure is such that when the separation of the rock takes place there is very little jar. The rook is simply cut at the point where the chisel acts; almost the whole force of the machine is concentrated between the two chisels, so that there is no danger of the specimen becoming deteriorated from the jar. I have, in this way, frequently cut the hardest rocks, both sides of which were covered with delicate crystals, without any damage to the crystals, in fact, without disturbing any of them in their positions.

The motion of the screw is so slow that the action of the chisels is like that of a very powerful shears. The chisels can be turned at. any angle which may be necessary to suit the form of the specimen, or may be made in any shape to suit the different kinds of work it is required to do.

For dressing soft rocks and slates, where a quick sharp action is required, a lever, H, is adapted to the wrought-iron arm, L, which may be easily removed when it is not required; to use it, the screw is turned up so as to allow the arm to drop upon the bed-plate. The heads are then adjusted as before, and while the specimen is held in the hand, the chisels are made to act by a series of short quick movements of the lever. This adjustment is of special use for trimming shales or soft rocks containing fossils, and is so effective that there is no danger of breaking the specimen which it is desired to trim. Every collector of minerals will appreciate the value of such a machine, for the most skilful adept in the use of hammer and chisels is often compelled to keep a cumbersome specimen in his cabinet, or run the risk, when the mineral has an easy cleavage or adheres slightly to the rock, of destroying it, for the stroke of the hammer, no matter with how great skill it is directed, will often exert its power, not upon the rock, but upon the crystal, which it will detach or cleave, after which there is no repair. The power which is exerted is very great, more than sufficient to trim into shape any specimen which would be required in a mineralogical, geological, or palæontological cabinet. Since the introduction of this machine into the mineralogical laboratory of the School of Mines, we have had very little use for hammers and chisels, and the attempt to dress an unwieldy specimen has not once resulted in disappointment.

BOSTON AND COLORADO SMELTING WORKS. *

BY T. EGLESTON, PH. D., SCHOOL OF MINES, NEW YORK CITY.

THE Boston and Colorado Smelting "Works are situated in the town of Black Hawk, Gilpin County, Colorado, on the Clear Creek Narrow Gauge Railway, 55 miles from Denver, in the Rocky Mountains, at an altitude of 7800 feet. It was one of the first works erected for the metallurgical treatment of gold ores, and the only one established in Colorado on a large scale which has been uniformly successful. Both gold and silver ores are treated, and gold, silver, and copper produced. The lead is not separated from the ores nor paid for, if it exists, and is entirely lost in the residues. The works were planned and built by Professor Hill, formerly Professor of Chemistry in Brown University, Providence, R. I., and is still managed by him, assisted by Mr. Richard Pearce, formerly professor in the School of Mines at Truro, England. They are very advantageously situated with regard to the ore-producing regions, having Boulder County on the north, which produces, besides ordinary gold ores, a series of tellurium minerals, such as altaite, sylvanite, and hessite, which are very rich in gold and silver. They are associated with copper and iron pyrites, blende, galena, and the carbonate and oxides of iron. Gilpin County itself produces for the most part the pyrites of iron and copper rich in gold, with a small quantity of galena and blende, which is rich in silver. In

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* By consent of the council of the Institute, this paper was first published in London Engineering, from which the engravings are here reproduced.

some mines native gold is found. Clear Creek County to the south furnishes mostly galena and blende very rich in silver. The works also receive mattes rich in gold and silver made at Alma, in Park County, and tellurium ores rich in gold from the southern part of the Territory.

The works are thus located in the very centre of the gold and silver producing regions of Colorado, and are also most favorably situated with regard to transportation. They treated in 1874, 30 tons of ore and tailings in 24 hours, and produced 700,000 ounces of silver, 12,000 ounces to 15,000 ounces of gold, and 225 tons of copper. With matte from Alma their production in 1875 will be 110,000 ounces of silver, 25,000 ounces of gold, and 250 tons of copper.

Gold Ores.--The gold ores are divided into three classes. The first class consists of auriferous copper pyrites containing from 2 to 10 per cent of copper, 2 ounces to 10 ounces of gold, and 2 ounces to 10 ounces of silver. These ores average 4 per cent of copper, 3½ ounces of gold, and 6 ounces of silver. The second class are tailings from the gold mills, consisting of pyrites with about 1½ per cent, of copper, 1¼ ounces of gold, and 4 ounces of silver. The third class consists of tellurium ores, which have a very silicious gangue, and contain 100 ounces to 200 ounces of gold, and 6 ounces to 10 ounces of silver. These ores come mostly from Boulder County, and are often worth $10,000 to, $15,000 to the ton.

Silver Ores.--The silver ores of the first class consist of surface ores, mostly free from sulphur, containing 70 per cent of silica. They contain 100 ounces of silver and 5 to 6 per cent of lead, and no gold. Those of the second class are sulphurets, rich in blende and poor in galena and pyrites; they contain 150 ounces of silver, 15 per cent of zinc and lead, and no gold.

The cost of material at the works is:

Wood per cord,	$5.00
Firebrick per thousand,	90.00
Common brick per thousand,	08
Wrought iron per pound,	08

The cost of delivering the silver in New York is 1¼ per cent, of its assay value, taken at the valuation of the works. The rate for gold is six-tenths per cent.

The general plan of these works is given in Fig. 1, Plate VII. The diagram, Fig. 1*, indicates the various processes, showing what becomes of each of the products in the different stages. The treatment consists of eight distinct operations, most of which are more or less subdivided. These operations are:

1. Sampling the ore.
2. Roasting the ore.
    A. Largo ore roasted in heaps.
    B. Small ore roasted in a reverberatory furnace.
3. Fusion for matte.
4. Ziervogel's process.
    A. Crushing and roasting the matte for sulphate of silver.
    B. Leaching the roasted matte and precipitation of the silver.
    C. Washing and fusing the cement silver.
    D. Precipitating the copper.
    E. Refining cement copper.
5. Treatment of the Ziervogel tub residues.
    A. Fusion for white metal.
    B. Roasting the white metal.
    C. Treatment of the pimple metal.
6. Treatment of the residues of the Ziervogel process by the Augustine process.
7. Treatment of the bottoms.
8. Treatment of the oxidized copper alloy.

I. SAMPLING THE ORE.

The ore is purchased in large and small sample lots varying from 50 pounds to 6 tons or 7 tons. It is sampled by first taking one-tenth of the lot, and putting it through a crusher* and a pair of Cornish rolls, and then sampling as usual. When the ores are sent by the owner for treatment the charge formerly was:
For ores containing $50, $35

For ores	containing	$50, $35
"	"	50, 36
"	"	70, 37
"	"	80, 38
"	"	100, 40
"	"	200, 50
"	"	300, 60

and so on.

The arrangement of July, 1874, was that the company should pay for gold ores at the rate of 85 per cent of the total value of the gold and silver contained (premium added) after deducting $35 per ton currency for treatment. The gold is estimated at $20 gold per ounce, and the silver at $1.25 gold per ounce, with the premium added, 3 per cent below New York quotations

The arrangement for silver at the same time is given in the table

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* Dodge's crusher is used in those works, and to some extent in Colorado, though Blake's crusher is preferred where there is a large and constant amount of work to do.

below. The prices are based on the premium on gold in New York, ranging between §1.10 and $1.15.

For ores containing	40 oz.	per ton,	34 cents	per *oz.*	in currency.
“	50	“	44	“	“
“	60	“	52	“	“
“	70	“	60	“	“
“	80	“	66	“	“
“	90	“	70	“	“
“	100	“	74	“	“
“	125	“	82	“	“
“	150	“	89	“	“
“	175	“	93	“	“
“	200	“	97	“	“
“	250	“	99	“	“
“	300	“	101	“	“
“	350	“	103	“	“
“	400	“	105	“	“
“	450	“	106	“	“
“	500	“	107	“	“
“	600	“	108	“	“
“	700	“	109	“	“
“	800	“	110	“	“
“	900	“	111	“	“
“	1000	“	112	“	“
“	2000	“	116	“	“

The copper is paid for at $1.50 currency for each unit by the dry Cornish assay. The prices given in Georgetown differ slightly from this. Below are given the prices of two different works as they were advertised in July, 1874:

Prices given for Silver by W. Bement, Georgetown.

Ounces of Silver per ton.	Price per ounce of Silver for ores containing from 5 to 10 per cent. of Zinc.	Price per ounce of Silver for ores free from Zinc, or containing less than 5 per cent.
	Cents.	Cents.
75 to 100	48	50
100 “ 125	55	60
125 “ 150	65	70
150 “ 175	75	80
175 “ 200	82	84
200 “ 250	85	88
250 “ 300	90	92
300 “ 350	93	94
350 “ 400	96	98
400 “ 450	99	100
450 “ 500	102	103
500 “ 550	104	105
550 “ 600	106	107
600 “ 700	107	108
700 ‘ 900	–	109
100 and upward	–	110

At Stewart's Mill, Georgetown, the following prices were paid:

	Ounces.		Cents.			
Ore containing	29!) silver or less,		105 for each oz., over 35 oz. no duction.			
“	300	“	94	“	“	“
“	325	“	95	“	“	“
“	350	“	96	“	“	“
“	375	“	97	“	“	“
“	400	“	98	“	“	“
“	450	“	99	“	“	“
“	500	“	100	“	“	“
“	550	“	101	“	“	“
“	600	“	102	“	“	“
“	650	“	103	“	“	“
“	700	“	104	“	“	“
“	750	“	105	“	“	“
“	800	“	106	“	“	“
“	850	“	107	“	“	“
“	900	“	108	“	“	“
“	1000	“	110	“	“	“
“	2000	“	112	“	“	“

The precious metals in the ores were formerly never paid for above a certain minimum, which for silver was 40 ounces, and for gold 1½ ounce. All above this minimum was paid for in currency at the rate of 85 per cent of its bullion value. For all copper above 2 per cent. $1.50 currency was given for each unit.

All the ores received are piled separately on the sampling ground. All the large pieces of gold ore are roasted in heaps, and are then passed through a crusher and rolls, and afterwards through a screen with four to the inch mesh. The tellurium ores are only crushed and passed through a ten to the inch mesh screen, and are then ready for smelting. The surface silver ores are crushed and passed through a four to the inch mesh screen, and then go to the furnace. The ores rich in sulphur are called heavy ores, and are crusned and roasted in a large reverberatory furnace.

II. ROASTING THE ORES.

A. *Roasting Ores in Heaps.*—The auriferous pyrites is broken to 2 inches square in a crusher and roasted in heaps of about 50 tons each. The piles are made in the usual way with a wooden chimney about 7 feet high in the centre. Wood is used as fuel. The amount consumed is two cords for 50 tons. The wood is burned out in about twelve hours, at which time the sulphur commences to burn. The pile is lighted at night, because the moisture in the fuel makes sulphuretted hydrogen, which would annoy the men in the daytime. The fire, except in case of accident, burns until the roasting is complete. The sampler takes charge of the piles. He has little to do except to throw fine ore on the cover when he sees that there is too much flame. He has two or three assistants, and with them he does all the weighing and sampling, and takes care of the piles. When the pile is finished the outside crust of unburned pyrites is taken off and put on to the next pile. The roasted ore is crushed and goes through a sieve with a four to the inch mesh, and is then ready for the smelter. One man does the whole crushing. The roasting is finished in about six weeks from the time the fire is lit. The amount of sulphur remaining in the ore is 4 per cent. As the ores contain considerable arsenic the pile is frequently covered on the outside with crystals of arsenious acid, which are often white, but generally colored with a slight trace of sulphur. They are generally found when there has been a hole in the cover of the pile, and their usual form is that of an octahedron with hollow faces.

B. *Roasting the Ore in a Reverberatory Furnace.*—The ore submitted to this process is said to be calcined* The tailings and finely divided copper ores are roasted in a reverberatory furnace, called a calciner, till they contain not more than one-half to four per cent of sulphur. There are six of these calciners in the works. They are marked K on the ground-plan, and are shown in detail at Figs. 2, 3, and 4, Plate VII. Only three of them are in use at a time; two of these work into the same flue. The total length of the furnace is 40 feet on the outside, including the fireplace. Each furnace has three step-hearths 10 feet long. They are 11 feet wide, and have six working doors, two doors to each hearth. The hearths are 4½-inches, the one above the other, and are equally divided in the length of the furnace. Each one is rectangular, with the usual waste space at the doors filled up. The two at the end have their corners rounded.

On comparing the relative dimensions of these furnaces, it will be seen that the surface of the hearth is 304 square feet. The surface of the grate is 16 square feet. If the fireplace is taken as unity, the relation between the surfaces will be as 1 to 19.

The fireplace is arranged for long sticks of wood, and has a door at the side. It is 5 feet long and 2 feet 8 inches wide. The bridge

* The word "calcining," as used in these works, means treating the ores or mattes in a fine state in an oxidizing atmosphere. The term " roasting " moans the treatment of metal ingots or mattes in large pieces in an oxidizing atmosphere. As these words are not used properly in a metallurgical sense, we shall speak of both as roasting.

has an air-hole in it. which is 4½ inches square, and communicates with the interior of the hearth by four openings. The width of the bridge is 28 inches, the height of the roof above the hearth is 28 inches, and at the flue-end it is 18 inches.

The furnace is built of red brick, firebrick being used only in the fireplace and on the first hearth. A charge of one ton is introduced on the hearth nearest the flue, so that there are three tons in the furnace at a time. The charge of ore on each hearth, spread out after being first put in, is 3 inches deep, but it swells, so as to be 4 inches to 5 inches in depth on the hearth nearest the fireplace ; this is particularly true of the tailings. As the charge is drawn once in eight hours, it takes twenty-four hours to complete the roasting of one ton of ore. One man to a shift, who brings his own wood, is all the labor that is required, so that two men work three tons in twenty-four hours. The ore is brought to the furnacemen, who then make the charge. One man brings all the ore for three furnaces. The men from the calciners always assist in charging the calcined ores into the matte-furnaces. The furnace burns 1½ cords in twenty-four hours. One day in a year only is required for necessary repairs.

III. Fusion for Matte.

The roasted ore is fused in a reverberatory furnace for matte. There are three of these furnaces, which are marked D in the ground-plan, Fig. 1, and arc given in detail in Figs. 5, 6, 7, and 8, Plate VII. Only two of them are in use at a time. They are constructed to use wood, so that the fireplace, which is five feet at the top of the bridge, is only 2 feet 6 inches at the grate; it is 5 feet long, and 4 feet 6 inches deep from the grate to the roof. The opening in the fireplace for charging fuel is at the end of the furnace, and not at the side as is usual. The fireplace door is of cast-iron; it slides in a groove, and is counterpoised with a weight. The bridge is 2 feet 6 inches wide, the fireplace side is 2 feet 3 inches, and the laboratory side 1 foot 10 inches from the roof. Just above the bridge there are a series of openings in the roof, 3 inches by 1 inch, for the admission of air, which follow on the roof the contour of the laboratory in two rows, the outside having eight and the interior eleven holes each. The laboratory is 15 feet 7½ inches long, by 9 feet 9 inches wide. The working door is at the end ; the two openings at the side are closed for this operation.

In comparing the relative dimensions of the furnace we find that the surface of the fireplace at the height of the bridge is 25 square feet, that at the grate is 12½ square feet. The laboratory has 143.18 square feet, so that the fireplace being taken as one, the relation is as 1 to 5.7.*

Each one of these furnaces has its own chimney, which is 50 feet high. The arrangement of the holes in the roof is a very ingenious one, for as the fireplace is very deep, and is constantly filled with long sticks of wood to a depth of over 3 feet, the wood distils and forms gas, which is burned by the air entering through these holes, so that the fireplace is really a generator for burning wood. Before this method was introduced by Prof. Pearce there was not sufficient air to produce a perfect combustion. Formerly the flue connected with the chimney was constantly burning out, and needed frequent repairs. The immediate effect of the introduction of these holes in the roof was the saving of fuel, and more equal distribution of heat. An opening has recently been made in the foot of the chimney for the introduction of cold air, and both because the combustion is better regulated, and because the cold air is mixed with the products of combustion on leaving the furnace, the repairs to the furnace are very much diminished.

The hearth of the furnace is slightly inclined towards the working door, and also to one side. It is made of two layers of brick, upon which fine quartz-sand is placed, which is mixed with a small quantity of wood-ashes, and then agglomerated. When the hearth is made the temperature is lowered, and the charge is introduced. The charge is made up of:

	Pounds.
Heap-roasted gold ores,	2000
Reasted tailings,	2000
Oxidized silver ores,	1500
Roasted silver ores,	1500
Raw pyrites,	800
Fluorspar,	250
Rich scorias,	500

After the charge is drawn, the furnace is repaired, if necessary, with clay, which is beaten in with a ladle-shaped instrument attached to a long handle. Such repairs are usually not made oftener than twice a week. The charge is introduced with a shovel by a wide door. The ore is introduced first and then the rich slags. The charge is

* In all these fireplaces with inclined sides, the surface taken as unity is the section at the bridge. As the grate-surface is smaller, the relation between the grato and fireplace surfaces should also be given.

so arranged that ten tons of mixed ores will produce one ton of matte. It will not do to make the matte richer, as there are always grains of it in the slag, and the loss would be greater. The slag is carefully calculated, so that it shall not be too basic, or otherwise it would cut the firebrick to get silica. The charge is evenly distributed over the surfaces of the hearth, which is almost at a cherry-red heat. It takes six men, working in groups of three at a time, nearly a quarter . of an hour to make the charge. As soon as it is made, the charging door is built up and luted or closed with sand. The fireplace is then charged, and the furnace is left with the full power of the draft for five or six hours. During this time the workmen clean up the slag-bed and tend to the fire, which requires looking after every twenty minutes. At the end of this time they stir the furnace carefully five or six minutes to bring up everything from the bottom, which should be perfectly smooth to the tool passing over it. This produces the reactions. The furnace is now left in repose for twenty minutes to effect the separation of the scoria and the matte. If lumps are found the stirring is done again, and kept up during the firing, or for about an hour. The slag is now drawn with a rabble into moulds prepared for it. The operation of skimming the slag takes about twenty minutes. When the door is opened to skim the slag it is quite hot and fluid, and there is a constant but quiet ebullition of sulphurous and sulphuric acid, the bubbles being about 1 inch in diameter, and quite uniformly distributed. Prof. Pearce asserts that the larger part of the gas is sulphuric acid. At the close of the skimming, as • the slag becomes cooler, the bubbles become larger and less uniform. Just before the skimming, pieces of sheet-iron, 3 feet by 2 feet, are placed in front of the slag-bed and to one side of it, to protect the workmen from the heat. The casting-bed is made 10 inches deep in front of the furnace to receive the plate slag, which ordinarily contains all the grains of matte. This casting-bed has fourteen divisions, which are connected one with the other. When the slag, which covers the matte to the depth of about 3 inches, is being skimmed, it is very easy to distinguish the matte below, which shows of a dark color and a more or less brilliant surface. As the rabble goes backward and forward, the slag does not close at once over it, and the surface is exposed for a very short time. When all the slag is drawn off, a new charge of ore is introduced. Four charges are made in twenty-four hours. During each one of the operations the stirring and rabbling are conducted in exactly the same way. While the slag is tapped the matte is left to accumulate, and is tapped only once in twenty-four hours. When the matte is to be tapped, all the doors of the furnace are opened so as to chill the last part of the slag a little, so that it will not flow out from the tap-hole. It is then tapped and made into plates 3 feet long, 14 inches wide, and 4 inches thick in the middle, the bottom being rounded. No slag flows out with it, because it is too much chilled. When all the matte has been tapped, the tap-hole is closed with damp sand. The charge makes about 14 plates. The operation of tapping the matte and stirring takes half an hour. Three men per shift of 12 hours are required to work two furnaces. Eight cords of wood are consumed in 24 hours. The plate slag contains on an average 5 per cent, of copper, but is often poor enough to be thrown away with the other slags. It is generally a silicate of protoxide of iron, but is sometimes more basic. The poor slag contains about 7 ounces of silver and a trace of gold. It is too poor to treat, and is thrown away. All the slag richer than this is put back into the furnace. The matte contains from 25 to 30 per cent of copper, 20 ounces to 30 ounces of gold, 600 ounces to 1000 ounces of silver, and some iron, lead, zinc, and antimony. When the hearth-bottom of the matte-furnace becomes loose and rises, as it sometimes does, the whole hearth material is taken out, crushed, and treated as ore. The flues of the furnace have to be repaired every two or three months. The roof is made over once a year. The outside walls last a number of years before it is necessary to rebuild the furnace. There are produced from this fusion the copper matte, which passes to the next operation, the plate slag, which is immediately put back into the furnace, and the poor slag, which is thrown away.

IV. Ziervogel's Process.

A. *Crushing and Roasting Matte for Sulphate of Silver.*--The matte produced from the previous operation must be roasted, and for this purpose it must be crushed fine. It is first broken up with sledges and then crushed in a Dodge crusher, with which one man can crush about 10 tons in a day. After crushing it is put through a twelve to the inch screen, and is then wheeled in a wooden barrow to the calciners, marked K on the general plan, where it is roasted for 24 hours, a charge being drawn every 8 hours. The charge is 1 ton on each hearth, so that there are 3 tons in the furnace at a time. One furnace working constantly does the whole work of the establishment; 90 per cent of the sulphur is removed in this operation. The roasted matte contains about 5 per cent sulphur, partly as sulphides and partly as sulphates. Where the matte is charged on the hearth the furnace is dark. This is necessary to prevent fusion, as there must be rapid oxidation at the lowest possible temperature. When the workman is not attending to the fire he is always rabbling the charge. When the charge on one hearth is finished it is moved to the next one by aspaddelle. On the middle hearth the heat is very dull, and from this temperature it is gradually raised until it is withdrawn from the furnace; on the last hearth the temperature is a bright cherry-red heat. The charge is drawn with a rabble into a "cub" beside the furnace. As there is but a small amount of sulphurous acid given off, the roasted matte remains here until it is cool enough to be wheeled in wooden barrows, when it is taken to the ball pulverizer. One and a half cords of wood in 24 hours is all the fuel used in this operation.

The ball pulverizer consists of a stationary horizontal sheet-iron cylinder 4 feet in length and 2 feet 8 inches in diameter, inside of which another cylinder of less diameter revolves. This inside cylinder is made with a east-iron headpiece, into which cast-iron bars are fitted so as to leave a space 1/64th of an inch between them. These bars are kept in position by a flange and wedges, and the heads are then securely bolted together. The material to be ground is introduced into the revolving cylinder through a trough in its axis. This cylinder or grinder contains one half-ton of iron balls, which when new are 3 inches in diameter.

The cold calcined ore from the cubs is thrown on to the crusher floor, and shovelled into bins, from which it is carried by an endless chain to a hopper which communicates with the charging-trough. The charge and balls revolve together at the rate of 37 revolutions per minute. The ore which is ground sufficiently fine, passes through the spaces between the bars, and falls into the stationary cylinder, which is hopper-shaped at the bottom, and communicates with a trough, through which an endless chain passes and carries the ore to a 60-mcsh screen; what remains on this screen is carried back again to the grinder. The crusher works between 3 tons and 4 tons in 24 hours, and has besides plenty of time for the necessary stoppages for repairs. Six tons might easily be put through in 10 hours, but from 3 tons to 4 tons is all that is required, so that a single crusher is more than sufficient. Very few repairs are done to the machinery. The bars wear, and when the openings become too wide, new bars are put in. Not more than 500 lbs. of balls are worn out in the course of a year. The men who do this work are obliged to wear wet sponges over their, mouths in order to protect themselves from the dust. One man, who also carries the wood to the calciners, brings the ore, and one man who shovels the ore and tends the grinder, are all that is required for the work.

Boasting for Sulphate of Silver.--From the ball grinder screens, the ground matte is deposited in a bin ready to be roasted for sulphate of silver. The furnace in which this operation is conducted is called the fine calciner. There are two of them, marked B B in the general plan, Fig. 1, Plate VII, and Fig. 12, Plate VIII. The furnaces are shown in detail in Figs. 9, 10, and 11, Plate VIII. They connect with four small dust-chambers, which are common to both furnaces, and connect with the same chimney. They are constantly in use except when silver is being melted, when only one of them is run. They have but one hearth, which is 11 feet 6 inches long, 3 feet 6 inches deep, and 10 feet 6 inches wide. This hearth is flat. The fireplace is 4 feet 6 inches long, 2 feet 6 inches wide at the bridge. The grate is only 1 foot wide. There are 11.25 square feet surface in the fireplace, and 100 square feet in the laboratory, making the relation as 1:9. The top of the bridge is 8 inches from the roof. The bridge is 2 feet wide, but 14 inches of this width is a curtain arch, the bottom of which is 16 inches above the hearth. Just beyond the curtain in the roof of the furnace there are a series of holes for the admission of air, of the same size as in the matte furnace. The first line goes straight across the roof, and is composed of five holes. The second follows the contour of the furnace and is composed of nine holes. The hearth of this furnace is made of a bed of old slag or stone covered with sand. On these, bricks placed on end and laid in cement are placed, which form the hearth proper.

The charge is 1600 lbs. of roasted crushed matte, which is thrown in with a shovel and made into a pile on the centre of the hearth Just before it is introduced all the dampers are closed. The hearth of the furnace at this time is dark. The fireplace is, however, glowing, but contains only embers, just sufficient to keep it hot. As soon as the charge is introduced it is levelled with the rabble and spread out over the hearth. "When spread out it is about 3 inches thick. It takes about 20 minutes to do this work, during which time the dampers remain closed and no fuel is put into the fireplace. As soon as the charge is completed the damper is slightly raised, but no fuel is charged. In about an hour the charge has a dull, blackish glow. The surface looks black, but it is red when stirred. The fireplace is now charged with a small amount of fuel, and the temperature gradually raised so as to keep it at about a dull red heat, but raising it slightly. The fireplace door is closed. The supply of air comes from the bridge holes, the working door, and the grate. The work at this stage consists of forming a maximum amount of sulphate of iron and some sulphate of copper, but the silver remains unchanged. The fumes of sulphuric acid commence to be given off from the decomposition of the persulphate of iron, and the charge increases in volume, becoming spongy. As the furnace door is open the workman is exposed to the acid fumes, and is, therefore, obliged to wear a respirator. The stirring is kept up and the heat gradually increased. From the second hour the grate is kept full until the end of the operation, the temperature being kept as uniform as possible. The ash-pit door is closed after the first hour, the air entering only through the working door and the holes in the bridge.. The flame over the curtain arch is curly, blackish, and reducing, but as there is more than 14 inches between it and the charge below, and the working door is constantly opened, it is so fully mixed with air, that in contact with the charge it is oxidizing. At the end of this time the heat is at its maximum, and the charge becomes dry, no longer sticking to the rabble. At this point, which is at the end of three hours, the sulphate of silver is formed. The sulphate of iron is decomposed at the end of two hours. The sulphate of copper, at the time all the iron is decomposed, is at its maximum, which is at the end of the third hour. When the silver is "out" a bar 2. inches square and 14 feet long is used to break up any lumps.. The charge is collected with it into the middle hearth. The pile is then, by a sliding motion of the bar on its side, cut down, bruised, stamped, and broken up, and in this way turned over twice from one side of the furnace to the other. In order to facilitate this work, the front of the working door is provided with a roller, on which the bar rests. The whole charge by this means is ground fine, and all the lumps broken up, and a perfect oxidation secured. It is essential to have as little sulphate of copper as possible, but about 1½ per cent is left so as to be sure that no sulphate of silver is decomposed. This operation with the bar lasts one hour, so that at the end of four hours the charge is ready to be withdrawn. At the end of the third hour assays commence to be made, and samples are constantly taken until the end of the operation. The first assay generally shows that the sulphate of silver is free, but it is reduced almost instantly to a metallic state by the suboxide of copper present, and spangles are formed which scintillate and sparkle, forming a most beautiful reaction. To make the assay, a sample of the hot charge is simply thrown into cold water in a small dish. The heat of the ore is so great that the temperature of the water is raised to boiling. Whatever silver is in the state of sulphate is dissolved by the boiling water. If there is any suboxide of copper present, the spangle reaction takes place. At the end of the fourth hour the exposure of the surfaces to oxidation from the action of the bar has converted all the copper from suboxide into protoxide, and no spangles are seen in the assay. The sulphate of silver consequently remains permanent. If any sulphide of silver was present in the charge, it is attacked by the sulphuric acid given off by the decomposing sulphates, and converted into sulphate. An average of from 90 to 95 per cent, of silver is thus rendered soluble, the rest being in a condition of arsenides, antimonides, or as fine particles within the sulphate of lead, and is not decomposed. The charges are constantly assayed, and the workmen, as they are skilled men, feel it for their interest to conduct the operation properly. It would not be safe to decompose the whole of the sulphate of copper, since there would be danger that some of the sulphate of silver would be decomposed and pass into the residues. The copper gives a blue color to the solution, so that when the spangles are no longer produced, and the liquor is a very pale blue color, the charge is drawn. None of this work is done at night, as the operation is an exceedingly delicate one, and requires to be constantly watched. As soon as the charge is withdrawn, the furnace is cooled by opening the doors and dampers, to get ready for another charge. Only two charges a day are made. It takes about ten minutes to discharge the furnace. The charge is drawn with a rabble into an iron barrow, and is wheeled to the brick cooling floor shown at B' in the general plan, Figs. 1 and 12. Each furnace is tended by one man only. The two furnaces burn together 1¼ cords of wood in 12 hours; they require only one day's repair in a year.

B. *Leaching the Sulphate of Silver.*--The charge from the sulphate of silver furnace is allowed to remain for twelve hours on the cooling floor and is then leached in tubs. These tubs are 3 feet high, 3 feet in diameter at the top, and 2 feet, 6 inches at the bottom (see *m*, in the general plan, Figs. 1, and 12, and Figs. 13, 14, and 15, Plate VIII). They arc provided with a double bottom pierced with holes which is covered with a cloth filter. They are charged with 1500 lbs. of the matte which has been roasted for sulphate of silver. The leaching is done by a current of boiling water kept hot by steam. The tubs are kept constantly full and discharged into a series of tanks below. It takes eight or nine hours to leach the charge; at first it is light, but in about an hour it shrinks and the water passes less freely through it.

The residues in the tubs contain all the gold and some silver which has not been separated. They are taken out and put on one side to be treated by the Augustine process to separate the silver, and the residues are afterwards treated for gold. All the sulphate of copper is dissolved out in the first stages of the work. In about seven or eight hours, assays of the liquid are made and the hot water stopped, when salt added to it shows no trace of silver. The time required varies according to the richness of the matte. Between 600 lbs. and 700 lbs. are leached in eight hours; generally about an hour is required for every hundred ounces of silver contained in the matte.

Precipitating the Silver.--The hot water charged with the sulphates of silver and copper from the solution tubs is run into a series of vats, *Sg*, shown in Fig. 12, and Figs. 13, 14, and 15, Plate VIII, and on the general plan, Fig. 1 at S. These vats are 12 feet long, 4 feet wide, and 2 feet 3 inches deep. Two sets of these vats, one in front of the other, are placed before each series of tubs. Each of them is divided into ten compartments, which are 24 inches X 20 inches and 27 inches deep. The liquid is discharged from the tubs into number one and communicates with number two at the bottom. The partition between two and three is low at the top, so that the liquid overflows into three, which communicates with four at the bottom, and so on. At ten the overflow passes into the tank below and follows the same circuitous course. Each compartment in the tanks is filled, as shown in Fig. 15, with plates of copper ¼ inch thick and 14 inches X 12 inches in size. Twenty of these plates, each having a precipitating surface of nearly 400 square inches, are placed in each compartment. In the bottom of the tank the plates are placed upright and are slightly inclined, being separated from each other by small strips of wood at the top. Over these the plates are laid horizontally, with strips of wood between each to prevent actual contact. This arrangement gives about 100,000 square inches of preciptating surface to each system. Both series of tanks are filled with copper in the same way. The tanks are kept perfectly covered with wooden covers. At the end of a week they are removed, and the copper plates shaken and washed in the liquid, to remove the silver sponge which falls to the bottom and is taken out. This sponge is very light and adheres very slightly to the copper. After the copper plates are taken out the liquid is allowed to settle.

The copper solution is drawn into the tanks *nn*, and the silver carried to the tubs *b*, to be washed to remove any traces of copper. It takes about two hours to get the tanks ready for another charge. More than half of the silver is deposited in the first four compartments. Here the copper plates last about four months. In the other compartments they last twelve months. The amount of copper dissolved is equivalent to the quantity of sulphuric acid set free from its combination with the silver.

C. *Washing and Fusing the Cement Silver.*--The cement silver is washed in a washer invented by Professor Pearce, and patented in England about eight years ago. It is a tub about 4 feet high and 4 feet in diameter at the top, and 2 feet at the bottom. It is, however, sometimes made a little smaller, being 42 inches high, 40 inches in diameter at the top, and 23 inches at the bottom. This tub, with its injector, is shown on the general plans, Figs. 1 and 12, at *b*, in Figs. 13, 14, and 15, and in detail at Figs. 16 and 17, Plate VIII. Two of these washers are placed on a raised platform having a spout connecting with the sulphate of copper tanks. About 3000 ounces of silver are placed on the false bottom of the tub. A mixture of one part of sulphuric acid to 100 parts of water is then poured in, in sufficient quantity to cover all the silver. Steam at a pressure of 50 lbs. is then turned on through the injector, and the arm *a* moved so as to open the air-holes. The steam and air pass down through the false bottom and up through the silver and sulphuric acid. A very violent ebullition is caused in the liquid by this passage of the air and steam.

The silver is thus kept in constant agitation, and fresh surfaces are continually exposed to the action of the acid. Beside this mechanical effect the current of air oxidizes the metallic copper and transforms it, together with the suboxide, into sulphate* The cement silver from the tanks still contains some traces of copper as sulphate and some metallic copper detached from the plates. At the end of two to three hours the liquid is run off through the spoilt into the tanks. The silver is washed for half an hour with clean water and steam, and then removed in buckets to be dried on top of the drying furnace, Figs. 18 and 19, Plate VIII. It requires from three to three and a half hours to completely purify the 3000 ounces of cement silver. After drying, the silver is melted in graphite crucibles in the furnace, Figs. 20, 21, and 22, Plate IX. It is cast

* This injector is also used in parting the rich auriferous copper alloy, for the eparation of gold, and manufacture of sulphate of copper.

into bars in the iron ingot mould, Fig. 23, and is found to be 999 to 999.5 fine.

D. *Precipitation of the Copper.*--The copper solution from the tanks *gS* runs into the tanks *n,* Fig. 12, which are divided into compartments like the tanks *gS,* and are also covered. These compartments are filled with scrap-iron, which is simply thrown in without any special care in piling. The spent liquor, which is sulphate of iron, when sulphuretted hydrogen or a polished steel plate shows no trace of copper, is discharged into the stream; the velocity of the discharge being regulated according as the action is quick or slow. The copper precipitates on the iron, and is left to accumulate. The compartments are cleaned out about once a month. The copper is removed from the iron by simply moving it backward and forward in the liquid. The iron so cleaned is at once placed in an empty tank to be used on a fresh charge. All the iron used is old scrap-iron, and is therefore not weighed. About 5000 lbs. to 6000 lbs. is used in each tank. The cement copper is allowed to drain and dry, and is then taken to the smelting furnace. It contains about 90 per cent, of metallic copper when it is fresh. The small amount of impurity is owing to the fact that the tanks are closed, thus preventing the precipitation of insoluble compounds of iron. The cement copper oxidizes very rapidly in contact with the air, so that when ready for the furnace it does not contain more than 80 per cent of copper in the metallic state.

E. *Refining the Cement Copper.*--The furnace in which the cement copper is refined is shown at A in the ground plan, Fig. 1, and in detail by Figs. 24 to 29, Plate IX. The fireplace is 5 feet long, and 28 inches wide at the top of grate. The grate has the same length, but is only 17 inches wide. The bridge is 2 feet wide. The laboratory is 6 feet 4 inches long and 4 feet 4 inches wide, and has two doors, one at the end, which is the charging door, and one at the side, which is the working door. Just over the bridge in the roof there are two rows of six openings each, for the introduction of air; these are covered with a hood to prevent the introduction of foreign substances. The furnace connects with the chimney by a flue, which is 2 feet square.

The fireplace, has 11.65 square feet and the laboratory 21.79 square feet, so that the relation between them is nearly 1 : 2.

This furnace runs once a month for 18 or 19 hours. A charge of 2500 lbs. of copper mixed with 50 lbs. of refuse charcoal is put in at 6 P.M. The fireman keeps up the fire during the night, and the refiner takes it at 7 A.M., and then skims off the slag and exposes the surface of the bath. Considerable sulphurous acid is given off, probably from the reduction of the sulphate of iron in the cement copper. The charge is worked for a "set," which takes three to four hours. This is done by striking the surface with the rabble and making waves. This is called beating the copper. The copper produced contains from 2 to 3 per cent of oxide of copper dissolved in it, but it is not necessary to refine it completely, as it is used at once in the tanks G. The copper is taken from the furnace with a ladle, and is poured into a cast-iron mould made of a frame in two- parts held together by clamps, and is slightly tapering, being larger at the bottom than the top. This frame is placed on a cast-iron plate 3 inches in thickness. The ladleful of copper poured in is allowed to set, that is, a film of suboxide of copper is allowed to form, another ladle is poured on, and so on until the mould is full. The cast-iron frame is then removed, and the plates fall out separately, as the oxide prevents anything more than contact. Twenty-five plates are made in this way at a time.

V. Treatment op the Ziervogel Tub Residues.

A. *Fusion for White Metal.*--The residues from the tubs consist of oxides of copper and iron with 20 to 30 ounces of gold, and 40 ounces of silver to the ton. They amount to about 22 tons a week. They are melted in the matte furnace, Figs. 5 to 8, Plate VII, with rich gold ores of the first class, containing iron with copper pyrites and variable quantities of gangue, and highly silicious tellurium ores. All the silicious pyritiferous ores are selected for this purpose. The ores are all crushed and put through a four to the inch mesh sieve. The charge is brought to the furnace in alternate barrows of residues and ore, but it is not mixed before charging, as it becomes mixed after it is thrown into the furnace. The charge consists of

	Lbs.
Tub residues,	4000
Raw gold ores of the first class,	2500
Gold ores of the third class,	900
Total.	7400

When there are no tellurium ores the charge of gold ores of the first class is made to amount to 3400 lbs. The treatment is exactly the same as before. A poor slag containing only two ounces of silver and a trace of gold is produced; it is very much poorer than those of the previous fusion. It has otherwise very nearly the same composition as the others, but there is no zinc either as blende or oxide in it.

The matte contains:

Copper,	60 per cent
Gold,	55 ounces.
Silver,	130 "
Sulphur,	30 per cent.

It is called white metal. If the matte was made richer in copper the slag would also be richer, and there would be more loss. The tapping is made twice in 24 hours. In other respects the labor, fuel, etc., are the same as in the matte fusion No. 3. This fusion for the treatment of tub residues takes place once a month and lasts a week. All the plate slag produced during this operation is put directly back into the furnace.

B. *Roasting the White Metal.*--At the end of a week all the mattes produced are recharged in large lumps, the charge being about 4 tons. It is roasted at a dull red heat for about ten hours with admission of air. The reaction which takes place between the sulphide and oxide makes a peculiar noise, which can be heard at some distance from the furnace. The operation is termed " roasting" for black copper, but it is stopped half way. As the sulphur is driven off some metallic copper is liberated.

The slag is very thick, and not more than 200 lbs. to 300 lbs. are produced. It contains from 8 to 10 per cent, of copper, and is highly basic, often containing crystals of magnetite. At the end of the ninth hour the doors are closed and the fireplace charged. The whole furnace is brought to a high heat, so that the whole charge is in intimate fusion. Just before tapping it is rabbled for five minutes, and then tapped into sand-moulds. The tapping is done as before, but moulds are made to receive the matte as the charge is greater. In the first three or four pigs there will be found plates or bottoms of metallic copper containing arsenic, antimony, and lead. These bottoms contain nearly the whole of the gold, with a small quantity of silver, from 3 to 5 per cent, of sulphur, and 80 per cent of copper. The matte is pimple metal, and contains about

Copper,	75	per cent
Gold,	2	ounces.
Silver,	140	"

From every charge about 600 lbs. of bottoms, and 3 tons of matte are produced. This bottom fusion takes three days, making ten days for this treatment of the residues. The labor is the same as in the matte fusion, but more wood is used, four cords being burned in twenty-four hours. Only two operations are made in twenty-four hours.

C. *Treatment of the Pimple Metal.*—The pimple metal is roasted again in the same way, treating it nearly five hours, and making four charges in twenty-four hours. Other bottoms are produced poorer in gold, but containing

Gold,	60 to 100 ounces.
Silver,	300 "
Copper,	75 per cent.
Sulphur	25 "

The pimple metal from this fusion contains :

Gold,	¼ ounce.
Silver,	120 ounces.
Copper,	80 per cent.
Sulphur,	20 "

the iron being entirely removed. This operation takes one and a half days. The bottoms are treated with the other bottoms. The pimple metal goes to the Ziervogel process B, but is kept entirely separate, because it contains no gold as does that of the process A.

VI. Treatment of the Residues of the Ziervogel, Process B by the Augustine Process.

The residues from the Ziervogel Process B, which contain 25 ounces of silver per ton, are roasted with salt in one of the furnaces, B, Fig. 12, for roasting for sulphate of silver in the Ziervogel process. The residues are charged moist, a charge being one ton. It is heated for two hours, until it is hot. Twenty pounds of salt are then added, and well rubbed into the charge for fifteen minutes.

The charge is then drawn, to prevent the loss of copper, as well as chloride of copper. Three charges are made in twelve hours. This requires one man, and three-fourths of a cord of wood.

Solution.—This material is treated with a hot saturated solution of brine, a tank, holding 1000 gallons of the brine solution, being always kept in reserve; 1600 lbs. of the chloridized residues are placed in a vat, and the solution allowed to constantly flow through it by an inch pipe for four hours.

The liquid which runs out of the solution tubs runs into tanks, Figs. 30, 31, and 32, Plate IX, where the silver is precipitated with copper in the tanks *i*, and the copper with iron, in the *tanks k*, as in the Ziervogel process. The salt solution containing chloride of iron, is collected in the tank *o*, and is pumped back into the tanks, and is used again. Chloride of iron, by constant boiling, becomes perchloride, and finally sesquioxide is precipitated. The salt solution lasts (with occasional renewals of water) indefinitely. The loss of salt, per ton of residue treated, is about 10 lbs. The residues from this treatment are either reduced and made into ingots, or sold as they arc, as residues. The precipitation is the same as in the Ziervogel process, except that chlorides are formed. The material is always kept separate.

VII. TREATMENT OF THE BOTTOMS.

Four tons of white metal from the Ziervogel treatment, gives 600 lbs. of bottoms. These are left to accumulate until they amount to 3500 lbs., enough for a charge in the small reverberatory furnace. The furnace in which this operation is effected is shown in the general plan, Figs. 1 and 12, at C, and in detail in Figs. 33 to 38, Plate IX. The fireplace is 6 feet long, 4 feet deep, 42 inches wide at the bridge, and 20 inches at the grate. The bridge is 2 feet wide. The laboratory is 9 feet long, 6 feet 9 inches wide, and connects with the chimney 2 feet 6 inches square, by a flue. The surface of the fireplace is 21 square feet, that of the laboratory 46.27 square; the relation, therefore, is 1:4. The furnace has a working door at the side and a charging door at the end. On the side opposite the working door there is a spont which ends in a wooden tank sunk in the ground, which is 4 feet 5 inches in diameter and 3 feet deep.

The object of the process is to oxidize the lead and other impurities, and to prepare the metal for treatment for gold. The charge is made at 7 A.M. It is first sweated at a low temperature for two or three hours, during which time some of the lead liquates and runs out of the furnace. It is then left to oxidize for three or four hours. In about seven hours the charge is well melted. The slag, which is skimmed at this time, is composed mostly of oxides of lead and copper, containing from 10 to 15 per cent, of copper, and is sent to operation No. 3. After the slag is withdrawn, the bath is beaten with a rabble for about two hours, all the doors being opened to admit an excess of air. It is again skimmed and tapped into water. The "pitch," that is the condition of the copper, must be such that the whole of the sulphur is eliminated before the oxygen is absorbed. If the pitch is right, the globules will all be round and hollow. This point must be seized with the greatest nicety, for if the charge remains too long in the furnace the globules will cast solid, and the charge must then be put back and worked with sulphur. The temperature of the water governs the size of the globules. They arc small when it is cold and large when it is hot, but it does not otherwise affect it. It takes about ten minutes to do this casting. The copper flowing from the spout falls on to a pole of green wood held underneath it, so as to scatter the copper. Care must be taken that the slag does not flow with the copper. To prevent it the doors are opened, so that the slag is cooled until it is pasty. One charge is made at a time, and only one or two per month. The globules contain 1000 oz. of gold, GOO *ox.* of silver, and a trace of lead. 20 tons of white metal give one ton of refined auriferous copper. Three cords of wood are used, one man tends the furnace, one man does the firing.

VIII. Treatment of the Oxidized Copper Alloy.

The copper globules are oxidized in one of the fine calciners, in which sulphate of silver is treated. One and a half tons arc charged at a time. The oxidation takes 36 hours. The globules are put into the furnace in a heap and spread out over the hearth. The charge will be 3 inches deep. The fireplace is charged at once, and the temperature is made as hot as the red bricks will bear, and as oxidizing as possible. It is constantly rabbled. At the end of 36 hours a portion is taken out and tested, to see that it will pulverize completely., If it does the operation is finished; if it does not, the oxidation is continued. The whole of the copper has been transformed by the operation into suboxide, and the charge is increased in weight about 500 lbs. by the operation. The grains are black on the outside, but if broken or rubbed, the streak is red. The charge is drawn out into an iron barrow and carried to the store-room. It is placed in bags, packed in petroleum casks, and shipped to Boston. One cask holds 650 lbs. Three cords of wood are used for the process, and two men do the work, one man to each 12 hours' shift. The men are required to bring their own wood.

Solution of the Oxidized Copper Alloy.—The oxidized product is treated with dilute sulphuric acid. This is done in a conical tub lined with lead having a false bottom. The bottom is hollowed so as to leave as little space as possible. A charge is 1500 lbs; over this sulphuric acid at 20° Baumé is poured. Steam and air are turned on and the boiling continued for four hours. The whole is not dissolved, but 90 per cent of the copper will be in solution. It is allowed to settle for an hour, and is siphoned off and a fresh charge put in. Two charges are made in a day. This is repeated until all the oxidized products have been treated. This work is not done at night. The residues are boiled two or three times in the same way to get out all the copper possible. The tub is then cleaned up and what remains is melted in plumbago crucibles. The bullion is from 600 to 800 fine of mixed metals. It contains from 40 to 50 per cent. gold and 20 to 30 per cent of silver. This is sent to the mint.

The sulphate of copper is crystallized and sold. The mother liquid is used to dilute the acid used for the solution of the oxides.

The working of these alloys of gold, silver, and copper was first tried in the works, and was given up on account of the high price of sulphuric acid. It was carried on for more than a year in Boston, but has quite recently been abandoned, and the separation of gold and silver is now to be done at the works by a procees invented by Professor Pearce.

In conclusion, I beg to present ray warmest thanks to Professor Hill, who afforded me every facility for making the plans of the works and for taking the drawings of all the furnaces, and to Professor Pearce, who gave all the information which was required, both at the works and after my return to New York, concerning the various processes carried out there.

THE BROWN COALS OF UTAH AND ADJOINING-TERRITORIES.

BY H. ENGELMANN, E.M., LA SALLE, ILLINOIS.

THE very extensive development of a brown coal formation, in the region of the Rocky Mountains, is well known to all of you. The existence of these coals was known years ago, but they were of no practical importance until within a few years, when the mineral wealth of that country began to be developed and railroads were built. As their qualities became better known, their adaptability to domestic manufacturing and metallurgical purposes was more appreciated. They are still much undervalued, although they are mined at some points on a very extensive scale. A large portion of this coal formation is of cretaceous age, while it appears to extend into the tertiary epoch; but whatever difference there may be in the ages of these coals of different localities, they all have some common characteristics which distinguish them from our Eastern stone coals of the carboniferous age, which some of them otherwise resemble so much, that even professional gentlemen have been led to very erroneous conclusions in regard to their coking qualities and adaptability as blast-furnace fuel with our present appliances, barring future inventions, not to speak of the glowing reports of oversanguine promoters of mining schemes.

These brown coals range in their properties from the perfectly dry sand-coal, which shows not the least sign of caking in the strongest heat, but rather disintegrates in the fire, through all grades of sinter coal—which two classes appear to comprise the preponderating mass of these coals—to, in a few instances, caking coal, and also to anthracite, which latter appears to be formed locally from such coals by the influence of erupted masses of igneous rocks in New Mexico. As types of these classes I will enumerate some coals on which I have experimented to some degree: the type of a *sand-coal* is the coal from the C*rismon Mine,* on Weber River, southwest of Evanston, on a branch of the Union Pacific Railroad. An average sample gave 54.9 per cent coke, including 4.5 ash. The coke was not at all caked, but consisted of loose grains retaining their original shape unaltered. This coal, which emits ammoniacal gas in coking, like the rest, slacks quickly when exposed, and has the excellent quality for domestic use which is common in European lignites, that it retains the fire for a very long time, smouldering under a cover of ashes, without requiring any special precaution. Its smell, when burning, is also the characteristic one of the European lignites.

A slightly sintering coal is that from the Van Dyke Mine, at Rockspring Station, on Bitter Creek, Wyoming, on the Union Pacific Railroad. An average sample gave 61.4 per cent coke, including 4.2 ash. It slacks less by exposure than the foregoing coal, and is a very fair blacksmith coal. It has, in part, a resinous lustre and subconchoidal fracture and a somewhat laminated or schistose structure. In the fire the pieces open out as if a closed fist was opened and the fingers stretched forth. In a very hot fire melting of the coal takes place in the interior of the mass, while the outside remains loose.

A more strongly sintering coal is the Wales coal from Reese's Mine San Pete Valley, Utah, but it is by no means a caking coal, as we will see below. From different portions of the bed I obtained from 68.0 to 72,2 per cent, of coke, including 12.8 to 16.0 ash, which cor?responds to from 56.4 to 59.5 per cent, of fixed carbon in pure coal and from 18.8 to 22.6 per cent ash in the coke.

A slightly caking coal (schwach-backende kohle) is that from Coal Creek, near Cedar City, Iron County, in Southern Utah, of which I had specimens, and an evidently trustworthy account through Bishop Lunt, of Cedar City. It resembled much the Van Dyke coal in appearance, and gave from 59.0 to 61.3 per cent coke, including 5.2 ash. In a crucible it cakes well, yet its caking capacity is less than that of Indiana block coal.

A strongly caking coal is that from Trinidad, Col., of which I obtained specimens through the kindness of Prof. Prime, Jr., Mr. A. Eilers, and Superintendent Fay of the Denver gas works. Different samples of it gave from 72.7 per cent. coke, including 7.5 ash—equal to 67.43 per cent of fixed carbon in pure coal—to 77.8 per cent, coke, including 11.4 ash, corresponding to 71.2 fixed carbon, and even 90.75 per cent coke, including 29.34 ash, corresponding to 82.7 per cent fixed carbon in pure coal.

The anthracite brown coal of New Mexico I have never examined.

Analyses of many of these brown coals prove that their calorific value and pyrometric effect, need not be inferior (see a paper by our former President, Mr. R. W, Raymond, read at a meeting of the Institute in 1873).* I must, however, state here, that many of the analyses which have been published, are evidently not made from average samples, but from selected pieces. Various published analyses of the Evanston coal, for example, would indicate that it was an article of superior purity, while in reality the coal shipped from Evanston to the Salt Lake market, during my stay in Utah, was so very impure that it had to be sold far below the price of the "Weber River coal, in order to find a market.

At a meeting of this Institute in 1872, our friend, A. Eilers, read a paper, in which he very justly pointed out the propriety of using gas-producers with step-grates for these coals. For many purposes the sinter coals merely require a large grate-surface, with narrow openings between the bars, and do well with the forced draft created by means of the exhaust steam; but even the driest sand-coals are an excellent fuel, not only for making steam, but for all kinds of reverberatory furnaces used in the treatment of ores and metals, iron included, if burnt in as generators in the proper manner. Where the most intense heat is required, it may possibly be advantageous to free the gas thus produced of its aqueous vapor before igniting it, in the same manner as blast-furnace gases are, at some works, dried before using them in reverberatories. I my-

* Vol. ii, Transactions.

self built a small and crudely constructed gas-producer for such coals early in 1873, in connection with experiments on the coking of these brown coals, as far as I know, the first ever built in Utah. The heat created was at any rate sufficient to bring my experiments to an untimely close, by fusing the Colorado firebrick of which my furnace was built, and which were not exposed to chemical action. I have seen it stated that at the Golden Smelting Works, Col., such coal is advantageously used as fuel in a pulverized state, but having for many years been familiar with the use of gaseous fuel, made often from all sorts of refuse, I confess myself a great admirer of its operation, and doubt whether pulverized fuel can be used with equal advantage. Many attempts have been made to coke these brown coals, which with the driest qualities have proved entire failures, and with the slightly caking ones an indifferent success. The cause of the ill success is to be found not merely in the dryness of the coal, but even more in their very great shrinkage daring the process, which causes them to break up; and in the great density of the resulting fragments, which often look like pieces of a hard gray slate, and require a high heat and strong pressure of blast for ignition, and cause so muddy a smelting that the resulting losses far outweigh any possible gain.

My experiments with these coals, especially in regard to their caking quality, have been mostly made during a prolonged stay in Utah. They have been quite extensive. I began on the smallest scale with a platinum crucible; then I worked by the pound, and finally by the half ton, in a furnace especially designed and built for the purpose. In the platinum crucible all the Western coals which I examined, showed a most characteristic difference from the stone-coals of the carboniferous formation. After coking, the surface of the latter, which had been in contact with the sides of the crucible, was of a lustrous jet black; that of the Western brown coals invariably steel-gray, even that of the coke of the highly bituminous Trinidad coal. The quick heat obtained on a very small scale causes some otherwise dry coals to cake more or less in the crucible, which cannot be made to cake by any heat which can be profitably applied in practice on a large scale. In such comparative experiments, the different samples must be of a uniform size of grain; equal quantities must be used, and the heat must be the same in all experiments of the same kind. For the following tests I used first, pieces of from one-tenth to one-quarter inch on a side in a platinum crucible; then the same powdered, which gave still more characteristic results, and suggested important conclusions; then single lumps with one-half inch on ;.. side on a platinum dish, which showed other properties of the coals in a characteristic manner; finally I tested the relative binding or caking capacity of the coals, by mixing equal weights of each with such weighed quantities of fine qnartz-sand, that after coking the cake would just bear a certain uniform weight without being crushed. The units of sand which the units of coal are able to bind, indicate its caking capacity. These latter numbers are only relative and vary with the heat employed, the varying quality of the sand, etc. These tests gave the following results:

1. *The Weber River coal* showed, as I have already said, not the least trace of caking. The single grain remained perfectly loose in the crucible (also at the highest heat of an assay furnace). It merely shrank in volume. The coal from the *Hinton Mine,* near Evanston, showed hardly more caking.

2. *The Van Dyke coal* from Rockspring Station, on Ritter Creek, Wyoming Territory, which I have before mentioned as slightly sintering, *a*. In grains: It requires a little more time for losing all its gas than caking coal in the same heat, viz., ten minutes; shows only some fluxing in the centre of the mass; all around this central portion the single grains protrude, are somewhat rounded at their edges, and sintered together wherever they touch each other; color on outside, dark gray. 6. In powder: Time required, 12½ minutes; coke slightly coherent, especially towards the centre, while the outside portions are almost loose powder; outside color gray. c. On the platinum dish a lump retains its shape, does not become spongy, cracks in all directions, part of it exfoliates so that the pieces spread apart at one end, remaining united at the other, *d*. Caking capacity not especially tested; is evidently zero. Larger samples of this coal, coked in an assay furnace with high heat, were also fluxed in the centre of the crucible, while the outer portions were as described before.

3. The coal from *Reese's Mine,* near Wales, San Pete Valley, Utah. This coal placed in grains in the platinum crucible gave a well-fluxed coke, forming a porous mass, while larger pieces fused only partially, and some of the coke was r??t changed in outline and showed a dense slate-like texture, which proves that this coal is still a sinter coal. Its percentage of ash is very high, as we have seen above, even after the most careful picking. The color of the coke where it touches the crucible is gray, and it is also shrunk considerably. The caking capacity was not tested, nor the regular series of tests made, but I experimented with it in various ways, sufficiently to satisfy myself

of the correctness of the position which I have assigned to it in the series of coal.

4. The coal from *Coal Creek*, near Cedar City, Utah, cakes considerably more than the Wales coal. *a*. In grains : It takes ten minutes ; the coke is fluxed and porous throughout, but little spongy, and not as hollow as from the following coals. On top it is Hat, not raised, and the single grains can still be recognized on the surface. Against the sides of the crucible it is somewhat rough; the single grains are well rounded off, but are plainly to be seen, in which respect it resembles the sinter coals. The surface against the sides of the crucible is shining dark-grayish, *b*. In powder: Time 12½ minutes. The coke shows only traces of hollowness, and a corresponding small protuberance on top. It is porous, somewhat shrunk, and breaks readily, in consequence of the tension produced by the shrinkage. Its surface is not shining black but steel-gray, and shows distinctly the single fine grains of coal. c. On the platinum dish a lump retains its shape very nearly, but cakes and becomes porous inside. It possibly expands a little, but the tension thus created renders it weak. *d*. The caking capacity of this coal was found to be 5½. By comparing this coal with the Indiana and Illinois block coal (of which below) it will be seen that it promises well as a *blast-furnace fuel in its crude state*, being less caking than the block coal, yet sufficiently so to enable it to bear a burden. The purity of this coal, and the occurrence of excellent iron ores in large quantities in its vicinity, give it additional importance. *It can also be coked with proper appliances*, although it is not exactly a well-caking coal, but stands on the line between caking and sinter coals. It appears, therefore, destined to become the furnace fuel of Utah, for which purpose it is far better adapted than the San Pete coals.

5. The coal from Trinidad, Southern Colorado (samples of which I obtained, as stated above). The different pieces varied, somewhat in appearance and behavior, and evidently represented different portions of the same stratum. Together, they probably closely approximate an average, *a*. In grains : Time from 8½ to 9½ minutes. One sample swelled far out of the crucible; coke perfectly fused, hollow in the centre; against the sides of the crucible it is shining and of a grayish-black. Another sample boiled up less ; coke also hollow in centre, but denser, and not quite so completely fused on outside, although perfectly caked ; color of outside, grayish, and less lustrous. Still another sample was intermediate. *b*. In powder: Time 9½ to 11½ minutes. The first sample swelled high up; coke hollow, other-

wise finely porous, outside shining gray. The second sample swelled somewhat, corresponding to a small hollow in centre of coke. Top of coke flat, uneven, gray ; surface against crucible gray, more dull than shining, *c*. On the platinum dish a lump of first sample swelled up, fused and caked, and lost all semblance of the original piece. Another lump of the same, at first exfoliated in the manner described with the Van Dyke coal, as if a closed fist was opened and the fingers stretched apart, but soon the whole softened and ran together completely, forming a very porous coke. Of the second sample one layer at once boiled up and fused, while the next layer first cracked in every direction, and then caked, forming a coke which resembled in outline the piece of coal, but was hollow, not however as porous as the first, *d*. The caking capacity of the driest part of this coal —which gave 90.75 per cent coke, including 29.34 ash—was 6, while the most bituminous part showed a caking capacity of 9, not far below that of the Pittsburgh, Pa., gas coal. This, then, is a strongly caking coal.

For comparison I will now cite the behavior of some stone-coals:

6. The *Brazil* (Indiana) *block coal*—the data in regard to which may be also applied to the *Murphysboro* (Illinois) *block coal*—*a*. In grains: Time from 8½ to 9 minutes; coke hollow, spongy, with protuberance on top; outside against the sides of the crucible quite uneven, not absolutely fluxed, with brightly shining black color, *b*. In powder: Time 10½ minutes; coke hollow, spongy—top raised somewhat, and more dull than bright in color—surface next the crucible black, but not as brightly shining as with the more caking stone-coals, c. On the platinum dish a lump is changed considerably in shape, in consequence of tar boiling out and caking on the surface, yet the original shape can readily be traced. The laminated structure can still be seen, but the laminae swell somewhat. It is only when the pieces are crushed fine so that the single lamincæ are much broken up, that the co?? ,e fuses well together. We can often see that the upper and under surface of a lump remain unbroken, while the tar boils out at the sides. If such an unbroken surface touches a corresponding one in the coke-oven, cementation is apt to be imperfect, *d*. The caking capacity is 7. This coal is therefore by no means as dry a coal as is frequently supposed. If there were any necessity for it, it might be coked quite readily with proper management.

7. *St. Clair County* (Illinois) *coal,* from the St. Louis market. It-was taken from the middle and upper part of the vein which is

purer and better than the bottom part. *a*. In grains: Time 9 minutes; coke hollow, spongy, with pitchy protuberance on top. The surface against the crucible shows some unevenness from incipient fusion, and is bright shining black, *b*. In powder: Time 10½ minutes ; coke hollow, spongy, top raised somewhat but rather flat, surface against crucible, smooth, shining black, *c*. In the platinum dish a lump puffs up and cakes and forms a swollen mass, which bears no resemblance whatever to its former shape, *d*. The caking capacity is 8.

8. *Gas coal* from vicinity of Pittsburgh, Pa., mine unknown, obtained from the St. Louis gasworks, a hard, very solid coal with subconchoidal fracture and resinous lustre, giving from CO to C7 per cent, coke, including from 3.5 to 5.5 ash. It was only tested as powder. Time, eleven minutes ; coke swelled high out of the crucible, quite hollow, spongy, with smooth shining black surface. Caking capacity, 9½.

From these comparative tests we see that there is a marked difference between the brown coals and the ordinary stone-coals. The surface of the coke, when they are treated as powder in the platinum crucible, is invariably gray on the side in contact with the crucible, while-the coke of ordinary stone-coal is shining black. Further, even in the most bituminous of the brown coals, the tendency to exfoliate shows itself occasionally, and in the ordinary ones it is strongly developed. With rare exceptions, the brown coals shrink much in coking, which causes them to split and break up. Moreover, even the caked portion, where caking takes place, is generally less porous, more dense than ordinary coke, and in many instances part of the coke has the appearance and texture of a hard compact slate. All the samples tested (which were far more numerous than I have enumerated above), with the single exception of the Trinidad coal, were considerably less caking than the Indiana block coal, and most of them showed no caking of note. Also, with the same single exception, they required a longer time for the evolution of their gas than the stone-coals tested for comparison. This may be duc to their shrinkage, whereby the transmission of heat may possibly be retarded.

On a large scale, such quick and intense heat as the coal receives in the crucible, where the whole process is finished in a few minutes, cannot be practically employed with profit, and therefore any attempt to coke the slightly sintering brown coals, even with improved ovens, without addition of foreign substances, must, fail, the sand-coals being entirely out of the question.

The supply of a cheaper fuel for the lead blast-furnaces of Utah and Nevada has been a very important problem, the cost of Eastern coke and Western charcoal being enormous, and their supply rather uncertain. Since the attention has been directed to the. more strongly sintering brown coals, and railroad transportation facilities have been extended, and are extending more and more, this problem approaches a solution. How far the present attempts at coking the San Pete coal are practically successful I am not aware. Even a small percental production of serviceable coke might prove an advantage if its quality is not such that the loss of metal is too much increased by its use in the cupola. Some of the best coals of this kind can probably be coked by using very narrow and high ovens, heated by burning the gases in the partition walls, similar to the Coppee furnace. Such ovens have been used in Europe for dry coals of a width even as small as 10 inches. The proper width of a coke-oven has, however, to be determined by experience for each kind of coal. A too narrow oven produces more small trash ; a too wide one does not allow the heat to penetrate with sufficient rapidity.

The Appolt vertical oven may also prove serviceable, or where a higher, especially a higher initial heat should be desirable, my method of using simultaneously with the coking gases in the flues of the oven, gases obtained from a distinct source (for which process I have taken a patent) might prove of advantage. This method was suggested by the results of the experiments with the slightly sintering coals. These experiments I have never been able to carry to a definite issue, having been called to a different field of work; but I have obtained some results which may prove interesting and useful. In these experiments I used principally the Van Dyke coal, because it was the best coal which I could readily obtain at that time.

I first tried an admixture of tar, as is used in the manufacture of briquettes, but found that the percentage required would be too great and expensive. Tar leaves very little coke, and therefore does not diminish the shrinkage of the coal. In small proportion it may prove useful, conjointly with an addition of caking coal, especially for binding the coal-dust. Then I used caking coal as an addition with much better results, and found the very best coal the most profitable. Its swelling, in a measure, corrected the shrinkage of the brown coal. The combination of good caking coals with drier ones in coking is by no means new. Many years ago it was the established practice in the Saarbrücken District in Western Germany, to mix, in coking, the coals from the more bituminous strata with that of the less bituminous ones. A few years ago extensive and successful experiments were made to utilize dry Austrian coal in this way; and even anthracite slack can thus be coked. The important question in our case was, how much of the caking coal would be required, or rather, with how little (on account of its cost) the desired result could be obtained, and by what means this amount could be further decreased? As I have said, my experiments did not result in a positive conclusion, but I am led to think that 1/5, or at the most ¼, of the whole mass might be made to suffice with such coals as the Van Dyke, if high heat was employed in the process. The brown coal must be crushed fine in order to obtain uniformity in the product, but while the larger pieces will remain whole and form solid pieces of coke, the finely crushed material refuses to reunite in the oven. The finer the crushing the more binding material is, therefore, required. On the other hand a certain proportion of fine is necessary to fill the otherwise empty spaces between the coarser grains. Especially for binding the fine dust, a small addition of tar may prove useful. The presence of moisture which, with caking coals, proves useful, appeared to have a bad effect by its cooling influence at the start, and a high initial and sustained heat appeared indispensable, otherwise the coke lacked solidity. I also tried to obstruct the outflow of the coking gases, hoping thus to retain and decompose more of the tar inside of the charge, but I found my appliances inadequate, and various difficulties presented themselves. I now expect more from collecting the tar outside of the furnace, and mixing it with the charge while heating the furnace with the remaining gases, to which gases from a separate producer are added to increase the heat. A high narrow oven, and compacting the charge in the oven immediately after charging, will apparently be essential for success.

While testing various charges with my crude appliances, part of which were never expected to give a serviceable coke, but were made to study the influence of certain mixtures or manipulations, I obtained some rather fair coke, of uniform porous texture and columnar structure, which ignited readily, and was bought by a foundryman of Salt Lake City, and gave good results in a small cupola with weak pressure. It was still too soft to bear transportation, and the percentage of trash was too great. It was obtained from 80 parts Van Dyke coal, with 20 parts Pittsburgh gas coal. Such coke, a little more solid, would be excellent for smelting the silver-lead ores. Often, however, I found such a tension in the product of my oven, especially when water had been used for cooling it, that the trash, when thrown on the fire, would decrepitate with loud reports, which would continue for a long time.

THE MIDLOTHIAN, VIRGINIA, COLLIERY IN 1876.

BY OSWALD J. HEINRICH, SUPERINTENDING ENGINEER, MIDLOTHIAN, VIRGINIA.

IN the coal review for the United States for 1875, the *Engineering and Mining Journal,* January 1st, 1876, remarks about the Richmond coal basin:

"It has contributed but little to the supply of fuel during the year past, notwithstanding the fact that it is the most favorably situated of all our coal-fields, and possesses a fuel of good quality, well adapted to many important uses. An unaccountable lethargy seems to have fallen on all who have touched this field ; and yet, in the future it can scarcely fail to become one of the great sources of coal supply."

In most respects indorsing the above remarks, I take occasion to lay before the Institute the following facts in defence of the Richmond basin; and not willing to criticize other mining enterprises in this field, I will make this one remark in general for all of them. While it is true that very little coal has been raised during the year in this field, it is equally true that even the little that has been raised could hardly be sold. When the output of the largest coal districts in the United States decreases, in consequence of the state of the market, it is not to be wondered at that the former small output of this basin dwindled down to almost nothing. But a far deeper-seated evil, under which this field is suffering, may be discerned from the following remarks, which I hope will show that the latter part of the above remark in the *Journal* is not altogether fair.

As the history of one mine in this district very nearly represents the history of the whole field, I will endeavor to give an account of the development of the Midlothian Mines, ranging amongst the oldest in the district, partially taken from a report of Col. Wooldridge, in 1841. Coal was mined in this neighborhood as early as 1700, and used (then so-called extensively) in the vicinity in 1775. A foundry in Richmond employed it during the Revolution to make shot and shell, and in 1789 the coal was sent to Boston, Philadelphia, and New York. The oldest mines discovered in this neighborhood were the old Black Heath pits, Buck & Cunliffe's, Ross & Currey's, lying northeast of the Midlothian, Wooldridge's, Bailey's, and the Green Hole pits, now owned by the Midlothian Mines; also nearer the James River, Trabue's and Sallis pits, all in Chesterfield County.

In 1841, the Maidenhead pits (Black Heath Company), discovered in 1821, were the principal openings. Formerly worked by Col. Health, they were sold in 1840 to English capitalists, and taken possession of by the same in 1841, under the name of the Chesterfield Coal and Iron Mining Company. Considerable work was done by that company, and a good deal of coal raised until, in 1852, by the bad management of its agent the company got tired of mining and stopped, at least upon a large scale. The ground was afterwards leased by the Midlothian Company, and worked to a very limited extent, and is now still owned by the Chesterfield Coal and Iron Mining Company. The mines adjoin the Midlothian Mines, and are in the same basin.

Previous to 1841, a number of old pits, the Union, Mill's, Green Hole, and Creek Company pits were worked with a limited production, but they were abandoned after 12 or 15 years. In all of them a good deal of the coal was left behind, as was proved by other parties entering the same ground afterwards.

The Midlothian Coal Mining Company was organized in 1836, but the sinking of the shafts preceded the organization of the company. The original tract consisted of 404½ acres. The company was organized by issuing 3000 shares at $100 each; one-third was sold to some thirty shareholders, by which $100,000 were raised and expended in sinking shafts, procuring a 60 horse-power engine and boilers, purchasing mules, and building a number of houses.

Four shafts were commenced by this company, and sunk in time to various depths. The old pump shaft, 777 feet deep (716 feet to the coal), the middle shaft 625 feet deep (612 feet to the coal), the wood shaft, 625 feet deep (probably 250 or 300 feet to the coal), and the Grove shaft, 622 feet deep (485 feet to the coal). In late years another shaft was carried down 1015 feet, and bored 322 feet below the shaft bottom, but no coal was found. It is the shaft furthest west from the eastern outcrop in this field.

In the fall of 1839, coal was struck in the pump shaft at 716 feet, the coal being 36 feet thick. At that time the other shafts were temporarily abandoned, being 625 feet, 300 feet, and 85 feet deep. In 1840, 300,000 bushels of coal were raised from the pump shaft, the force employed being about 150 men, and 25 mules. The capacity of the work was rated to be 1,000,000 bushels per annum. The area of ground occupied by these old pits in the main basin is about 84 acres, with average thickness of coal, say 20 feet, it being as thick as 50 feet in places.

In 1855, a serious explosion occurred, killing about 55 men. At that time the lower works, gained by an incline, became precarious on account of a heavy influx of water from the old mines (Chesterfield Coal and Iron Mining Company) northeast of Midlothian, from which the water had been tapped.

In December, 1856, attempts were made to tap the water from the old White Chimney Works, to the rise, to gain new ground; by miscalculation, having no maps, the water broke through, flooding the pit and drowning a number of men. In 1858, a 500 horse-power Cornish pumping engine was put up to drain this ground. Although the bottom of the shaft was gained, the mine took fire, and after another attempt to regain the lost ground in 1861, all lower works had to be abandoned, leaving a column of pumps, a train of loaded cars, a fire-engine, etc., behind in the hasty retreat. During the late war, raising coal in large quantities was confined to the rise works about the White Chimney shaft. Already, previous to the war, a new shaft had been commenced about 825 yards west of the old pump shaft, and carried at various times to a depth of 1015 feet. After the war, this work was recommenced, and 322 feet bored below the shaft bottom without finding the coal. The company's financial affairs being in a precarious state, several attempts were made to reopen some of the old works, without success, until in 1867 the company finally failed, being involved in debt about $180,000. The property was sold, and was purchased by the present owner, and is held by him now, in fee simple, after a prolonged lawsuit lasting five years. The first four years after he gained possession were spent in working out some of the old ground nearer the outcrop.

A description of those troublesome times was rendered to the Institute at the Boston meeting in 1873. After the coal of that ground had been exhausted to the level of drainage by the first column of the pump in the pump shaft, the serious question arose: What next?

But two courses were open. Either an attempt should be made to enter the old deep works of the pump shaft, or explorations should be made for the continuation of the basins formerly known, in new sections of the property.

In regard to entering the old works, the following facts had to be considered:

1. What amount of coal had, probably, been left behind?
2. In what condition were the old works when abandoned?
3. What was the probable quality of coal to be obtained?
4. What was the prospect of a regular supply of coal?
5. What would be the probable expense of the undertaking?
6. What was the prospect for succeeding at all, or, at least, at remunerative figures?

Subject 1. The section of land of that part of the old basin in which the pump-shaft is located, contains about 84 acres of coal surface, upon an assumed general line of pitch of 25° to 30°. The probable average thickness of the coal assumed to be 21 feet, the amount of coal contained per acre in said ground, in round figures, may then be taken at 33,880 tons (taking 1 cubic yard per ton), or, in the whole ground, 2,845,920 tons of 2000 lbs. Allowing one-fifth for disturbed ground, it would leave 2,276,736 tons of coal. From the above statement it will be seen that the life of the pit has not exceeded twenty-five years, of which, at least, twelve or eighteen months for work were lost in consequence of accidents. The greatest capacity of the pit, as formerly stated, being 1,000,000 bushels, equal to 35,000 tons per annum, a production most probably never realized at any time, would make a production, in twenty-three working years, of 805,000 tons. From the best information, probably 600,000 tons have been raised, which would leave 1,676,736 tons of coal yet in the ground, partially in solid spots, but mostly in the old pillars 60 feet square, in which the works had been laid out. By judicious work, probably two-thirds of it might be obtained, or, in round numbers, about 1,000,000 tons. At a moderate valuation of twenty - five cents profit per ton, the net earnings may be estimated then at $250,000, which may yet be realized from this ground.

Subject 2. From all evidences of living and trustworthy witnesses, the condition of the works were in a very critical state when abandoned. Parts of the lower works had been badly pillaged. The main shaft pillars greatly weakened, so that all but the pump-shaft have now caved in. Even higher up in said shaft, largo breaks have occurred, bringing the shaft out of plumb. The shaft being formerly divided in a double hoist and pump chamber, it could now be only redeemed for either one or the other.

Subject 3. While formerly the coal from these works was of a first-class quality for gas coal, the constant crushing and various exposures by spontaneous combustion have unquestionably deteriorated a good deal of it for various purposes, making it particularly unfavorable for distant transportation and rehandling, a fact which has been fully demonstrated. While it might answer well enough for our home markets, it could not well enter the market for shipments North, which must be the main dependence of the future, as it has been in former years, for these mines.

Subject 4. It will be evident to any person familiar with coal mining that in such ground, once or twice partially passed over, no regularity of supply could be obtained. Passing through the old pillars or robbing them when retreating, would afford a tolerable and ultimately a more regular supply. Passing the old gangways and tumbled ground, would make plenty of rubbish and still more dead work. To-day, coal, to-morrow, rock and dirt, and the next day still something else, would be the order of the day, as has also been fully proved.

Subject 5. To estimate with reasonable accuracy from what is known of this old pit the expenditure to redeem it, is almost beyond the calculation of any one unless he has been through it. If such is the ease it may be roughly guessed at. To do so it would be indispensable to take into consideration that the following items have to be accomplished : 777 feet of shaft cleaned out, retimbered, and, if used for a pump shaft, 3 columns of 16-inch pumps put in. About half of the old columns, would be available, the pumping-engine being still in place; 500 feet of shaft for an upcast, to be cleaned out and retimbered; from 1000 to 1200 feet of incline regained, and a donkey-pump put up at shaft bottom to drain the water below it; about 1000 feet of connection to the rise towards the upcast shaft to be made, and the necessary engines for hoisting and fixtures for raising coal to be put up; from 15 to 18 months of pumping with a 500 horse-power engine would be required to drain the pit, the expense of which item alone would be about §10,000 to $12,000. With the conviction that on entering the mine spontaneous combustion would have to be guarded against, the delays in cleaning out rubbish, retimbering, and all the perplexing incidents met with in such an enterprise, it is easy to see that §100,000 would not be too high an estimate to make a job permanent enough to last until the coal was extracted.

Subject 6. The former history of this pit having fully proved that a large quantity of water, much gas, and plenty of spontaneous combustion would be encountered, it was self-evident that by using one shaft only—the pump shaft—there was no prospect of maintaining the pit at all for any length of time, and moreover, the life of every man in the pit would be endangered. To make the long connection with the upcast would be also a most hazardous undertaking, to be accomplished only with great difficulty and expense. But if even all this were successfully accomplished, it would be necessary by driving out from either side of the shafts to maintain a long line of timbered ground, which, in many instances, would have to be protected against spontaneous combustion, all at a great cost, and under the constant necessity of repair. If the desired extremity of the pit were successfully reached in the course of years the chances were that fire in the rear would cause a regular stampede, with a loss of half, if not all, of the machinery, pumps, rails, wagons, and all the requirements necessary to raise coal. When the above points, hastily stated, are seriously considered they call for careful deliberation and sober council. Such, then, was the situation when a second proposition was made, namely, to adopt both courses.

1st. To get the property in working order again, and to make it productive, by sending its superior coal to the great market of the North.

2d. To redeem, if possible, and at some reasonable figure, the yet valuable ground described above, with some prospect of success, it was recommended to go into new ground adjoining, not infected with the sins of bur forefathers in mining, which are at the bottom of all the evils existing in this section of country.

Accordingly explorations by boring were commenced in April, 1873, and after sufficient evidence had been collected, the cleaning out of a shaft (the "Grove shaft"), south of the old works, was commenced. Although it was well known that this shaft was located in troubled ground (having been sunk to coal 485 feet and 622 feet to the bottom by the old company, and only 4 to 6 feet coal reported), still it was considered to be the only shaft available, as it was probable that coal could be reached sooner from it than by sinking a new shaft, which has been actually proved. Furthermore, the location of this shaft to the rise of the deep works (if the basin continued further south from the old pump shaft), made this an available point to test this ground, and it would serve afterwards as the regular upcast for the deeper works. Coal was found by two bore-holes to the dip of this shaft, in one instance at 477 feet, in the other at 598 to

608 feet. The latter point being 595 feet west of the shaft, proved the existence of three seams of coal 14½ feet, 12 feet, and from 3½| to 4 feet thick. The two larger seams were divided by slaty benches, which frequently is the case in this field. To reach these points it was necessary to cross-cut the stratification, particularly as a narrow basin existed nearer to the shaft, both points being therefore opened out by such a tunnel. Since May, 1873, exclusive of six mouths cessation during the beginning of the financial crisis, work has been going on to complete the winning of this new pit, and the erection of the surface structures, and early in January, 1876, the first coal was shipped.

The following work was required to get into operation :

1. Cleaning out and retimbering 622 feet of main shaft, 11 x 11 feet, and providing the same with an air-tight brattice, as only one shaft is now available to operate the pit.

2. Cleaning out and retimbering 180 feet of a jacked pit, to raise the surface waters, and putting in an Allison & Bannan steam-pump of 160 feet column, 6 inch diameter, with a 6½-ineli steam-cylinder; and 4½-inch plunger.

3. 858 feet of rock tunnels driven (20 feet landing, 12 x 16 feet; 75 feet, 10 x 7 feet; 828 feet, 8 x 7 feet wide); 198 feet driven through disturbed ground; 250 feet old rock drifts cleaned and widened out; 230 feet incline cleaned out and timbered ; 492 feet of gangway driven and timbered in various seams, from 4 to 12 feet, and 112 feet in inferior ground.

4. 136 feet of return air-course to engine-house, near top of shaft, driven through loose ground, and walled and arched in brickwork.

5. New engine-house erected, 43 x 50 feet; also new boiler-house, 50 x 50, and a fan-house for a 23-feet diameter fan, 7 feet wide (system, Guibal), all in solid, rubble masonry. A waste-bank, 210 x 64 feet, 12 feet high, incased by solid masonry, and a brick chimney, 18 feet base, 56 feet high, erected.

6. Pit-head of 30 x 20 feet base, 70 feet high from floor of engine-house, and also a platform of 88 x 62 feet, 19 feet high in front of shaft, put up to convey the coal from the shaft to the various screens upon the landing platform.

7. For the purpose of separating the different grades of coal, slating the same thoroughly, and stocking about 500 tons of coal at the pit, a loading platform of 78 x 47 feet, 20 feet high, has been erected, provided with four stationary screens, making three grades of coal,

permitting the loading (hereafter) of twelve hopper cars, of 10 tons capacity at a time.

8. For hoisting purposes, a double cylinder direct-acting engine, with link motion, 24-inch cylinder, 5 feet stroke, has been reconstructed from two old engines existing upon the property. They are firmly put up upon a solid foundation of masonry. The capacity of the engine is calculated to be about 130 horse-power. It lifts with great ease 1 ton of coal per minute from shaft bottom (624 feet), including the changing of cars. At present only one platform cage is used, allowing only ½ ton to be lifted at the time, but provision is made to use double platform cages.

9. To run the fan and some auxiliary machinery, a steam-engine, 14-inch cylinder, 30-inch stroke, will be put up soon in the same engine-room.

10. A battery of four new boilers, 42 inches diameter, 24 feet long, with centre and side flues, have been put up, permitting a very economical use of fuel, using, by experimental trial, only 2100 lbs. of coal for each boiler in 24 hours, during a week's trial upon measured coal. Space is also provided for a second battery of plain cylinder boilers (now on hand) in the same boiler-house, if needed. The exhaust steam circulates in a heater, through which the feed water passes in a series of pipes, after being drawn from a pond (also newly made), by the steam donkey-pumps.

The coal for engine purposes is delivered directly from the shaft to a coal-house adjoining the boiler-house, whence it is brought on a small tramroad in front of the boilers, and upon this same road the ashes are conveyed up to the waste-pile in rear of the boiler-house.

The capacity of the work is such that whenever the pit is extensively opened out, 500 tons of coal in 12 hours could be raised through the shaft, and, by the extension of the loading platform, separated ready for shipment.

Accordingly, the first part of the programme is so far completed, that the new ground has been gained. To perfect it in future, and regain if desirable the old ground of the pump-shaft workings, the following plan is proposed. After fully ascertaining, by a series of bore-holes, the continuation of coal at the level of the lowest works in the pump shaft, a new deep shaft (probably 900 to 1000 feet), to be used as a pump shaft for the new and old ground, will have to be sunk about midway between the termination of the old works and the boundary line of the property. From the bottom of such a shaft, in connection with an incline to be started from the present new works, the complete ventilation of the mine can be secured.

If then it is deemed advisable to take up the old mine, the north bottom level should be turned off into the roof of the coal at a distance sufficiently far from the old works, to secure a strong safety pillar (never to be holed into hereafter), and after passing this pillar a sufficient distance to the north, the rock drifts would be changed again to enter the old works at its lowest points. During this time, the old pump shaft could be retimbered between the old timber at less expense, and made use of as an upcast and hoist shaft. Extending now the bottom works to the extremity of the north boundary of the property, where most of the solid coal is left behind, a regular homeward work could be carried out at less cost in maintaining back ground, and with more assurance of protection against spontaneous combustion by working separated sections clean out as far as possible. Precarious or too much pillaged ground could be skipped over in the retreat, and cut off more effectually. But if in course of time the pit should be worked out, or prove to be untenable, the rock drift by which the old works were entered, would form a safe ground to cut off forever the old works, and let the water rise without affecting the new ground, and at the same time, relieving the pump of a good deal of labor. Having hastily sketched the outlines of this programme, I refrain at the present from entering into estimates of cost. But it can be easily perceived by the expert, that this plan, although apparently more costly, will at the end, with all its advantages, prove to be the only economical plan, with assurance of success on the one side, and absence of risk on the other. It possesses all the advantages the old ground may afford, and will obviate many of the difficulties otherwise to be contended with.

In conclusion of my remarks I will only add, that a branch railroad to the main stem of transportation for this mine, namely, the Richmond and Danville Railroad, has been built. This enables a direct line of transportation from the mines to James River at Richmond, or to West Point upon the York River, where the largest vessels can float.

THE WORTHINGTON COMPOUND DUPLEX PRESSURE PUMP AT THE BESSEMER WORKS OF THE ALBANY AND RENSSELAER IRON AND STEEL COMPANY, TROY, NEW YORK.

BY ROBERT W. HUNT, TROY, N. Y.

THE first pump of this character, made by H. R. Worthington, and, so far as the writer is informed, the first and only one of this kind ever constructed, is now in daily use in the above-named works.

The water-pressure necessary for the working of the hydraulic machinery of this plant had been supplied, up to the time of the building of this pump, by two Worthington Duplex High Pressure Pumps, having steam-cylinders of 20 inches diameter and 12-inch stroke, with water-plungers of 7½ inches diameter; eight inlet and eight outlet valves of 2½ inches diameter, and pumping into a 6-inch pipe.

These pumps required a large amount of steam, and, in consequence of the various additions to their duty, their capacity became far short of the work required.

In preference to putting in another engine of the same class, it was decided to accept Mr. Worthington's proposition to build the compound one under description, he guaranteeing that it should be equal to the demands of the works, and at the same time cause a saving of from 5 to 6 tons of coal per day from the amount required to run the two old pumps.

The new engine has been in operation about one month, and so far has exceeded the most sanguine expectations. It consists of two high-pressure cylinders of 21 inches and two low-pressure ones of 363/8 inches diameter, by 36-inch stroke, with water-plungers of 9½ inches diameter. There are two air-pumps of 20 inches diameter by 18-inch stroke; the condenser being 24 inches diameter by GO inches high.

Both cylinders are jacketed with wood and felt, and the low-pressure cylinder also with live steam. The high and low pressure steam-cylinders are in line and immediately adjoining each other, while the inconveniences attending an internal stuffing-box are avoided by having two piston-rods for each of the low-pressure cylinders, running through stuffing-boxes on the outside of the smaller high-pressure ones. The steam-valves are very ingeniously designed balanced slide ones ; and by a clever arrangement, the necessary oil for lubricating the various inclosed parts, is forced through pipes by a small hand-pump, placed on the platform directly under the throttle-valve.

The water-valves are arranged in eight separate nests, four in the inlet and the same number for the outlet, each nest containing seven valves of 2½ inches diameter. The inlet and outlet pipes are both of 6 inches diameter. The pump is required to supply, at a pressure of from 370 to 400 lbs., one 13-inch and four 12-inch hydraulic cranes, each having a lift of 10 feet, and a ladle crane of 15 inches X 6 feet 6 inches lift; three 7 inches X 5 feet, and one 7 inches X 7-feet cylinders on pulley-cranes; two 12 inches X 2 feet 4-inch rams under the converters; a 6-inch X 8-feet cylinder attached to a rack rotating the screws which set the middle roll of the blooming train ; also a 9-inch X 6-feet cylinder which raises the tables of the same train, and a 5-inch X 6-feet cylinder moving the pusher attachment to the tables; and two 9-inch X 16-feet cylinders working the stock-lifts for the cupolas of the converting works, and one 6 inches X 7 feet for that of the foundry, all of these being in constant use day and night.

The pump meets this duty in the most satisfactory manner, and it has not been found necessary at any time to open the throttle-valve beyond one-third of a turn. The steam pressure usually carried is from 50 to 60 lbs., but as an experiment all this work has been done with only 20 lbs.

While I am not prepared to give the actual saving of fuel, I am well convinced that it is beyond Mr. Worthington's guarantee.

The machine is necessarily somewhat complicated, but as its speed has never exceeded 25 double strokes per minute, and that speed for only a fractional part of a minute, it does not seem probable that it will be liable to get out of order.

The two old pumps have been permitted to remain as a reserve, in case of accident, and in consideration of past services performed to the best of their ability.

THE CORNWALL IRON MINE AND SOME RELATED DEPOSITS IN PENNSYLVANIA.

BY T. STERRY HUNT, LL.D., F.R.S., BOSTON, MASS.

I HAVE in a previous communication called the attention of the Institute to the geognostical relations of the crystalline iron ores belonging to the Eozoic rocks of North America, at which time I noticed (1) those associated with the gneisses of the Laurentian series, (2) those of the crystalline schists of the Huronian, as seen in Northern Michigan and in many localities along the Appalachians; (3) those of Southeastern Missouri associated with petrosilex porphyries and schistose rocks, and presumed to be nearly of the same age with those of the Huronian schists; and (4) the highly titauiferous ores of the Norian or Labradorian series from Essex County, N. Y., and from various parts of Canada. It may here be remarked that, although the presence of titanium is most marked in the Norian ores, this objectionable element is sometimes found in the schistose ores of the Huronian, and to a lesser extent in certain Laurentian magnetites. The ores of each of these geological divisions have their individual peculiarities, which serve to distinguish them to such a degree that the magnetites and specular ores of the Laurentian are as dissimilar to those of the Huronian as are the crystalline silicated rocks of the two series. As it happens that these mineralogical dissimilarities correspond to differences in composition and in adaptability to different processes of manufacture, which, in the present condition of the iron industry, are objects of special consideration to metallurgists, it will be seen that these geognostical distinctions become of great practical importance.

During the past year I was desired by the Geological Commissioners of Pennsylvania to devote a few weeks to certain geological studies in the eastern part of the State, in the course of which I was enabled to make, with regard to its crystalline iron ores, some observations to which I desire to call the attention of the Institute. I may mention, in passing, that the great South Mountain belt, from the Schuylkill to the Delaware, is composed of Laurentian rocks, in which are found the characteristic ores of the series like those of the Highlands of New Jersey and New York, and of the Adirondacks. Numerous workings near Rittenhouse Gap, in the Eisenthal, and at Seisholtzville, Barto, and Bechtelsville, show the existence of valuable deposits of these ores, and it can hardly be doubted that a systematic and careful exploration of the whole of this mountain region by the aid of the dipping-needle will develop many more. The similar Laurentian region of the Welsh Mountains to the south of the Red Sandstone belt offers a not less inviting field. Pennsylvania is now a tributary for these ores to New Jersey, the Hudson, and Lake Champlain, while the great area of ore-bearing Laurentian rocks within her borders remains comparatively unexplored.

But I have now to bring to your notice an important class of crystalline iron ores, chiefly magnetites, which alike by their geological position and their mineralogical associations and characteristics differ from those already noticed, and appear to belong to a distinct ore-bearing horizon. I allude to those ores which are found over Pennsylvania, along both borders of the Mesozoic red sandstone formation which stretches through the State; including on the south side the ores of Warwick and the Jones Mine, and on the north side a line of deposits from Boyertown, and the vicinity of Reading, to beyond the Susquehanna, including the great Cornwall Mine near Lebanon. Those ores were, by Prof. H. D. Rodgers, referred to what he designates as the Primal slates, which he regarded as the lowest member of the Paleozoic series; though by some later observers, the Cornwall Mine, and certain related deposits west of the Susquehanna, have been referred to the Mesozoic sandstone. It would be foreign to my present purpose to set forth the reasons which lead me to conclude that they are, all of them, really contemporancous deposits included in the Primal slates, which corresponds to a portion of the Lower Taconic series of Emmons, and belong, in my opinion, to a lower horizon than the Potsdam sandstone of the New York system. That they are met with only along the borders of the Mesozoic sandstone formation, is due to the fact that these ancient ore-bearing rocks, from their decayed condition and their inferior hardness, have been removed by denudation, except where protected by the proximity of the newer sandstones, or of eruptive rocks, as is the case at the Cornwall Mine. This remarkable deposit of magnetic iron ore rises from the surface along the northern border of the Mesozoic sandstone, which here forms the southern limit of the great Auroral limestone valley. The area of the ore exposed measures about 4000 feet in a direction nearly cast and west, with a transverse breadth of from 400 to 800 feet, and includes three hills, separated by two valleys running nearly north and south. Of these hills the eastern, which is the highest, is said to be 960 feet above tide-water, and a little over 300 feet above the brook flowing in the ravine which divides it from the middle hill. This, which is larger in area than the others, rises, in its highest part, nearly 100 feet, while the western hill is a little lower. A careful inspection shows that these elevations arc due to the presence of a great ridge of eruptive rock, apparently a dolcrite, which surrounds the eastern hill on the south, east and north, forms the northern border of the middle hill, and sweeps around the northern and western sides of the western elevation. Although now broken through at the two transverse valleys, this great belt of eruptive rock was probably once continuous, and being curved in form, like many of the dykes of the Mesozoic, has evidently served to protect the inclosed ore-bearing strata, which both to the east and the west have been eroded and swept away in past geological ages. Transverse intersecting dykes and tongues of eruptive rock arc seen in various parts of the eastern hill to penetrate the mass of ore, without, however, apparently altering in any way its character; and we must, I think, conclude that this trap, which was intruded into the ore-beds, has no farther connection with their present condition than is implied in its protection of them from waste and removal. From the valley which separates the middle from the eastern hill, the western face of the latter is seen to consist of nearly horizontal beds of ore lying between upright bounding walls of trap, the extremities of the curved rim of this rock, which surrounds, on the other sides, this great mass of iron ore. At the base, the inner surfaces of these walls are, probably, not more than 500 feet apart; but, as they ascend, they arc separated 600 feet or more. Between these ore is found in nearly horizontal strata, sometimes slightly contorted and associated with layers of a greenish granular silicate, approaching hornblende in composition, and more rarely with a chlorite-like mineral or with serpentine. Besides these, small quantities of iron pyrites, sometimes cobaltiferous, are found, and portions of copper, chiefly in the forms of copper pyrites, malachite, and red oxide. These latter ores arc in some parts of the deposit so abundant that they are selected in mining the iron ore and sold to the copper smelters. The whole of the deposit as mined, with the exception of the richly cupriferous portions and some thin layers in which the silicated minerals predominate, is fit for the furnace, and will probably yield an average of 50 per cent, of iron, while large quantities can be selected which are much richer and are nearly pure magnetite. Its associated minerals, not less than its comparative softness and friability, due to the slight adhesion of the crystalline grains, serve to distinguish it from the magnetites of the Laurentian rocks. I have not been able to find any analysis of the ore of this great deposit,* but it is, probably, like the other similar ores of the region, comparatively free from phosphorus, since the pig metal made from it has been largely used at Harrisburg as an admixture for the production of Bessemer steel, for which purpose the small proportion of copper which it contains does not seem to unfit it. The small amount of sulphur, which is present in the form of pyrites, may be readily expelled, if desired, by a preliminary roasting, and has been spontaneously removed by oxidation in the weathered portions of the ore at the surface of the deposit, which are carefully reserved and command a high price for fettling in the puddling furnace. The facilities for mining this ore are very great, the horizontal layers being worked in successive benches, forming wide terraces on the hillside, which are accessible by railway tracks and locomotives. I am informed that the greatest production of this mine has been about 200,000 tons yearly, but it would be easy, if demanded, to supply a much larger quantity of the ore, the more so as workings are not confined to the eastern hill, but extend to the others named, which afford also very large quantities of ore. As regards the further extent of the deposit, it may be noticed that excavations in the plain, to the east of the hills, and, consequently, outside of the limits of the trap, show the existence of large quantities of similar ore, which were mined at an early period. In the area of the middle hill, moreover, as I am informed by Mr. Boyd, the obliging superintendent of the mine, two borings have been sunk to depths of 240 and 335 feet below water-level, the whole distance being in iron ore. The strata in this portion offer but gentle inclinations, so that these measurements do not much exaggerate the real thickness of the immense mass of ore which lies beneath the surface.

Proceeding eastward along the same geological boundary small deposits of magnetic ores, very like in character and in mineral asso-

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* See the note appended to this paper.

ciations to those of Cornwall, have been mined at Wheatfield, seven miles west of Reading, and again at the Roudenbusch Mine and at Fritz's Island, in the Schuylkill. Others are met with to the west of Cornwall, and in the vicinity of Dillsburg, beyond the Susquehanna, openings have been made on many similar deposits. These, though of comparatively small extent, yield a superior magnetic ore, closely resembling that of Cornwall in the character of the associated silicates, and in the presence of small quantities of copper and of cobalt. From the analyses by Mr. McCreath it appears that these ores contain considerable proportions of both lime and magnesia in the form of silicates. In one of the deposits near Dillsburg the magnetite is associated with some specular hematite, which in another opening prevails to the exclusion of the magnetic species. These Dillsburg ores are interposed in granular silicious rocks, and are associated in most cases with eruptive traps, not unlike those of the Cornwall Mine, a fact which has served to confirm the popular notion that these ore deposits are in some way dependent upon the eruptive rock. It is, however, found in some cases where these traps cut across and interrupt the ore deposit, that this is continued mi-changed on the farther side of the dyke, and at Wheatfield, where similar ores are mined, these traps are wanting, although the miners, firm in the conviction that trap-rock is an indispensable condition of a successful mine, maintain that the granular detrital quartzite with which the ore is here interstratified is itself a trap.

At Boyertown, in Berks County, similar deposits have been long known, and layers of magnetic ores of no great thickness have been worked down slopes of about 45° to the southeast, in one instance, to a depth along the incline of 400 feet. A vertical boring made near by, in 1873, after penetrating 376 feet of rock, passed through 211 feet of granular magnetic ore, which with an inclination of 45° corresponds to a thickness of about 140 feet. A shaft measuring 7 by 13 feet had, at the time of my visit in September last, been sunk to a depth of 300 feet to open this great bed of ore, which, judging from the quality of that mined at the slopes, and from a partial analysis of that from the boring, bids fair to be of great value, and probably well adapted to the manufacture of Bessemer metal.

I can only allude in this connection to the very extensive deposits of similar ores in the same geological position at the Warwick and the Jones Mines, on the south side of the sandstone belt, which, though somewhat more sulphurous than those of Cornwall, have been mined and smelted for a century, and are greatly esteemed. The facts which I set before you suffice to show that, apart from the brown hematites of the valley, which have been in the past such a source of wealth to the State, and besides the magnetites of the South Mountain from the Delaware to the Schuylkill, Pennsylvania has, along the border of the Mesozoic sandstone, iron resources of as yet unknown magnitude, of which the Cornwall bed is but a single example, preserved above the surface by the fortunate accident of protecting walls of trap. For each deposit of great thickness like this, there are undoubtedly very many smaller ones, but the form, of these, as I have seen in several instances, is lenticular, so that if they are pinched out in some cases they open out to greater widths in others, as is strikingly seen at Boyertown, where the deposit, of no great thickness at the outcrop, expands at the point reached in the boring to 140 feet. While the ores of all these deposits along this geological horizon agree in certain qualities, it need not be said that careful metallurgical trials, guided by minute chemical analyses, will be necessary before their true values can be fully made known. It also remains to be determined whether these same ores can be traced beyond the limits of Pennsylvania into New Jersey on the one hand, and into Maryland and Virginia on the other. I deem it proper to state that the object proposed in my late preliminary examination of the ore deposits above noted, was geognostical rather than economical, and that farther and much more detailed studies, alike geological, mineralogical, and chemical, must be made before the history of these important ores can be considered complete. Such a work will doubtless be the care of the new geological survey of Pennsylvania, in the published reports of which Messrs. Prime, Frazer, and McCreath have already performed a similar task for the brown hematite ores of a large portion of the State. Meanwhile my report to Professor Lesley, the director of the survey, will contain a detailed account of my own observations.

I may remark, in concluding, that these magnetic and specular ores of the Primal slates, have very close geological relations with the brown hematites of the region, some of which are known to belong to the same Primal slates. These ores, which I believe to come from the alteration of deposits of carbonate, and in many cases of sulphuret of iron, oxidized *in situ,* are in certain deposits of the region interstratified with crystalline magnetic and specular oxides, the whole being imbedded in the clays which have resulted from the more or less complete decomposition of the inclosing crystalline rocks.*

A NEW ORE OF COPPER AND ITS METALLURGY.

BY T. STERRY HUNT, LL.D., F.R.S., BOSTON, MASS.

THE Jones Mine (or Johannes Mine, as it was originally called, from a former proprietor), situated near Springfield, in the township of Caernarvon, Berks County, Pennsylvania, has long been known as a large deposit of magnetic iron ore, associated with more or less copper pyrites, and with malachite and chrysocolla. It occurs in a belt of soft schistose rocks which rest upon the Laurentian gneiss of the Welsh Mountain, and to the northward are soon concealed by the unconformably overlying Mesozoic sandstone of the region. These metalliferous strata belong to the Primal slates of Rodgers, which, in many other localities in this region, include similar deposits of iron ores associated with more or less copper, and often accompanied by chloritic and argillaceous schists, and, more rarely, by serpentine and small lenticular masses of crystalline limestone. To this same horizon belong the iron ores of Boyertown, Fritz's Island, and Roudenbusch, near Reading, Wheatfield, Cornwall, and Dillsburg (all of which are found along the northern border of the Mesozoic belt of

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* By the kind permission of Dr. F. A. Genth, of the University of Pennsylvania, I am now enabled to append to this paper the following hitherto unpublished analyses of the Cornwall ores.

	I.	II.	III.	IV.	V.	VI.
Magnetic Oxide of Iron...... =	78.278	62.198	67.268	68.965	53.175	41.131
Sesquioxide of Iron.......... =	....	....	....	22.794	....	50.298
Oxide of Copper............. =	1.840	1.480	Trace.	0.250	1.300	0.030
" Cobalt............. =	0.200	0.095	0.153	0.067	0.076	0.105
" Manganese......... =	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Alumina..................... =	....	....	0.083	1.303	....	1.094
Magnesia.................... =	1.286	2.695	1.867	1.228	3.193	1.369
Lime........................ =	1.000	1.110	1.210	0.150	1.510	0.020
Phosphoric Acid............. =	0.072	0.010	0.006	0.013	0.003	0.006
Sulphuric Acid.............. =	0.030	0.204	0.105	....	0.187	....
Silicic Acid and Quartz...... =	11.082	28.000	18.240	2.200	37.860	3.840
Copper Pyrites.............. =	0.352	1.818	0.232	....	0.604	....
Iron " .... =	5.222	1.792	8.299	0.684	1.479	....
Water, etc.................. =	0.629	0 598	2.522	2.943	0.613	2.107
Metallic Iron............... =	59.229	46.422	52.666	65.952	39.380	64.992
" Copper.............. =	1.589	1.814	0.080	0.200	1.246	0.024
Phosphorus.................. =	0.032	0.004	0.0026	0.0057	0.0013	0.0026
Sulphur..................... =	2.910	1.672	4.549	0.045	1.076	....

the region), and probably also those of the Warwick Mine on the southern border.

The iron ore of the Jones Mine is found in massive beds intercalated in the schists, and has been very extensively mined; the earlier workings going back, it is said, more than a century. Some layers in the iron deposit are so charged with copper pyrites as to have been reserved as copper ores, and the adjacent schists have furnished considerable quantities of massive malachite, which is however no longer found. On one side of the great open pit in which the magnetic ore is now mined, there occur irregular layers of a greenish earthy-looking matter, which was found a few years since to contain considerable copper in an oxidized form. This, under the name of clay-carbonate of copper, has been mined by Mr. C. M. Wheatley, who has, within the last few years, extracted from shallow pits or drifts several thousand tons of this ore, yielding from six to seven per cent of copper. Recent excavations show that this material forms irregular layers interstratified with the soft and apparently decaying schists already noticed, which dip beneath the great mass of the magnetic iron ore. These, for a thickness of several feet, present alternations of the so-called clay ore in a state of comparative purity, with layers of a coarser granular matter poor in copper, the whole marked with ferruginous bands which coincide with the bedding. These various layers are often cut by small transverse veins of quartz. For a thickness of six or eight feet, at least, the strata are charged with the cupriferous mineral, and the car-loads of the material, as now excavated, average from three to six per cent of copper, while layers of half an inch or more in thickness will yield ten or twelve per cent.

These pure portions have a pea-green or apple-green color when moist, becoming greenish-white on drying, when the mass falls into a powder, which is seen under the microscope to consist of minute, transparent, shining scales, mixed however with some grains of quartz and a small portion of magnetite. A qualitative examination of this material showed that it contains no carbonates, and is not of the nature of a clay, but consists of a hydrous silicate of magnesia, copper-oxide, alumina, and iron-oxide, constituting a kind of copper-chlorite. It is but feebly attacked by dilute acids, while strong acids, and, notably, sulphuric acid diluted with two or three parts of water and aided by a gentle heat, readily and completely decomposes it, with separation of flocculent silica, which, by solution in dilute soda-lye, is readily separated from accompanying quartz and magnetite. A single somewhat rough analysis made in this way, gave me, for 100 parts,—-insoluble sand, 14.10; silica, 24.00; alumina, 13.00; magnesia, 15.15; ferric oxide, 7.11; cupric oxide, 15.30; water, 11.50 = 100.70. The qualitative examination of a considerable portion of another and less pure specimen, gave me an appreciable quantity of zinc, and a distinct trace of nickel.

The metallurgical treatment of this ore presented an interesting problem. From its infusible character it can only be used in small admixture in. the smelting furnace, while the cost of its treatment by acids is considerable, since the copper can only be removed by the complete decomposition of the silicate by acids. Unlike chrysocolla, a simple copper-silicate, which, as my friend Mr. James Douglas, Jr., has found, is completely decomposed when digested with a hot solution of ferrous chloride in presence of chloride of sodium, this complex silicate is very slightly attacked by such a solution, either before or after simple ignition. I found, however, that after heating it to low redness in a close vessel with carbonaceous matter, this ore readily gives up its copper to the action of a solution of ferrous chloride as above. The explanation of this is doubtless that the copper of the silicate is first reduced to the metallic state, and, subsequently by cooling in contact with air, is converted into a mixture of cupric and cuprous oxides, which readily decompose ferrous chloride with formation of cuprous and cupric chlorides. Portions of the ore heated for three or four hours to low redness with a small admixture of charcoal or bituminous coal-dust, and then cooled in contact with air, readily gave to a hot solution of ferrous chloride mixed with common salt the whole of their copper, which was chiefly dissolved as cuprous chloride, as is evident from the fact that only about 47 parts of metallic iron were required to precipitate 100 parts of metallic copper from the colorless solution. These reactions have since been utilized, so that several thousand pounds of this ore are now treated daily in the works of the Chemical Copper Company at Phœnixville, Pa., for the extraction of the copper.*

APPENDIX.

A portion of the specimen of this copper silicate of which the analysis has been given above, was freed by careful washing alike from the coarser grains and from the lightest portion which remained long suspended in water. The material thus purified was somewhat richer in copper than before, and has been carefully analyzed by my friend, Mr. George W. Hawes, of New Haven, who found insoluble

* See paper by Prof. Silliman on page 350.

sand, 6.22; silica, 28.93; alumina, 13.81; ferric oxide, 5.04; ferrous oxide, 0.27; magnesia, 17.47; cupric oxide, 16.55; water, 12.08 = 100.37. This, deducting the insoluble matter, gives for 100 parts : silica, 30.73 ; alumina, 14.67 ; ferric oxide, 5.35 ; ferrous oxide, 0.29 ; magnesia, 18.55 ; cupric oxide, 17.58 ; water, 12.83 = 100.00. This, as remarked by Mr. Hawes, gives, on calculation, an oxygen ratio between sesquioxides, protoxides, silica, and water, of 4 : 3 : 6 : 4, very nearly, which puts this mineral, if it be a homogeneous substance (as its microscopic characters would indicate), among the chlorites, some of which it resembles very closely in its atomic ratios. Before the blowpipe on charcoal it swells, then fuses quietly into a black globule, giving the usual reactions for copper. The iron is almost wholly in the state of sesquioxide, as shown by two determinations of the amount of protoxide of iron. The two gave, respectively, 0.27 and 0.29.

This copper-chlorite appears alike from its physical and chemical characters to constitute a distinct mineral, species, for which I propose the name of VENERITE, in allusion to the mythological and alchemistic name of copper.

WHAT STEEL IS,

BY FREDERICK PRIME, JR., PROFESSOR OF METALLURGY, LAFAYETTE COLLEGE, EASTON, PA.

AT the last meeting of the Institute, Mr. A. L. Holley read a paper on "Steel," in which he proposes for it a definition so opposed to the one generally received, as to call for some remarks. Until within the last five or six years there has been no dispute on the subject, and it seems worth while to investigate the matter. For not only does a proper tax on all importations depend on a proper appreciation of the term steel, but it is necessary to know whether steel, or wrought-iron, or homogeneous iron are requisite in all processes of manufacture in which malleable iron is employed, on account of cost, strength, etc.

Karsten* says: "Iron may be obtained, either as an unforgeable, unweldable metal, which melts at a high heat, termed *cast-iron ;* or as a ductile, weldable, soft metal, which can only be melted at the

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* Karsten, Handbuch der Eisenhüttenkunde, 3d ed., vol. i, p. 6. Berlin, 1841.

highest artificial temperature it is possible to produce, called *wrought-iron;* or, as a hard metal, which is ductile, less weldable, and more fusible in proportion as it decreases in weldability, which is called *steel."*

He also adds, in a subsequent memoir:* "When combined with carbon, not exceeding certain limits, iron increases in tenacity, and, consequently, in elasticity, malleability, and ductility. The increased hardness becomes perceptible to a striking degree, if the metal be suddenly cooled after having been highly heated. It is to this property of carbonized iron which distinguishes steel from wrought-iron; *since it has been agreed to call all wrought-iron which hardens in being suddenly quenched steel.* The results obtained by analyzing many kinds of iron show that the amount of carbon in iron must be 0.2 per cent. to 0.25 per cent, before it will temper. The more free iron is from foreign matters, especially silicon, sulphur, and phosphorus, the larger is the amount of carbon required to render the hardening perceptible by suddenly lowering the temperature. In the best Swedish wrought-iron, as well as in wrought-iron made in Germany, from spathic and limonite ores, 0.35 per cent. carbon does not suffice to cause a greatly increased hardness by quenching; nevertheless, the degree of hardness is so considerable, that the metal is properly called *steely-iron.* The passage from this hard or steely-iron to steel, is so insensible, that it is necessary to assume some empirical sign, in order to know whether the metal should be called wrought-iron or steel. Only when the iron attains, through the absorption of carbon, after quenching, such a degree of hardness as to give sparks with flint, can a claim be made to call it steel. And this degree of hardness is attained in wronght-iron having a carbon percentage of 0.5 per cent when less free from foreign matters, and of 0.65 per cent when almost entirely free from foreign ingredients. In the latter, carbon amounting to 1-1.5 per cent, corresponds to that combining proportion, by which the steel, after tempering, attains the greatest hardness combined with the maximum tenacity. By increasing still farther the amount of carbon, the steel attains a greater hardness, it is true, but its tenacity commences to decrease, and its weldability is so slight, that steel containing 1.75 per cent, carbon, has almost entirely lost its welding power. When the carbon

* Ueber die Carburete des Eisens; rend before the Academy of Sciences at Berlin, 1846. Reproduced here somewhat at length, as Percy, in his Metallurgy of Iron, has so condensed it as, in places, to render Karsten's views somewhat obscure.

amounts to 1.8 per cent., it can then be worked and drawn out under the hammer, only with great difficulty, although it may then combine very great hardness with a still considerable degree of tenacity. Steol containing 1.9 per cent. carbon, or more, is no longer malleable when hot, and 2 per cent, of carbon appears to be the limit between steel and cast-iron, when the product in the soft condition, *i.* c, before tempering, can no longer be drawn out when heated, without cracking and falling to pieces under the hammer."

Gruner says :* " The crude cast product, resulting from the reduction of the ores of iron maybe called cast-iron. It is an impure iron, which is not malleable, at least when heated, but which may be tempered by being suddenly cooled. The name *ivrought-iron* is given to a metal more or less refined, obtained from cast-iron, or in the direct way from iron ores; it is malleable hot or cold, but not capable of being tempered. The practical man will call every intermediate product *steel,* which may be tempered, but which remains malleable hot and cold when not tempered, and this metal will be steel, whatever be the method followed to obtain it. According to this, in its properties, as well as its manufacture, steel is comprised between the limits of cast-iron and wrought-iron. It cannot even be said where steel begins or ends..................... After all, that which distinguishes the three products is solely, as shown long since by Karsten, the relative proportions of carbon, of which a portion is simply mingled with the iron, the remainder intimately combined with it, or rather in a state of solution."

Gruner also shows in the same memoir (p. 22) that the limit of tempering to any perceptible extent is between 0.25 and 0.5 per cent, of carbon.'

Percy, Wedding, and Kerl† in their respective works on iron give practically the same definitions as Karsten, and Tunner‡ does the same.

Mr. David Forbes§ says in this connection that the tempering quality has been regarded from the oldest times as the " all-characteristic property of steel."

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* Grunor, The Manufacture of Steel, translated by Lenox Smith, p. 8. New York, 1872.

†Percy, Metallurgy of Iron, London, 1864, p, 102. Wedding,Hanclliuch der Eisenhiittenkunde, Braunschweig, 1864. I Abthl., p. 130, and III Abthl., 1874, p. 1. Kerl, (irundriss der Eisenhütenluinde, Leipsie, 1875.

‡Oesterreichische Zeitschrift für Berg- ünd Httttenwesen, 1875, p. 491,

§Journal Iron and Steel Institute, 1875, p. 343.

Hitherto, then, the definition of steel has been an iron possessing the quality of tempering combined with great tenacity, weldability, and malleability both in the hot and cold states when not tempered. The advantages of this definition are :

I. The exclusion of cast-iron.

II. The exclusion of malleable iron containing an amount of carbon less than about 0.5 per cent.

III. It includes all malleable iron possessing the above properties, whether made by the cementation, Bessemer, Martin, Siemens, or any other processes.

IV. It is scientific in that it classes bodies together possessing similar properties, and excludes those which do not have them.

V. It is practical, as a good smith can readily distinguish steel from wrought-iron, and classify the different grades of steel.*

In addition to the above qualities should be added the resilience or spring of iron, the importance of which has been overlooked by most metallurgical writers. Mr. H. M. Howc† calls attention to this property in an able series of recent papers. He proposes using this property to define steel as "a compound or alloy of iron whose modulus of resilience (or spring) can be rendered by proper mechanical treatment as great as that of a compound of 99.7 per cent, iron with 0.3 *per* cent, carbon can be by tempering," The author very frankly admits "that one of the advantages of resilience—that one and the same modulus of resilience could mark the boundaries between steel and both cast and wiought iron—is hypothetical." Practically, also, too little is as yet definitely known as to the resilience combined with the chemical properties of iron to adopt this definition. In practice, too, it would be impossible to determine the modulus of resilience in each bar of steel, or even one bar from each lot purchased from the manufacturer, in order to ascertain whether the steel was of the desired quality or possibly only wrought-iron.

Let us now pass to the more persistent opponents of the present accepted definition of steel.

When an attempt is made to overthrow an old definition or conception of substance, whose general characteristics and properties have become familiar to the great mass of the civilized world, and to replace this definition by another which shall include new sub-

* See Artielo on Iron and Carbon, Mechanically and Chemically Considered, by John B. Pearse, in this volume, p. 157.
† See Engineering and Mining Journal, 1875, vol. xx, p. 213 et seq.

stances differing in their characteristics, and at the same time exclude old ones having these properties, very cogent reasons should be assigned for the act.

Our honored President, Mr. Holley, belongs to a group composed of himself, Messrs. Greiner, Phillipart, Jordan, Hackney, and many manufacturers of Bessemer and open-hearth metal, who propose to overthrow the definition I have given as the current one. With energy worthy of a better cause in a paper read before the last meeting of the Institute, he gives his definition, pronounces *it* to be the current one, and claims that "several high metallurgical authorities and clever writers have of late proposed to disturb this natural and somewhat settled nomenclature." (!)

Mr. Holley defines steel as follows: "All the compounds of iron which have been cast in malleable masses, are called steel, the term wrought-iron being still confined to malleable iron made from pasty masses, and hence laminated in structure." All the persons above mentioned coincide in this definition.

The reasons that he advances in favor of this definition are :

I. That all cast malleable irons have the property of homogeneity in common. The objection to this is that while acknowledging the homogeneousness of irons thus prepared, this classification unites irons which have no other property in common.

II. Other definitions to include the (so-called) softer steels, have failed to obtain general recognition. This is not so, as they, together with all cast-steels, have been called " homogeneous irons," and have obtained very frequent recognition as such. The term " ingot-irons " has also been proposed to distinguish all cast malleable irons, and is a capital one, being short, easily remembered, and confined to this class of irons. The objections to Mr. Holley's definition are many.

I. A very reasonable objection is that it " pirates " a time-honored term. In answer to this, Mr. Holley says that people who do not know that steel is soft and ductile are not competent authorities. If he will compare Karsten's and Gruner's definitions, he will find that they ascribe these qualities to steel, *together with* that of *tempering.*

He continues: " I venture to assert that the charge, specially brought by the inventors of new definitions, against the existing (!) use of the term steel—the charge of upsetting the recognized order of things—is wholly without foundation. Nobody invented the term steel as supplied to the soft homogeneous products."

On this point I venture to take direct issue with Mr. Holley, and, to show that he is mistaken, refer to the following extract from hi co-worker, Mr. Greiner.* " In a note on the uses of steel, read in 1869 before the Association of Graduates of the School of Arts, Manufactures, and Mines, of Li6ge, I have proposed to reserve this term [steel] for all malleable products of iron manufacture obtained in a state of fusion."

And this is what Mr. Jordanf says: "We wish that it were possible to become accustomed to calling wrought-iron all manufactured products, which have not been in a state of fusion, where the grains of iron have come to nature, and have solidified in the midst of a slag more or less fluid, and which are definitely more or less heterogeneous alloys of iron and carbon. The term steel would then be applied to all products formed by fusion, in which the grains of iron are formed by crystallization from a mass entirely fluid, and which are homogeneous alloys of iron and carbon."

This was the condition of things in 1872, when Mr. Jordan dis-. tinctly states that Karsten's and Gruner's definition was the commonly accepted one, and that being unable to adopt the proposed definition in his report, he follows the usual one in his description of processes. Mr. Holley says that by 1875, the growth, so as to include what he calls soft steels, has been a gradual one. I think even he will acknowledge that it takes more than three years for an old definition to have been *so gradually* supplanted by a new one, as to be entirely overthrown.

II. A second and most weighty objection is, that the proposed definition will class a great portion of what has hitherto bean called steel among the wrought-irons. The answer, such a weighty one, (!) is that if we do not call those cast malleable irons—containing the lowest percentages of carbon, and which do not temper—steel, there is no name for them.

When new products are obtained either by new or old processes, the ordinary custom is to give such products new names. Tims, when the locomotive was invented, it was not called a land-steamboat. When chemists discover new elements, which perhaps in most of their characteristics resemble already known ones, they do not give the name of the old element to the new one, but give it a new name.

Revue Universelle des Mines, 1873, vol. xxxiii, p. 28.

† Jordan, Industrie du Fer en 18(57, in Revue do l'Exposition deParis, vol. iv, p. 280. Published in 1872.

If, then, by the addition of spiegeleisen or ferro-manganese we are able to produce cast malleable irons containing less carbon than those at first manufactured, and which are well adapted to replace in the arts wrought-iron, as for example in the manufacture of boiler plates, why should not new names be applied to these products? We must not expect new products to become at once widely known, any more than a newly-fledged doctor who has his own way to make, can expect to at once jump into a full practice. And, indeed, this very application of the name steel to soft homogeneous irons produced by the Bessemer and Martin processes, has been prejudicial to their introduction, for persons having the well-known definition of steel in their minds, have been deterred from using homogeneous iron under the name of " soft steel " for this purpose.

In the connection of having no name for soft homogeneous irons, it is amusing to listen to the following piteous plea advanced by Mr. Phillipart* for the proposed definition of steel: " If we have to maintain the old definitions, we can no longer class as steels almost the whole of the Bessemer and Martin products distributed in commerce. In place, then, of considering ourselves as having entered on the age of steel, we have arrived (following the opinion of an eminent metallurgist) at the age of cast malleable or homogeneous iron." Again: "If we consult the scale of hardness of pure steels we find that the metal does not commence to temper until the amount of carbon is over 0.40 per cent. What will become, in this case, of the greater portion of the Bessemer and Martin products?"

Mr. Greiner† also says, in answer to the objection that the new definition will exclude steel produced by cementation: " Not 5 per cent, of the products which the manufacturer employs under the name of steel will temper." Suppose the Secretary of the Treasury were to say that gold is no longer a legal tender, because it forms but 5 per cent, of the circulating medium; that greenbacks have been made a legal tender by Act of Congress, and that the National banks support him in his assertion. Would we be any the less ready-to accept gold as a legal tender, and would we not tell him that he could keep the greenbacks if he would pay us gold for them?

In support, too, of the objection we have stated, Mr. Phillipart, at the close of his article, feels himself obliged to propose a new definition for puddled steel, viz.: "The term puddled steel could be

* See. Revue Universelle des Mines, 1875, vol. xxxvii, p. 576, et seq.
† Ibid., p. 564, et seq.

perfectly well replaced by that of granular-iron or steely-iron, the adjective steely recalling the fact that in this case the metal is susceptible of being tempered like certain cast-steels."

Does Mr. Holley accept this, too, as the commonly received definition?

III. A third objection is that the proposed new definition will include some varieties of cast-iron. On this point all the gentlemen maintain a dignified silence. But following Mr. Holley's graphic method of reasoning, it may not be out of place to ask, where the line should be drawn between steel and cast-iron, according to the new definition? For he very firmly claims that "exact definitions must be based on differences which always exist in every form and phase of the materials defined; and not on differences which, however great they may be in certain forms and phases of the materials, run together at one point, and there cease to be differences. . . . The latter [proposed] classification is therefore exact and complete." Is, then, the line to be drawn between the products obtained from a blast-furnace and cupola, or between those produced in a blast-furnace and a Bessemer converter, or between those obtained from a Bessemer converter and a Siemens furnace? The truth is that the line of demarcation between wrought-iron and steel is just as clearly tiefined, and no more so, under the accepted definition, as that between steel and cast-iron under the proposed one. The changes are gradual, and hence the different species of iron run imperceptibly into one another. If Mr. Holley thinks he escapes the gradual transition from wrought-iron: to steel on the one hand, he falls just as certainly into the difficulty of separating steel from cast-iron on the other. Can he state precisely the point at which cast-iron ceases to be such, and becomes steel ?

IV. A fourth objection to the new definition is that "a considerable range of wrought-irons and [so-called] bar-steels cannot bo distinguished by the observation of their fracture, nor by bending, nor by the usual quick mechanical tests." To this Mr. Holley replies that iron and steel are bought "by specification of manufacture," which does not answer the objection, but evades it. And he goes on to say, in support of his argument, "The practical usefulness of a name does not, therefore, lie so much in its discrimination between metals after they are made, as in specifying the method and quality of their manufacture;" an assertion to which few persons will assent.

Before leaving Mr. Holley's paper, I would call attention to a very hypercritical reason which he gives for the use of the term "steel," rather than that of "homogeneous iron." He says: "We may call these compounds homogeneous iron, but we must then add the percentage of carbon and designate them as ' ten carbon homogencous iron,' up to say 'fifty carbon homogeneous iron,' for there is a vast range of grades and uses between these carburizations. Now is it not easier to say 'ten carbon steel,' up to 'one hundred and fifty carbon steel,' thus including all the varieties of ingot metal ?" To most persons it would seem as easy to say " homogeneous iron" as "steel," and far better to do so if nearer the truth.

Mr. Phillipart, in the paper before quoted, follows very much the same argument as that adopted by Mr. Holley. He says if we adopt the classification of irons

"Containing but little carbon and not tempering;
Containing enough carbon to temper;
Containing much carbon and not malleable;

how shall these different products be distinguished? Should they be classified separately under the names of wrought-iron, steel, and cast-iron? What difficulties this classification would introduce into these products!"

Would it, however, do so one-thousandth part as much as to call all steels which have not been cast wrought-irons? And how, then; should ordinary wrought-irons be distinguished from all blister or other steels which have not been fused?

Mr. Greiner, in the paper which I have previously quoted, says: "We agree with Mr. Holley that the only classification able to embrace the majority of cases is based on the molecular condition of the metal, rather that on its atomic characteristics; on the *mechanical structure,* and not on the chemical elements which compose it, any more than on the physical properties which are the most apparent at first sight."

But, is not all homogeneous or ingot iron graded by its carbon percentage? And acknowledging that carbon exerts a mechanical effect on the qualities of iron, is this not due to a chemical combination between the carbon and iron? It is well known that the greater the percentage of carbon in steel the harder it is, but no one will, for a moment, assert that any graphite which is present in some grades of steel exerts any influence in increasing its strength. If then the mechanical structure is dependent on the chemical composition, his argument fails.

The fallacy of the new definition of steel is that the engineers who advocate it regard it from the purely mechanical standpoint, and make the mistake of regarding the method of obtaining the product as of more importance than the product itself. Those of them who are known, have acquired their reputations as mechanical engineers, and not as chemists. Now the advocates of the old definition regard it from both the chemical and mechanical point of view. They say that steel is a malleable iron, between about such and such carbon percentages, which will temper.

The strongest objection made by the advocates of the new definition is really the weakest, viz., that it is impossible to accurately define the limit between wrought-iron and steel. I say the weakest, because the more science investigates nature the more apparent does it become that there are no sharp lines of demarcation, but that there are gradual transitions in all directions. We find it so in geology, botany, zoology, physics, and chemistry. In the last so much so that no chemist will now assert what he calls elements are actually such, but only that he is unable, in the present condition of the science, to decompose them into any further ultimate substances.

In the discussion now going on as to the definition of steel, are, on the one hand, the distinguished metallurgists mentioned in the introduction to this paper, to whom must be added Siemens, all advocating the retention of a definition whose origin is lost in the past centuries; on the other, engineers who wish to introduce a new definition for it, and who are of course supported by the manufacturers of Bessemer and Martin products; on the one hand men all well known and honored for the work they have done in their endeavors to raise metallurgy from an empirical to a scientific basis; on the other, men, some of them also well known, but as mechanical engineers and not as metallurgists.

In the present state of the discussion, however, there is little hope of the advocates, on the two sides of the question at issue, coming to a mutual understanding, for they start from entirely different premises.

MR. E. B. COXE said that the use of the term *steel*, by manufacturers, was mainly to give an increased value to their products. If a particular brand of coal acquired a good reputation, there would be a general adoption of that name by coal dealers. We meet with the same phenomenon in all trades. Intelligent engineers no longer order steel simply by name, but specify what kind and composition of steel is wanted. It is no more possible to give a general definition of steel, as met with in the arts, than it is of brass or bronze.

MR. FRANK FIRMSTONE said the definition that had been proposed some time since--a product that would forge, harden, and temper, seemed practically to cover the ground, and asked what was the objection to it?

MR. HOLLEY: What are you going to call the new products?

PROF. B. W. FRAZIER said that the older definition of steel was one of kind, while the newer one was based on methods of manufacture. He thought the qualities and composition of the material a better basis for a definition than the accidents of its manufacture.

PROF. T. EGLESTON spoke of the experiment, referred to by him at a previous meeting, of melting wrought-iron in crucibles without change of composition. This fused product would, by the new definition, be steel. He protested against the fusion of metallurgy in mechanical engineering.

DR. J. LAWRENCE SMITH spoke of the experiments of Matthiesen, who by fusing pure wrought-iron, perfectly protected from the action of the air and carbon, obtained a product as soft as lead.

MR. J. B. PEARSE said, in reference to the changes produced in melting pure iron, that, ordinarily, the greater the care taken in melting in a crucible the more likely the metal is to change. For *care,* in this case, means the melting in a graphite pot and surrounding the pot with carbon, both solid and in a gaseous state.

In reference to the line of division between wrought-iron and steel, Mr. Pearse illustrated his remarks by producing a bar of Bessemer metal made at Neuberg, Styria,. some ten years ago. It was ¾ inch square, and had been rolled to that size from a small ingot about 4 inches square. After the bar had been "graded " it was so soft that the smith thought it worth while to treat it exactly as he would to harden steel, that is, heated it to a full red heat and then plunged it immediately into water. This he did with the end of the bar, heating it for about 4 inches back from the end. About the centre of the part heated, the smith made a cut about one-sixteenth of an inch deep on each side of the bar. The bar would not break at one blow, but required several powerful blows to fracture it. It then exhibited the fibrous fracture and dull color of wrought-iron, exactly like that of a broken rod of the best twice-rolled puddled iron. The corners were bent out of shape, and every fracture exhibited the softness and the ductility of the metal thus treated. Now, a few inches away from the part thus heated and cooled *(i. e., hardened)* the smith made exactly similar cuts on each side of the bar, where the metal had not been affected. At this place the bar broke on the edge of the anvil under about two blows in the same direction, and with the usual fracture of steel. The corners are square and the fracture crystalline and conchoidal, like that of any mild steel.

The difference caused by a treatment, which, in the case of steel, would harden the metal, but in this case softens it, shows hat we have in this bar another metal, viz., *iron.* The bar contains rather less than 0.17 per cent carbon. We can, therefore, say that below this point we have *iron* and not *steel,* and that the point at which the metal softens, when treated as if to harden it, marks the dividing line between iron and steel..

This point and this division are, then, not arbitrary, but lie in the *nature of things.*

THE SPATHIC IRON ORES OF THE HUDSON RIVER.

BY R. W. RAYMOND, PH.D., NEW YORK CITY.

I DESIRE to call the attention of the Institute briefly, and by no means in the way of an exhaustive description, to the interesting developments recently made on the east bank of the Hudson River, in the mining of spathic iron ores. The mines to which I refer arc those of the Hudson River Spathic Iron Ore Company, situated at Oakhill on Hudson, Columbia County, N. Y., five or six miles from the city of Hudson, and opposite the town of Catskill. The ore occurs in beds, constituting apparently members of the stratified series of rocks on that side of the river, coursing nearly north and south, parallel with the river, and dipping east. The principal outcrops are presented in a range of low hills, about one mile from the river, along the crest, on the western face of which the stratum of spathic ore is more or less exposed. The length of the line in this range, along which, at various openings the ore has been discovered in profitable quantity, is about two miles. To the northward, the hills are somewhat higher, and the stratification may possibly be disturbed, though the rapid examination of the locality which I made in November last did not include any determination of this point, and the suggestion is merely a conjecture, supported to some extent by the contours of the surface, and by the circumstance, reported to me, that the continuation of the bed had never been traced in that direction. To the southward, on the other hand, the surface is lower, and it appears likely, from various explorations, that the ore-bed is either less tilted, and is buried under other formations, or that its continuation is more silicious and calcareous, so that it is not workable as an iron ore. The thickness of the bed, as exposed in the workings of the company, is perhaps ten or twelve feet. At one point I observed a thickness of sixteen feet. About a mile and a half further east, another outcrop has been discovered, probably indicating a parallel bed, or the same bed, brought again to the surface. But the ore is reported to be poor and unfavorably located for mining. It is the range first described, lying back of the old Livingston manor-house, and largely on the Livingston estate, which is actively worked by the Hudson River Company, 15,000 tons having been shipped during the navigation season of 1875, and a capacity for much larger shipments during the present year having been developed, if the demand for iron ores shall warrant their extraction. The works are altogether open quarries, and extraction is, and for a long time will be, exceedingly cheap. The ore can be mined and hauled to the dock at the river, I should think, for less than §1.50 per ton. It is delivered to purchasers at the dock for $2.00. I understand that this price is to be reduced for the coming season.

In appearance, the ore resembles a fine-grained dark-gray silicious limestone, except where by weathering it has become peroxidized, assuming a dark-red color. Fragments along the outcrop frequently present the appearance of brown hematite on the outside, while the centre is unaltered. Red Hill, the most northerly locality opened upon the range, derives its name from the dark-red color imparted to rocks and soil by the weathering of the edge of the spathic ore-bed. It is strange that so marked an indication of the presence of iron should have passed unnoticed for so many years. Even the State geologists do not seem to have noted the occurrence of the carbonate of iron in this locality. The rocks underlying it are slates, and I believe the overlying formation is calcareous also,—a shale or limestone. It may be that the bed between is only in certain places sufficiently ferruginous to be called an iron ore, and that, taking sections across the series at other points, they found no special zone of spathic iron in the general succession of calcareous strata.

Since calcic and ferrous oxide are interchangeable in the carbonates, such a variation would not be unusual.

The Livingston and Miller Mines are the two other principal openings. Here the ore is less altered, and grayer in appearance. In all three places, considerable sorting must be practiced, to obtain a uniform maximum richness of the ore. It seems to vary in quality, principally in its contents of silica and lime, within short distances, or in different ?ies of the bed, parallel with the walls. The weight of the pieces affords the readiest test of their value as ore.

The quality of the ore may be inferred from the following analysis and reports of blast-furnace managers :

Analysis of Hudson River Spathic Iron Ore.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Peroxide of Iron,	62.98	43.90	61.50	52.62		67.36		43.44
Protoxide of Iron,					42.37		40 13	15.80
Sesquioxide of Manganese,						1.80		
Protoxide of Manganese,				1.44			0.73	1.07
Alumina, ...	3.31	3.49	4.89	2.13		2.50	2.28	2.46
Lime,	1.00	1.75	2.45	1.33	6.93*	.85	1.27	1 43
Magnesia,				2.61		1.02	3.81	2.86
Silicious matter, . .	21.05	22.25	31.15	14.77	21.28	14.68	23.02	14.00
Carbonic acid, . . .	11.25	27.82		21.94	24.27		27.30	14.24
Phosphoric acid, . .	Very light trace.			0.43	0.67	0.48	0.38	0.41
Sulphuric acid, . .	Rather heavy trace.			0.47†		0.11†	0.22	0.34†
Bisulphide of iron, . .					4.48		1.41	
Water, ...				2.16		11.91		4.49
	99.59	99.21	99.99	99.90	100.00	100.71	100.55	100.54
Metallic iron, . . .	45.52 ?	34.14 ?	47.20 ?	38.80	34.26	47.15	31.87	42.54
Phosphorus, . . .				0.19	0.29	0.21	0.167	0.184
Sulphur, ...				0.47	2.39	0.11	0.84	0.34

I. Red ore, analyst, chemist of Lackawanna Coal and Iron Company.
II. Gray ore, analyst, chemist of Lackawanna Coal and Iron Company.
III. Gray ore, roasted, chemist of Lackawanna Coal and Iron Company.
IV. Gray ore, J. B. Britton.
V. Surface ore, C. F. Chandler.
VI. " Brown hematite " (surface ore ?),
VII. " Carbonate " (gray ore ?),
VIII. " Carb. and hem." (weathered ore ?),
Analysis furnished by the company. Chemist's name not given to me.

Remarks.--The amount of metallic iron in I, II, and III I have obtained by calculation, assuming the iron to be wholly protoxide in

* And water. † Sulphur.

II, while of the 62.98 per cent, of oxide of iron reported in I, I have assumed that 18.41 per cent, is protoxide, to satisfy the carbonic acid present, and the remainder peroxide. To these analyses may be added three determinations by Mr. Britton of the metallic iron in samples of gray, red, and mixed gray and red ore roasted, giving 36.34 per cent., 49.55 per cent., and 53.39 per cent., respectively.

It appears from these analyses, that the ore, in its undecomposed state, is an impure spathic iron, containing about 35 per cent, of metallic, iron, 14 to 23 per cent, of silicious matter, 7 per cent, of earths and manganese, and say 0.40 per cent, of phosphoric acid. The amount of sulphur is variable, depending apparently on the amount of disseminated pyrites. Prof. Chandler's analysis shows in one case 2.39 per cent, of sulphur from this source—an amount which I imagine to be considerably above the average. The quantity of phosphorus in the ore is not too large to permit its successful use for foundry and mill irons, but it would exclude it from the manufacture of Bessemer iron. Roasting of course expels the carbonic acid and (from weathered ore) the water, and thus increases the percentage of iron in the ore, as the analyses show.

The. yield of iron in the furnace, is variously given. According to one founder with whom I conversed, it is not more than 30 per cent, of the weight of the unroasted ore. Mr. Wright, President of the Peekskill Iron Company, estimates it at 35 per cent., and Mr. William Atkins, Superintendent of the furnaces of Atkins Brothers, at Pottsville, Pa., says that having used during the last season about 4500 tons of the spathic ore, he found it to yield about 38 per cent. For these variations of estimated yield there are two reasons. In the first place, the ore is not used alone, but smelted with other ores. At Peekskill, 35 per eent. of it was used, I suppose with the well-known "Croft" magnetic ore. At Pottsville, from ¼ to 3/8 the ore charged was spathic ore, the remainder being usually Cornwall ore, or New Jersey or Port Henry magnetite. The yield of the spathic ore by itself is, therefore, largely a matter of surmise. In the second place, the mines were worked last season by a contractor, who found it profitable to ship as many tons as possible, and was not interested in a rigid sorting of the ore. From some of the openings a good deal of very lean material was sent away.

According to the testimony of the two consumers I have named, the behavior of this ore in the furnace is in the highest degree satisfactory. It melts easily and gives a very fluid cinder, for which reasons it is strongly recommended as an addition to refractory magnetites. According to Mr. Wright, the use of 35 per cent, of it effected a decrease of about 7 per cent, in the limestone required, and a reduction in the amount of fuel consumed. According to Mr. Atkins, it made " a good hot cinder," and caused the magnetic ore worked with it to melt more easily. He reports that by using the spathic ore he can carry from 10 to 15 per cent, more burden, and that it requires about 15 per cent, less lime than "ordinary hematite." I believe that both at Peekskill and at Pottsville the ore was charged without previous roasting.

The development of this deposit is worthy of special attention, because it suggests forcibly the possibility of similar discoveries elsewhere in the older rock-formations, of carbonates of iron which have hitherto been overlooked, both by the geologist and by the exploring miner. The gradual exhaustion of our surface brown hematites in many localities renders the discovery of easily smelting ores to take their place more important than will be for a long time to come the opening of new sources of supply of hard and refractory magnetites.

THE MINTS AND ASSAY OFFICES OF EUROPE.

BY PIERRE DE P. RICKETTS, E.M., PH.D., SCHOOL OF MINES,
NEW YORK CITY.

HAVING had occasion while in Europe during the past summer to visit some of the foreign mints and assay offices connected with the same, I thought a brief description of the general process of coining employed, and such items connected with assaying as were new, might prove interesting to the Institute.

The principal foreign mints are: the Royal Mint, London and the mints in Paris, Brussels, Utrecht, Berlin, Vienna, Copenhagen, St. Petersburg, Stockholm, Madrid, Milan, Rome, and Constantinople.

My time only permitted my visiting a few of the principal and largest given in the list, and for a description of the remainder I am indebted to the kindness of Mr. James M. Napier, who in company with the deputy master, and chemist of the Royal Mint, made a complete inspection of all the European Mints in 1870.

The methods of "making money" vary greatly, but the process of minting or coining it is conducted on the same general principle.

Many of the details of manufacture in the different mints vary, but I think that the following heads will include the whole subject, and give a comprehensive idea of the system of coining as it is now employed in the mints of Europe.

1. Melting the metals for coinage.
2. Transferring the fused metals to moulds (pouring).
3. Making the bars.
4. Rolling the bars into bands or fillets.
5. Annealing and adjusting the bands.
6. Manufacture and preparation of the blanks or coin-disks.
7. Coining.
8. Weighing and adjusting coins.

As auxiliary operations we have

1. Manufacture of medals.
2. Making dies, etc.
3. Treatment of waste and refuse.

The metals must pass through each of these operations before they are converted into coin, and I will, therefore, describe each in turn, noting such points as are peculiar to any one mint.

1. *Melting the Metals for Coinage.*--The fusion is performed in crucibles of wrought-iron, cast-iron, black lead (graphite), and clay, in a common air-furnace, the crucible resting upon a block or brick placed on the grate-bars, the fuel used being coke or charcoal. The furnaces are built as low as possible to facilitate the removal of the crucibles, charging, etc.

The mints vary in choice of crucibles, some using iron and others black lead or clay. The largest black-lead crucibles for silver melting contain about 700 lbs., and are in use in Berlin.

2. *Transferring the Fused Metals to Moulds (Pouring).*--Gold is either poured or ladled; silver is generally ladled, except at the Royal Mint, London, where it is poured. Copper, bronze, etc., are removed from the crucible by both methods as found most convenient. When the metal is poured a lever and tongs are employed to move and tilt the crucible. As a rule most of the mints ladle out the fused metal to prevent loss of labor and injury to the crucibles by handling when filled with heavy charges; much heat is also saved and less fuel is used when this method is employed.

3. *Making the Bars.*--These are made in closed cast-iron moulds of various shape?, the moulds being opened as soon as the poured

metal has solidified. In the Royal Mint the moulds are packed in a frame and have a T-shaped section, each alternate mould being turned or reversed, so as to have any required recess, thus making one set of moulds serviceable for more than one width of bar. The general size of the bars is 15 to 24 inches long, by 3/16th to 1 inch thick, and under 2 inches in width. By having them of a minimum thickness, as at Brussels, where they are made 3/16th inch, much annealing is avoided and time saved.

After the bars have been cast, the ragged edges caused by the joints in the moulds are trimmed either by hand or machine, the latter generally consisting of a pair of steam shears. The ends of the bars are often uneven, and have to be cut before passing to the next operation.

4. *Rolling the Bars into Bands or Fillets.*--The bars are first passed through roughing and then through finishing rolls; the latter being accurately adjusted, so as to make the band of the exact thickness required.

In Brussels the finishing rolls are larger than the roughing, which is exceptional, the reverse being usual. The rolling is generally done cold. "Hot rolling is practiced at Stockholm in roughing the silver, the finishing being done cold. The rolls used upon the hot metal are hollow, and kept cool by cold water flowing through them."

5. *Annealing and Adjusting the Bands and Fillets.*--The bands are annealed in some cases after each passage through the rolls, in other cases less frequently. To anneal, the bands are placed upon the floor of the annealing furnace, either includes in a case or cover or exposed.

In one or two cases muffle furnaces are employed, the flame not being allowed to come in contact with the charge. Sometimes the bands are placed upon a carriage, which can be run in and out of the furnace, thus saving labor.

Before cutting the blanks or coin disks, the bands, if not sufficiently close, are adjusted and gauged. For this purpose draw-benches are employed in some of the mints, in others the rolling mill is found to answer.

To determine the size the bands are either gauged or tested by cutting out trial blanks and weighing them, the blanks being taken from different parts of the fillet.

6. *Manufacture and Preparation of the Blanks or Coin Disks.*--The disks are cut from the prepared bands, by punching with steel punches, worked by a crank or screw-press. The punch fits into a

die below. The hand-presses are employed, as a rule, for cutting trial blanks.

After the blanks are cut they are weighed, to separate the light and heavy ones. This is clone by hand and by automatic machines. The latter are so arranged that the scale-pan takes one of three positions, according to the blank, which must be either heavy, right weight, or too light. As soon as the scale-pan arrives in position the blank is knocked off by a wire into one of three openings, placed in regular order to correspond with the position of the scale-pan. The working of the machine is quite rapid, and the blanks are divided or sorted without the large amount of labor that hand-sorting would require.

After weighing, the light blanks are remelted, while the heavy ones are generally reduced to the proper weight by cutting, shaving, or filing. This operation is performed both by hand and machine.

Sometimes to aid in reducing the blanks they are annealed; this also aids in the process of edge-rolling, which is done by machine, the blanks being rolled between two planes or plates, which press the edge and thickens it.

Finally, the blanks are prepared for coining by pickling and cleaning them in an acid solution. For this a perforated cylinder, which revolves in a tank filled with the acid, is used, also a perforated pan, in which the blanks can be placed and dipped. This latter method is still used in the Royal Mint, London.

After treating with acid the blanks are dried in sawdust, cloths, etc.

7. *Coining.*--The prepared blanks are placed between two dies, one above and one below, the upper being movable. Both dies are inclosed in a collar to prevent the escape of metal during the process of coinage. By making the interior of the collar rough or smooth, any desired appearance may be given to the edge of the coin.

The dies are generally worked by machine. The screw fly-press is used in London, while eccentric and lever presses are mostly employed on the Continent. The blanks are supplied to the press by a slide connecting with a hopper or tube.

8. *Adjustment of Coins.*—At most of the mints, after coining, the coins are weighed separately before they are placed in circulation, although in some cases, for test purposes, they are weighed in bulk. Automatic machines are also used.

AUXILIARY OPERATIONS.

1. *Manufactures of Medals.*--In most of the large mints the medal department forms an important feature, especially in France and Italy.

On account of the small number struck off, compared with coins, the presses are mostly worked by hand; sometimes the small medals are made in a coining press. For very large medals the blanks are cast and hammered, and annealed repeatedly, according to the prominence of the relief to be struck. Sometimes the medals are struck hot and finished cold.

2. *Making Dies, etc.*--Generally in making the dies the rough block is cut from a bar of steel while hot, save in Paris and Brussels, where they are cut cold in a lathe. To impress the die a hand fly-press is generally employed.

3. *Treatment of Waste and Refuse.*--All the old crucibles and the ashes and sweeps of the different departments are treated, to extract any metal they may contain. The process in general use is washing, crushing and amalgamating with mercury, various machines being used. The " scissel " or scrap left from cutting out the coin disks is returned to the crucible and melted. In some of the mints the amount of " scissel " is very large, reaching as high as 50 per cent, of the total coinage.

Incidental to coining there are certain chemical operations which have led to the establishment of assay offices in nearly all the mints, and the employment of competent chemists to superintend the separation and treatment of bullion and the assay of coins.

In some of the mints, as in Paris, there is connected with the assay office a department for testing jewelry, etc., the touchstone and acids being the principal tests.

The parting of gold and silver bullion is usually effected by treatment with nitric acid, both on a large scale and in testing in the laboratory. For the determination of silver bullion, the method by precipitation with salt solution is generally employed, save at the mint in Brussels, where hydrobromic acid* is used; also muriatic acid.

* Through the kindness of Mr. Arthur Nyst, Assayer to the mint in Brussels, I am enabled to give the method employed by him of preparing pure hydrobromic acid. In order to obtain bromine free from iodine, and chlorine, commercial bromine dissolved in potassic bromide is digested with oxide of zinc, and

The coins to be assayed are sampled by punching out disks or sections, the former method being generally employed for silver, and the latter for gold and copper coins.

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the mixture then heated to boiling to distil off the bromine. To obtain this result with certainty, proceed as follows: Potassic bromide free from iodine is first made; for this purpose commercial potassic bromide is dissolved in the cold, in its weight of water, and bromine is added little by little to the solution until the liquid, which at first is strongly colored brown by the iodine set free, becomes orange, owing to the formation of bromide of iodine. It is then evaporated to dryness under a hood, and the bromide fused in a plumbago crucible. The fused bromide is put into its own weight of water, and the solution introduced into a glass distilling apparatus with the addition of oxide of zinc equal to one-tenth the weight of the dry bromide; the oxide of zinc should be very dense, in which condition it is hut slightly affected by the dissolved bromine It is obtained in this state by strongly heating basic nitrate of zinc, made by pouring a solution of one part of oxide of zinc in nitric acid of 22º B. on to two parts of zinc-white. By means of a stop-cock funnel attached to a long tube leading to the bottom of the solution, three times, by weight, as much bromine as is contained in the bromide below is introduced. By keeping this proportion all the bromine employed is taken up by the solution of the bromide, and the chlorinized bromine in dissolving in the bromide sets free a quantity of bromine proportional to the amount of chlorine contained in the bromine employed. The bromine in the solution of bromide contains now only bromide of iodine, which at the end of twenty-four hours' contact with the oxide of zinc, takes the form of iodate and oxybromide of zinc, both insoluble in the liquid.

By submitting this liquid to distillation, bromine, free from chloride and iodine, is obtained, but containing some bromoform, and probably some bromide of carbon, since for its preparation we use commercial bromine. This bromine serves for the preparation of the hydrobromic acid.

The following is the mode of preparation of the hydrobromic acid by the action of bromine upon water in the presence of red phosphorus.

In order to prepare the hydrobromic acid without being incommoded by the vapors of bromine, we should place in the water a quantity of red phosphorus in proportion to the quantity of bromine used. In any case it is necessary that the quantity of phosphorus placed in the water should not exceed one-eighth part by weight of the bromine to be converted. As to the quantity of water employed, it should be by weight three or four times that of the bromine. The vessel in which the phosphorus and water are contained should be placed in a water-bath, and kept at a low temperature. The phosphorus should be held in suspension in the water by means of a glass rod. By means of a stop-cock funnel, provided with a long slender tube, the bromine, prepared as above, is introduced. If it appears that the phosphorus is about to be exhausted, a small quantity more is added to the liquid. Care should be taken that the bromine does not touch the red phosphorus upon the bottom of the vessel, lest it take fire and break the vessel. If the liquid begins to fume it is a sign that it is too warm or too concentrated; if too warm it should be cooled, and if it is too concentrated, distilled water should be added or a portion drawn off and replaced by distilled water. The operation is ended when the liquid shows only a slight coloration due to the excess of bromine. The liquid is submitted to distillation as soon as

In the London Mint a new shape of cupel is employed, which holds four charges at once, being rectangular and having four depressions, one in each corner. Considerable attention has been paid in the London Mint to the assay of alloys by the spectroscope, and Mr. Roberts, the chemist, was engaged for some time upon experiments on the liquation, fusibility, etc., of alloys of silver and copper; also in the preparation of pure gold and silver trial plates. The results of both investigations are given in detail in the Report of the Deputy Master of the Royal Mint for 1874.

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possible, the first part being rejected, since it contains some bromoform with water. If during the distillation of the hydrobromic acid alliaccous vapors are given off which are persistent, some pure bromine should bo added to the liquid until it is feebly colored by it If the distilled acid gives off an alliaceous odor, bromine should be added until a permanent color is obtained, and then submitted to a second distillation. The first distillation may be carried on until the liquid assumes a syrupy consistence, provided, however, a gas smelling strongly of garlic is not produced before this moment. Hydrobromic acid thus made remains colorless.

For titration the entire quantity of the distilled hydrobromic acid, which should be colorless, is first brought to about 10° B. It keeps much better- than if fuming. Ten c.c. of the acid are placed in a vessel containing 200 c.c, of distilled water, into which a solution of nitrate of silver with no excess of acid is run, care being taken not to add too great an excess.

The cloudy liquid is heated until clear, stirring at the samp, time the bromide of silver with a glass rod, so that no nitrate of silver is retained in it. It is then assumed that all the hydrobromic acid is transformed into bromide of silver. It is then allowed to cool, and when the liquid containing the bromine is clear it is decanted, and the residue washed as long as the water contains any silver. The bromide of silver is then dried at 100 c.c., and weighed in a vessel of known weight. This result gives us the necessary data for making a normal solution of the acid, so that 100 c.c. will precipitate one grain of silver in the form of bromide. Of course the whole operation must be conducted in a room provided with yellow glass. The pipettes employed all overflow, this style having replaced the old stop-cock arrangement. Mr. Nyst informs me that the above process is much more delicate than the ordinary salt solution, and from the experiments made I should most certainly consider it so, although the salt process is sufficiently accurate for all practical purposes.

DESCRIPTION OF A DOUBLE MUFFLE FURNACE.

DESIGNED FOR THE REDUCTION OF HYDROUS SILICATES CONTAINING COPPER, ETC., LIKE THE SO-CALLED " CLAY ORE " OF JONES'S MINE IN PENNSYLVANIA.

BY PROFESSOR B. SILLIMAN, NEW HAVEN, CONN.

THE experiments detailed by Dr. Hunt,* having demonstrated the fact that the copper contained in the " clay ore " of Jones's Mine, was rendered completely soluble in the bath of ferrous chloride, used in the Hunt and Douglas process, after heating in contact with carbonaceous matter in a close vessel, I set myself to devise a form of muffle furnace adapted to the treatment of large quantities of these and similar ores by a continuous process. The result is shown in the diagrams on Plate X, reduced from the working drawings, after which this furnace was built early in 1876, at Phænixville, by the Chemical Copper Company on their works at this place.

The peculiar character of this ore determined the form, dimensions, and position, with reference to charging and discharging of these muffles. The ore arrived from the mine with from 20 to 25 per cent, of moisture, and when dried at 212° F., or more slowly at lower temperature, it falls to a light incoherent powder, with occasional lumps of undecomposed rock. In this condition it is readily mingled with coal-dust or any like reducing agent, and requires no other preparation for the muffle than the use of the shovel, to mix it well with the reducing agent. As it is a remarkably good non-conductor of heat, it was obvious that the mass, to be heated through in a reasonable time, must not be too thick, while the weight of the mass must be sustained in a way to avoid undue strain upon the walls of the muffle. These walls must be as thin as practicable, to favor the more rapid transmission of heat, and must, therefore, be so constructed as to admit, of being stayed on the sides at frequent intervals to resist the lateral thrust of the very mobile mass of pulverulent ore, which, for obvious reasons, must be charged at the top and drawn from the bottom of each chamber. These considerations led to the form adopted, viz., two vertical muffles, standing upon very strong bridge tiles, seen in longitudinal section, on the line E, F, and in plan in Fig. 3, on the same plane. (Plate X.) The vertical section of the muffle is seen in Fig. 4, drawn in the plane G, H, of the longitudinal section, Fig. 6, which is the key to all sections.

The walls of the muffles are built of the best firebrick, very care-

* See paper by Dr. Hunt, page 325.

fully laid, one course thick (about 4½ inches), and bonded to the surrounding walls at frequent intervals, as seen in Figs. 4 and G. The dimensions of the muffle chambers are each, in height 10 feet, in depth 12 feet, and in width 2 feet, calculated to hold from 14,000 to 15,000 lbs. each of dry ore. This ore, as mined, measures about 33 cubic feet to the miner's ton of 2352 lbs., and by drying suffers very little change of volume, the cubic foot of dry ore weighing about 75 lbs. It was expected that this volume of ore could be treated in from 24 to 36 hours, the chief ground for this expectation being the action of gas retorts, which afforded the nearest known term of comparison. We shall see beyond how far this expectation was realized in actual experience. The fireplace, seen in Figs. 3, 4, and 6, was placed centrally beneath the two muffles, and the course of the heat is clearly indicated by the arrows seen in the several sections, being in the main outward from the fire, and then upward, by way of the outer walls, and downward again between the muffles, whore the current is directed by a horizontal diaphragm seen in longitudinal section, Fig. 6, on the line C, D, compelling the escaping gases toe seek the ascending flue to the drying floors and chimney only after enveloping the whole area of the muffle walls. In this as in all points of detail, I was greatly aided by the long experience of Mr. William Edmondson in building gas furnaces. The effect of this mode of distribution of the heat is all that could be desired, giving a remarkably uniform temperature to all parts of the muffles. The drying floor exposes an area of over 500 square feet of surface, beneath which the heat passes on its way to the chimney, as seen in Fig. 1, the flues being covered by large flat tiles sustained on the dividing Walls, as seen in Fig. 6. Each muffle is provided with two charging-holes, as seen in Fig. 6, covered by an iron plate, perforated with a gas-tube for the escape of gases and vapor of water given off in the process, and serving also as convenient handles for opening the feed-holes. The doors of discharge are seen in Fig. 2, counterpoised and rising in vertical guides, the wagons to receive the reduced ore being placed immediately under the discharge.

The chemical reaction by which in these muffles the copper silicate is reduced to metallic copper is sufficiently simple, and may occur either by the direct action of carbon on the cupric oxide, $C + CuO = CO + Cu$, or by the joint action of hydrocarbon gases and carbonous oxide on the copper oxide producing water and carbon dioxide. Practically it was soon discovered that anthracite-dust alone worked quite too slow, and required by far too high a temperature to be of any economic value, charges thus treated remaining, even after 80 hours' continuous treatment, only partially reduced. The dust of bituminous coal worked much more efficiently, the reduction being quite complete, but the time required being still greatly in excess of what was expected, or indeed requisite, as the result proves. But this mode of treatment was followed for many months, and with excellent results, the reduction being quite complete. With the use of about one-tenth of bituminous coal-dust to the charge of dry ore, the materials being incorporated upon the drying-floor, and about 1500 lbs. of dust to the charge being used, the time consumed in the reduction was about 60 hours. This was too long, reducing the effective result of the muffles in the amount of ore to be treated, and increasing unduly the consumption of fuel in the furnace. Resort was then had to coal-tar, one barrel of which (about 400 lbs.) taking the place of 1500 lbs. of bituminous coal-dust, and completely reducing the charge in about 30 hours, and at a lower temperature than is required with the use of coal-dust. It is easy to see why this should be so. Coal-tar is a liquid hydrocarbon, deprived, in the act of its production from bituminous coal, of all light products, volatile at temperatures much below redness, but capable, at a high temperature, of conversion into heavy hydrocarbon vapors. When coal-tar is commingled, therefore, with the dry ore, and the charge is thrown into the muffles, no chemical action takes place until the mass reaches the temperature of dull redness in the dark (under 500° C.), at which temperature it is known that reduction of even ferric oxides occurs in a stream of hydrocarbon gases. But at this temperature the coal-tar begins to give off vapors abundantly, which, penetrating the already heated mass at the opportune moment, do the work of reduction with rapidity and very thoroughly. With anthracite-dust, charcoal-dust, or dust of coke, the reaction is at first only between the carbon and the oxygen of the ores, and this can happen only at a much higher temperature, and more slowly ; the carbonous oxide formed next reacting with the cupric oxide to form CO_2. With bituminous coal-dust a considerable part of the hydrocarbon gases are given off at a temperature below the reducing point of the copper salt, and are thus practically lost, while the coke remaining acts slowly, for reasons already stated, as well as from its being mechanically in a disadvantageous condition. Hence, the time consumed in effecting the decomposition is, by far, too great, even with bituminoiis coal. But the coal-tar leaves nothing to be desired, and when it is employed the proportion and dimensions of the muffles appear to have been calculated almost exactly for the desired result. Only in the mode of heating them is there room for an important improvement. The use of a gas-producer has been decided on to fill one or both the spaces seen upon the sides of the muffle in Fig. 1, and by this mode of heating a more efficient and economical result may reasonably be expected.* It is proper to add that nine months' continuous use of these muffles has demonstrated their efficiency and economy, as no repairs have been required in the apparatus, and the renewal of the fire-box--which was found in good condition after a nine months' uninterrupted campaign--will be rendered unnecessary by the introduction of a gas-furnace. The beautiful display of burning zinc, with its faint glow of lambent green flames amid the orange glow of the incandescent ore, as the charges were drawn into the wagons, by night, has been described as one of the most beautiful of metallurgical phenomena. This happens, however, only when the temperature is higher than has been found needful in steady working, and near that at which the ore slags. Consequently, it is no longer seen as the process is now conducted. The reduced copper is oxidized at once by the air on drawing the charge, and in this condition it is readily dissolved in the Hunt and Douglas bath. A remarkable change is effected in the texture of the calcined ore, which is thus rendered quite granular and free to the passage of the liquors of the bath, while before heating, and the consequent loss of the water of hydration, it is quite impervious to water and like a clay.

THE USE OF THE MAGNETIC NEEDLE IN SEARCHING FOR MAGNETIC IRON ORE

BY PROF. J. C. SMOCK, OF THE STATE GEOLOGICAL SURVEY OF NEW JERSEY.

THE magnetic and polaric properties of magnetite, or magnetic iron ore. are fundamental facts in magnetism. The disturbing effect of this mineral upon the magnetic needle in land surveying must have been very early observed. The difficulties arising from this source are still almost insurmountable in making accurate surveys in districts where this ore occurs to any extent, either as a rock

* This gas-producer calculated for anthracite pea coal is now ready (October, 1876).

constituent, or in well-defined ore masses. In the Highland range from the Hudson to the Delaware Rivers, the ordinary method of running lines with the compass, is sometimes impossible, and property boundaries are located by well-established landmarks, rather than by the course of the needle. Notwithstanding these well-known facts, the general application of this property of deflection in the needle, by the presence of magnetite, to searches for this mineral, is comparatively of recent date. There are, however, authenticated instances of this use of the magnetic needle more than a century ago. The mining of iron ore in the Highlands began in the early part of the eighteenth century, and the Sterling, Ringwood, Dickerson, Andover, and Oxford Furnace Mines were all worked before the American Revolution. And these, with other old mines of this district, must have been opened shortly after the location of the larger patents and tracts of land, and the settlement of the country. And some of these ore masses were, most probably, discovered through disturbances observed in the action of the needle in making laud surveys. This may have suggested the employment of the compass in searches for ore. Such use of the needle was made by the celebrated London Company, that took up the Ringwood tract. This company surveyed the country with thoroughness and success. And nearly all of the older and larger mines in this Highland belt are commonly reported to have been discovered through the use of the compass, in searches for ore.

The more general use of the magnetic needle for this purpose does not go back more than thirty years. In 1854, when the Geological Survey of New Jersey, under the direction of Dr. William Kitchell, began, the ordinary surveyor's compass was used by a few persons who were sufficiently experienced, or skilled by observation, to properly interpret its indications. At that time the number of large mines was not much greater than at the beginning of the century. The introduction of the miner's or dip compass shortly afterward, made the use of the needle much more convenient and extended, and work with it was done with much greater rapidity and accuracy than formerly. Contemporary with its introduction, began the greater frequency of discoveries, and the opening of many new mines and ore localities, so that this might be taken as an era in iron mining in New Jersey. Dr. Kitchell estimated the amount of iron ore raised in that State, in 1855, at 100,000 tons. In 1864 this had been increased to 264,600 tons, and in 1868 to about 300,000 tous. But the increase in the number of mines, from 1868 to 1874, is most remarkable. In the first-named year there were 115 mines and mine-groups, whereas, in 1874, the number of mines and ore localities had increased to nearly 200 in number.

It may be safely stated that all of these were first made known by the use of the needle. Or in other words, the average annual production of the State had been increased fully fifty per cent, by the addition of these new producing localities found by the compass. So much the iron men owe to this little guide, or *true* divining-rod. It should also be stated, that in many cases there are no surface indications of ore, other than those of the compass.

At the present time, nearly every mine superintendent, and many landowners, have their dip compasses, and, as opportunity offers, go out in search of new lines of attraction. A few persons follow this business as a specialty, and open mines and deal in mineral properties. They are known as " ore hunters," or " prospectors," or " mineral dealers." For several years preceding the panic of 1873, the increasing demand for ore stimulated the search for new supplies, and many lines of attraction were found, and nearly every farm in this long belt was covered by a mineral lease.

Magnetism of Minerals and Rocks.--Magnetite is not, however, the only mineral which may disturb the needle and exhibit the deflection from the plane of the magnetic meridian termed *attraction.* Nor is this phenomenon of deflection confined to rocks containing this mineral. A large number of minerals are capable of producing slight deflection when they are brought near the needle. Serpentine, amphibole, pyroxene, hematite, and franklinite are some of the more powerful of these in their effects upon the magnetic needle. Many rocks also show some magnetism, particularly the darker-colored and more dense, igneous and volcanic rocks. This applies to the rock in masses as well as in hand specimens. In nearly all cases the magnetic disturbance is increased by heating to fusion or by oxidation. Probably in all these cases the magnetism is closely related to the presence or formation of both ferrous and ferric oxides in the mineral or rock species. Many of these exhibit polarity as well as magnetism. The greater intensity of this disturbing force in rocks and ores near the surface may be thus explained by an oxidation process through the agency of atmospheric forces. For a full statement of this subject of magnetism of minerals see an article by H. Tasche in *Jahrbuch der Kaiserlich-Königlichen Geologischen Reiclisanstalt,* VIII, Jahrgang, 1857. These phenomena observed in other minerals are interesting, but not of so great practical importance, since the experiment made with delicate instruments rarely showed more than two degrees of deflection, and practically they may be neglected. Very accurate and detailed magnetic surveys will yet be needed to embrace these elements in their range of work, and these elements will have to be eliminated to get at the correct indications coming from magnetite alone. Several lines of attraction observed in New Jersey, as yet unexplained, may be owing to the presence of strata containing these minerals, but it is very doubtful.

In practice, the attraction is to be referred to the near presence of magnetic iron ore, although the converse is not always correct, since there is a great range in the magnetic intensity exerted by ores, and some are so slightly magnetic that the deflection is perceptible only when the experiments are made with extreme care. Thus it is possible to pass with a dip compass right over large veins of ore, and yet fail to discover any attraction. Slight attractions over large and well-known veins are common in New Jersey. But careful surveys will generally reveal the disturbing effect and indicate ore. On the other hand, strongly magnetic and polaric ores are also common. In some instances the attraction is felt powerfully through wide intervals of rock or dirt or air. Hence no conclusions can be safely drawn from the amount of deflection or the magnetic intensity. These differences in the ore render the work of observation in some localities extremely easy, while in others there is need of repeated work, and that done slowly and cautiously.

As a rule the surface ores are most thoroughly magnetic, and this fact makes the survey of unexplored ground more easy. This difference between surface and bottom ores can be seen at almost any mine in this region.

Geological Occurrence of Magnetite, in New Jersey.--The magnetite, as is well known, in this highland range, occurs either as a constituent of the rock strata, or in lenticular masses, imbedded between strata of rocks or walls. These ore bodies, in nearly every instance, have their shoots or longer axes in northeast and southwest lines, descending or pitching to the northeast, and they dip toward the southeast, and generally at steep angles. They may, therefore be considered as approximately lying in the magnetic meridian and in a position to be influenced by terrestrial magnetism. Such an ore body would therefore have one pole at the uplifted or southwest end, while the other would be depressed beneath the surface toward the northeast. And the former ought to attract the north or positive pole of the magnetic needle, giving what is termed positive attraction, while the other end would exhibit a negative attraction. Or we may look at the two sides of this flattened, cylindrical ore body, the northwest and southeast, as poles, in which cases the former would give a negative, the latter a positive attraction. And experiments everywhere show these to be the results, just as here predicted of them.

But these ore masses or veins do not all trend in the above stated general or prevalent direction. Sometimes their course is from east to west or approximately such, while in other instances the trend or strike is more nearly north and south.

In the east and west strike the two sides of the vein constitute the poles, and of course such lines are necessarily short, and the magnetism feeble. The more nearly the axis of the shoots of ore or vein corresponds to the magnetic axis, other things being equal, the stronger the magnetism and the more clearly the line and character of the attraction.

From these general statements it will be evident that positive attraction will be most commonly observed, the northeast end being too deeply buried to exert any measurable effect upon the compass at the surface, and as a rule the attraction diminishes toward the northeast until it is gradually lost. But from the geological structure of this region it is well known that these veins are very frequently broken by faults or consist of separate shoots, lying in a general northeast and southwest direction. In each of these cases there are a series of ore masses, and the opposite ends of these must show opposite kinds of attraction.

Hence, where there is a fault, and at the interval between two distinct shoots, both positive and negative attraction will be observed within short distances. On the south side it will be negative, on the north positive. Hence, a change from positive to negative entirely across the vein indicates a fault. Such transitions are common, and when met with the projector understands it to be a fault, or offset. It is possible, therefore, *a priori,* to predicate the character of the attraction, if we have given the mode of occurrence of the ore. And from these the converse reasoning is safe, and practice, repeated in hundreds of cases in mining in New Jersey, has proved the correctness of these deductions.

Styles of Compass.--Formerly the ordinary pocket box-compass, in which the needle is horizontal, was used in searching for attraction, the observer holding it in his hand and noting from point to point the amount of deflection from the magnetic meridian. Sometimes, and where a more careful survey was required, the land surveyor's compass was used, and then lines were run back and forth, across the course of the vein, sighting ahead and noting from point to point in these lines the bearing of the object toward which the .line was directed. When these lines were properly located, and the points of observation fixed, and the several observations on them recorded, good work was done. But it was necessarily slow, as each observation required some time, particularly if the attraction was slight.

About ten years ago the miners', or dip-compass, was introduced. This has its needle balanced on a horizontal axis, and free to move in a vertical plane only. In the most common form this is from two to four inches in length and is shut in a flat, circular brass box with glass sides, in some cases open, in more improved forms protected by movable brass plates or covers, which are taken off while in use. This style of compass has superseded the horizontal surveyor's instrument, and has come into very general use. It is often called the dipping-needle or dip-compass.

As in this form the needle cannot move horizontally, care must always be taken to ascertain the magnetic meridian, and to hold the instrument in the plane of that meridian, otherwise the needle, under the influence of terrestrial magnetism alone, will assume an inclined or vertical position, and thus show a dip, or attraction, where, in reality, there is none. Neglect of this precaution has misled many an observer, and intentional disregard of it has very frequently deceived the ignorant or unsuspecting. The extent to which deception in this manner has been practiced is hardly conceivable by those unacquainted with the magnetic iron ore districts of the Highlands.

In Sweden, a miner's compass, having its needle mounted upon a pivotal joint, which allows of motion, both vertically and horizontally, and inclosed in a glass sphere, or cylindrical brass case, has been used in ore searches. But there is objection to this form in the unsteadiness of the needle, which has so much play that more time is requisite in making observations with it.

A newer form, designed by Prof. Cook, of the State Geological Survey of New Jersey, about five years ago, and constructed by W. & L. E. Gurley, of Troy, removes the objection in the Swedish compass, by allowing the needle, which is balanced on its horizontal axis, to move horizontally through a small fraction of a great circle. This, therefore, shows the magnetic meridian much more quickly than the Swedish instrument; and then, if there be any attraction, it is manifested in the dip, avoiding any possible danger of deception, through the action of the earth's magnetism upon a needle not placed in the magnetic meridian. This most improved compass has its movable brass sides for safety in carrying, and the ordinary ring set in the brass edge, whereby to hold it. The graduated circle is the same as in the old form. Those who have had much experience in magnetic surveys, give the preference to this compass, as the most accurate, convenient, and most efficient, either for rapid preliminary observations, or for detailed exploration.

In use, the compass is generally held about on a level with the eye of the observer, or so that, he can conveniently watch the movement of the needle, and read off the graduated circles the amount of dip. After some experience great dexterity is acquired, and from the vibrations, the experienced eye can readily detect what will probably be the character and the amount of the dip, or attraction. Such an observer may move along on a slow walk and observe, or, as it is technically termed, *catch* the attraction, if there be any in the course he may follow.

Surveys.--In a preliminary survey of any given tract, the usual practice is to go rather rapidly on zigzag lines, from northwest to southeast; or, if attraction be known, or found at any given point, to walk northeastward and south westward from that point, following on the supposed, or assumed course of the ore, and thus ascertaining its longitudinal extent. This gives the general direction and length of the line, or belt of attraction. This preliminary survey does not generally require more than a single line of observations, and these are not located or recorded, excepting so far as the observer may refer them, in his memory, to any landmarks that may be prominent or convenient for further observations.

Detailed surveys, or what may be properly termed "magnetic surveys," may be more or less varied, according as the nature of the attraction may seem to require a greater or less number of observations within a given area.

In general, the most convenient and most expeditious method, and, at the same time, that which is best suited to show the character of the attraction or observations, consists in taking observations on lines at right angles to the course of the vein, or across the belt or line of attraction. "Where the prevailing course, or strike, is northeast and southwest, as in the Highlands, these should be northwest and southeast lines. Of course, they may be at greater or less distances apart, according as the nature of the attraction may indirate, or the degree of detail demanded in the survey. In general, they may be from 50 to 200 feet apart, or, in exceptional cases, as close as 20 feet. The stations, or points of observation in these lines, may likewise be at varying distances, from five to twenty-five feet apart. Ten feet has been found to be convenient, and sufficiently close for careful and valuable surveys. Such detailed observations, to be of value, must be located and recorded; or, in other words, mapped. For this purpose it is easier to run parallel lines, or such as are approximately so, and make the observations at regular intervals.

Stakes may be driven at the ends of these, and a subsequent survey may be made to locate them. The observed dips, or the amount of attraction, can then be placed at fixed intervals on these lines. Such a method is much more expeditious than a far more detailed survey at *irregular* points. While a great deal of work has been done by the numerous prospectors in this iron ore district, and large areas have been covered by a network of closely placed observations, very little work has been recorded on maps.

Geological Survey of New Jersey.--The geological survey of New Jersey has traced out some lines of attraction, and placed them upon record--upon geological maps--but these do not show the character or the amount of attraction. The scale of these maps is too small for the exhibition of these facts. Three sketch-maps, but of limited areas, giving the observations and their location, appeared in the "annual report for the year 1873." These were on a scale of 80 feet to an inch. In these the dots represent the stations, and the figures the observed amount of attraction, the minus sign indicating a negative attraction, and the figures alone, positive attraction.

During the past summer the Green Pond Iron Mining Company had a magnetic survey made of its large tract of 600 acres of mineral land, in Morris County, about 15 miles South of Dover, N. J. This was crossed in a preliminary survey by lines 200 feet apart, running northwest and southeast, and then the areas, where over 5° of attraction were observed, were covered by lines 50 feet apart, with observations at intervals of 15 feet. This map shows three separate lines or belts of attraction which trend north 54° east (referred to true meridian). The openings on one of these lines have been such as to expose a large *vein* of ore, or rather a long line of *shoots* of ore.

Deductions from Indications.--Having made such a survey, we are very naturally asked what inferences follow certain indications or what are such surveys worth ? The diversity in the character of lines of attraction may be very great, almost as varied as the possible arrangement of the stations, but certain general characters are recognized as indicative of corresponding occurrences of ore beneath, and all the varied phenomena may be classified in a few groups, described by a few generalizations.

The line of attraction may be long and steady or regular, that is, there may be a line of maxima dips, from which, toward either side, these diminish and at length disappear; and these maxima may correspond more or less closely in amount as well as in location. Such a line indicates regularity below, either in the form of an ore vein or a series of stratified ore-bearing rocks, of nearly homogeneous character throughout. Conversely, if in the line the attraction be irregular in amount, very strong in close juxtaposition with slight or weak attraction, or if the maxima in the several parallel lines which cross the vein, are not in line, but varying from side to side or in amount, on one slight, on the next strong, etc., such indications show irregularity in the occurrence of the ore.

Generally such very irregular attraction is found wherever magnetite occurs as an inconstant and accessory mineral constituent of unstratified, granitic, or syenitic rock masses. Inasmuch as the attraction in such places is apt to be very strong, frequently holding the needle vertically, it is likely to mislead the ore hunter, and many instances of fruitless work in digging and shafting for ore on such attractions have been observed in New Jersey. Popularly a few strong observations far outweigh the longer lines of constant but slight dips. But there is a variation in the character as well as in the amount of the dip, that is, the dip or attraction is sometimes positive and sometimes negative. And here, too, the transitions from the one to the other may be very sudden, and frequently recurring within limited areas.

From what was stated at the outset, positive attractions would be anticipated as the predominant character, prevailing along the whole line, excepting on the northwest side, and in those cases where the ore may not be continuous, either on account of faulting or in consequence of its occurrence in separate shoots, lying *en echelon* in the general course of the vein. In these a negative attraction would be anticipated, and this is found to be the case. And hence such transitions from positive to negative are indications of breaks in the ore mass, faults or separate ore-shoots. Repeated observations over faults prove this.

Conclusions.--This method of examining ground for magnetic iron ore is so well understood and so extensively practiced in New Jersey, that such a description is hardly more than a statement of facts there gathered.

In the further extension of such surveys, greater care is requisite both in the manner of taking observations and in recording them upon carefully constructed maps. Hereafter more attention must be paid to the slighter attractions and to the regular work of accurately mapping them. Such care is necessary, not only to discover new lines, but also to so ascertain the character of known ones as to enable the miner to locate properly his trial pits and shafts. And it appears proper to put this before the attention of mining engineers and geologists, wherever there are magnetite iron ores, since careful preliminary works with the magnetic needle may in other States as well as in New Jersey, largely increase the number of localities whence our supplies of ore may be drawn.

THE MANUFACTURE OF FERRO-MANGANESE IN GEORGIA.

BY WILLARD P. WARD, CARTERSVILLE, GEORGIA.

IT is the object of the present paper to bring to the notice of members of this Institute, the results of experiments made during the past six months in the manufacture of the alloys of iron and manganese in the blast furnace. The ores at hand and available for the purpose were brown hematites, containing but a very small percentage of manganese, and various manganese ores containing a small percentage of iron.

It is hardly necessary here to call attention to the statements regarding the production of iron-manganese alloys from such ores, which are given by all the well-recognized authorities on metallurgy. Suffice it to say, in a few words, that they hold that the operation is practically impossible, and that in the use of oxides of iron and manganese, mechanically intermixed in the same ore, much difficulty has been found in producing spiegeleisen. Spathic ores, containing manganese chemically combined, are alone recommended for the production of spiegel, and even then it is said that well-managed furnaces produce only about 75 to 80 per cent, of spiegel, the balance of the production being white laminated pig or gray iron.

The first experiment, which was made in July last, resulted in the production of gray iron, which contained 8 to 10 per cent. of manganese; but as this was not the product desired, and as there was no literature on the subject showing that such iron could be used in the Bessemer process, this trial was regarded as a failure, and the furnace continued in blast, making gray iron till August, no manganese ores being used. The next experiment resulted in the production of white iron, containing 6 to 7 per cent, of manganese, but too much phosphorus (0.75 per cent.) to be available for Bessemer purposes. Up to that time I had supposed that phosphorus might bo eliminated in the furnace in the presence of considerable amounts of manganese. One reason for *my* entertaining such a notion was the comparison of the analyses of the spiegeleisen of the Müsen Company, and the ores from which it was made; the former by Fresenius and the other by Peters. The spiegel contained 0.059 per cent, of phosphorus and the ore 0.50 per cent. When it was found that no such elimination of phosphorus took place, but that, as usual in the smelting of iron ores, all the phosphorus contained in the charge made its appearance in the metal, ores from other banks, containing less phosphorus, were employed, and the result was the production of spiegel iron containing about the same percentage of manganese as the last, and only 0.12 to 0.15 per cent. of phosphorus. For about two months the furnace was worked on nearly the same burden, and nothing but spiegeleisen of slightly varying composition was produced. At times the percentage of manganese in the charge was increased, and resulted in the production of a higher grade of spiegel for a few days, but at the end of that time the furnace would begin to work badly, and the old charge would be resumed. A number of trials all resulted in the same way, apparently proving the statement of Kerl : " By a considerable excess of manganese oxides in the charge, a white iron is produced containing less carbon, less hard, and more infusible, without any increase in the percentage of manganese."

About the first of October I determined to make a new experiment with more manganese ore and a much lighter burden than any that I had hitherto employed. This resulted in the production of an iron containing 18 to 20 per cent. of manganese.

From this time on, the proportion of iron ore employed was gradually diminished, and the manganese ore slightly increased; by which means, when the constituents to form a proper cinder were present in the charge, alloys containing as high as 60 per cent. and over have been produced. But the proportion of fuel employed to the metal produced was so large that a hot blast was erected and put in operation, by the use of which, and the employment of a mixture of coke and charcoal in the place of charcoal, considerable economy resulted, and the production was increased.

The following is an analysis of ferromanganese made at Diamond Furnace, Cartersville, Georgia, by Dr. O. Wuth.

Manganese (metal),	55.22
Silicium,	031
Phosphorus,	.471
Slug	26.58

THE EFFECT OF MANGANESE IN BESSEMER METAL.

BY DR. AUGUST WENDEL, TROY, N. T.

IT is a well-known fact to all Bessemer steel manufacturers using a blooming mill, that ingots show large cracks in the first few passes of the rolls, which, in the following ones, do not always roll up satisfactorily.

This deficiency in the quality of the product is generally called " red-shortness," though, in the writer's opinion, mostly unjustly so. Different explanations for the said peculiarity are given by the leading authorities, each works selecting one element as a special scapegoat for the inferior quality of the ingot. The sulphur is generally first charged as being the principal cause of all mischief in this direction ; then, after ascertaining that sulphur is not higher than the average, and sometimes lower in the very worst heats, silicon has to bear its share of abuse. How and why silicon should affect the working qualities of the metal, the writer could never precisely learn, but is convinced that the doctrine of its pernicious influence is an established one with many.

In cases where silicon failed to explain everything, resort was taken to calcium, aluminum, and some other known or unknown elements, without settling the difficulty; and lastly, when the skill of the chemist became exhausted, " practical men " came to the same conclusion, which many leading blast-furnace managers had arrived at before, that analytical chemistry was good for nothing, but to disagreeably hamper the flight of their imaginations. The trouble did not rest, however, entirely with the chemist, but with those who rather too hastily jumped at conclusions derived from his results.

Before making a few remarks on this subject, I would like to state that I do not propose to discuss anything about red-shortness, legitimately so termed, but about the conditions necessary to allow the Bessemer ingots to stand the strain of the two first grooves in the blooming mill, the absence of which quality the writer may term "want of body," no other appellation being known to him.

Every steel manufacturer knows that steel, rolling very badly in blooming, may be hammered to perfection, and, therefore, the mechanical test cannot be consistently taken as a criterion for its rolling qualities. Real red-shortness, however, will show sooner or later in the material, no matter how worked. The conditions favorable to prevent this " want of body," are apparently due to the right proportion of carbon, silicon, and phosphorus to manganese, other conditions being equal; and the necessity of keeping this proportion within the proper limits, seems to increase with the increased size of ingots. From many analyses made, both of good and bad steel, I came to the invariable conclusion, that with steel Laving little phosphorus, in order to give certain satisfaction, the coefficient $\frac{Mn}{C+\frac{1}{2}Si}$ was larger than 0.8; and, with such as worked doubtfully or badly, it was smaller than this fraction, meaning, by the symbols, the respective percentages of the elements, carbon, silicon, and manganese, as estimated by the analysis of the steel.

This assumption may seem arbitrary, and the small quantity of manganese in the product may be considered only indicative, that there was not sufficient manganese present for the complete deoxidation of the metal; but, on the contrary, the writer claims that a certain surplus of manganese must be present as a constitutional element of metal intended for blooming. This latter assertion may easily be reconciled with the many observations of those who feared the bad influence of silicon on the quality. Those heats that contained silicon to a considerable degree, were generally blown rather short, and consequently contained not only silicon, but proportionately more carbon than they should have according to this coefficient, especially if at the same time the Spiegel had lost an unusual amount of manganese in melting.

Hot heats, that are liable to be blown too short, come mostly in this category, and this led to the opinion that the highly silicious irons were more likely to produce this want of body, a defect which may be easily remedied by blowing sufficiently, that is, removing both silicon and carbon as much as possible, before recarburization. This explains why steel from hot heats almost invariably rolls badly when blown too short, but I have seen a most excellent quality of steel from heats excessively hot.

A theory about the beneficial influence of the manganese in preventing the want of body may not be necessary, as the remarks in this paper are entirely empirical. But, I am inclined to assume that manganese combines with carbon and silicon in certain proportions in lieu of iron, thereby changing the constitution of the metal, although such a statement may seem very heterodox in view of the preponderance of iron present.

The second and more important part of these considerations, is the influence of phosphorus on the want of body. It is a well-known fact, that phosphorus does not increase the red-shortness of steel or wrought-iron, and that, on the contrary, many metallurgists claim that the bad effects of sulphur are counteracted or modified by the presence of phosphorus. But the writer is clearly convinced, that this dictum cannot be applied to Bessemer metal rolled in a blooming mill.

Some time ago, Bessemer steel came under the writer's observation, of which the analysis showed the following composition :

Carbon, ...	0.28	0.29	030
Manganese, ...	0.907	0.837	0.925
Phosphorus, ...	0.524	0.498	0.513
Sulphur, ...	0.088	0.086	0.084

I only give the analysis of three heats, as sufficient to represent the composition of others, whose working qualities were the same. This metal showed less sulphur than the average then manufactured ; the quantity of manganese was more than sufficient to neutralize both carbon and silicon, and still the ingots crumbled up under the rolls, and most of them had to be taken from the tables in many pieces after a few passes. Both low and high heats were tried, but either way it was impossible to roll the ingots without disintegrating them. This steel showed only a very slight reaction, if any, in the vessel on recarburization ; and looked, when poured into the moulds, exactly like decarburized, or rather, unmanganized metal. The only explanation for this strange behavior might be that the Spiegel used on this occasion, contained little or no manganese. That this was not the case both the analysis of the Spiegel, containing about 11 per cent., and of the steel, subsequently showed.

The percentage of phosphorus in this instance was excessive, but afterwards I was fortunate enough to observe a similar bad run of steel with phosphorus as low as 0.20 per cent. Now phosphorus by itself does not impart such peculiarities to iron as those described above, and the only way to escape from this dilemma was to take for granted a large affinity of phosphorus and manganese at the temperature of the molten metal, both combining to some kind of phosphide of manganese in the act of recarburization ; so that manganese instead of combining with the oxygen of the bath, combines with the phosphorus present, partly or entirely, and so becomes rather paralyzed in its proper sphere. The fact of the manganese percentage being unusually high rather strengthens this opinion, inasmuch as the manganese, by simply combining with phosphorus, will not show any decrease of quantity otherwise produced by the oxidation of this metal. An explanation like the one given may be contrary to the traditional notions concerning the affinity of elements, but it must be doubted whether the affinities have been much studied at temperatures and under conditions such as those we arc concerned with at present. Is it not just as unlikely that gas-bubbles should be retained in a molten metal where such a high temperature ought to give them a high degree of tension ? And still they stick, to the great discomfiture of Bessemer men. It seems to be much less of an improbability that manganese should combine with phosphorus in preference to oxygen, which fact, if it be one, may become just as disagreeable to the manufacturer.

I purposely refrain from giving any formulæ of polycarburets and polyphosphides, which, hypothetical as they always must be, would have to be made probable by synthetic experiments outside of the compass of this paper. Smaller quantities of phosphorous of course could not paralyze the deoxidizing influence of manganese, but will do so to a certain degree *as* observed by me.

In order to overcome the bad influence of phosphorus in the rolling of Bessemer ingots, I would suggest that the percentage of manganese in the steel should be four times as large as that of phosphorus, in addition to the quantity required for the neutralization of carbon and silicon, according to the coefficient given above. The proportions given by me may need modification, but they certainly do not yield a larger percentage of manganese than required, if the manufacturer, desires to be safe. This would not exclude the possibility that sometimes steel with smaller percentages of manganese may roll tolerably well. I need hardly say that steel made from manganiferous irons by blowing short and without recarburization does not come under these considerations.

As an illustration of my theory I must add a few remarks about the irregular working of different heats made from the same irons and blown with the same care. It must have puzzled every manufacturer to find that a very bad blow is sometimes made between two excellent ones. This led the writer first to the opinion that not the absolute qualities of one or more elements in the iron, but rather some relative proportions of elements changeable in conversion, influence the working of the metal.

There are two kinds of bad heats which prominently present themselves in this connection. In the first place the bad rolling heat does not show any abnormal carbon percentage, it being the average, and still the ingots break badly at the rolls. In that ease the manganese percentage is low, which is easily accounted for by an excessive loss of manganese in melting the Spiegel.

The second kind shows a percentage of carbon much lower than the average, which is explained by the fact that the heat in question did not get the requisite amount of Spiegel, by carelessness or otherwise. Now as the carbon in this case varies with the manganese percentage, the latter must be high enough to neutralize the carbon, but in most cases it is not high enough to counteract phosphorus. The steel, with some mixtures, will roll to perfection with low carbons. What mixtures will do it? Those low in phosphorus.

The moral from this is easily drawn. If you cannot reduce your phosphorus, take care to keep your manganese as high as possible.

Before attempting to utilize, for Bessemer works, irons with P. higher percentage of phosphorus than has hitherto been allowed, it would be well to investigate whether the quantity of manganese necessary to insure the good rolling of the ingot does not impart too much brittleness to the product when cold; and, according to results obtained, the manganese must be kept to the required limits.

The statement of the Terre-Noire authorities, that one part of phosphorus imparts to the metal a hardness equal to two parts of carbon, seems to be rather preposterous. According to this statement, some iron rails would compare very favorably with those of steel in wear, and still they show more wear, excluding lamination.

Phosphorus cannot be substituted for carbon, but the manganese combines with phosphorus and renders the metal hard and stiff, just as carbon would do. This is the reason why phosphorus steel with little carbon is hard, but it would be simply cold short with an insufficient quantity of manganese. In the first place the metal is a phosphor-manganese steel; in the second, a carbon-manganese steel, with phosphorus. Open-hearth manufacturers have better opportunities to obtain a varying quantity of elements in their product than Bessemer people, who are somewhat hampered by being forced to introduce too large quantities of manganese, in order to give body to their ingots for reasons sufficiently explained; and therefore, from them, we have to expect important developments in iron metallurgy. In order not to get confused on the terms hardness, brittleness, cold-shortness, etc., which are used promiscuously by many theorists, according to their several predilections, I will now conclude this paper, and leave it to the United States Test Commission to investigate how the varying relative proportion of elements influence the strength of the material.

THE CEDAR POINT IRON COMPANY'S FURNACE, NO. 1 *AT PORT HENRY, ESSEX COUNTY, N. Y.*

BY T. F. WITHERBEE, PORT HENRY, N. Y.

IT is proposed to *give, first,* a description of the works; *second,* a report of the first six months of the present blast; and *third,* such improvements as have been suggested by the practical working.

The site selected for this furnace was, at the time of commencing work, October, 1872, entirely covered by the navigable waters of Lake Champlain. A coffer-dam was first built of cribs of round timber filled with stone, forming three sides, while the shore answered for the fourth. Considerable excavating was done with a steam-dredge, a hole being left for it to pass out. The opening was then built up, and the cribbing banked up with blue clay from the bottom of the lake, to render it water-tight and the clam pumped out; the remainder of the excavating being done by hand. All of the foundations, with the exception of the elevator-tower, and fifteen feet of the east side of hot blast, rest on the Potsdam sandstone, which forms the shore line, dipping into the lake at an angle of fifteen degrees.

Owing to jogs in the formation, a much greater depth was found necessary than was at first anticipated, the foundation under the stack being 35 feet square at bottom, by 30 at top, and 40 feet high of solid cement stone masonry, with 5 feet of firebrick on top of that—making a total height of 45 feet.

The hot-blast foundation is 55 feet square by 35 feet high, of dry masonry, with the exception of 7 feet of the top, laid in cement, and containing the hot-blast gas and chimney flues.

The engine and boiler foundations are not so high, being nearer the shore. Altogether, nearly 40,000 perches of stone masonry were required in foundations.

The stack is 70 feet high by 27 feet diameter at mantles, tapering from that point to 7 feet 3 inches from tunnel-head, where it is 22½ feet diameter, flaring from thence to top, to same diameter as at mantles. The, boiler-plate shell rests on heavy cast-iron mantles, which are in turn supported by six cast-iron columns.

The weight of cast-iron in foundation is as follows: 6 base plates, 12 tons; 6 columns, 18 tons; 6 caps, 9 tons; 6 mantles, 36 tons. Total, 75 tons. Thickness of shell, first course, ½ inch, the remainder, 5/16th inches. The stack, as at present lined up is 16 feet bosh ; 13 1/2 feet under bell at top ; crncible, 5½ feet diameter, by 7 feet high, at commencement of bosh, incased with galvanized wrought-iron water-boxes, up to within 12 inches of tuyere arches, and 1 foot below bottom of hearth; angle, of bosh, 71 degrees; closed hearth, with the Lürmann cinder-block in two places, taking cinder out on the east side.

Cubic contents of stack as follows:

Shaft, G509 cubic feet; bosh, 1764; crucible, 166 ; total, 8439.

Tunnel-head is closed by an ordinary bell and hopper, handled by a pneumatic cylinder. Diameter of bell 7½ feet.

The casting-house is of brick, 112 feet long by 60 feet wide by 20 feet high at the caves, covered with a galvanized corrugated iron roof. It extends past the stack to the first two stoves, which form the south end of it, leaving a space available for pig-beds of only 60 by 60 feet—too short by 30 feet at least. The gases are conveyed down by a firebrick lined wrought-iron flue 6 feet 3 inches in diameter, from which branches 4 feet in diameter lead to the boilers and hot-blast stoves. Each branch has a butterfly valve to shut off or regulate the flow of gas. As a precaution against explosions, the flues have four 30-inch safety valves and one safety cover, 38 inches square, besides boiler doors and explosion-valves on the stoves.

The boiler-house is of brick, 66 feet long by 72 feet wide, with iron roof, and contains boiler capacity sufficient for two furnaces, consisting of eight boilers, each 55 feet long and 5 feet in diameter, connected together two and two by transverse mud-drums 10½ feet long by 5 feet diameter, and also by steam-drums 9 feet long by 4 feet diameter,

Iron in shells 3/8 inches thick, and in heads ½ inch, of Bay State C. No. 1. Each set has grate-surface 5 feet by 11 feet for direct firing; two, four, six, or eight can be used, as required. By a system of air-passages in the walls, the gas is supplied with highly heated air for combustion.

A large brick flue runs across the west end of boilers, connecting them to a wrought-iron firebrick-lined chimney, 115 feet high by 8 feet 7 inches at bottom and 6 feet at top. The draft of each set is controlled by a butterfly damper. Each steam drum has one 6-inch Richardson safety valve, set to blow off at 60 pounds. A long copper "goose neck" pipe connects each drum to an 18-inch wrought-iron steam-pipe, 105 feet long, which conveys the steam to the blowing engine and pumps.

The blowing engine is a side lever condensing one, built by Henry G. Morris, Philadelphia, Pa., and is of the following dimensions: Steam-cylinder, 60 inches diameter; blast-cylinder, 100 inches diameter, each 8 feet stroke; capacity of blast-cylinder, 872 cubic feet per revolution. Two fly-wheels weigh 23 tons each. Two side levers 11 tons each. Two cross-heads 2¼ tons each, of Bessemer steel. Diameter of main shaft and beam centre 18 inches. By means of an adjustable cut-off, steam can be made to follow to 7/8, or cut off at ¼ stroke. The condenser draws its water from a well in the basement of enginer-room, which is supplied from the lake The engine-house is of brick, 66 feet long, by 60 feet wide, by 32 feet high at the eaves, and is covered by a slate roof, on top of which is a cupola for the admission of air to the engine.

The engine-house is calculated for two engines; the place intended for the second one is now used *as* a machine-shop. The pumps are in the basement of engine-room, and draw water from the lake through a 16-inch cast-iron pipe, and also through a timber sluice-way, 24 inches square, in which the 16-inch pipe is laid. Two direct acting Knowles's pumps supply the tuyeres and hot-blast stoves with water. Steam-cylinders 24 inches, and water-cylinders 16 inches diameter by 24 inches stroke ; capacity of water-cylinders, 20 gallous per stroke. The water is delivered direct to stoves and tuyeres by a 4-inch pipe, and also to a wronght-iron tank in the boiler-house, 51 feet 9 inches long by 8 feet diameter, with a standpipe 7 feet diameter by 24 feet 6 inches high, the whole holding about 25,000 gallons. From this tank, water is also conveyed to stoves and tuyeres by a 4-inch pipe, connecting, finally, with the one mentioned as leading directly from the pumps, making a complete circuit. All of the pipes run uncovered in the open air, and are kept from freezing by pumping water from the hot well, when required. The speed of the pumps is controlled by a Fitts's governor-valve, worked by a tank and float placed on the second floor of the engine-room, and at same height as overflow in main tank. Should the water fall below a certain point, an alarm whistle would be blown, and call the attention of the engineer to the fact. One of the pumps exhausts into the condenser of the blowing-engine, while the other has a Craig & Brevoort condenser. Both can be run non-condensing, if required. The two feed-pumps are also in the basement, and consist of one letter A, and one 10 by 6 by 18 inches, Knowles's mining pumps. Water is taken from the hot well, and also from main water-pipe and tank.

An important improvement, suggested by Mr. George H. Reynolds, of New York, is applied in connection with the introduction of the feed-water. As originally planned, it entered the side of the mud-drum, and rose through the connecting nozzle up into the boiler, spreading over the bottom on account of its greater specific gravity. The improvement consists of putting into the nozzle a light sheet-iron pipe, to carry the water up to the bottom of the lower gauge-cock, thus securing the advantages of top feed.

The Taws & Hartman Pneumatic Elevator was built by the Delamater Iron Works, New York. Cylinder 36 inches diameter by 74 feet 2 inches stroke, working a 4-barrow platform, two going up on either side of the cylinder at once. The usual safety devices are applied; four ¾-inch steel wire ropes connect the piston to the platform. The elevator also works a car on an inclined plane to bring up the coal and flux from the wharf to the level of the scale-house.

Blast for operating the hoist is usually taken from the main engine, but can be supplied by a Knowles's direct-acting blowing engine, with 14-inch steam and 30-inch air-cylinder by 36-inch stroke. This engine was put in principally to furnish *cold,* and consequently, *dry* air, in extremely cold weather, and thus prevent the hoist from freezing up.

Four Whitwell firebrick stoves heat the blast; each stove is 29½ feet high by 22 feet in diameter, with about 11,000 square feet of heating surface. About 525 tons of firebricks were used in lining each stove, besides fire-clay mortar and packing (blast-furnace cinder crushed up).

The blast is carried from the stoves to the furnace by a wronght-iron pipe 46 inches in diameter and 5/16 inch thick, lined with 14 inches of firebrick. This pipe connects with a continuous bustle wind-pipe inside the column, 30 inches in diameter, of wronght-iron, 5/16 inch thick, and lined with 9 inches of firebrick. A wronght-iron chimney 115 feet high, lined with bricks, serves for the four stoves.

Connection is made with the Lake Champlain and Moriah Railroad, and also indirectly with the New York and Canada Railroad by 1200 feet of trestle, built through the lake most of the way, and about 26 feet above the water. The Lake Champlain and Moriah Railroad delivers the ore and most of the flux used at the scale-house doors, direct from the mines and quarries. The coal so far has been delivered by canal-boats on the wharf, but can be received directly from the Delaware and Hudson Canal Company, *via* the New York and Canada Railroad, whose track runs within 50 feet of the works on the west side. The latter road has freighted most of the iron so far. The dock on which coal is stored has a frontage of nearly 500 feet, which will be rapidly extended by the enormous quantity of cinder made.

The stock used at this furnace is as follows, viz.: Spring Mountain and Philadelphia and Reading anthracite coal, containing about 86 per cent, of carbon.

Flux.--White crystalline limestone and magnesian limestone.

Ore.--Witherbees, Sherman & Co.'s new bed magnetic. (Samples of the materials and products are here shown.) The ore is known as *pure* and *lean*. The *pure* contains by analysis, from samples weighing 1½ tons:

Metallic iron,	68.24
Oxygen with the iron,	26.01
Insoluble silicious matter,	4.82
Water,	38
Sulphur,	none.
Phosphorus,	.038
Lime,	14
Magnesia,	none.
Alumina,	.28
Loss and undetermined,	.502
	100.000

The lean ore is a *mechanical* mixture of nearly pure magnetic oxide and pure quartz, the variation from a pure oxide being made up by a silicate of lime and magnesia. It will thus be seen that a rough test for quartz can be made by taking the specific gravity of samples and making the necessary calculations. The specific gravity of the ore is 5.158, and the quartz 2.5785, the ore being almost exactly twice as heavy as the quartz. When a complete chemical analysis cannot be conveniently made, the above method is found useful as a guide to fluxing.

The ore is used in about the following proportions : one-quarter pure and three-quarters lean, which latter quantity is again divided into *chunk* and fine, by dropping it from the cars into screens. The fine, as regards yield of metal, is intermediate between the chunk and pure, and amounts to about one-quarter of the total amount of ore used. All of the coal is used excepting chestnut and smaller sizes, the large lumps being broken. The chunk ore is broken into pieces equal to 4-inch cubes, and flux into 6 inches. The pure ore is mostly fine; that portion which is in lumps is broken more or less, according to its liability to crumble.

The behavior of Champlain ores in the blast-furnace is somewhat peculiar. When fluxed with limestone alone, it is impossible to run on *soft* iron continuously, it being necessary to occasionally run off into *hard,* and clear out the crucible, the cinder also becoming sticky. With a mixture of common and magnesian limestone in proper proportions, No. 1 and No. 2 iron can be made as long as desired. The explanation seems to be this : the magnesian cinder being more refractory, of course requires a higher temperature for its fusion, which happens to be the proper temperature for the production of soft iron, and if it *has* a sticky point, it is at a much higher heat than is often attained in the blast-furnace.

Mr. George W. Jamme, Superintendent of the Crown Point. Iron Company, was the first to use magnesian stone with that object in view, in the Champlain region. Varying amounts of the two fluxes have been used; equal parts of each give the best results; their analyses are as follows, viz.:

	Common Limestone.	Magnesian Stone.
Lime,	53.50	37.00
Magnesia,	51	12.32
Carbonic acid,	42.50	43.39
Insoluble matter,	2.43	2.84
Oxide, iron, and alumina,	52	2.54
Water,	17	.38
Phosphorus,	001	.091
Undetermined and loss,	.369	.569
	100.000	100.000

An attempt is made to form such a cinder as will contain 5 parts base to 4 acid, calculated according to the method proposed by Mr, Kenneth Robertson. After making the proper allowance for the self-fluxing properties of the ores, fuel, and fluxes, the charge requires, of equal parts of the above limestones, the following percentages :

New Bed, Pure,.....8 per cent.	New Bed, Fine,............32.4 per cent.
" Chunk,...6O "	Anthracite coal,........3 "

Cinder taken in equal amounts from 84 consecutive tappings, analyzed as below:

Silica 47.94	Sulphide of calcium,.........1.75
Lime,..................................31.20	Phosphoric acid,..............014 P.06
Magnesia............................4.36	Undetermined and loss,......986
Alumina, ...12.01	
Protoxide iron, ...1.55	100.000
" manganese, ...19	

Blowing In.--The stack was filled from July 30th to August 10th, 1875, and contained, when full, 12 cords of brands to top of bosh, and 6 mixed in from that point up, 166 tons of coal,

Tons.	cwts.	qrs.	lbs.
7	19	32	3common limestone.
7	19	3	23 magnesian "
10	9	3	8 blast-furnace cinder.
25	19	0	12 new bed pure ore.
38	11	2	18 " " loan "

The weight of charge, when full, being 3000 lbs. coal, 2800 lbs. ore, 920 Ibs. stone, all lowered down in tubs, except the lust three rounds, which were dumped by the bell, for the purpose of showing the distribution of the materials. It was then predicted that the bell was too large, which was, for a time, apparently confirmed by the working. The ore and stone were mostly in an annular ring, two feet wide, tight up to the lining.

The furnace was fired August 10th, at 10.43 p. m. Owing to trouble with a drop-valve, blast was not applied until some five hours later than intended--going on at 12.30 P.M., August llth. Two of the stoves were fired with wood for 24 hours previous to the admission of gas, at 1.30 P.M., and also for about one day after, when on gas, after which, burning waste was used to light them through the air-valves, until hot enough to ignite themselves. The first nine days after blast was put on were more instructive than amusing. As soon as the air entered the crucible an unusual leak of gas was noticed, principally through the boshes back of the casing. No particular attention was paid to it, *as* it was supposed it would soon tighten up itself; on the contrary, it slowly increased, and in 24 hours was burning out all around the bottom of the bosh casing, and threatening to burn up the blast conductor and pipes. Water was used from time to time to put out the flame and cool things down, and afforded temporary relief.

Owing to the uncertainty of the behavior of the Whitwell stoves it was intended to *blow in hot,* but, much to our surprise, the first four days indicated the reverse, so the ore charge was not increased until August 15th, when a change took place. By this time the stoves were pouring in a very hot blast, and the furnace soon got much too hot--while the engine was in no condition to supply more blast on account of the dosing with emery it received just before starting. By the 17th, the leakage of gas had become so serious that holes were cut through the bosh-casing to admit water directly to the brickwork, and the blast was shut off for six hours to allow the leaks to seal up; all, however, to no purpose. Two of the stoves were next shut off to cool down the blast. The whole bosh-casing was now at a bright heat, and in some places badly *budded,* although a stream of water was constantly playing upon it. Charging was stopped at 11 o'clock A.M., on the 19th, to let the stock get down 20 or 25 feet in order to lessen the pressure in the boshes, which was not, however, exceeding 4½ lbs. Finally, the blast was taken off at 11.30 P.M., 19th, to save the. columns and wind-pipe from destruction It was not even possible to snuff a tuyere, and a *short,* but by no means *sweet,* blast seemed completed, and orders were given to shut down.

A sleepless night had infused more grit into the writer, and at 6 A.M., 20th, it was decided to try again. Owing to a misunderstanding, the tuyere-pipes had been taken down, so it was 12 M. before a start could be made. As soon as blast went on the gas again appeared, and also two streams of water to meet it. This was kept up for 18 hours, when the leaks perceptibly diminished, and by 12 M., 21st, entirely ceased, and have never since appeared. The water had cooled down the dam, so it was impossible to cast, and all of the iron went out with the cinder.

August 25th, regular castings commenced near the top of the dam, and not until the 31st was the bottom got. As any one knows how a furnace acts when working well, I will only mention some of the minor difficulties encountered and how remedied. The first irregularity noticed was a tendency to alternately *drive* and then *hang back.* This was traced to the manner in which ore was received at the stock pile. Cars were dumped generally near night, then for several hours nothing but *chunk* ore would be charged, followed by all *fine.* The greatest trouble proceeded from the filling from Saturday night until Monday afternoon, during which time a large amount of fine ore would be put in. When it got clown to the boshes, a tightening up would occur, the blast-pressure in exceptional instances going up above 12 lbs. per square inch. Generally a slip would soon take place and the pressure go down to 7 or 8 lbs. A remarkable fact in connection with such working is that no hard iron was made. To remedy the difficulty, screens were put under the trestle, to separate the fine from the chunk, which enables us to ,use the two kinds in regular proportions. Since this was done, November 1st, 1875, but little trouble has been experienced.

The Lümann cinder-block was not adopted at first, as it was thought best to make the usual effort to save the royalty. That was soon found to be a losing game, on account of the tremendous blowing necessary to free the tuyeres from cinder, so the Blast could be shut off, and also to the cooling effect of the escape of so much gas, and unnecessary stoppages. The block was put in during November, 1875, and it is worthy of notice that steam blew off for the first time the same day, and it was soon found necessary to increase the ore charges over 400 lbs., besides the necessary flux. Of course, the cinder-blook added nothing to the carrying capacity of the fuel, but prevented the unnecessary loss of heat, gas, and time attendant upon the old style of working. The expense for cinder-blocks has not been excessive, although nine or ten have been burned out; two were destroyed by carelessness. All the rest have been again made serviceable by tapping in copper plugs. Iron blocks will not stand our cinder. The passage of small quantities of iron through the bronze blocks used is the cause of their failure. We consider theLürmann system a necessity.

Coil-blast tuyeres were first used, but failed to stand. Only two have been burned out fairly, while nineteen have been destroyed by sledging them open. The leaks made in this way are small, so that water would only enter the furnace when blast was off, and they have been used in that condition for two weeks or more. Now we use bronze tuyeres, which cost only about half as much as iron ones, and are much more durable and can always be cleaned, which is not the case with iron.

The most serious trouble we have found to arise from want of room for iron in the crucible; when working regularly it is necessary to cast every four hours, consequently the lost time is increased at least 50 per cent., and the scrap in the same proportion. With a crucible of proper size I think the production per day would increase five to ten tons, as it seems to be merely a question of capacity to melt, reduction and carbonization being far in advance.

The Cedar Point Iron Company was the first to adopt the Whitwcll stoves in this country, and the second to go in blast with them, in fact, *the first* to use them with anthracite. In the practical working of them we would say we have had *absolutely no trouble,* and *much benefit.* With them the furnace is under the most perfect control, much more so than is the case with iron stoves. We have found it very convenient at times to get up an uncommonly high heat; for instance, when the cinder was becoming pasty or black, a little more gas turned to the stoves would invariably regulate the working. Such derangements will generally cure themselves, without any extra attention from the men in charge; when our cinder "sharpens up" we always have more gas than while working hot, the result is, the blast temperature will increase and the normal process be restored. The stoves were cleaned after five and a half months' use, when from two to three barrels of dust were removed. It was nearly all found opposite the second, third, and fourth chimney-doors from the chimney-valve side. It required the labor of three men a half-day to clean each stove, including breaking and remaking the joints of cleaning doors. No cooling down to clean is necessary.

As to the relative (economy, while it is not fair to compare them with iron stoves as to *first cost,* I do not consider it would be very unfavorable to the Whitwell's, providing a really first-class iron plant was erected. No repairs have yet been called for, and no evidence of any required in the near future. I would not recommend less than four stoves to a modern coke or anthracite furnace, on account of stopping off to clean. We work three on gas and one on blast, that is, each stove is six hours on gas and two on blast, which does better than working two and two, as recommended. There is no lack of gas at the stoves or boilers, although at first some coal was burned for fear that something *might* turn up. The temperature has been taken regularly with a Siemens pyrometer, and averages made. It was as follows:

September,..............1336½°	December,....................1398°
October.......................1370°	January,.......................1384°
November,..............1397°	

During August, heats were not taken regularly, and we only know, under the circumstances, it was too high. The highest degree yet shown is 1750°.

Ample opportunity has been afforded to compare the carrying capacity of this furnace with others using anthracite coal, and all Champlain magnetic ores of. almost precisely the same percentage of iron. Without going into particulars we would say it amounts to *many hundred pounds* in our favor. I attribute that mostly to the increased temperature of the blast. I am aware that the utility of "superheated" blast is questioned by an eminent authority, but I consider it one of those things that every furnace-man can best determine for himself *after actual trial.* There is nothing to indicate that our maximum burden is yet reached.

The best carbon duty yet shown is 2.78 according to Mr. Hartman's formula, which, in my opinion, is an uncertain standard for comparison, as it must follow that the more silicious the ore, the higher the carbon *duty ought* to appear. It is generally admitted-that ore, weight for weight, throws more duty upon the furnace than limestone, besides a smaller amount of iron would remain to be carbonized.

I have been often asked about the supposed *fall in temperature* of the blast, from the beginning to the end of a turn, and would say, if the man in charge of the stoves understands his business, and attends to it, the variation ought not to be 50° in two hours; we have never found 30° yet. The whole secret in maintaining an oven heat, lies in getting the combustion well toward the chimney side of the stove, and not heating the first two or three chambers any hotter than the stove is, two-thirds back. We had some difficulty in getting the gas so far back at first, because our chimney was found to be about 75 feet too short. We have helped the draft a good deal, by putting the exhaust from the air-hoist into it, 45 feet from the top. The temperature in the chimney-valve ranges from 180° to 240° when on gas, but had gradually crept up to 380° just before cleaning.

Judging by our experience, I predict, if the merits of the Whitwell stoves were appreciated, few more iron ones would be erected.

The following table shows the production of iron and averages for five months, ending January 31st, 1876. It will be noticed that September was the second month of the blast, and, following our August trouble, made quite a difference with the totals and averages.

	Iron made.	Average quality.	Average per day.	Best day.	Best week.	Yield of ore.	Coal per ton.	Temp. of blast.
1875.						per ct.		
September, .	1028½	1.61	34¼	45	266	54 4/10	1 4/10	1336½°
October, . .	1316½	1.60	42½	62½	331	59 2/10	1 3/10	1370°
November, .	1252	1.95	41 7/10	54	284	56 6/10	1 8/10	1397°
December, .	1253	1.96	40 4/10	48	288	54 8/10	1 27/100	1308°
1876.								
January, . .	1200	2.03	41 6/10	48	303	58½	1 26/100	1384°
Totals and aver'gs	6140	. . .	40 1/20	. . .	280 7/20	. . .	. . .	. . . .

Taking the last four months, October, November, December, and January, our burden before that time not being anywhere near on, the amount per day was, 41.11.0.4.

The above is not given as anything remarkable in general furnace-work, but so far as the Champlain ores are concerned is far ahead of anything yet done, both in quantity and quality.

The following improvements seem called for. The stack will be relined and refitted to about the following dimensions: Bosh, 17 to 18 feet; tunnel-head, 15½ to 16½ feet; crucible, 8 feet diameter by 9 feet high, cased with water-plates up above the tuyeres, with the wrought-iron casing left off, and iron hoop substituted therefor. Closed hearth and Lürmann cinder-block retained. Bronze tuyeres, six or seven in number, set from 6 to 7 feet from bottom of crucible, which may seem too high, but unless it can be shown that the tuyere, cinder-notch, and iron tap, have something in common, probably no objection can be raised. On the contrary, it has many points in its favor, among which I will mention less liability of the tuyeres becoming obstructed, and the removal of the *principal,* or *only,* cause of explosions, viz., the tuyere lying in a bath of melted iron. As is the practice at many works, they would be set to project into the crucible from 8 to 12 inches.

The blowing engine has the common fault of too low steam piston speed. If it were to be built now I would have the steam-cylinder 90 inches in diameter, by 12 feet stroke, and leave the blast-cylinder as it is, 100 inches by 8 feet. That plan would allow the vacuum, which costs nothing, to do the blowing, thus giving the stoves about 75 per cent, more gas. The consequent reduced boiler capacity would make up for the increased cost of engine. The stoves might be improved somewhat in details. All cleaning door joints ought to be plain flanges, faced off, and faced covers bolted on by a *few* bolts.

Another air-valve would be an advantage, say in the sixth wall of a nine-wall stove, although it might not be necessary with a chimney of proper height. The chimney-valve casings ought to have at least 4 inches of lining, not on account of the heat (never 400°), but to make a more substantial job. The present lining is only 2½ inches, which makes a shaky arch on 24 inch radius. The joints between the valve-seats and false seats of the chimney, and gas inlet valves, are made with "whiting and salt" cement. I would recommend, instead, metallic lead run in and caulked; several have been made over in that way, and stand well. It is a joint much more easily and more quickly made. Our stoves arc lined with bricks made by Sayre & Fisher, and Philip Neukumet, and show no signs of failure. In order to protect the crucible walls, holes were drilled into the brickwork 2 feet above the tuyeres, about half way through the walls; pipes were put in those holes, carrying water where most needed. With, that arrangement little or no water is required around the tuyeres. It is suggested that the same plan would be useful in preserving the boshes when applied in several sets of holes, at different elevations.

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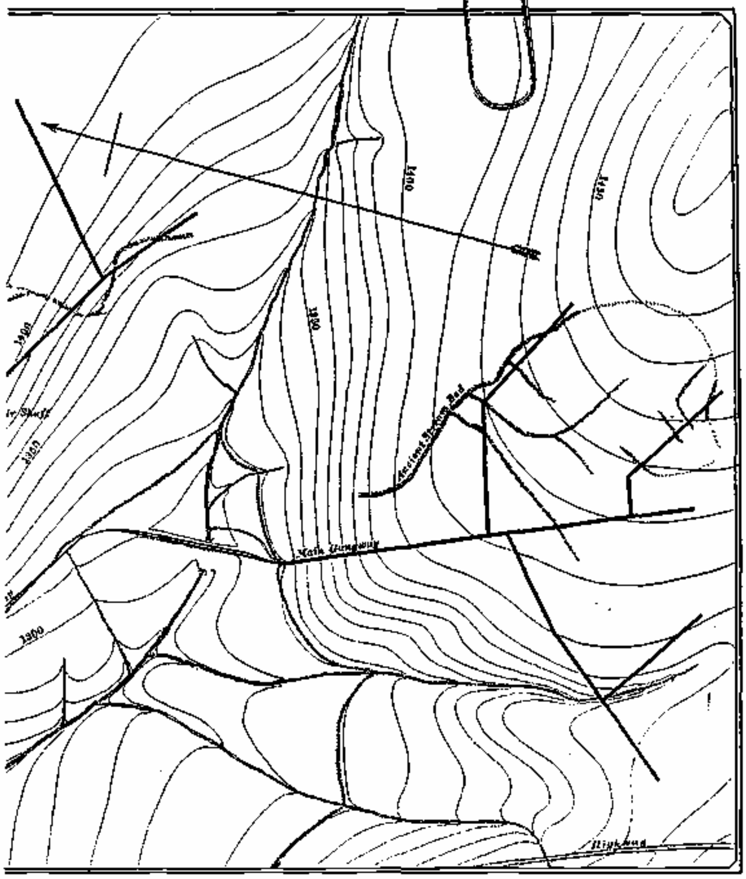
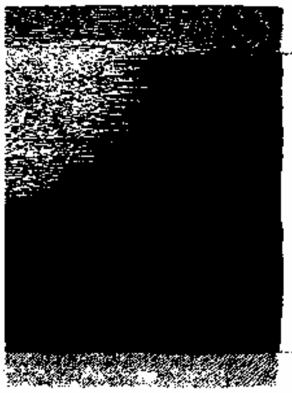
PLATE I.





Branch at A.