TRANSACTIONS

OF THE

AMERICAN INSTITUTE OF MINING ENGINEERS.

VOL. I

MAY, 1871, TO FEBRUARY, 1873.

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PREFACE.

THE present volume contains the rules of the Institute, a list of members and associates, an abstract of the proceedings of the first two years, and a number of papers selected from those proceedings. There is, therefore, nothing new in it. The papers have all been published, according to the custom of the Institute, in the *Engineering and Mining Journal,* and many of them have been copied into other periodicals. They are republished here, solely to enable members and associates to preserve them in convenient form.

Various considerations have determined the selection of papers for this purpose. Some have been omitted at the request of the authors, who, having modified the views expressed in them, naturally deprecated a republication of those views. Others have been omitted, in order not to devote too large a proportion of space to single topics, or single branches of mining or metallurgy, in view of the fact that the membership of the Institute extends throughout the whole country, and represents numerous departments of these industries. Some, on the other hand, have been chosen, although not laying claim to special originality, because they contained information of importance, not easily accessible elsewhere, the presentation of which, in a form convenient for reference, was generally desired. Under this head may be mentioned the translation by Professor Prime, of Akerman's treatise on the Consumption of Heat in the Blast Furnace, a contribution not less valuable to the Institute than an original essay.

It is believed that the selection made will be found to include the largest variety of important contributions, and will prove, on the whole, the most acceptable to the largest number of members and associates, considering that the means at command did not permit a complete republication of all papers and proceedings. The report of discussions is necessarily fragmentary, due in some cases to imperfect records, and in others, to the fact, that being desultory in character, they possessed no permanent value.

The list of members and associates here given has been corrected down to the close of the Easton meeting, in October, 1873; the papers and proceedings, however, do not extend over any meeting subsequent to that of February, 1873, in Boston. From the list of members and associates, the names of those in arrears for one year or more, have been struck off, except in a few special cases, where absence from the country, difficulty of communication, presumed loss of dues *in transitu*, or similar explanations have seemed sufficient ground for delaying this action until more conclusive advices could be obtained. The names of all persons who have ever been elected as members or associates will be found in the proceedings of the different meetings.

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AMERICAN INSTITUTE OF MINING ENGINEERS.

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RULES.

ADOPTED MAY, 1873.

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 all suitable persons desirous of being connected with the Institute and duly elected as hereinafter provided. Each person desirous of becoming a member or associate shall be proposed by at least three members or associates, approved by the Council, and elected by ballot at a regular meeting upon receiving three-fourths of the votes cast, and shall become a member or associate on the payment of his first dues. Each person proposed as an honorary member shall be recommended by at least ten members or associates, approved by the Council and elected by ballot at a regular meeting on receiving nine-tenths of the votes cast; *Provided*, that the number of honorary members shall not exceed twenty. The Council may at any time change the classification of a person elected as associate, so as to make him a member, or *vice versâ*, 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, due notice having been mailed in writing by the Secretary to the said member or associate.

III.

DUES.

The dues of members and associates shall be ten dollars, 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 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 beld 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 proposers, at any time not less than thirty days before the annual meeting; and the Secretary shall, not less than two weeks before the said meeting, mail to every member or associate (except honorary members, 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 any 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 meetings 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 fact or opinion, advanced in papers or discussions, at its meetings.

VIII.

AMENDMENTS.

These Rules may be amended, at any annual meeting, by a two-thirds vote of the members present.

PROCEEDINGS OF MEETINGS,

MAY, 1871, TO FEBRUARY, 1873.

WILKES-BARRE MEETING,

May 16th, 1871.

WILKES-BARRE, PA., April, 1871.

THE great development of the mines and metallurgical works of this country during the last few years, accompanied as it has been by the investment of enormous sums of money in purchasing lands, and in the erection of improvements, requires that advantage should be taken of the accumulated knowledge of engineers, superintendents, and others, in mastering the problems which are constantly presenting themselves for our action. Among those may be mentioned the consideration of more economical systems of mining in our coal and metalliferous mines, improved methods of transportation above and below ground, unwatering and ventilating mines, the mechanical preparation of coal and other minerals, the various metallurgical processes, and, in fact, every question tending to the attainment of two great objects:

1st. The more economical production of the useful minerals and metals.

2d. The greater safety and welfare of those employed in these industries.

In European countries, where the arts of mining and metallurgy have long been the subject of the most careful study, no means have been found so effectual in attaining the end above proposed as the free interchange of experience among those actually engaged in these industries, and this object has been accomplished, mainly, through the medium of institutes, associations or societies, composed of those engaged in these occupations, and by the periodical publication of essays or papers, communicated to such societies by their members. It must be evident to all practical men that the interchange of the varied experience of those engaged in such occupations in this country could not fail to advance very materially the desired objects; it is, therefore, proposed to establish an *American Institute of Mining Engineers*, which will hold its meetings periodically in the great mining and metallurgical centres, where works of interest, such as mines, machine shops, furnaces, and other metallurgical works, can be inspected, and the members exchange their views, and consult for mutual advantage upon the difficulties encountered by each ; these transactions or proceedings, when published, would form a most valuable and greatly-needed addition to our professional literature. It is proposed that a meeting of those sympathizing with the object above mentioned shall be called for the purpose of organizing such an association, the place and time of meeting being Wilkes-Barre, Pa., and the month of April or May.

Communications indicating the opinion and wishes of all, both as to these points, and also as to the organization and objects of the Institute, will be gladly received by any of the undersigned, and a notice of the date of meeting, which will be arranged to suit the greater number, will be duly communicated. Any one who may have devoted himself to a particular subject connected either with mining or metallurgy, and who may be possessed of new facts in reference to it, would greatly aid in furthering the objects of the proposed association by preparing a paper giving the result of his experience, to be communicated at the first meeting. It is expected that the desire for the advancement of professional knowledge, combined with the attractions of a visit to the most beautiful of our coal fields, the Wyoming Valley, will insure a large attendance from all parts of the country.

Signed,

ECKLEY B. COXE, Drifton, Pa.
R. P. ROTHWELL, Wilkes-Barre, Pa.
MARTIN CORYELL, Wilkcs-Barre, Pa.

The foregoing circular having been extensively circulated by mail, and also by publication in the leading engineering papers, the following named gentlemen assembled in Wilkes-Barre, Pa., May 16th, 1871, and organized the AMERICAN INSTITUTE OP MINING ENGINEERS :

Bruin well, J. H.,	Fairchance, Fayette Co., Pa.
Daddow, S. Harries,	St. Clair, Pa.
Drinker, H. S.,	Philadelphia, Pa.
Drown, Thomas M.,	Philadelphia, Pa.
Ganjot, E.,	Pottsville, Pa.
Haight, Ogden,	New York.
Hick, W. B.	Wilkes-Barre, Pa.
Hoffman, Daniel,	Pottsville, Pa.
Jones, Lewis S.,	Wilkes-Barre, Pa.
McNair, Thomas S.,	Hazleton, Pa.
Mercur, Fred.,	Wilkes-Barre, Pa.
Neal, R. C.,	Bloomsburg, Pa.
Petherick, Thomas,	Pottsville, Pa.
Raymond, R. W.,	New York.
Rothwell, R. P.,	Wilkes-Barre, Pa.
Silliman, Prof. J. M.,	Easton, Pa.
Sturdevant, W. H.,	Wilkes-Barre, Pa.
Symons, W. R.,	Pottsville, Pa.
Thomas, James,	Wilkes-Barre, Pa.
Timpson, James A.,	Wilkes-Barre, Pa.
Ward, Willard P.,	New York.
Williams, T. M.,	Wilkes-Barre, Pa.

Mr. R. P. Rothwell was elected temporary Chairman, and Mr. R. W. Raymond temporary Secretary.

A Committee appointed to prepare rules for the Institute reported a series of rules, which, after some discussion, were adopted in the following form:

RULES:

ADOPTED MAY 16TH, 1871.

1. The objects of the American Institute of Mining Engineers are to enable its members, comprising Mining Engineers and other persons interested in mining and metallurgy, to meet together at fixed periods for the purpose of reading papers upon and discussing subjects which have for their aim-the economical production of the useful minerals and metals, and the safety and welfare of those employed in these industries, and to circulate among its members, by means of its publications, the information thus obtained.
2. The, Institute shall consist of Members, Honorary Members, and Associates. Members and Honorary Members shall be Mining Engineers. Associates include other persons interested in mining and metallurgy. All these classes shall be equally entitled to the privileges of membership except as hereinafter provided.
3. The annual subscription of each member and associate shall be ten dollars, which shall be payable in advance at each annual meeting or immediately after his election.
4. Any member who shall make a donation of one hundred dollars, or upwards, shall become a Life Member, and any associate who shall make a like donation shall become a Life Associate, and shall not be liable for any further annual subscription.
5. Honorary members shall not be called upon to pay any annual subscription. The number of honorary members shall not exceed twenty.
6. Persons desirous of becoming members or associates of the Institute shall be proposed by at least three members or associates, approved by the Council, and elected by ballot at a regular meeting upon receiving at least three-fourths of the votes east.
7. Every person proposed as an honorary member shall be recommended by at least ten members of the Institute, approved by the Council, and be elected by ballot on receiving nine-tenths of the votes cast.
8. The officers who shall constitute a Council for the direction of the affairs of the Institute, shall consist of a President, who shall be a Mining Engineer, six Vice-Presidents, at least four of whom shall be Mining Engineers (the words "Mining Engineers" in these rules comprehend Engineers connected either with mining or metallurgy), nine Managers, at least six of whom shall be Mining Engineers, a Secretary, and Treasurer. All these officers shall be members or associates of the Institute, and shall be elected at the annual meeting (except in cases of vacancies), and shall be eligible for re-election, with the exception of any President or Vice-President who may have held office for the three immediately preceding years, and such two Managers of the Mining Engineers and one other Manager who shall have attended the fewest Council meetings during the past year, but such members shall be eligible for re-election after being one year out of office; and such election shall be made in the manner following: A.—Anv member of the Institute shall be at liberty to nominate in writing, and send to the Secretary, not less than thirty days prior to the annual meeting, a signed list of such persons as are considered suitable to fill the various offices ; which list, having been duly stamped with the Institute seal, together with the list of such officers as shall be eligible for re-election, and a copy of this Rule, shall be posted, at least ten clays previous to the annual meeting, to all members

of the Institute, who must strike out or add to such list so as to leave a record of their votes for Officers, not exceeding the number to be elected ; but nothing shall prevent any member nominating in writing subsequently (specifying the classes as aforesaid), and up to, and on the day of, and prior to the election taking place, any other member or members to fill the various offices, nor shall anything prevent the members, whether present or absent, from having power to vote for any other member or members, although he may not be nominated as before provided for. The voting papers, being so filled up, must be returned through the post, addressed to the Secretary, or be handed to him or to the Chairman, in all cases so as to be received before the hour fixed for the election of officers. B.—The Chairman shall, in all cases of voting, appoint scrutincers of the lists, and the scrutiny shall commence on the conclusion of the other business of the meeting, or at such other time as the Chairman may appoint. On the conclusion of the scrutiny the voting papers shall be destroyed, and the List, prepared and verified by the scrutincers, shall be kept until the next annual meeting. C.—In the event of any vacancies occurring in the number of officers subsequent to the annual meeting, such vacancy or vacancies shall be filled by the Council. D.—At meetings of the Council five shall be a quorum.

9. General meetings of the Institute shall take place on the third Tuesday of February, May, August, and November, 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 see 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.
10. Every question, which shall come before any meeting of the Institute, shall be decided by the votes of the majority of the members then present.
11. The funds of the Institute shall be deposited in the hands of the Treasurer, and shall be disbursed by him according to the directions of the Council.
12. All papers sent for the approval of the Council shall be accompanied *by* a short abstract of their contents.
13. 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 Instatute 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, and notice thereof shall be posted to all members. The reading of papers shall not be delayed beyond such hour as the President shall think proper, and if the election of members or other business shall not be despatched soon enough, the President may adjourn such business until after the discussion of the subject for the day.
14. Members elected at any meeting between the annual meetings shall be entitled to all papers issued that year.
15. The copyright of all papers communicated to and accepted by the Institute shall be vested in it, unless otherwise agreed upon between the Council and the author; and such communications shall not be published for sale or otherwise without the permission of the Council.
16. All proofs of discussion forwarded to members for correction must be returned to the Secretary not later than seven days from the date of their receipt, otherwise they will be considered correct and printed.

17. The Institute is not, as a body, responsible for the facts and opinions advanced in the papers which may be read, nor in the abstracts of the conversations which may take place at the meetings of the Institute.
18. The author of each paper read before the Institute shall be allowed twelve copies of such paper (if ordered to be printed) for his own use, and shall have the right to order any number of copies at the cost of printing and paper, provided they are not intended for sale.
19. Any member of the Institute shall have power to introduce a stranger to any meeting, but the latter shall not take part in any discussion without the consent of the meeting.
20. Any member who has not paid his subscription for the space of one year after it is due, shall not be entitled to vote at elections, or to receive a copy of the Transactions of the Institute.
21. The place of holding the general meetings for the ensuing year shall be fixed at each annual meeting, by a vote of the Institute; or, in default of such determination, by the Council; the place for special meetings shall be fixed by the Council; and notice of all meetings shall be given by mail or otherwise to all members and associates, at least twenty days before the time appointed for said meeting.
22. No alteration shall be made in any of the Laws, Rules, or Regulation? of the Institute except at the annual meeting.

The following resolution was then offered and passed:

Resolved, That the Chairman appoint a committee of five, to whom all applications from persons not present at this meeting, desiring to be connected with the Institute, shall be presented, and the said committee shall report at the meeting to-morrow a list of suitable names so nominated; and that all persons who have recorded their names at this meeting, and all persons who shall be so reported by the said committee, and all persons elected at the present series of sessions, constituting the May meeting of the Institute, shall be considered as Associates of the Institute; and the Council to be hereafter elected under the rules shall report at the August meeting the said persons in two lists, as Members and Associates, for adoption by the Associates then present; and that all persons to be permanently classed as Members or Associates shall signify the same to the Council before the August meeting.

The committee appointed, as provided by this resolution, reported at the subsequent sessions, May 17th and 18th, the following names with approval:

Allison, Robert,	Pottsville, Pa.
Beadle, Jesse,	Shickshinny, Pa.
Blake, W. P.,	New Haven, Conn.
Blandy, John F,	Philadelphia, Pa.
Coghlan, David,	Scranton, Pa.
Coryell, Martin	Wilkes-Barre, Pa.
Coulter, W. S.,	Ashley, Pa.
Courtis, W. M.,	Wyandotte, Mich.
Coxe, Eckley B.,	Drifton, Pa.
De Saules, A. B.,	Orange, N. J.

Egleston, Prof. T.,	New York.
Eilers, Anton,	New York.
Ely, E. B.,	New York.
Frazer, Prof. P., Jr.,	Philadelphia, Pa.
Friedrich, N.,	Drifton, Pa.
Harden, J. H.,	Wilkes-Barre, Pa.
Hawley. C. E.,	Wilkes-Barre, Pa.
Hoffman, J. R.,	Pottsville, Pa.
Hosie, John,	Tamaqua, Pa.
Jenkins, Theo. P.,	New York.
Johnson, George,	Pittston, Pa.
Kenrick, W. W.,	Wilkes-Barre, Pa.
Maynard. Prof. G. W.,	Troy, N. Y.
McClellan, Arthur	Drifton, Pa.
Oliver, Paul A.,	Wilkes-Barre, Pa.
Parrish. Chas.,	Wilkes-Barre, Pa.
Parrish, Fred.	Wilkes-Barre, Pa.
Parsons, C. W.,	Wilkes-Barre, Pa.
Pechin, Edmund C.,	Dunbar, Pa.
Potter, Prof. W. B.,	St. Louis, Mo.
Prime, Prof. F., Jr.,	Easton, Pa.
Pumpelly, Prof. Raphael,	Cambridge, Mass.
Richter, C. E.,	Philadelphia, Pa.
Ricketts, R. Bruce,	Wilkes-Barre, Pa.
Roberts, W. H.,	Mauch Chunk, Pa.
Stearns, I. H.,	Wilkes-Barre, Pa.
Stewart, W. *S.*	Wilkes-Barre, Pa.
Swoyer, J. H.,	Wilkes-Barre, Pa.
Thomas, David,	Catasauqua, Pa.
Thomas, Samuel,	Catasauqua, Pa.
Wentz, H.,	Wilkes-Barre, Pa.
White, John,	New York.
Whiting, S. B.,	Pottsville, Pa.
Williamson, J. Pryor,	Wilkes-Barre, Pa.
Williams, Morgan B.,	Wilkes-Barre, Pa.
Zehner, W. D.,	Summit Hill, Pa.

An election for permanent officers of the Institute resulted in the choice of the following:

PRESIDENT.

DAVID THOMAS,	Catasauqua, Pa.

VICE-PRESIDENTS.

R. W. RAYMOND,	New York.
E. B. COXE	Drifton, Pa.
W. R. SYMONS,	Pottsville, Pa.
W. P. BLAKE,	New Haven, Conn.
J. F. BLANDY	Philadelphia, Pa.
J. H. SWOYER,	Wilkes-Barre, Pa.

MANAGERS.

R. P. ROTHWELL,	Wilkes-Barre, Pa.
T. S. McNAIR,	Hazleton, Pa.
G. W. MAYNARD,	Troy, N. Y.
RAPHAEL PUMFELLY,	Cambridge, Mass.
THOMAS PETHERICK,	Scranton, Pa.
T. M. WILLIAMS	Wilkes-Barre, Pa.
THOMAS EGLESTON, JR.,	New York.
E. GAUJOT,	Pottsville, Pa.
FREDERICK PRIME, JR.,C	Easton, Pa.

SECRETARY.

MARTIN CORYELL, ... Wilkes-Barre, Pa.

TREASURER.

J. PRYOR WILLIAMSON, ... Wilkes-Barre, Pa.

During the sessions of this meeting the following papers were read:

On the Distribution of Mining Districts in the United States, by R. W. Raymond.

On the Relation between the Speed and Effectiveness of Stamps, by R. W. Raymond.

On Mine Ventilation, by S. Harries Dadclow.

On Mine Ventilation, by Daniel Hoffman.

On the Waste of Coal in Mining, by R. P. Rothwell.

At the conclusion of the discussion on Mr. Rothwell's paper, a committee was appointed, consisting of Messrs. E. B. Coxe, Thomas S.,.McNair, Daniel Hoffman, E. Gaujot, R. P. Rothwell, and William B. Hicks, to consider and report on the Waste in Coal Mining.

Before adjournment the following resolutions were passed:

Resolved, That the thanks of the Institute be tendered to the owners, operators, superintendents, and other officers of mines and works in the neighborhood of Wilkes-Barre for the courtesy with which they have opened the establishments under their charge to the inspection of the members, and especially to Messrs. Stearns, Brastow, Coulter, and Hindman, of the Lehigh and Susquehanna Railroad, and Messrs. Timpson, Swoyer, Mercur, and Thomas, of Wilkes-Barre, and Mr. Butler, of the Dixon Manufacturing Company, for their unwearied attention to the entertainment and instruction of visitors, and also to the Lehigh Valley, and Lehigh and Susquehanna Railroad Companies, for facilities extended to members travelling over their lines.

Resolved, That the Council be authorized, if they deem advisable, to publish the papers and proceedings of these meetings in the *Engineering and Mining Journal.*

BETHLEHEM MEETING,

August 15th, 1871.

THE Institute assembled in Packer Hall of the Lehigh University, the President, Mr. David Thomas, of Catasauqua in the chair.

Professor Henry Coppee, President of the Lehigh University, made an address of welcome to the Institute, and placed at its disposal a convenient hall for purposes of meeting.

Mr. Thomas tendered his resignation as President of the Institute, as advancing years prevented him from actively participating in its meetings. The Institute declined to accept the resignation, and, on the assurance that active duties would not be expected of him, Mr. Thomas was induced to withdraw it.

Invitations were received from Mr. B. C. Webster, President of the Lehigh Zinc Company, to visit the mines and works of the company; from Mr. Charles Brodhead, to visit the Chapman Slate Quarries; and from the Lehigh Coal and Navigation Company, to visit their works at Summit Hill and Mauch Chunk and the Nesquehoning Tunnel.

The Council reported the names of persons already elected in the two classes of *members* and *associates.*

The following resolutions were passed:

Resolved, That a committee of three be appointed, who shall take into consideration the printing and publishing of papers originating with the Institute, and that a uniform system as regards size and execution be adopted.

The committee appointed consisted of Messrs. R. W. Raymond, E. B. Coxe, and the Secretary.

Resolved, That the Council design and prepare a seal for the Institute at the earliest practicable time.

Resolved, That a committee of six, with power to add to its numbers, be appointed to examine into the question of the more economical production of iron in this country.

The committee appointed consisted of Messrs. G. \V. Maynard, Samuel Thomas, Thomas M. Drown, Edmund C. Pechin, Walter Crafts, and Willard P. Ward.

A communication was received from President Coppee, of the Lehigh University, offering the Institute a room in Packer Hall as a permanent repository for its collections, archives, etc.; also the use of the large hall for meetings.

The thanks of the Institute were tendered to President Coppee for the offer, but the Institute did not deem it advisable at that time to take definite action on it.

During the sessions of this meeting the following named gentlemen were elected members or associates of the Institute:

Bell, Rufus J.,	Wilkes-Barre, Pa.
Bennett, D. R.,	Jenkintown, Pa.
Bowden, J. H.,	Wilkes-Barre, Pa.
Bradford, H.,	Reading, Pa.
Bruckner, William,	El Paso, Texas.
Bryden, Andrew A.,	Pittston, Pa.
Buck, Stuart M.,	Boston, Mass.
Coryell, Miers,	Shanghai, China.
Crafts, Walter,	Columbiana, Ala.
Dinkey, James A.,	Mauch Chunk, Pa.
Fisher, Clark,	Trenton, N. J.
Geary, Jos. W.,	Pottsville, Pa.
Goodwin, H. Stanley,	Bethlehem, Pa.
Harden, J. W.,	Wilkes-Barre, Pa.
Harris, Wm. J.,	Ebervale, Pa.
Hewett, C.,	Jenkintown, Pa.
Hewitt, Abram S.,	New York.
Hunt, Joseph,	Catasauqua, Pa.
Hunt, Thomas, *	Catasauqua, Pa.
James, E. P.,	Bethlehem, Pa.
Lee, Col. Washington, *	Wilkes-Barre, Pa.
Lord, John C., *	Morristown, N. J.
McMillan, Charles	Bethlehem, Pa.
Newton, Henry,	New York.
Parrish, George H.,	Wilkes-Barre, Pa.
Phillips, Thomas,	Summit Hill, Pa.
Thomas, Zora B.,	Wilkes-Barre, Pa.
Torrey, H. F.,	Providence, Pa.
Vinton, Prof. F. L.,	New York.
Webster, B. C.,	Bethlehem, Pa.
West, B.,	Bethlehem, Pa.
West, John,	Bethlehem, Pa.
Whitney, A. J.,	Harrisburg, Pa.
Wright, Harrison,	Wilkes-Barre, Pa.
Yates, Alfred Curtis,	Mahanoy City, Pa.

* Since deceased.

The papers read were as follows:

Preliminary Report of the Committee on Coal Mining, by E. B. Coxe, Chairman.

On an Apparatus for Measuring the Depth of Shafts, by Prof. F. L. Vinton.

On the Works and Mines of the Lehigh Zinc Company, by H. S. Drinker.

On an Eccentric Theodolite, by Prof. F. L. Vinton.

On the Topography of the Lake Superior Copper Region, by J. F. Blandy.

On the Use and Advantages of the Prop Screw-jack, by E. Gaujot.

On Sontag's Apparatus for Giving a Free Fall to the Bit in Boring Artesian Wells, by Willard P. Ward.

Remarks on the Application of Anthracite Iron for the Production of Bessemer Steel, by G. W. Maynard.

On the Difficulties in the Identification of Coal Beds, by R. P. Rothwell.

Professional Morality, by R. P. Rothwell.

The invitation of Mr. Webster was accepted by all the members present, who enjoyed a day full of instruction and good cheer. The excursion provided by the Lehigh Coal and Navigation Company was participated in by a number of the members after the adjournment of the Institute.

The invitation of Mr. Charles Brodhead was declined for want of time.

The following resolution was passed before adjournment:

Resolved, That the cordial thanks of the Institute are hereby tendered to Mr. B. C. Webster, President of the Lehigh Zinc Company, and to the Superintendents of the different branches of the Company's works, for their attention and hospitality; to the Lehigh Coal and Navigation Company for the facilities provided for inspecting the Company's works; also to Mr. Charles Brodhead, for his invitation to visit the Chapman Slate Quarries.

TROY MEETING,

November 21st, 1871.

THE first session of this meeting was held Tuesday evening, in the chamber of the Common Council, the President, Mr. David Thomas, in the chair. Mayor Carroll, of Troy, gave a cordial welcome to the Institute, which was responded to, on behalf of the Institute, by the first Vice-President, Mr. R. \V. Raymond.

The Council reported the names proposed for membership with recommendation for election. The following named gentlemen were duly elected:

Anthony, J.,	Williamstown, Pa.
Babcock, George,	Troy, N. Y.
Blake, Theo. A.,	San Francisco, Cal.
Blossom, T. M.,	New York.
Boalt, James A.,	San Francisco, Cal.
Bowman, Amos,	San Francisco, Cal.
Chester, Prof. A. H.,	Clinton, N. Y.
Dewey, C.,	Pittsfield, Mass.
Dock, Gilliard	Shamokin, Pa.
Emerson, G. D.,	New York.
Endres, John J.,	Pittsburgh, Pa.
Firmstone, Frank,	Easton, Pa.
Fowle, W. B.,	Philadelphia, Pa.
Frazier, Prof. B. W.,	Bethlehem, Pa.
Gardner, George A.,	New York.
Goodyear, Watson A.,	San Francisco, Cal.
Griswold, Chester,	Troy, N. Y.
Griswold, J. A.,*	Troy, N. Y.
Hague, J. D.,	San Francisco, Cal.
Halm, 0. H.,	Eureka, Nev.
Harkness, T. C	Wilkes-Barre, Pa.
Harris, Samuel,	Hudson, N. Y.
Henry, E. T.,	Oxford, N. J.
Holley, A. L.,	Brooklyn, N. Y.
Howe, H. W.,	Troy, N. Y.
Hunt, Dr. T. Sterry,	Boston, Mass.
Jannet, J.,	Troy, N. Y.
Knapp, John A.,	New York.
Laughlin, Henry A.,	Pittsburgh, Pa.

* Since deceased.

Lesley, Prof. J. P.,	Philadelphia, Pa.
Lyman, Benj. Smith,	Philadelphia, Pa.
McFarlane, James,	Towanda, Pa.
McIntire, Prof. Chas.,	Easton, Pa.
Miner, W. P.,	Wilkes-Barre, Pa.
Moffat, E. S.,	Dover, N.J.
Nason, Prof. H. B	Troy. N.Y.
Pettee, Prof. W. H.,	Cambridge, Mass.
Plympton, Prof. G. W.,	New York.
Roads, J. G.,	Pottsville, Pa.
Roads, J. 0	Pottsville, Pa.
Roe, G.,	Mineville, N. Y.
Robertson, Kenneth,	Boonton, N. J.
Sackett, Charles E.,	Albany, N. Y.
Scranton, W. H.,	Oxford, N. J.
Smith, Lenox,	New York.
Smith, T. Guilford,	Philadelphia, Pa.
Speer,.J. Z.,	Pittsburgh, Pa.
Squire, Joseph,	Helena, Ala.
Taylor, J. F	Pittsburgh, Pa.
Terhune, R. H.,	Troy, N. Y.
Thomas, John,	Hockendauqua, Pa.
Treadwell, George A.,	San Francisco, Cal.
Witherbee, J. G.,	Port Henry, N. Y.
Witherbee, T. F.,	Port Henry, X. Y.

During this session the following papers were read:

On the Increase in the Production of Iron, by David Thomas.

On the Attainment of Uniformity in Bessemer Steel, by Thomas M. Drown.

On the Efforts heretofore made by the Japanese to Produce Pig Iron by our Methods, by W. P. Blake.

On the Silver Smelting Processes of the West, by O. H. Hahn, A. Eilers, and R, *W*. Raymond.

On Wednesday morning the Institute visited the new blast furnace of the Corning Iron Company, at Albany, and the Burden furnace, shops, and power at Troy.

The second session was held at 8 o'clock, Wednesday evening, when the following papers were read •.

On the Block Coal of Indiana, by T. Guilford Smith.

On the Compound Propeller Pump, by T. Guilford Smith.

On Krupp's Steel Works, at Essen, Germany, by Prof. T. Egleston.

On the Recent Explosion of a Blast Furnace at Youngstown, Ohio, by Edmund C. Pechin.

On the Economy of the Blast Furnace, by Prof. F. Prime, Jr.

On Electricity and Rocks, by R. W. Raymond.

The following resolution was then passed :

Resolved, That the thanks of the Institute are due to the mayor and citizens of Troy, for their cordial and hospitable welcome, and for the tender of accommodations for our sittings; to the press of the city, for its careful and kindly reports of our proceedings; to the proprietors of metallurgical works, for the courtesy with which they have received our visits; and to the local committee, for the completeness of its preparations for our profit and entertainment.

On Thursday morning the Institute started on a trip to Port Henry, Lake Champlain, on the invitation of the Champlain and Moriah Railroad and Mining Company.

Proceeding by special car on the Rensselaer and Saratoga Railroad to Whitehall, the members embarked on the new steamer. Vermont for Port Henry. A session of the Institute was held in the cabin of the steamer, Vice-President Raymond presiding, the proceedings being confined to subjects connected with the Champlain iron regions. Mr. John Rogers, one of the oldest iron manufacturers in this part of the country, made a few remarks, in which he welcomed the Institute to this region, and described its early history and progress.

Mr. Maynard made an interesting communication on the ores of the Champlain region ; and was followed by Prof. Blake, who spoke of the mineralogy of the Sandford beds, near Port Henry, as studied by him twenty years before.

On the arrival of the steamer at Port Henry the members were conveyed to the railroad, where a train was waiting to take them to the mines, situated about seven miles from the Lake, the joint property of Messrs. Witherbees, Sherman & Co. and the Port Henry Iron Company. After a short inspection of the mines, the most imposing as well as the most extensive in the country, the members visited the Fletcherville Charcoal Blast Furnace of Messrs. Witherbees, Sherman & Co.

On returning from the furnace, the Institute was hospitably entertained by Mr. Sherman, at the Sherman House at Moriah. During the evening a final session was held, when the following papers were presented:

On the Ores of South Mountain and Cumberland Valley, by J. W. Harden.

On Blast Furnace Slags, by Kenneth Robertson.

On the Importance and Advantages of the Institute of Mining Engineers, by Martin Coryell.

The following resolution was passed, and the Institute then adjourned :

Resolved, That the thanks of the Institute are due, and are hereby heartily offered to the Champlain and Moriah Railroad Company for its graceful and abundant hospitality; and especially to Messrs. George Sherman, George S. Rowe, Walter Teft, S. L. Morrison, and Thomas F. Witherbee, for their personal attention to our comfort and entertainment.

PHILADELPHIA MEETING,

February 20th, 1872.

THE Institute assembled on Tuesday evening, in the building of the University of Pennsylvania. In the absence of President Thomas, Vice-President Raymond occupied the chair. The Institute was welcomed in an eloquent and thoughtful address by Prof. J. P. Lesley, to which Mr. Raymond responded.

Invitations were announced from the proprietors of Sellers' Tool Works, Whitney's Car-wheel Works, the Baldwin Locomotive Works, Lewis & Brothers' White Lead Works, the Southwark Foundry, Harrison's Boiler Factory, the University of Pennsylvania, and the Academy of Natural Sciences.

The following gentlemen, being duly recommended by the Council as members and associates, were unanimously elected:

Alexander, John S.,	Philadelphia, Pa.
Biddle, E. R.,	New York.
Britton, J. Blodget	Philadelphia, Pa.
Brooks, Maj. T. B.,	Marquette, Mich.
Brown, D. P.,	Pottsville, Pa.
Canfield, Edw.,	Dover, N. J.
Cogswell, W. B.,	Franklin Iron W'ks,.N.Y.
Cornwall, Prof. H. B.,	New York.
Edwards, Daniel,	Danville, Pa.
Estabrook, John D.,	Philadelphia, Pa.
Firmstone, William,	Easton, Pa.
Fritz, John	Bethlehem, Pa.
Gignoux, Charles	New York.
Grant, E. M.,	Tuskegee, Ala.
Humphreys, A. W.,	New York.
Ingham, W. A	Philadelphia, Pa.
Keyes, W. S.,	Eureka, Nov.
Kimball, Dr. J. P.,	New York.
Law, Charles,	Pittston, Pa.
Neilson, W. G.,	Philadelphia, Pa.
Newberry, Prof. J. S.,	New York.
Pearse, John B.,	Steel Works P. 0., Pa.
Ricketts, P. De P.,	New York.
Scranton, Col. Charles	Oxford, N. J.
Sontag, Hugo	Cologne, Prussia.
Stecle, Thomas C.,	Summit, Pa.
Wharton, Joseph	Philadelphia, Pa.

The papers read were :

On the Capacity of Ventilators for Coal Mines, by R. P. Rothwell.

On Titaniferous Iron Ores, by G. W. Maynard.

Wednesday morning and afternoon were spent by the members in visiting various industrial establishments in the city.

The Institute resumed its sessions Wednesday evening, when the following papers were read :

On the Iron Column of Delhi, in India, by Benjamin Smith Lyman.

On a New Machine for Testing the Strength of Metals, by Thomas M. Drown.

On Rolling-Mill Machinery, by A. L. Holley.

On the Manufacture of Steel Rails, by J. B. Pearse.

On Thursday three sessions were held. At the morning session a brief paper by the President, Mr. David Thomas, was read, on the Anthracite Furnaces of the Lehigh Valley; followed by a paper on a New Electro-Magnetic Separator for Iron Ores, by R. W. Raymond ; and one on Pillars of Coal, by S. Harries Daddow.

The afternoon session was called to order by Vice-President Coxe, who announced that the Council had received with regret from Mr. David Thomas, a letter renewing his resignation of the Presidency, on account of advanced age and infirm health. In accepting this resignation, the Council unanimously resolved to propose Mr. David Thomas to the Institute for election as its first honorary member.

Mr. Thomas was thereupon unanimously elected.

Mr. Coxe then announced that the Council had appointed Mr. R. W. Raymond to fill the vacancy created by the resignation of Mr. Thomas; Mr. R. P. Rothwell as Vice-President, to fill the vacancy caused by the appointment of Mr. Raymond as President; and Prof. J. P. Lesley to fill the vacancy caused by the appointment of Mr. Rothwell as Vice-President.

The following papers were then read:

On the Utilization of Coal-Dust as Fuel, by E. F. Loiscan.

The Method and Cost of Mining Red Specular and Magnetic Ores now practised in the Marquette Iron Region of Lake Superior, by Major T. B. Brooks.

On the Utilization of Blast Furnace Slags, by Prof. Thos. Egleston.

At the evening session the papers read were:

On Explorations for Iron Ore, by Major T. B. Brooks.

On Blast Furnace Fuel, by S. Harries Daddow,

On Surveying in Geological Work, by Benjamin Smith Lyman.

The following resolution was unanimously adopted:

Resolved, That the thanks of the Institute are hereby presented to the University of Pennsylvania for its tender of a hall for our sessions; to the owners of metallurgical and mechanical works who have so cordially received our visits; and to the very efficient Local Committee, to whose zeal and tact the success of this pleasant meeting has been largely due.

Before adjournment the President briefly congratulated the Institute upon the unmistakable success of its first four quarterly meetings. The character of the papers presented, the vigor and good temper of the discussions, and the great social enjoyment and professional profit which all have derived from the meetings, have been so many pledges of the future prosperity of the Institute. No one has been urged to join the Institute; its doors arc open to the profession and to the public interested in its objects, but it is not a beggar for members or associates. Assured in its vitality and progress, it is assured also in the expectation that the Mining Engineers and Metallurgists of the country will gather around it, not for its sake, but for their own.

ANNUAL MEETING, NEW YORK,

May 21st, 1872.

THE Institute assembled in the rooms of the Geographical Society at the Cooper Union, Tuesday evening at 8 P.M. President Raymond called the meeting to order, and introduced Mr. Abram S. Hewitt, who welcomed the Institute to New York. President Raymond, in behalf of the Institute, replied.

The President then read the following report of the Council for the past year.

The Council respectfully report that the American Institute of Mining Engineers has held four meetings--at Wilkes-Barre, Bethlehem, Troy, .and Philadelphia, respectively--all of which have been well attended, and socially and professionally most successful. The proceedings of these meetings having been published in the *Engineering and Mining Journal,* and sent to all members and associates, are sufficiently well known. Forty-four papers, by twenty-six authors, have been read. These papers embrace a wide range of subjects, and prove the practical character of the proceedings of the Institute.

The finances are in a satisfactory condition. By the report of the Treasurer it appears that $1290.10 have been received, $519.90 expended, and that $770.20 now remains in the treasury exclusive of fees for 1872. This fund, it is hoped, will be so increased by voluntary subscriptions as to enable us before long to issue a volume of our most important transactions in a permanent form.

The Council has made a favorable arrangement with the Scientific Publishing Company, publishing the *Engineering and Mining Journal,* by which that journal became the organ of the Institute for the first publication of the proceedings, papers, and notices to members. This arrangement it is proposed to continue through the present year unless the Institute shall otherwise direct. It is not intended to supersede the publication of an annual or occasional volume, but to maintain an interest in the Institute, and to serve the convenience of members while our funds do not permit a more ambitious publication.

One member has made himself a life member, an example which the Council hopes will be imitated by others.

A large number of persons, 201 in all, have been duly recommended, approved and elected members or associates, but no person has been so elected except when voluntarily offering his own name as a candidate, or when it was offered by his friends in his behalf. The Institute has requested nobody to join its ranks, and the Council begs leave to make this general reply to rumors, which have reached it of the surprise which many worthy and eminent Engineers and Metallurgists are said to have felt because they were not elected to membership. In many cases the names sent to the Secretary as candidates have been accompanied by insufficient addresses, and this has led to considerable trouble; many elected members and associates not receiving papers and notices duly mailed to them. A considerable number have from this cause failed to pay their dues or to attend the meetings, and the Council presents a resolution to suit this case. For the future it is hoped that members, by seeing to it personally that their exact addresses are in the hands of the Secretary, will avoid the recurrence of such annoyance.

The report was adopted, and the President then offered the following resolutions by direction of the Council, which were also adopted:

Resolved, That all persons elected members or associates at the Philadelphia meeting, or who, having been elected at any time, have failed to receive due notice of their election, shall be considered as elected from this date, and shall pay in dues ten dollars only until May, 1873.

Resolved, That the Council be hereby authorized to make all necessary or advisable changes in the classification from associates to members, and *vice versa.*

AMENDMENT TO THE RULES.

To amend Rule IX to read:

"General meetings of the Institute shall be held on the third Tuesday of Febvuary, May, and October, and the May meeting shall be considered the annual meeting.

The Council reported the following names for election, with approval :

Blair, Thomas S,………………………………Pittsburgh, Pa.
Bonnell, Samuel, Jr.,………..………………………New York.
Brodie, W. M., ,…………………………………Bloomfield, N. J.
Butler, Cyrus, ,................……………………....New York.
Church, John A., ,………………………………….New York.

Cox, Prof. E. T.,	Indianapolis, Ind.
D'Aligny, H. F. Q.,	New York.
Fisher, Howell,	Pottsville, Pa.
Fitzhugh, Gen. Charles L.,	Pittsburgh, Pa.
Fulton, John,	Saxton, Pa.
Gage, James R.,	St. Louis, Mo.
Gowen, Franklin B.,	Philadelphia.
Guy, William E.,	St. Louis, Mo.
Harris, Stephen,	Pottsville, Pa.
Harris, Joseph S.,	Pottsville, Pa.
Hearst, George,	San Francisco, Cal.
Herring, A.,	Crown Point, N. Y.
Heuschkel, Robert,	Boise City, Idaho.
Irving, Prof. Roland D.,	Madison, Wis.
Jannin, Henry,	San Francisco, Cal.
Jillson, J. C.,	Pittsburgh, Pa.
Lane, C. C.,	Victoria, British Columbia
Love, Robert,	Plymouth, Pa.
Morgan, Daniel,	Danville, Pa.
Munroe, Henry S.,	Yokohama, Japan.
Niblock, James G.,	Brazil, Ind.
Oettinger, Dr. P. J.,	New York.
Packer, E. A.,	New York.
Park, James, Jr.,	Pittsburgh, Pa.
Platt, Franklin,	Philadelphia.
Pleasants, Henry,	Pottsville, Pa.
Ricketson, J. H.,	Pittsburgh, Pa.
Schulz, William,	Berlin, Prussia.
Silliman, Prof. Benjamin,	New Haven, Conn.
Spencer, William,	Buck Mountain, Pa.
Van Lennep D.,	Unionville, Nevada.
Van Rensselaer Schuyler,	New York.
Walz, Dr. Isidor,	New York.
Wayne, James M.,	Diamond City, Utah.
Welch, Benjamin G.,	Riverside, Pa.
Wood, Malt. P.,	Terre Haute, Ind.

The gentlemen named were unanimously elected.

Excursions were announced to the Stevens Institute of Technology, at Hoboken; the blasting operations at Hell Gate; the caisson of the Brooklyn Bridge; the School of Mines, of Columbia College; the Cooper Union; the Chrome Steel Works, and other manufactories. An invitation to a reception at the house of Mr. Abrarn S. Hewitt was also presented.

The following papers were then read:

Researches on the Consumption of Heat in the Blast Furnace Process, by Prof. P. Prime, Jr.

On the Metallurgical Value of the Lignites of the Far West, by A. Eilers.

On Thursday, May 22d, three sessions were held.

At the morning session the papers read were:

On the Block Coal of Indiana, by John S. Alexander.

On the Determination of Combined Carbon in Steel, by J. Blodget Britton.

On the Extraction of Bismuth from certain Ores, by Dr. T. Sterry Hunt.

The President announced that the Council, having received the proper recommendation, signed by ten members, unanimously presented Mr. I. Lowthian Bell, of England, distinguished for valuable services in scientific iron metallurgy, to be made an honorary member of the Institute. Mr. Bell was then elected by a unanimous ballot.

At the afternoon session the following papers were presented:

On the Economical Results in the Treatment of Gold and Silver Ores, by John A. Church.

On the Records of the Emma Mine, by Prof. W. P. Blake.

On a New Method of Sinking Shafts, by Eckley B. Coxe.

Scrutincers appointed to examine the ballots for officers for the ensuing year reported the following gentlemen elected :

PRESIDENT.

R. W. RAYMOND, ... New York.

VICE-PRESIDENTS.

ECKLEY B. COXE, ... Philadelphia.
W. R. SYMONS, ... Pottsville, Pa.
W. P. BLAKE, ... Now Haven, Conn.
J. F. BLANDY, ... Philadelphia.
R. P. ROTHWELL, ... New York.
THOMAS EGLESTON, ... New York.

MANAGERS.

G. W. MAYNARD .... New York.
THOMAS PETHRICK, ... Pottsville, Pa.
E. GAUJOT, ... Pottsville, Pa,
FREDERICK PRIME, JR., ... Baston, Pa.
J. P. LESLEY, ... Philadelphia.
E. C. PECH IN, ... Dunbar, Pa.
T. B. BROOKS, ... Marquette, Mich.
T. M. DROWN, ... Philadelphia.
ABRAM S. HEWITT, ... New York.

SECRETARY.

MARTIN CORYELL, ... Wilkes-Barre.

TREASURER.

J. PRYOP. WILLIAMSON, ... Wilkes-Barre.

The morning of Thursday, the 23d, was spent by the Institute in inspecting the collections, laboratories, and workshops of the Stevens Institute of Technology, under the guidance of President Morton and the Professors of the several departments. The members were subsequently entertained by Mrs. Stevens at her mansion at Castle Point.

At the evening session of Thursday the following papers were read :

On Malleable Cast-iron, by R. H. Terhune.

On Eureka, Nevada and other Base Metal Districts of the West, by R. W. Raymond.

After passing the following resolution of thanks for hospitality received, the Institute adjourned to meet in Pittsburgh in October.

Resolved, That the thanks of the Institute are hereby tendered to our fellow-member, Mr. Abram S. Hewitt, for his generous and most delightful reception. To the Trustees, President, and Faculty of the Stevens Institute of Technology for their active and munificent hospitality, and for the instructive display of the unrivalled apparatus of their Institution.

To the authorities of Columbia School of Mines and other institutions, and the proprietors and managers of interesting engineering and metallurgical works for their cordial invitations. To the Cooper Union and Geographical Society for the use of their rooms, and to the Local Committee for the successful arrangement and conduct of this most successful meeting.

PITTSBURGH MEETING,

October 16th, 1872.

THE Institute assembled on Wednesday evening at the Western University, and was called to order by President Raymond.

Mr. James Park, Jr., of Pittsburgh, made the address of welcome, which was responded to by President Raymond.

The Council reported the following names, with approval, for election :

Ashburner, William,	San Francisco, Cal.
Asmus, George,	Now York.
Baillic, Nathaniel,	Uniontown, Pa.
Bowie, A. J., Jr.,	San Francisco, Cal.
Brown, A. J.,	Treasure City, Nev.
Butler, J. G., Jr.,	Youngstown, Ohio.
Chamberlin, J. G.,	Lcetonia, Ohio.
Clark, R. Neilson,	Canyon City, Colorado.
Cornell, A. B.,	Youngstown, Ohio.
De Crano, E. G.,	San Francisco, Cal.
Engelmann, H.,	Salt Lake City, Utah.
Faber du Faur, A.,	New York.
Janin, Louis, Jr.,	San Francisco, Cal.
Johnson, George J.,	Salt Lake City, Utah.
Kent, Joseph C.,	Phillipsburgh, N. J.
Kent, William St. G.,	Phillipsburgh, N. J.
Liebenau, Charles von,	Silver City, Idaho.
MeClintock, A. H.,	Wilkes-Barre, Pa.
Miller, Thomas N.,	Pittsburgh, Pa.
Millholland, James A.,	Mount Savage, Md.
Peters, Ed. D., Jr	Dudley, Colorado.
Reese, Jacob,	Pittsburgh, Pa.
Schirmer, J. F. L	Denver, Colorado.
Smith, W. S.,	Fairplay, Colorado.
Stoelting, Hermann,	Georgetown, Colorado.
Sweet, W. A	Syracuse, N. Y.
Tripple, Alexander,	New York.
Van Arsdale, W. H.,	Swansea, Cal.
Willard, Dwight D.,	Bordentown, N. J.

The following resolution was then offered and passed :

Resolved, That gentlemen present, not members, be invited to take part in the discussions of the Institute at the various sessions of the present meeting.

A paper was then read by Mr. Edmund C. Pechin on the Position of the American Pig-iron Manufacture.

Three sessions were held on Thursday the 17th.

At the morning session the following papers were read :

On the Precipitation of Gold on a Reverberatory Hearth, by R. W. Raymond.

On Phosphorus in the Ashes of Anthracite Coals, by J. Blodget Britton.

On the Longwall System of Mining, by J. W. Harden.

Mr. Jacob Reese invited the Institute to inspect, at his works, the process of cutting cast steel by means of a rapidly revolving wrought-iron disk.

Mr. Henry A. Laughlin invited the Institute to visit the coal washing and coking plant at his works on the Monongahela River.

At the afternoon session the papers read were :

On a Comparison between Certain English and American Blast Furnaces, by Frank Firmstone.

On a New Occurrence of Telluride of Gold and Silver, by A. Eilers.

On Coking under Pressure, by John A. Church.

On Coal Washing and Coke Ovens, by J. J. Endres.

On the Analysis of Coals, by Prof. E. T. Cox.

On a Hand-Drill, by Edmund C. Pechin.

The concluding session, Thursday evening, was occupied in the reading and discussion of the following papers :

On Three High Rolls, by A. L. Holley.

On the Wickersham Process of Refining Pig-iron, by E. C. Pechin.

Before adjournment the following resolutions were presented and passed:

Resolved, That the Institute has learned with pain of the death of Mr. Thomas Hunt, one of its most intelligent and honored members, and that we extend our sympathies, in this sad bereavement, to his family and his personal friends, in which latter class all of us who knew him are included.

Resolved, That a copy of this resolution be transmitted by the Secretary to the family of Mr. Hunt.

Resolved, That the thanks of the Institute are tendered to the Western University for the use of their hall; to the citizens of Pittsburgh, particularly those engaged in the various branches of the iron business, for the interest they have taken in the proceedings; to the proprietors of furnaces and other manufacturing metallurgical and mechanical works, for their cordial invitations and free offers of information; to the press of the city for its appreciative reports, and to the local committee for the judicious arrangements they have made for this meeting.

Friday was spent by the members in visiting numerous blast furnaces, rolling-mills, steel works, etc. In the evening the Institute was entertained at a grand banquet at the Monongahela House, given by the iron and steel manufacturers of Pittsburgh.

BOSTON MEETING,

February 18th, 1873.

THE Institute assembled in the Hall of the Boston Natural History Society on Tuesday evening.

Dr. T. Sterry Hunt, of the Boston Institute of Technology, after a brief address of welcome to the Institute, read an introductory paper on the Geognostical History of the Metals.

President Raymond responded to the welcome of Dr. Hunt.

The following names were then presented to the Institute, with the recommendation of the Council, for election :

Adams, J. M., ... Silver City, Idaho.
Daggett, Ellsworth, ... Salt Lake City, Utah.
Geist. Alfred W., ... Boston. Mass.
Hays, Dr. S. Dana, ... Boston, Mass.
Heinrich, Oswald J., ... Midlothian, Va.
Johnson, J., ... Braidwood, Ill.
Leckie, Robert G., ... Actonvale, Canada.
Lyman Edward, ... Troy, .N. Y.
Maltby, William, ... Braidwood, I11.
Nichols, Lyman, Jr., ... Boston, Mass.
Ordway, Prof. J. M., ... Boston, Mass.
Rand, Theodore D., ... Philadelphia, Pa.
Richards, Prof, Robert H., ... Boston, Mass.
Rockwell, Prof. Alfred P., ... Boston, Mass.
Roepper, Charles W., ... Bethlehem, Pa.
Schulz, A. von, ... Central City, Colorado.
Singer, William P., ... Pittsburgh, Pa.
Spillsbury, E. G., ... New York.
Wells, Calvin .... Pittsburgh, Pa,

The session concluded with the reading and discussion of a paper, by Henry Englmann, On the Mines and Ores of the Little Cottonwood Canyon, Utah.

The second session was held on Wednesday morning, when the following papers were presented:

On the Midlothian Coal Mines, by Oswald J. Heinrich.

On the Probable Existence of Microscopic Diamonds in California, by Prof. Benjamin Silliman.

On the Magnetites of Clifton, St. Lawrence County, N. Y., by Prof. Benjamin Silliman.

On the Occurrence of Tin Ore at Winslow, Maine, by Dr. T. Sterry Hunt.

Mr. R. W. Raymond exhibited some unusual forms of crystals of cement copper, produced by the Hunt & Douglas process, from Lexington Copper Mine, Davidson County, Va.

At the third session, on Wednesday afternoon, the President announced, on behalf of the Council, the resignation of the Treasurer, J. Pryor Williamson, and the appointment of Theodore D. Rand, of Philadelphia, to serve as Treasurer for the remainder of the year; the resignation of the Secretary, Mr. Martin Coryell, and Manager Dr. Thomas M. Drown, and the appointment of each of the gentlemen named to the position formerly held by the other. The President remarked that these changes were the result of friendly consultation among the officers of the Institute, and dictated solely by considerations of convenience in carrying on its business.

Announcement was also made, that, in accordance with the precedent established last year by vote of the Institute, payment of annual dues by members or associates elected at the February meeting, should be considered to extend to the annual (May) meeting of the following year.

Papers were then read as follows :

On a Mining Transit and Lamp for Underground Surveying, by R. W. Raymond.

On the Use of the Plummet Lamp in Underground Surveying, by Eckley B. Coxe.

On the Recent Improvements in the Diamond Drill, by Prof. W. P. Blake.

On the Mining and Metallurgical Laboratories of the Boston Institute of Technology, by Prof. R. H. Richards.

Mr. Frank Firmstone exhibited some specimens of blast furnace products from Allegheny County, Va., consisting of, 1st, clusters of long, slender crystals, found inside of blisters in the crust which formed in the lining of the furnace while blowing out; and, 2d, lumps of so-called "cadmia," which collected in thick, hard crusts round the throat of the furnace while in blast.

On Wednesday evening the Institute attended, by special invitation, the regular meeting of the Boston Natural History Society. After adjournment, the members of the Institute were entertained by Mr. Bouve, President of the Society, at his house.

A fourth session was held, at the Institute of Technology, on Thursday morning. A paper, by Mr. J. W. Harden, of Philadelphia, on the Wasting of Coal at the Mines, was read, and a communication was received from Mr. J. Blodget Britton, of Philadelphia, with reference to the appointment of a commissioner, by the Centennial Commission in Philadelphia, for the purpose of analyzing and classifying the iron ores of the country. It was referred to the Council, with power to act.

The following resolution was then passed :

Resolved, That the thanks of the Institute be presented to the Officers of Harvnrd University, the Massachusetts Institute of Technology, and the Boston Society of Natural History, and to those citizens of Boston whose cordial hospitality and intelligent sympathy have contributed so largely to the interest and profit of our meeting ; also, to the Local Committee of the Institute, for the efficient and successful arrangements in connection with our session.

The remainder of the morning was passed in inspecting the laboratories, museums, etc., of the Institute of Technology. The members then visited Harvard University at Cambridge, where they were received and entertained by President Eliot at his house.

After a hurried visit to the principal departments of the University, the members returned to Boston.

On Friday morning a number of the members started for North Adams, Mass., to visit the Hoosac Tunnel, but the great snowstorm which swept over New England on that day giving reason to fear a considerable detention, caused the majority of the party to abandon the plan at Pittsfield, and to continue their homeward journey *via* Albany. Those who pushed on to carry out the original programme of the Local Committee had less trouble than was anticipated in reaching the tunnel, and after a pleasant and satisfactory visit, returned without greater hardship than a considerable delay on the road.

PAPERS.

WILKES-BARRE MEETING,

MAY, 1871.

THE GEOGRAPHICAL DISTRIBUTION OF MINING DISTRICTS IN THE UNITED STATES.

BY R. W. RAYMOND, PH.D.

PROFESSOR W. P. BLAKE, in a note to his Catalogue of California Minerals, pointed out that the raining districts of the Pacific slope are arranged in parallel zones, following the prevailing direction of the mountain ranges. This interesting generalization has been more fully illustrated and connected with the geological history of the country by Mr. Clarence King, who sums up the observed phenomena as follows:

"The Pacific coast ranges upon the west carry quicksilver, tin, and chromic iron. The next belt is that of the Sierra Nevada and Oregon Cascades, which, upon their west slope, bear two zones, a foot-hill chain of copper mines, and a middle line of gold deposits. These gold veins and the resultant placer mines extend far into Alaska, characterized by the occurrence of gold in quartz, by a small amount of that metal which is entangled in iron sulphurets, and by occupying splits in the upturned metamorphic strata of the Jurassic age. Lying to the east of this zone, along the east base of the Sierras, and stretching southward into Mexico, is a chain of silver mines, containing comparatively little base metal, and frequently included in volcanic rocks. Through Middle Mexico, Arizona, Middle Nevada, and Central Idaho is another line of silver mines, mineralized with complicated association of the base metals, and more often occurring in older rocks. Through New Mexico, Utah, and Western Montana lies another zone of argentiferous galena lodes. To the east, again, the New Mexico, Colorado, Wyoming, and Montana gold belt is an extremely well-defined and continuous chain of deposits."

These seven longitudinal zones or chains of mineral deposits must not, in my opinion, be held to constitute a complete classification. The belts of the Coast Range and the west slope of the Sierra are well defined, both geologically and topographically ; but it is not so easy to separate into distinct groups the occurrences of gold and silver east of the Sierra. For instance, the gold of Eastern Oregon, Idaho, and Western Montana, together with such occurrences in Nevada as those of the Silver Peak and New Pass districts, and numerous instances of sporadic occurrence of particular ores of silver or argentiferous base metals, cannot be brought within the classification above given. Either more zones must be recognized, or a greater mincralogical variety must be acknowledged in those already laid down. The latter alternative is, I think, the more reasonable. According to the principles set forth in a discussion of mineral deposits in my report for 1870,* it appears evident that the agencies which affect the general constitution of geological formations are far wider in their operation than those which cause the formation of fissures; and that the causes influencing the filling of fissures are still more local in their peculiarities than those which form the fissures themselves. Thus, of the area covered by rocks of a given epoch, more or less uniform in lithological character, only a small portion may have been exposed to conditions allowing deposits of useful minerals, even when such deposits arc contemporaneous, as in the case of coal. Still more limited is the field for the formation of fissures; but it must be freely confessed that in the case before us, the corrugation of half the continent into parallel mountain ranges offers good grounds for the expectation of vast longitudinal systems of fissures. When we come to consider the filling of these fissures, however, it is evident that the mineralogical character of the vein-material must vary, to some extent, as to the gangue, but to a still greater extent as to the nature of the ores. Even single mines, in the course of extensive exploitation, have produced ores differing as widely as do those of the different zones enumerated by Mr. King. I am, in fact, strongly inclined to consider freedom from base metals, for instance, a peculiarity due in many cases to secondary processes, and not to be relied upon as characteristic for single veins even, to say nothing of whole groups, districts, and continental zones.

Nevertheless, the generalizations of Professor Blake and Mr. King on this subject are highly interesting and valuable. The criticism here made is not in opposition to their views so much as in qualifi-

* Statistics of Mines and Mining in the States and Territories west of the Rocky Mountains, by R. W. Raymond, U. S. Commissioner of Mining Statistics.

cation of a possible rash application on the part of the general public. The zonal parallelism does exist, though in a somewhat irregular way ; and it is clearly referable, as these writers have shown, to the structural features of the country, the leading feature of which is the longitudinal trend of the mountain ranges.

Subordinate to this trend (or, more strictly, resulting from the same causes as produced it) appear the predominant longitudinal strike of the great outcrops of sedimentary rocks, the longitudinal axes of granite outbursts, and, finally, the longitudinal vents of lava overflows and the arrangement of volcanoes in similar lines. It is evident that in crosssing the country from cast to west we traverse a series of different formations, while, *by* following routes parallel with the main mountain ranges, we travel upon the continuous outcrops of the same general age.

Mr. King distinguishes in the history of the entire Cordillera two periods of disturbance which have been accompanied by the vending of mountain chains and the ejection of igneous rocks. Such periods would afford the conditions of solfataric action, thermal springs, and the generation of acid gases and metallic sublimates and solutions, and thus favor the formation of metalliferous deposits. The first of these periods, he says, culminated in the Jurassic, produced over the entire system a profound disturbance, and is, in all probability, the dating-point of a large class of lodes. To the second, or tertiary period, he assigns the mineral veins which traverse the early volcanic rocks.

The expression "culminated in the Jurassic," merely refers, no doubt, to the fact that the cretaceous strata of California repose uneonformably upon the upturned and metamorphosed Jurassic slates, having been themselves neither tilted nor highly metamorphosed. Perhaps it is well to remember, however, that the cretaceous is a weak point in the California series, at least, as determined by leading fossils; and perhaps the results of more complete stratigraphical surveys will indicate that there are gaps of no little significance, dynamically and chronologically, in this part of the geological record. At all events, the period of the folding of the Sierra Nevada (presumably that of the formation of many metalliferous deposits) was in some sense post-Jurassic, rather than Jurassic; and probably this is the meaning of Mr. King, who speaks of it in another passage as " late Jurassic."

The lodes which are referred to this period are of two types: first, those wholly inclosed in the granites, the outburst of which accompanied the upheaval of the earlier stratified group, or in the metamorphosed Jurassic and sub-Jurassic strata; secondly, those which occupy planes of stratification or jointure, thus following in general the dip and strike of the country rock, while they present in other respects the indications of fissure-veins. The veins of the Reese River granite are examples of the first type; many gold veins of California, the Humboldt mines, etc., are given as illustrations of the second. The White Pine district, the mineral deposits of which arc said to be inclosed conformably between strata of Devonian limestone, is declared to be "a prominent example of the groups comprised wholly within the ancient rocks."

We have hitherto supposed the strata immediately overlying the argentiferous limestone at White Pine to be deep-water Carboniferous ; bat their Devonian character seems to be demonstrated by Mr. Arnold Hague.* More practically important is the assignment of these deposits to the earlier period of geological disturbance. Mr. King appears here to include in one group *all* the White Pine deposits, the "Base Range" as well as "Treasury Hill ;" yet the striking distinction in mineralogical character is worthy of regard. The deposits of Treasure Hill arc notably free from base metals; and it seems to me that in their present form they must be due to a secondary action, which has concentrated and reeombined the metallic elements of older deposits. It should be added, however, that although the chlorides of Treasure Hill are as pure as those of Lander Hill, they do not appear, like the latter, to yield in depth to such silver ores as characterize the fissure-veins of Reese River district—ruby silver, for instance. Nor are they fissure-veins, so far as we, can now decide.

To the Tertiary period of orographical disturbance are referred the volcanic overflows and the veins wholly or partly inclosed in volcanic rocks. Under this head Mr. King classes many important veins of Mexico, several of those which border the Colorado River, in the United States, and, in general, that zone which lies along the eastern base of the Sierra Nevada. The Comstock lode is adduced as the most prominent example of this type, and the Owyhee district in Idaho is also referred to it, because, although in granite, it presents a series of volcanic dikes, which appear to prove, by the manner of their intersections with the quartz lodes, that the latter are of

* See Volume on Mining Industry of the United States Geological Exploration of the Fortieth Parallel.

Tertiary origin. It will be seen that although the extent and number of the deposits of this class are inferior to those of the earlier period, they include some of the most brilliant instances in the history of mining. As Mr. King, however, points out, many of the veins which are wholly inclosed in the older rocks may nevertheless be due to this Inter period of disturbance. Nor does he ignore the bearing of this thought on his determination of the earlier period as Jurassic. He confesses that in more recent strata, formed from debris of Jurassic rocks, ore-bearing pebbles have not been found ; but he regards this fact as a piece of negative evidence merely.

The distribution of mineral deposits east of the Rocky Mountains follows somewhat different laws. Here we have but one longitudinal range,—that of the Alleghanics, which is accompanied by a gold-bearing zone of irregular extent and value. In the Southern States the strata flanking this range present a remarkable variety of mineral deposits. On the eastern slope of the Rocky Mountains, again, occurs what may perhaps be denominated a zone or longitudinal series of coal-fields. But between these mountain boundaries the geological formations of the. country cluster, as it were, around centres or basins. We have such a group in Michigan, another in the Middle States, and a third in the Southwest.

The deposits of the different metals, ores, and useful minerals, in the country cast of the Rocky Mountain, vary widely in age. The ores of gold, copper, and iron, in the prc-Silurian schists of the South ; the galena and cobalt ores of the Southwest, and the copper ores of Lake Superior, in the lower Silurian rocks; the argillaceous iron ores of New York, and other States west of New York, in the Upper Silurian, and the salines of the same group; the bitumen, salt, coal and iron ores of the Subcarboniferous; the coal and iron of the Carboniferous; the coal, copper, and barytes of the Triassic; the lignites of the Cretaceous, and the fossil phosphates of the Tertiary period, are instances which may serve to show how great is this variety. It is not within the province of this paper to discuss the mineral deposits of the Mississippi Basin, the Appalachian Chain, or the Atlantic Coast. I shall content myself with brief mention of two points. The first is the greater relative age of the metalliferous deposits as compared with those of the inland basin and the Pacific slope. On this side the period of greatest activity in such formations was over before it began in the West. The great gold and silver deposits beyond the Rocky Mountains appear to be post-Devonian, post-Jurassic, and even Tertiary in their origin. The vast volcanic activity which affected so wide an area in California, Oregon, Washington, Idaho, and Nevada, is not represented in the East.

The other point is the peculiar relative position of our coal and iron deposits. This was eloquently described by Mr. Abrams Hewitt, United States Commissioner to the Paris Exposition, in his admirable review of the iron and steel industry of the world. I cannot do better than quote his forcible words:

"The position of the Coal-Measures of the United States suggests the idea of a gigantic bowl filled with treasure, the outer rim of which skirts along the Atlantic to the Gulf of Mexico, and thence, returning by the plains which lie at the eastern base of the Rocky Mountains, passes by the great lakes to the place of beginning, on the borders of Pennsylvania and New York. The rim of the basin is filled with cxhaustlcss stores of iron ore of every variety, and of the best quality. In seeking the natural channels of water communication, whether on the north, cast, south, or west, the coal must cut this metalliferous rim; and, in its turn, the iron ore may be carried back to the coal, to be used in conjunction with the carboniferous ores, which are quite as abundant in the United States as they are in England, but hitherto have been left unwrought, in consequence of the cheaper rate of procuring the richer ores from the rim of the basin. Along the Atlantic slope, in the highland range, from the borders of the Hudson River to the State of Georgia, a distance of one thousand miles, is found the great magnetic range, traversing seven entire States in its length and course. Parallel with this, in the great limestone valley which lies along the margin of the coal-field, are the brown hematites, in such quantities at some points, especially in Virginia, Tennessee, and Alabama, as to fairly stagger the imagination. And, finally, in the coal-basin is a stratum of red fossiliferous ore, beginning in a comparatively thin scam in the State of New York, and terminating in the State of Alabama in a bed 15 feet in thickness, over which the horseman may ride for more than one hundred miles. Beneath this bed, but still above water-level, are to be found the coal-seams, exposed upon mountain sides, whose flanks are covered with magnificent timber, available either for mining purposes or the manufacture of charcoal iron. Passing westward, in Arkansas and Missouri, is reached that wonderful range of red oxide of iron, which, in mountains rising hundreds of feet above the surface, or in beds beneath the soil, culminates at Lake Superior in deposits of ore which excite the wonder of all beholders; and returning thence to the Atlantic slope, in the Adirondacks of

New York, is a vast, undeveloped region, watered by rivers whose beds arc of iron, and traversed by mountains whose foundations are laid upon the same material. In and among the coal-beds themselves are found scattered deposits of hematite and fossilifcrous ores, which, by their proximity to the coal, have inaugurated the iron industry of our day. Upon these vast treasures the world may draw for its supply for centuries to come; and with these the inquirer may rest contented, without further question-for all the coal of the rest . of the world might be deposited within this iron rim, and its square miles would not occupy one-quarter of the coal area of the United States."

This vivid description rests upon a geographical rather than a geological grouping. But it is none the less intimately connected witli the underlying geological facts. Its strongest application is, however, economical. If any material thing may stand as the type of force, it is coal, the deposits of which may well be called vast storehouses of power-the product of solar activity through uncounted years-laid up for the use of man; and iron, on the other hand, may symbolize the inert, dead matter, awaiting the touch of power to wake it into efficient life. These arc prime elements in our universe of industry. Take them away and our present civilization is annihilated. Put them together in the hand of an intelligent and mighty nation, and that nation could recall the world from the chaos of barbarism. But they need each other, and it is in the wonderful combination of both, as well as the exhaustless abundance of each, that America finds sure promise of enduring power.

Thus East and West bear witness of our great inheritance of natural wealth. Every period of geological change has been laid under contribution to endow with rich legacies some portion of our land. Our territory epitomizes the processes of all time, and their useful results to man. Divided, yet in a stronger sense united, by mountain chains and mighty rivers, our diversified mineral resources may figuratively represent, as I firmly believe they will literally help to secure and maintain our characteristic national life, a vast community of communities, incapable alike of dissolution and of centralization; one, by mutual needs and affections, as the continent is one; many, by multiform industries and forms of life, as the members of the continent are many.

ON THE RELATION BETWEEN THE SPEED AND EFFECTIVENESS OF STAMPS.

BY R. W. RAYMOND, PH.D.

THE question, what is the best proportion among weight, fall, and speed of stamps, is one which has not yet received thorough and systematic examination. In considering the economical application of stamping machinery, we meet, at the beginning, with serious difficulties in obtaining accurate data for comparison. The weight and fall of stamps vary as the shoes and dies wear out; and this may lead to a change of speed also. Moreover, defects in engines, boilers, or machinery for the transmission of power, may occasion serious losses, which cannot fairly be charged to the arrangements of the stamps proper. Again, the capacity of stamp-mills is directly dependent, in some degree, upon the nature and extent of discharge, fineness of screens, and other peculiarities of the battery. Finally, the hardness and tenacity of the rock crushed varies so much that comparisons between different localities cannot be implicitly trusted. The safest experiments are those made in the same mill, by changing first one and then another condition of working; but this is seldom

possible for such conditions as weight and lift of stamps, and only within narrow limits for their speed.

We may eliminate questions of friction, transmission, and generation of power, in the case of stamps, by measuring the power actually developed by their fall. Thus, the weight, multiplied into the fall in feet, and the number of drops per minute, gives us exactly the number of foot-pounds exerted by each stamp. Dividing by 33,000, the number of foot-pounds per minute in one-horse power, we have the horse-power per stamp, from which the effective power of the whole mill may be obtained. Dividing the amount of rock crushed daily by the effective horse-power, gives us the daily amount per horse-power; and this is the best measure that can be obtained for the effectiveness of the stamps. A complete discussion of the subject would require us to determine the exact influence of the discharge, etc., and the exact resistance offered by different classes of rocks, for both of which points the data are wanting.

Professor J. D. Hague, in the third volume of the United States Geological Exploration of the Fortieth Parallel, gives a valuable table of the operations of a number of mills in Gilpin County, Colorado. The discussion of this table leads to some interesting results, which I shall briefly set forth. I give a portion of it, rearranged to suit the object in view, and furnished with additional columns.

Relative Efficiency of certain Stamp-mills in Gilpin County, Colorado.

Number.*	Name.	Number of stamps running.	Weight of stamps in pounds.	Fall in inches.	Drops per minute.	Total horse-power developed.	Total tons of ore crushed daily.	Tons daily, per horse-power developed.
1	Hurd's, ...	20	660	14	30*	14.0	17	1.21
2	Black Hawk, . . .	60	850	14	15	27.0	30	1.11
3	Polar Star, ...	24	425	14	30	10.8	15	1.38
4	Chicago, ...	20	450	14	40	13.5	15	1.11
5	Nesmith, ...	20	550	14	35	13.2	17½*	1.32
6	University, ...	15	500	15	30	8.1	11½*	1.41
7	Holbrook's, . . .	13	500	14	30	6.6	11½*	1.73
8	Miley & Abbe's, . .	25	584	12	28	12.4	26	2.10
9	Sensenderfer, . . .	20	459	12	34	9.2	15	1.62
10	Holman, ...	12	400	12	22	3.2	7½	2.34
11	Bates, ...	8	425	12	30	3.1	7½	2.43
12	Smith & Parmelee, .	25	550	14	35	17.0	22½	1.32
13	Gregory No. 1, . .	20	850	14	16*	9.6	13	1.35
14	Star, ...	12	500	12*	40	7.3	7½	1.03
15	Narragansett, . . .	40	750	14	30	31.8	37½	1.18
16	Montana, ...	30	750	12	40	27.2	33¾*	1.24
17	Pacific National, . .	24	600	12*	35	15.8	22½	1.47
18	Gilpin Company, . .	18	500	16	32*	11.6	11½*	0.98
19	First National, . .	25	900	14	28	22.3	22½	1.01
20	Ophir, ...	4	500	14	30	12.7	18¾	1.47
21	Whitcomb's, . . .	12	430	13	32	5.4	11½*	2.12
22	Quartz Hill, . . .	12	550	16	22	5.9	7	1.19
23	Blue, ...	12	700	8	40	6.8	12½*	1.84
24	Carondelet, ...	12	350	12	50	6.4	21	3.30
25	Gleason & Company,	8	650	15	27	5.3	7	1.31
26	M[illegible]ey & Johnson, .	16	500	12	40	9.7	19*	1.96
27	Delaware, ...	15	500	12	26*	5.9	13	2.20
28	Perrin, ...	10 12	450 600	12* 13	45* 23*	11.6	16½*	1.42
29	Lincoln, ...	12	625	14	24	6.4	12½*	1.96
30	Beloit, ...	12	450	16	28*	6.1	6½*	1.08
31	Trust, ...	30	700	14	25*	18.6	20½*	1.10
32	Winnebago, . . .	20	500	15	30	11.3	15	1.32
33	Eureka, ...	18	450	15	25	7.7	12	1.55
	Totals, ...	656	396,110	. . .	. . .	383.0	537	51.16
	Numerical averages,	19.88	603.83	15.34	29.69	0.58	0.82	1.55
	Dynamical averages,	19.88	603.83	13.53	28.31	0.58	0.82	1.40
	Gross averages, . .	19.88	580.27	13.41	30.82	11.60	16.27	1.55

I have taken from the report the names of mills, number of stamps running, weight of stamps, fall in inches, number of drops per min-

* Estimated, generally from maxima and minima given. Thus 15 to 20 is put at 17 1/2.

ute, and tons of ore crushed per day. To these columns I have added one giving the total horse-power developed and one giving the tons of ore crushed daily per horse-power developed. These figures are obtained by separate calculations for each mill. At the bottom of the table certain totals and averages have been added. The total number of stamps explains itself. The total weight is arrived at by multiplying the number and weight for each mill, and then aggregating these products. The total .horse-power, again, is a simple addition. The methods of obtaining averages require more detailed comment. In several columns the numerical differs decidedly from the dynamical average; thus, if we multiply the number of stamps in each mill by their fall, add these products, and divide the sum by the total number of stamps, we obtain a numerical average of the fall; and a similar process gives us a numerical average of the number of drops per minute; but if we should attempt to deduce from the total number of stamps, their average weight and (numerical) average fall and speed, the total horse-power developed, we should obtain a result different from that which is arrived at by simply adding the totals given in the column of horse-power developed. The reason is obvious. In taking a merely numerical average we leave out of account the weight of the different stamps; it is therefore necessary to multiply the number *and weight* of stamps of each mill into the drop, and to divide the sum of these products by the aggregate weight of all the stamps of all the mills. In calculating the average speed, the drop, as well as the number and weight, must be included. This can be best illustrated by an example, comprising, for the sake of simplicity, only two mills. I take, almost at random, Nos. 2 and 11 from the table, viz.:

Black Hawk: 60 stamps, 850 pounds, 14 inches, 15 drops, 27 horse-power.

Bates: 8 stamps, 425 pounds, 12 inches, 30 drops, 3.1 horse-power.

The totals would be 68 stamps, 54,400 pounds, and 30.1 horse-power.

The numerical averages are obtained as follows:

$$\begin{array}{lrcrl} \textit{Fall.}\text{—} & 60 \times 14 & = & 840 & \\ & 8 \times 12 & = & 96 & \\ \hline & 68 & & 936 & \text{Average fall, 13.76 inches.} \\ \textit{Speed.}\text{—} & 60 \times 15 & = & 900 & \\ & 8 \times 30 & = & 240 & \\ \hline & 68 & & 1140 & \text{Average speed, 16.76 drops per minute.} \end{array}$$

But these averages would give us

$$54{,}400 \times \frac{13.76}{12} \times 16.76 \div 33{,}000 = 31.68 \text{ horse-power},$$

whereas the aggregate horse-power, as we know by calculating it separately for each mill, is 30.1 horse-power.

The dynamical averages, on the other hand, are obtained as follows:

$$\begin{array}{llll} \textit{Fall.}\text{—}60 \times 850 = & 51{,}000 & \quad 51{,}000 \times 14 = & 714{,}000 \\ \phantom{\textit{Fall.}\text{—}}8 \times 425 = & \underline{3{,}400} & \quad 3{,}400 \times 12 = & \underline{40{,}800} \\ & 54{,}400 & & 754{,}800 \end{array}$$

Average fall $= 754{,}800 \div 54{,}400 = 13.87$ inches.

$$\begin{array}{ll} \textit{Speed.}\text{—}714{,}000 \times 15 = & 10{,}710{,}000 \\ \phantom{\textit{Speed.}\text{—}}\underline{40{,}800} \times 30 = & \underline{1{,}224{,}000} \\ \phantom{\textit{Speed.}\text{—}}754{,}800 & 11{,}934{,}000 \end{array}$$

Average speed $= 11{,}934{,}000 \div 754{,}800 = 15.81$ drops per minute.

If now we calculate the total horse-power upon these dynamical averages, we have

$$54{,}400 \times \frac{13.87}{12} \times 15.81 \div 33{,}000 = 30.1 \text{ horse-power},$$

which agrees with the total from the table.

A third sot of averages, which I call, for convenience, gross averages, is obtained by disregarding the number as well as the weight of stamps, and considering only the number of mills. Thus, in the case just given, the gross averages would be 637.5 pounds, 13 inches, and 22.5 drops. This has little value for accuracy; but it is the usual manner in which casual observers estimate the mutter, and it shows what is the fashion or prevailing custom among owners of mills. Bearing these distinctions in mind, we have the following results, based on a comparison of thirty-three mills:

Total number of stamps, 656; average number in each mill, 19.88; total weight of stamps, 396,110 pounds; average weight, 603.83 pounds; average weight reckoned by mills, without reference to their size, 580.27 pounds; average fall in inches, reckoned from the number of stamps only, 15.34 ; average fall in inches, reckoned from the number of mills only, 13.41; average fall in inches, reckoned from number and weight of stamps, or average fall of the average stamp of 603.83 pounds, 13.53; average speed by stamps, 29.69 drops per minute; average speed by mills, 30.82 drops per minute; average speed of the average 603.83-pound stamp, falling 13.53 inches, 28.31 drops per minute; total horse-power developed, 383; average per stamp (obtained by dividing by the total number of stamps), .58;

horse-power developed by the average stamp at average fall and speed (calculated from the dynamical averages), .58, which necessarily agrees with the foregoing; average per mill, 11.60 horse-power; total number of tons crushed daily, 537 ; average per stamp, .82; average per mill, 16.27; total number of tons crushed by the development of thirty-three horse-powers, one in each mill, 51.16; average per mill or stamp, numerically, 1.55; actual daily product per horse-power developed by the average stamp, 1.40 tons. These figures admit of further profitable discussion.

The difference between the gross and dynamical averages of weight of stamps indicates that the larger mills carry, on the whole, heavier stamps. The difference between the gross and dynamical averages of fall is slight, while both of these are considerably less than the numerical average, showing that the larger mills, on the whole, adopt a greater full than the gross average, but the greater aggregate weight of metal in the smaller mills nearly restores the dynamical average to the prevailing fashion, as shown by the gross average. The differences in the averages of speed are more difficult to explain. It appears that 30.82 drops per minute is the fashion, and that the few large mills running at 15 and 16 do not reduce the numerical average below 29.69. But when the fall is taken into consideration, it appears that the slow-running stamps (as might be expected) drop further, thus increasing their effect, and reducing the real effective average speed to 28.31 drops per minute. The difference between the dynamical and numerical averages of daily product per horse-power shows that the mills developing less than 11.6 horse-power crush, on the whole, slightly more in proportion than those of greater capacity; but in view of the very great variations in the final column of the table, this residual difference is comparatively insignificant, and it may be assumed that deficiencies in economy are pretty equally divided between the two classes. If the matter turned upon the daily management only, the larger mills being presumably under more skilful management, might be called upon to show better results; but the conditions here discussed are mainly those of original construction; and some of the largest mills in this table are among the oldest and the worst.

How far is this exhibit invalidated by the conditions of discharge, size of screens, etc., and hardness of rock, not included in it? By the former, I think, not to any great extent, as it may safely be assumed that these conditions have been made as favorable in every case as the form of the battery and the necessities of amalgamation will allow, and, moreover, that the mortars and screens are of one general pattern, the California high mortar not being in favor, and Russia iron, punched, being preferred to wire screens, and slits to needle-holes. Variations in the diameter of shoes are, I must confess, more common, and constitute an element which I have disregarded only because the data are wanting. But this element, if included in the discussion, would strengthen the conclusions arrived at, since the mills having the largest diameter of shoe, us the Black Hawk and Gregory, which have 9-inch shoes, do not reach on that account even the average efficiency. It may be inferred, therefore, that in crushing average quartz the conditions of weight and speed arc more influential than slight variations in the crushing surface.

The hardness of rock is a serious disturbance to the calculations. Surface-rock differs considerably from the deep quartz in this respect, and doubtless affects unfavorably the apparent results of the larger mills. It should be distinctly understood, therefore, that the general conclusions deduced from the table at the beginning of this chapter arc modified by special conditions. If any mill shows a considerable departure from the average effectiveness, it is fair to inquire what kind of rock it is crushing before concluding that its superior or inferior capacity is due to the weight, drop, and speed of the stamps.

With these qualifications, we may assume that the average or normal stamp of Colorado weighs about 600 pounds, drops about 13.5 inches, about 28 times a minute, and crushes 82 tons daily, or about 1.4 tons per horse-power developed. This is probably less than the average efficiency, measured in the same way, of California stamps. It is, indeed, somewhat in excess of the estimate of Mr. Ashburner, whose observations some five years ago led him to fix upon 1.25 tons daily per horse-power, as the average result of the stamp-mills of California, but improvement of construction since introduced have increased their capacity.

The mill at Lone Pine, Invo County, is said to crush per horse-power, daily, 3.81 tons, with 650-pound stamps, dropping 8 inches, 60 times per minute.

The table of quartz mills in Tuolumne County, California, gives the following results when reduced :

Name of Mill.	Weight of stamp.	No. of drops per minute.	Height of drop in inches.	Tons daily, per horse-power.
Clio, ...	500	60	8	1.65
Eagle, ...	500	80	6	1.48
Golden Rule, ...	750	70	6	1.26
Knox & Co., ...	500	65	6	1.62
App, ...	600	80	6	2.20
Heslep, ...	500	60	7	1.51
Trio, ...	400	60	8	1.24
Mooney & Co., . . .	800	40	10	2 06
Oliver & Harris, . .	600	65	9	1.13
Reist, ...	500	55	8	2.16
Rawhide, ...	600	70	8	1.47
Patterson, ...	500	60	8	1.24
Musser, ...	500	60	8	1.65
Soulsby, ...	500	60	10	1.24
Starr King, ...	500	60	8	1 65
Gilson, ...	500	60	8	1.65
Grizzly, ...	500	60	8	1.65
Bonita, ...	500	60	8	1.65
Consuelo, ...	500	60	8	1.65
Monitor, ...	500	60	8	1.65
Hazle Dell, ...	500	60	8	1.65
Shanghai, ...	500	60	8	1,65
Hunter, ...	500	60	8	1.65
Sell & Martin, . . .	500	60	8	1.37
Nonpareil, ...	500	60	8	1.65
Burns & Co., ...	500	60	8	1.65
Rattlesnake, ...	500	60	8	1.65

The stamp mills of Sutter Creek mining district, in Amador County, California, show, by a similar calculation, the following results:

Name of Mill.	Weight of stamp.	No. of drops per minute.	Height of drop in inches.	Tons daily, per horse-power.
Eureka, ...	650	76	9	1.67
Badger, ...	500	79	9*	1.18
Rose, ...	500	75*	9*	1.46
Lincoln, ...	450	79	9	1.48
Mahony Brothers, . .	600	70	11	1.14
Mahony, ...	600	70	11	1.07
Keystone, ...	600	74	9	1.59

* Estimated.

The table of quartz mills in Eldorado County, California, yields, under discussion, the following results:

Name of Mill.	Weight of stamp.	No. of drops per minute.	Height of drop in inches.	Tons daily, per horse-power.
Pacific, ...	500	75	8	1 32
Harmon, ...	300	75	8	1.76
Reed, ...	600	75	10	1.32
Independence, . . .	665	80	9	1 24
Crystal, ...	650	70	9	1.45
Stillwagon, ...	400	65	9	1.65
Star, ...	400	80	9	1.72
Confidence, ...	300	80	7	3.93

The quartz mills of Colfax district, Placer County, show:

Name of Mill.	Weight of stamp.	No. of drops per minute.	Height of drop in inches.	Tons daily, per horse-power.
Live Oak, ...	600	60	12	1.83
Rising Sun, ...	800	65	11	1.38
Green Emigrant, . .	700	75	10	1.51
Pioneer, ...	800	60	10	1.24

Some of the quartz mills of Nevada County, California, show the following results:

Name of Mill.	Weight of stamp.	No. of drops per minute.	Height of drop in inches.	Tons daily, per horse-power.
Eureka, ... {	700	10†	68	1 66
	850	10†	60	1 70
Empire,*	800	10†	62	1 06
North Star, ...	950	10†	60†	1.30
Idaho, ...	950	10	60	1 62
Pittsburgh, ...	650	10†	82	1.63
Allison Ranch, . . .	1000	11	60†	2.00

Four mills in Sierra County, California, show the following:

Name of Mill.	Weight of stamp.	No. of drops per minute.	Height of drop in inches.	Tons daily, per horse-power.
Brush Creek, ...	700	62	8½	1.29
Independence, ...	700	60	8	.89
Alaska, ...	700	60	8½	.99
Docile, ...	750	85	7½	1.41

* Destroyed by fire in 1870. **Estimated.

Some of the quartz mills of Yuba County, California, give:

Name of Mill.	Weight of stamp.	No. of drops per minute.	Height of drop in inches.	Tons daily, per horse-power.
Pennsylvania, . . .	650	70	10	1.30
Donnebroge, ...	720	70	10	1.18
Rattlesnake, ...	650	70	10	1.30
Sweet Vengeance, . .	650	70	10	1.30
Scabby Hill, ...	600	70	10	1.41

The quartz mills of Oregon gulch, Butte County, California, give:

Name of Mill.	Weight of stamp.	No. of drops per minute.	Height of drop in inches.	Tons daily, per horse-power.
Nisbet, ...	600	68	10	1.45
Cambria, ...	600	68	10	1.45
Sparks & Smith, . . .	750	68	10	1.16

The quartz mills of Plumas County, California, show the following relative efficiencies:

Name of Mill.	Weight of stamp.	No. of drops per minute.	Height of drop in inches.	Tons daily, per horse-power.
Eureka, ...	750	65	9	1.45
Mammoth, ...	750	60	8	1.83
Woodward & Co, . .	500	60	10	1.76
Bullfrog, ...	750	60	8	2.20
Crescent, ...	850	70	10	1.35
Judkins & Kellogg, .	750	65	8	2.03
Caledonia, ...	750	65	8	2.03
Dixie, ...	400	60	7	2.94
Batchelder's, ...	400	45	7	4.71*
Lone Star, ...	600	50	7	2.83
McClelland, ...	400	35	7	4.66*
New York, ...	600	60	9	2.44
Pennsylvania, ...	750	60	8	2.20
Indian Valley, ...	600	60	9	2.44
Whitney, ...	750	65	11	1.55

The quartz mills of Shasta County, California, show the following calculated efficiency

Name of Mill.	Weight of stamp.	No. of drops per minute.	Height of drop in inches.	Tons daily, per horse-power.
Washington, ...	600	60	6	1.83
Highland, ...	500	60	6	2.20
Honeycomb, ...	600	60	6	1.83
Potosi, ...	600	60	6	1.83
Mammoth, ...	600	60	6	1.83
Jollie, ...	300	60	6	2.75
Peck's, ...	500	60	6	2.20

* These figures are so large that they should be rejected as involving either an error in the report, or some unexplained peculiarity of conditions of operation.

The Hermit Hill, in the Sweetwater district, Wyoming, shows the following: Weight, 650; speed, 80; drop, 8 1/2; tons daily per horse-power, 1.79.

An interesting comparison may be made with the stamp-mills of Australia and Brazil. The rough averages given for the different Australian districts cannot be very closely discussed; but by taking the arithmetical means of the maxima and minima of horse-power and product given, we have:

District.	Weight of stamp.	Height of drop in inches.	Number of drops per minute.	Horse-power expended per stamp.	Tons daily, per horse-power.
Ballarat, ...	400 to 850	7 to 10	50 to 85	1.00 to 2.00	1.66
Beechworth, . .	442 to 775	5 to 14	40 to 90	.75 to 1.50	2.13
Sandhurst, . .	500 to 800	6 to 18	25 to 75	.66 to 2.00	1.50
Maryborough, .	450 to 800	6 to 22	50 to 75	.50 to 2.50	1.33
Castlemaine, . .	450 to 800	6 to 15	35 to 75	.50 to 2.00	1.70
Ararat,. . . .	500 to 675	7½ to 10	60 to 72	.75	1.83
Gipp's Land,. .	600 to 750	7 to 10	60 to 80	.75 to 1.50	1.58

The stamp-batteries of the Port Philip Company, at Clunes, Australia, show :

Weight of stamp.	Drop. in.	Speed.	Tons daily per H. P.
600	8*	75	2.42
800	8*	75	3.30

This is extraordinary efficiency; but the batteries are aided by rock-breakers, *and have a double discharge.*

The stamp-mills of Cornish pattern in use at the Morro Velho mines, Brazil, show:

Name of Stamp-mills.	Weight of stamp.	Blows per minute.	Lift of stamp-heads in inches.	Tons daily, per horse-power.
Lyon, ...	640	63	10	1.19
Cotesworth, ...	640	61	11	1.30
Susannah, ...	640	65	12	95
Herring, ...	640	78	12	95
Powles,.	640	67	12	1.41
Addison, ...	640	73	12	1.05

Comparing the stamp-mills of Colorado with all these examples from other regions, we notice that the speed of their stamps is, on the average, much less, and that, to say the least, the efficiency is no greater than that of more rapid running. But the argument for a

* Estimated.

higher speed is fairer if the Colorado mills arc compared among themselves. Returning, therefore, to the table given above, we notice that of eleven mills exhibiting a greater efficiency than the average of 1.55, five are run at a speed exceeding the average of 30.82, two at 30, and the remaining four at 22, 24, 26, and 28, respectively. The highest efficiency is attained by the Carondelet mill, having the lightest stamps (350 pounds), run at the highest speed (50 drops per minute), and crushing daily 3.30 tons per horse-power. The Blue mill, on the other hand, develops nearly the same horse-power, but crushes only little over half as much. In the latter case, twice the weight of metal is dropped two-thirds as-far, four-fifths as often; and while the power is nearly the same, this different application of it appears to be far less advantageous.

On the other hand, there arc instances in the table which seem to contradict such a conclusion. The slow rate of running insures an immediate and adequate discharge; and much of the advantage of a rapid rate is lost when the discharge is not ample. The remarkable increase in product secured by the use of a double or even a continuous discharge around the whole battery-box would doubtless influence millmen to adopt this improvement, were it not for certain difficulties, partly real, partly imaginary, in its use.

If we consider economy as well as efficiency in crushing, the advantage of a high rate is evident. With the same machinery, wages, etc., and, if the mill is well built, with little or no extra repairs, a large increase in capacity is secured. Moreover, the first cost may be reduced by the use of lighter batteries. Probably, also, the increased speed may be attained with less than the proportional increase of fuel.

The objections to higher speeds in Colorado mills are partly set forth in my report* for 1871, in the words of a writer in the *Central City Register*. His argument is, substantially, that experience has shown different rates of speed to be best for different kinds of ores. Instances are given in which, upon an increase of speed, the yield of gold per ton fell off; and it is claimed that this test should decide what rate is to be adopted in each case. In other words, the, rapid running of the stamps, and consequent augmentation of product crushed, causes greater agitation within the battery-box, and requires a larger supply of water to clear the discharge and

* Statistics of Mines and Mining in the States and Territories west of the Rocky Mountains, by R. W. Raymond, U. S. Commissioner of Mining Statistics.

carry away the greater amount of pulp. The excess of agitation in the battery may prevent the accumulation of gold on the interior plates, and the excess of current on the aprons may prevent the accumulation of gold there. These objections are most plausible when the gold is most finely divided in the quartz. I propose to consider them briefly.

This reasoning amounts to the confession that the conditions most favorable to economical crushing must be partly sacrificed to secure efficient amalgamation. Is this sacrifice really necessary, or is it merely involved in the method of amalgamation adopted in the Colorado mills? The attempt to catch the greater part of the gold on the interior plates interferes directly with the greatest efficiency of the stamps. The success of the amalgamation at this point is in inverse proportion to the success of the crushing and discharge. There is a certain advantage gained in the force with which the pulp is dashed against the plates; but this force is liable to overdo, and thus undo, its own work, and actually remove the adhering amalgam. The same effect can be more completely secured outside of the battery.

But the arrangements outside are generally poorly adapted for the purpose. The pulp is swept over a small, steep, and smooth amalgamated surface; and it is no wonder that so little gold is caught upon the aprons. The Port Philip, Australia, mills have five distinct steps or drops in the outer plates, where the Colorado mills have none. If this arrangement were adopted, an excess of water would occasion no loss, and the efficiency of amalgamation would be increased.

The principal objection appears to be the clogging of the outside riffles or steps with pulp, or the removal of amalgam by the falling of the pulp over the steps. But it strikes me that if Australian mills can overcome these difficulties we ought to be able to do the same.

Even retaining the present patterns of outside aprons, the effect of a greater amount of water could be neutralized by spreading the discharge over a wider surface. Let us suppose, for instance, that a twenty-stamp mill is run at a low speed, for fear of losing gold if more quartz and more water were passed through it in a given time; and that ten of the stamps, run at a high speed, would have the same crushing capacity as the whole mill at present. Why not run ten stamps in this way, and discharge upon the apron surface of the whole twenty *1* After the pulp is once through the screens, and slidured by the product of the three factors mentioned, that is, by the number of foot-pounds delivered per minute (which is certainly not the ease), there would still be good reason for preferring rapid running. After the necessary stability and strength are secured, increased weight of machinery is an evil. If equal results can be achieved by substituting speed for weight, the change is advisable.

10. In the case of the Colorado mills, the argument is still stronger. Their (gross) average weight of stamp, 580 pounds, is not excessive; their average drop, 13 1/2 inches, is not too large to admit of high speed; but their average speed, say of) drops per minute, is extremely low, and might be doubled with advantage. A bad arrangement for amalgamation is one excuse, which should be removed, not pleaded. Another serious objection, which Colorado experts are not so free in expressing, is a bad construction of battery foundations and frames. It is feared that high rates of speed would rack or upset the batteries. The California mortar rests on a vertical block, and the blow of the stamp does not communicate vibrations to horizontal timbers.

1 believe the views I have expressed are coining more and more to be those of American millmen, even in Colorado. The true evidence of this tendency is to be found in the patterns of the new mills, rather than the practice of those persons who are frequently obliged to adapt themselves to the proportions or condition of antiquated machinery. Moreover, the manufacturers frequently adhere to the old patterns, or at least put higher prices upon machinery constructed after new ones; and few engineers have the opportunity of dictating from their own experience the details of their mills. Mine-owners think a stamp is a stamp, and a steam-engine a steam-engine; and desiring so many stamps with so much horse-power to run them, pick up what they want wherever they can get it most cheaply—at second-hand, if possible. But many causes, and particularly the keen competition among custom-mills, are bringing about a wholesome progress in this matter.

*REMARKS ON THE WASTE IN **COAL** MINING.*

BY R. P. ROTHWELL, M.E.

AT this our first meeting I beg to call the attention of the members of our Institute to what is certainly a question of the greatest possible importance to the industries we represent; and more particularly to the welfare of the coal and iron trades: I refer to the enormous waste of coal in mining and in its preparation for market, as now practised in our anthracite coal-fields. It is a fact which many of you can certify to, that we are wasting fully *one-half of all the coal in the veins we are now working,* and there are cases, which might be mentioned where this proportion, immerse as it is, has been greatly exceeded.

The popular belief that our deposits of anthracite coal arc "practically inexhaustible," is very far from being founded on facts. On the contrary, supposing the present rate of increase in the production to be maintained, it is probable that a maximum yield for our coal-fields would be attained in about fifteen years; there are in fact some of our smaller basins where the principal veins are nearly exhausted and the production has already attained its maximum. There arc others, again, where the depth attained—and it must be borne in mind that we commenced working at the surface outcrop—moderate though it is (scarcely ever reaching eight hundred feet), has so increased the cost of mining as to imperil the capital invested, and though it requires but little foresight to predict the time when the difficulties of mining will be very considerably increased by reason of the greater depth, greater quantity of water, fire-damp, and other fruitful sources of cost, yet, ignoring these recognized facts, we continue to waste more than one-half of the coal where it is obtained with the least danger, expense, and trouble, that is, near the surface—either above water-level or at a moderate depth below it.

The inspection of almost any accurate mine map will satisfy you that, on an average, we leave fully one-third of the coal in the ground as pillars to support the roof; in some places more than one-third thus remains, while it is very rare that less than one-quarter is left. In almost every case this coal is absolutely lost, for it will very rarely pay to reopen gangways and lay roads to it after that portion of the mine has been abandoned. Is it necessary in all cases to support the roof, and where it is, may not some artificial support, stone or iron—for wood appears too perishable—be found cheaper than coal at certain depths? But, in addition to this source of waste, we have another, which, though not so great in per cent., yet attracts much more attention, and is in reality much greater than has generally been supposed, that is, the loss in breaking up the coal for the market. The mounds of "culm," or "coal dirt," which we meet with at every step in our mining districts, testifies sufficiently to the amount of this waste, and the loss of coal from these two sources amounts to fully as much as our shipments to market, or say about 15,000,000 tons per year at present! This is a condition of things which, as engineers, as individuals interested in the industries whose welfare our organization is intended to advance, or as citizens, having the prosperity of our country at heart, we should not allow to continue till we had exhausted every available means for improvement.

The question naturally forces itself on us, is there such a waste in coal mining in other countries, where veins as large, as highly inclined, and otherwise as difficult to work as ours, are mined? and if not, cannot their systems of mining, or some modification of them, be applied here to advantage?

The system of leases under which the operator pays for coal shipped, but not for coal wasted, and for the larger sizes frequently a larger royalty than for the smaller sizes, greatly aggravates the evil. When the leases are, morcover, for short periods, the combination of conditions is most mischievous. It then makes no difference to the lessee how much coal is wasted or left in the ground. His efforts are directed to getting to market as much coal of the most salable sizes in the given time.

The proper plan, in my estimation, would be to have the leases so drawn that the operator would pay for coal a certain sum per foot in the vein, instead of paying by the ton shipped. I think, also, that the breaker system could be improved. In fact, in the breaker which the members have visited (Mr. Swoyer's), provision has been made for separating at the outset the coal which does not need to pass the rolls.

Mr. Rothwell concluded with a recommendation that a committee be appointed to consider this subject, and report at *a* future meeting of the Institute.

DISCUSSION.

MR. SWOYER showed that the cost of land on the surface interferes with the long-wall system. He explained that in the Wyoming region the tendency was towards permanent leases', so that the tenant regarded the coal as his own, since he had, in fact, bought it, but paid in instalments instead of cash down. He complained of the whims of consumers as to uniform sizes of coal, asserting that this was the only reason of the great investment of capital, and the great waste of coal in the breakers. Combined with short leases, this state of things produced much mischief. If he had a short lease of a coal mine, and, for some reason, small sizes were to bring a relatively high price in market, he would naturally convert all his coal to small sizes, in spite of the actual waste, because of the present financial profit. Under a long lease, on the other hand, he could afford to consider the ultimate value of the eoal. He thought the best arrangement between owners and operators would be to pay the royalty on the coal as it was raised, before it was prepared.

Mn. HOFFMAN reviewed the paper of Mr. Rothwcll at sonic length. He thought it possible to retain the pillar and chamber system of mining. It might come to be a serious question whether the small villages over coal mines were worth the reservation underground of so much coal to support them. He was not aware of a higher royalty being paid for one size of coal than another. He thought the general adoption of long leases would improve the economy of coal mining more than any other simple remedy—the operator to mine so many tons per year, and observe proper rules of working.

ME. ROTHWELL replied that in the Wyoming region the lessees often actually paid less royalty for chestnut and the smaller sizes than for lump or steamboat coal.

MB. RAYMOND called attention to the difference between actual and economical exhaustion of mines, as illustrated in recent discussions as to the duration of English coal mines. Economical exhaustion might take place long before the mineral was all extracted, simply by reason of increased expense. It did not follow, because of the abundance of coal in the anthracite regions, that a reckless waste of it would not bring about in many cases a premature economical exhaustion. Just as soon and as long as a mine could not be profitably worked, it was practically exhausted. Moreover, mineral wealth was given to a country but once. Such resources would not grow again, like products of the soil. With regard to the particular case under consideration, he had no doubt the Council would appoint a committee to consider it, and report deliberately upon it. Hasty theoretical recommendations were of little benefit. It was clear that we must suggest something feasible, and not commercially ruinous, to our friends the operators, or else our talk about their waste would be fruitless. He had been a strong partisan of the long-wall system; but he must frankly admit that he saw many difficulties in the way of its employment in large "pitching" seams, and in localities where, of several workable seams, the lowest was at present working, because it was, by reason of greater thickness or better quality, or any other circumstances, the most profitable. Villages on the top might in time decay, by the suspension of the mines which support them in a double sense. Cases of the sudden rise and full of mining towns in the West were given. On the whole, the present system of mining in the anthracite regions, bad as it was, was a system hanging together, and much study would be required to suggest practicable amendment.

BETHLEHEM MEETING,

AUGUST, 1871.

PRELIMINARY REPORT OF THE COMMITTEE UPON THE WASTE OF ANTHRACITE COAL.

BY ECKLEY B. COXE, CHAIRMAN.

AT the first meeting of the Institute, a paper was read by Mr. Rothwell, calling attention to the importance of at once considering the great waste of anthracite coal under the present system of mining and preparing that fuel for market, and a committee was appointed to examine and report upon the method no\v in use.

About the time the committee were selected, a general resumption of work, after the long strike, took place in the coal regions, and the members of the committee have not in consequence had as much leisure to devote to the study of the question as its importance demands.

In the present preliminary report we shall merely sketch out the plan which we propose to pursue in our investigations, so that when our fellow-members are called upon to assist us in our work by furnishing statistics, etc., they may understand more clearly for what object our inquiries will be made.

As one of the most practicable methods of obtaining the information requisite for an intelligent consideration of our subject, we propose to send, from time to time, to members and others interested in the mining of anthracite coal, printed sets of questions relating to points under consideration. We would here impress upon our fellow-members the importance of filling up these papers as far as they can from their own knowledge. We would, of course, wish each question to be answered as fully as possible, but we do not expect every one to answer them all. One question well answered would be of more use to us than the whole paper filled up with answers, many of which are mere guesses. We propose to consider our subject under three heads, viz.:

I. The waste of coal in mining.

II. The waste of coal in preparing it for market.

III. The waste of coal in transporting it to market.

I. *The Waste of Coal in Mining.*—This question may be considered from two points of view. We propose first to examine the various methods employed, both in this country and in Europe, for working veins of the size of those most common in our anthracite coal-fields, with a view of determining the waste and the cost of getting' the coal under each system.

The various methods of working thick veins now in use in England, France, and Germany, such :IK the Staffordshire " Square Work," the French " Methode par remblais," and the Silesian method of drawing down the roof, and the long-wall system for veins of moderate thickness, are particularly worthy of notice. The object of this investigation will be to determine the best method which can be practically employed in Pennsylvania for mining anthracite. Should it be found that the existing system is the best, or, at least, that it is likely to remain the usual one, we shall then take up the second portion of this division of our subject, which is, to make a careful and thorough examination of the present system of mining anthracite with a view of suggesting any modifications by which the expenses of mining or the waste may be diminished. The committee hope to be aided in this portion of their work by all those practically engaged in mining anthracite. These two subdivisions constitute the most important, and perhaps, strictly speaking, the only questions referred to us, but the committee feel that the report would be incomplete were the other two divisions of the subject, viz., the waste in preparing the coal and the waste in transporting it to market, left unnoticed. In treating these questions, we shall follow the same general plan as in the case of the " waste in mining."

II. *The Waste in Preparing Coal for Market.—Vie* propose first to consider the present manner of preparing anthracite coal for market in comparison with the methods adopted for other coals in other places. It is important to determine how far it would be possible to do away with the use of breakers, at least so far as the crushing is concerned, so that the coal may be shipped nearly as it comes from the mines, the only preparation besides the removal of the slate being a separation into three or more sizes. It would be very desirable to determine how much inducement (in a diminution of prices) could be offered to consumers to take their coal with less preparation. For example, a large manufactory now using broken and egg might be willing to hike the run of the mine with the lump, steamboat, and the coal which would pass between bars placed one inch apart, taken out, provided they could obtain it at a less price. Another might use the large coal instead of the prepared sizes. In other words, can we teach the community that it is their interest to use the coal as it comes from the mine, by showing that the waste must be paid for by them?

The second portion of this division of our subject would consist of a discussion of our present system of preparing coal for market, with a view of diminishing both the expense of preparation and the waste. Under this head would come the consideration of the best form of breaker, of slate-pickers, of screens, self-dumps, etc.; and of the best methods of using the slack or fine coal. The committee would here call attention to the importance of so arranging the breakers that the coal will not be allowed to drop, but always to slide when it is necessary to convey it from one level to another, sliding causing much less waste of coal.

The third division of our subject belongs more properly to civil than to mining engineering, but there are some points to which it would be well to call attention.

III. *The Waste in Transporting Coal to Market.*—We shall begin the consideration of this question by discussing the means adopted in various parts of the world for transporting large quantities of coal by railroad, canal, and sea, and by comparing them with those adopted here, with a view of determining the best method of moving coal to market. Under this head would come the consideration of the drops used at Newcastle for transferring the coal from cars to vessels, the use of steam colliers, and the use of machinery for unloading vessels. We will then discuss our present system, and endeavor to point out any improvements in the method of handling the coal, by which the expense and waste could be diminished.

One point to which the committee would here call attention is the great waste of coal occasioned by the variable height of the cars used for transporting it. When constructing a breaker at present, it is necessary to place the lips of the shoots and pockets so far above the railroad track, that not only the highest car in use at the time, but also any one likely to be built will have room enough to pass under them. The ears at present in use vary much in height, and many are provided with brakes which project from six inches to a foot above the rest of the car. In consequence, the cool is obliged to fall several feet from the lip of the shoots, causing considerable waste by breakage, and damaging the cars.

It would be very advantageous if the railroad companies would adopt a uniform height for the ear, which should be as small as possible (measured from the bottom of the car), would avoid the use of projecting brakes, and would compel operators, when constructing their breakers, to bring the lips of the pockets as low as possible. The members of the committee hope, with the aid of their fellow-members, to carry out the above, programme, and to throw some light upon the important subject of the waste of anthracite coal.

ABSTRACT OF REM ASKS ON THE DIFFICULTIES IN THE IDENTIFICATION OF COAL-BEDS.

BY R. P. ROTIIWELL, M.E.

THE first difficulty mentioned is that in some instances two or more beds of coal separated by sandstone or slate rocks of considerable thickness in one part of a basin, are found running together in another part. Of course, we may happen to strike first the part of the basin where there is but a single seam, and in this case the bed would appear to divide into two or more branches within a short distance. Such cases are not rare in the anthracite coal-fields.

I would suggest as an explanation of this phenomenon the gradual sinking of the peat-marsh—the embryo coal-bed—on one side, and the moving forward of the marsh, so that on one part of the bed the formation of peat would still be progressing, while another part, being under water, would be covered with mud and sand. Thus we have different portions of the same bed of different ages. Now if the sinking of the marsh be stopped for a time, the bed will become thicker in the portions left exposed, and if the sinking now changes in direction, so that the part that had previously gone down commences to rise, we should have the phenomenon of a bed, continuous throughout, with one portion overlying another, and separated from it by rock strata. These are exactly the conditions observed in splitting beds. While one side of the lake is sinking, and the peat-marsh moving on in that direction, the other side may be rising, and another peat-bed be there forming over the first bed, and separated from it by a slate or sandstone rock; or we have two distinct beds, not in any way connected—never running one into the other—and yet they are being formed at the same time.

Since the *flora* of a country is continually changing—witness, for example, Canada and this country, where in some places the entire native small plants have absolutely disappeared, having been driven out, like the red man, by European invaders—the *flora* of different parts of the same coal-bed, formed at different times, will probably differ more than that of distinct beds formed at the same time.

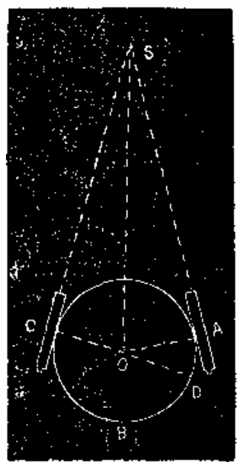
The careful study of the intervening rocks, as well as of several beds, is frequently required to enable us to identify the same bed at different portions of the coal-basin. The character of the coal itself is so exceedingly variable, within short distances in the same bed, that we cannot place much reliance upon the similarity of the coal in different places, as showing that the beds arc identical.

ON AN ECCENTRIC THEODOLITE.

BY PROFESSOR FRANCIS L. VINTON,
Of the School of Mines, Columbia College.

THE eccentric theodolite I exhibit is one constructed by the Stackpoles of New York, from drawings, considerably modified, of Combes's theodolite. The telescope is on one side of the horizontal limb, and the vertical circle is opposite to the telescope; thus they nearly balance each other, making already the construction lighter than in the instrument of Combes, where the telescope and vertical circle are together on the same side, and are both balanced by a considerable weight. The instrument stands upon three levelling screws or feet, an improvement upon the old or general style of mounting a transit on four feet—for indeed the instrument is easier levelled, and, moreover, stands more stable on three than on four points of support. The general advantage of an eccentric theodolite is evident, namely, that it can measure any and all vertical angles, from 0 to 360, without being interfered with by the horizontal limb as is the transit; besides this advantage, it needs no preparatory adjustment or correction for eccentricity ; on the other hand, however, that correction must be made during the measurement of each angle. It will be seen, however, that such correction amounts to no more trouble than the taking of the angle twice, although there are three different ways of correcting. Let us first imagine that we have to obtain the eccentricity of the instrument, in order to apply that value itself as a correction if we choose. The eccentricity may be considered the length of the radius from the centre of the horizontal limb to the optical axis of the telescope. To measure that, let the zero of the vernier be brought to coincide with the zero of the horizontal limb, and let the telescope be directed and fixed on an object at 7 or 8 met. distant, then unelamp and turn the telescope horizontally until it comes to the other side of the horizontal limb, then turn the telescope over to bring the objective towards the same object and sight it once more.

FIG. 1.

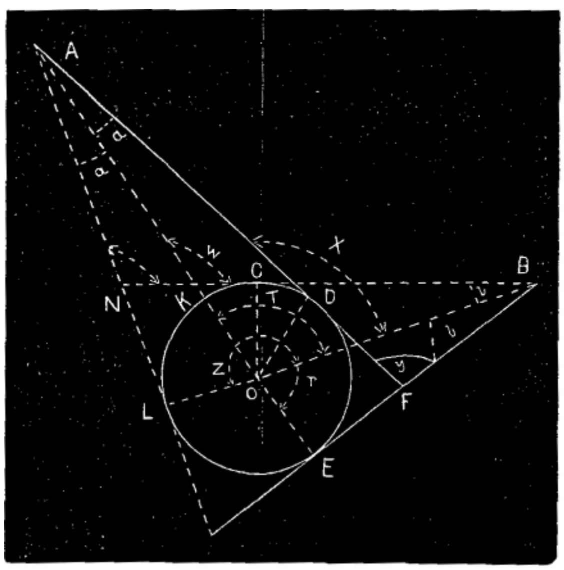


Clamp and read the angle A D B C. Subtract 180° from that and we have the angle A O D, which is equal to A S C. Now, finally, the distance O S must be accurately measured, and that being done, we have in the triangle O A S, the known line O 8, the known angles O S A and O A S. whence the line O A can be determined equal to the radius of eccentricity.

This being done, we may now at any time correct an observed angle by the application of a coefficient as follows: First observe that the error due to eccentricity is the difference between the real angle and the one the instrument measures. This error will always be different for different distances of the objects which subtend any angle in question ; but a general expression for it is easily obtained. This error is null if the two objects happen to be at equal distances from the centre of the instrument, and is greater the nearer the object be to the instrument, while yet differing in distance.

Suppose the real angle to be measured be represented on Figure 2, by A O B, the angle measured by the telescope turned first upon A and then upon B, going from the right side around to right, is y. The difference between T and y is demanded. The angle A F B is equal to the angle DOE, the measured angle, and observing that the angle X is an exterior one to both the triangles G F B and G O A, we have at once $y + b = T + a$, or $y + b - a = T$ (1). Here the correction to apply to y, the measured angle, is $b — a$. But both these angles are known, since we suppose the radius O D = O E to he known, and that the distances O A and O B are measured sooner or later. Supposing, as in the present ease, that the measurement has been taken with the telescope to the right, it is evident that the measured angle y is greater or less than O A, or in short, if with telescope to the right the first object sighted be nearer than the second, then will the measured angle be greater than the real.

If, however, the measurement commenced with telescope to left, the case would not be the same, the correction would be different in sign, though the same in numerical value. If, in fact, we consider the telescope to the left, and as passing from L to C during the measurement of the angle, we have the measured angle L O C — A N C = z, and the real angle will be = T, as before. Then, considering the exterior angle W to the two triangles A K N and K O B, we will find the equality $z + a = T + b$, whence we have z + f a —b = T (2). Here the correction to apply to z, the measured angle is $a — b$, whence we see that z will be too small if O A is smaller than



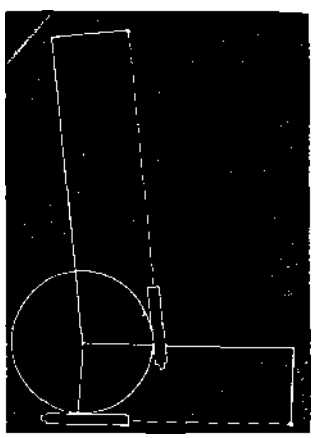
O B; that is, in this case, with telescope to left, if the first object sighted be nearer than the second, the measured angle will be too small. In cither case the coefficient of correction can be applied.

But it is easier, without calculating, to make it apply itself by taking two observations of the same angle, once from the left and once from the right. For, if we add together equations (1) and (2), we find that $z + y = T$, therefore, if we measure the two angles found by sighting first from one side and then from the other, and take their half sum, we have the veritable angle between the objects and the centre of the instrument. If the distances O A and O B be equal, we see from either equation (1) or (2) that the measured angle, either from left or right, is equal to the real angle.

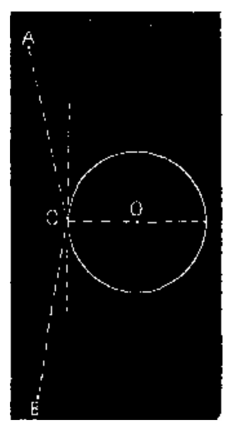
Again, another method of correction could be used. Having obtained the radius of eccentricity we might construct a staff with a sight on an offset arm at a length from the staff equal to the radius of eccentricity. By using such a sight the instrument would measure an angle absolutely parallel to the real, and consequently equal to it, at one observation. By the same method we could set off a given angle, since with the theodolite and staff the angle can be quoted from the sight or end of the arm, and the position of the staff will give the two points subtending the required angle at the centre of the instrument.

However, though the use of such a staff would obviate the necessity of taking two angles at each station, still, the latter artifice is much the more accurate, and is advantageous in that it repeats the

FIG. 3.



Fro. 4.



angle. In the note-book are columns for the angle to left, and for the angle to right, with one for their half sum. The adjustments of this instrument are the same as for other angular instruments, consisting, in short, of making three lines of the instrument perpendicular to each other.

The levelling is very easily done; but it is, moreover, particularly important in instruments which take angles whose planes are inclined to the horizon as a mine theodolite constantly does, that the telescope axis be most accurately perpendicular to the axis of its rotation, so that it may describe a plane and not a cone. To determine whether this instrument be perfect in this particular the telescope may be turned first on object A and then on object B. These points being marked, must be found in the same right, line with C, if the instrument be in adjustment. The point C is to be in a vertical plane with the axis of rotation of the telescope, and at a distance from O equal to the radius of eccentricity.

ABSTRACT OF A PAPER ON THE MINES AND WORKS OF THE LEHIGH ZING COMPANY.

BY H. S. DRINKER, C.E.

I. THE MINES.

THE first discovery of zinc on the property now worked by this company was made by the celebrated mineralogist, Prof. William Theodore Ropper, in 1845. Different claimants kept the property in continual litigation till 1861, when everything was satisfactorily settled by the purchase of the land by the company, who have worked it ever since.

The mines are situated in a valley, four miles south of Bethlehem, Pa., in Lehigh County. The valley is from two to three miles broad, and is bounded on the north and south by syenitic hills. Syenite underlies the valley, and upon this is deposited the Potsdam sandstone, then a layer of slate, and, finally, a dolomitic limestone, belonging to the Chazy or Black River formation, in which the zinc deposits are inclosed. The rocks occur in folds, and have evidently been subjected to tremendous pressure from below, the zinc deposit being found in an anticlinal axis, in nearly vertical veins. It is supposed that the zinc was originally disseminated through the dolomite, in the form of carbonate or sulphide. This ore, it is sup-posed, was dissolved by the carbonic acid water, which, at the same time, eroded the limestone. The sulphuric acid, resulting from the decomposition of iron pyrites, converted the zinc into the form of sulphate of zinc, and from this, by the action of the animal matter contained in limestone, the zinc was precipitated as sulphide (blende), which is therefore the primary ore of the present zinc deposits. The silicates and carbonates at present found, are doubtless formed by the action of air and water upon the original deposits. The presence of zinc, disseminated through the dolomite of the valley, can easily be found.

The general strike of the stratified rocks of the valley is northeast and southwest, but the most important zinc veins run cast and west.

The blende usually found in these mines is of a very peculiar texture and appearance, resembling closely the limestone in which it occurs. The cleavage has a waxy lustre, and the ore. is a massive blende containing from four to five per cent, of iron. Occasionally small crystals are found, but the crystallized "black-jack" of other mines is not found here. Smithsonite and calamine are also found. An earthv variety of the former mineral, of a light yellow or brown color, is abundant as an over; and the latter, mixed with decomposed rock, clay, etc., forms one of the principal surface ores.

A compact clay, containing from 26.32 per cent, of zinc, unctuous and with an eminently conchoidal fracture, is believed by Prof. Hopper to be a true mineral. Greenockite occurs as a yellow coating on the blende. Coslarite, pyrite, wad, melanterite, calcite, and other minerals, are also present.

The mines were originally worked as open cuts, commencing at the outcrop, found by Prof. Hopper. The ore was easily and cheaply extracted so long as it was possible to pursue this system. From twelve to fifteen thousand tons per year were taken out in this way, at a cost of about a dollar per ton. At present, the cost of mining a ton of blende is $6, and a ton of earthy ore $12. About twenty thousand tons of both sorts are mined per year.

Pumping.—The chief difficulty encountered in working thesemines is the large amount of water which must be kept under con- trol. In 1854 the open cut of the Ueberroth mine, twenty feet deep, was drained *by* centrifugal pumps, which were subsequently replaced by a double-acting pump, capable of raising 200 gallons per minute, from a depth of 40 feet. In 1861, a Woodward pump, now in use at the smelting-works of the company, was put up. This was, however, too small to do the work, and in 1863 a Corliss engine, driving four centrifugal pumps, capable of pumping about 2500 gallons per minute, was put up. In 1866, the West engine, still in use, and capable of pumping 5700 gallons per minute, with 16 strokes, was erected, and the same year the shaft was sunk to a depth of 132 feet. The centrifugal pumps have since been removed, as the loss by friction was found to be 47 per cent.

The West engine was designed and erected by Mr. John West, the engineer of the company, under whose direction the colossal engine, for the new main pumping-shaft, has since been built, and is now being erected. The first West engine erected was of 300 horse-power, and worked three 22-inch lift-pumps, at the rate of 16 strokes per minute. The engine is a horizontal, condensing, double- acting engine, and besides the three lifting-pumps, also drives a small 12-inch lifting-pump, which raises water for condensing and ore-washing, from the adit level, about 45 feet.

A single-acting Bull engine, on the Cornish principle, with a 50-inch steam cylinder and 10 feet stroke, designed by Mr. West more than twenty years ago, is supposed to be the first Cornish engine ever built in this country. It was moved to these mines, and is still in use. It works a 22-inch pump at 7 1/2 strokes per minute, raising a column of water 160 feet to an upper adit. The capacity of this pump is about 1800 gallons per minute.

A 20 horse-power engine, raising from 230 to 240 gallons per minute, is at work at another shaft.

The new pumping engine, of which so much has been said, was also designed by Mr. West. It is expected to be in working order before the end of the year. It was built by Merrick & Sons, South-wark Foundry, Philadelphia; much of the casting being subcontracted for by Lazell, Perkins & Co., of Bridgewater, Massachusetts.

The steam is to be supplied by sixteen boilers, each 50 feet long, 36 inches in diameter, and built of 5-16ths iron.

Balanced valves, 20 inches in diameter, and with 1 3/4-inch lift, are used to admit steam to the cylinder, which is of cast-iron, 110 inches in diameter, and 10 feet stroke, and weighs 30,398 lbs. The cylinder bottom weighs 26,798 lbs., and the head 24,540 lbs., making the total weight of the cylinder and heads 81,736 lbs., or 40 net tons. The cylinder jacket is of cast-iron, 1 5/8 inches thick, and weighs 26,928 lbs. A space of half an inch is left between the cylinder and jacket, the latter being lagged with well-seasoned wood. The exhaust valves are 30 inches in diameter, and lift 3 inches.

The condenser is situated directly beneath the cylinder, and a channel-way leads from it to the air-pump. The condenser and bonnet weigh 33,075 lbs., and the bottom 24,213 lbs., making a total of 57,288 lbs. The piston-rod is of wrought iron, 14 inches in diameter and 22 feet long. The cross-head weighs 15,740 lbs., and is fastened to the piston-rod by a nut weighing 1100 lbs. A parallel motion is employed to keep the piston-rod vertical.

The working-beam is in four parts, lattice patterned, and weighs in all 95 net tons.

The connecting-rods run from the working-beam to the fly-wheels, and are 41 feet 2 1/2 inches from centre to centre, and 15 inches in diameter in the middle. They weigh over 16,250 lbs. each. There arc two fly-wheels, one on each side of the cylinder, each of which is 30 feet in diameter, and weighs, with weights bolted in, about 92 tons. The pump-rods are attached to the other end of the working-beams by back and centres, running through its four parts. One of these centres weighs 2374 lbs.

There are two wooden main pump-rods, 2 feet by 3, made of six pieces of one foot square Georgia pine lumber. The bucket-rods and the plunger-stockings are attached to them by means of set-offs, and a plunger-head.

There are to be four lift-pumps of 31 1/2 inches in diameter, discharging into four tanks, resting on bearers, 96 1/2 feet from the surface. Four plunger-pumps force the water from the tanks to the surface. As the shaft is carried down, the lifting-pumps will not be required to raise the water more than one hundred feet. A fifth plunger and a fifth lifting cylinder will be provided, so that the work of lowering the pumps, as the deepening of the shaft will render necessary from time to time, will be much shortened in time, and seven of the eight pumps can be kept almost continually in operation. The engine can be run under a pressure of 60 lbs. To the inch, and would then exert nearly 3000 horse-power. It is, however, not intended to run at so high a pressure, but it is intended that the engine shall pump 17,000 gallons of water per minute from a depth of three hundred feet. All the larger parts of the engine are made to resist a strain eight times greater than it is calculated they will ever be called upon to sustain.

Total Amount of Water to be Pumped.—The following summary may be interesting as showing the total pumping capacity of all the pumps about the mines:

The new engine,	17,000	gallons per minute.
The West engine,	5,700	gallons per minute.
The Bull engine,	1,800	gallons per minute.
The small engine,	235	gallons per minute.
Total,	24,735	gallons per minute.

or 35,618,400 gallons per day.

II. THE WORKS.

The blende, as it comes from the mines, is crushed in a Blake's crusher, and passed over a sieve with one mesh to the inch. The larger pieces, which pass over the sieve, arc separated from the gangue by hand, and the ore sent directly to the works, or roasted in heaps 26 1/2 feet long, 14 1/2 feet wide, and 8 feet high, holding 50 tons. The ore is placed upon iron grates supported by two lateral walls and one central wall, all of stone. The centre wall is three feet thick, beinff twice the thickness of those on the sides. Wood placed beneath the grates is used for firing. The small stuff which passes through the sieve, when it comes from the crusher, is, at present, laid aside for future treatment. The crusher needs about 10 horse-power, and, with one man to feed it, does the work of four men breaking ore by hand. The silicates and carbonates are washed, sized, and the larger pieces sent at once to the works. The sands are concentrated by buddling or jigging. The conical washer, in which the ore is washed, is 10 feet 2 inches long, 5 feet 2 inches in diameter at the large end, and 3 feet at the smaller end. The ore is fed in at the larger, and worked up to the smaller end by means of teeth 6 1/2 inches wide and high, set slanting. From the washer, the ore passes into a revolving screen attached to it. The meshes of this screen are 3 1/4 inch. The pieces which are too large to pass through this screen are sorted by hand, and the ore sent at once to the works. The silicious ore deposited by the water is rewashed in the roller before being budded. Sometimes the earthy ore occurs hard enough, and sufficiently free from sand, to dispense with washing.

The buddies used are of the regular Cornish pattern, the pulp being fed at the centre, and the discharge being on the circumference. The sand pile, when formed in the buddle, is 13 feet 8 inches in diameter, and 2 feet deep on an average, being higher in the centre, and sloping down towards the margin. Each buddle holds about fifteen tons. Sweeps, five feet in length, attached to revolving arms, push the pulp along as it runs over the conical pile already formed, serving to keep the surface in good condition, and facilitating the deposition of the particles according to their specific gravities. When a buddle is finished, the pile is divided into concentric- rings. The innermost of these is regarded as ore, and, after a little more treatment, sent to the works; the next is reworked in the same buddle, and the third portion in another buddle. Keeves are also employed. These are 3 feet in diameter at the top, 2 feet at the bottom, and 3 feet deep. After stirring the ore thoroughly with water till the tub is full, it is allowed to settle, the keeve meanwhile being tapped with an iron bar.

A continuous jig is being tried for concentrating the sand. The dressed ore is transported to the smelting works, which are situated in South Bethlehem, about four miles distant, by wagons drawn by four mules each, and carrying 3 1/2 tons.

Metallurgical Processes.—The oxidized ores used for the preparation of zinc-white generally contain about 20 per cent, of zinc. Three hundred pounds of ore, mixed with one hundred and fifty pounds of pea or dust coal, are fed together through chilled-iron rollers and then on to a screen for the purpose of sizing. Fine and coarse ores are not treated together, though subjected to the same subsequent process, which consists in a volatilization of the oxide of zinc by heat, a cooling of the gases, and the collection of the zinc-white in long bags of ordinary muslin, the gaseous substances passing through the interstices in the cloth.

The furnaces are of two kinds, single and double. The former are charged only at one end, and only hold a little over a third of the charge of the latter, which are provided with a working door at either end. The single furnaces are 5 feet long and 3 feet wide, covered with an arch of firebrick, which, at the centre, is three feet above the hearth. The opening into the flue is 18 inches square, and the hearth consists of an iron grate made of heavy rolled iron, with perforations to allow the air to pass through. The front opening or charging door is three feet long, and arched so as to be one foot high at the centre. These furnaces cost about §150, and are charged with 240 lbs. Of ore, 120 lbs, of coal, and 100 lbs. pea coal as a bed. The double furnaces have an opening 30 inches square into the main flue, and are provided with grates, of similar construction to those used in the small furnaces, 16 feet long by 5 feet wide. The working doors arc of the same dimensions as those of the small furnaces. The walls are all of firebrick, 8 inches thick, and last about eight years without repairs. The double furnaces are charged with 640 lbs. Of ore, 320 of coal, 240 of pea coal as bedding. No fluxes are added, the object being to keep the charge from becoming impervious to the blast, which is furnished by four fan-blowers.

The process lasts four hours for each charge, and considerable attention, on the part of the workmen, is necessary to keep the cinder porous and avoid the cooling of the fire by an excess of blast. Each workman has four furnaces under his care, and cleans and charges one each hour.

The oxide vapor passes from the furnaces along a conducting channel over a sheet of water, into a cooling tower 75 feet high and 80 feet in circumference at the base. Much of the dump, impure oxide settles in this tower, and the remainder is conveyed down another tower 50 feet high, and by an exhaust fan is forced, through a conducting channel, into the bag-rooms. This conducting channel is floored with sheet zinc, and serves as a cooling-chamber, in which another portion of impure oxide collects. The muslin bags in the bag-room are 30 feet long, and are attached to the sheet-iron tubes that convey the oxide from the cooling-chamber, so that they hang down perpendicularly. They are shaken by the bagmen every four hours, and the oxide removed every twelve hours. After some preparatory treatment this oxide is packed and shipped.

The Spelter Works.—Both blende and oxidized ores (silicates and carbonates) are used in this branch of the work. The latter are roasted in large kilns, with one ton of coal to ten of ore. The diameter of these kilns, at the largest part, is about 10 feet. The roasting requires twenty-four hours. The roasted material is crushed with coal, 100 tons of ore to 40 of coal, and when sifted is ready for charging into the retorts.

The blende, after being roasted in heaps at the mines, is first crushed and then roasted as nearly dead as possible, in reverberatory furnaces, after being mixed with 40 per cent, of coal-dust. From one to two per cent, of sulphur is, however, still left in the ore.

The retorts are made at the works of a mixture of fresh fire-clay and ground fragments of old retorts, and are 42 inches long, 9 inches in diameter outside and 6 inside. The condensers fitting by a level in the retorts, are 16 inches long, 6 inches in diameter at the largest and 3 at the smallest end (from outside to outside), the shell being a little over 1/2 inch in thickness. Fifty-six retorts are placed in each furnace, in seven rows, eight retorts being in a row. Beneath the retorts is placed a row of six so-called cannons to break the heat. These are 3 feet 4 inches long, and 7 inches in diameter, outside, and are not charged. The retorts rest at the back on ledges, and at the front on plates of firebrick 24 inches long, 9 1/2 inches broad, and 2 inches thick, supported by vertical firebrick pillars 11 inches high. The furnaces are built in groups of four, the internal walls being entirely of firebrick, and the external ones of common brick, lined with firebrick. The walls of each furnace inclose a space 8 feet 3 inches by 2 feet 6 inches, the internal walls being about 18 inches, and the side walls 2 feet 6 inches thick. The slant at which the retorts are placed varies with the purity of the ore, but is generally from 3 to 6 inches from end to end. The furnaces have a frame-work of cast-iron to add strength, and flat iron plates are placed in ront of the etorts to support the condensers, ladles, etc.

Forty pounds of the mixture previously mentioned, is charged very twelve hours nto each retort, excepting those in the upper row, which are charged every twenty-four hours, with skimmings, impurities, etc., containing from 60 to 65 percent, of zinc. As soon as oxide of zinc is seen burning at the ends of the condensers, prolongs of sheet iron, tapering to a fine point, are put on to the condensers to save the escaping zinc. Every twelve hours the zinc is collected in ladles, and poured into moulds 7 inches by 24, and 1 inch deep, forming ingots which weigh from 40 to 45 lbs. each.

A block of four spelter furnaces costs about §5000, and one double reverberatory furnace for roasting, about $2500.

The process which actually takes place in the retort is the following: The air introduced with the charge causes an imperfect com- bustion of a portion of the carbon present forming carbonic oxide (CO), which reduces oxide of zinc to a metallic state, by taking oxygen from it, and forms carbonic acid (CO_2). We have then present in the retort, at a high temperature, oxide of zinc, carbon, and carbonic oxide. By the reduction of two atoms of zinc-oxide to a metallic state, one atom of carbonic oxide is converted into carbonic acid, and one atom of carbon into carbonic oxide, and so the process goes on, continually repeating itself till the contents of the retort are exhausted. The following formula may make the action clearer :

$$2ZnO + C + CO = 2Zn + CO + CO_2.$$

From carbonate and silicate ores containing 47 per cent, of zinc, there can be actually extracted from 34 to 35 per cent., and from roasted blende containing 47 per cent., 33 to 34 per cent. The difference is due to the presence of the small quantity of sulphur previously mentioned.

The spelter works deliver about 65 hundredweight of metal per day to the rolling-mill, where it is remelted in a reverberatory furnace and run out into shallow moulds of various sizes according to the gauge of sheet metal on which the mill is running. After passing through the rolls till reduced to the proper thickness, and having been previously annealed and trimmed, the sheets are packed in casks containing 1200 lbs. each.

TOPOGRAPHY WITH ESPECIAL REFERENCE TO THE LAKE SUPERIOR COPPER DISTRICT.

BY JOHN F. BLANDY, M.B.

IT is not my intention in this article to consider this subject in the light of the geographer or geologist, but rather in that of the mining engineer, and to endeavor to show the necessity and value to him of studying the minor details of the field or district in which he may be engaged. It has been said by a distinguished geologist that " the natural boundaries of the geographer are rarely described by right lines. Whenever they occur, however, the geologist may look for something remarkable." And again : " Physiognomy is no idle or doubtful science in connection with geology. The physiognomy of a country indicates almost invariably its geological character."

Our country furnishes examples enough of the truth of these remarks, and in no part of it is it so beautifully illustrated as in our own State, which has been so ably described by Prof. Lesley in his admirable little work on the "Topography of Coal."

As the great mountain lines become guides to the geologist in determining and mapping out the geography of the formations, so do the minor details of topography become guides to the mining engineer in conducting his explorations, discovering of dislocations, and determining the character of the deposits which are the object of his search. It is therefore requisite that he should, whilst making his surveys, pay the strictest attention to every variation of the landscape and surface of the ground. Until he has mapped out every feature he may be unable to read the geological changes which may have passed under his view. In particular he should note all sudden changes in the course of streams, any prominent knolls of ground, and the different angles of slopes of the hills, as they often tell the direction of the dip of the rocks even though the rocks may not be visible. Knolls, forming with each other regular lines, mostly de-note the presence of a hard stratum of rock, the character of which it may be valuable to know. The exact mapping of such knolls is necessary to the discovery of displacements in the strata, in a region where fracture veins are found; and on the contrary, should such displacement in the line of knolls or outcropping of a belt be found, then it is a sure indication that such fracture veins do exist. It is hardly necessary to give in detail the many results to be derived from an accurate noting of every natural feature. We may feel sure, however, that there is a natural reason for the existence of every such feature just where it is found—a reason why the stream runs on one side of the valley and not on the other; why it is rapid at one point and gentle in another, and why the hill is steep on one side and slopes smoothly away in the opposite direction.

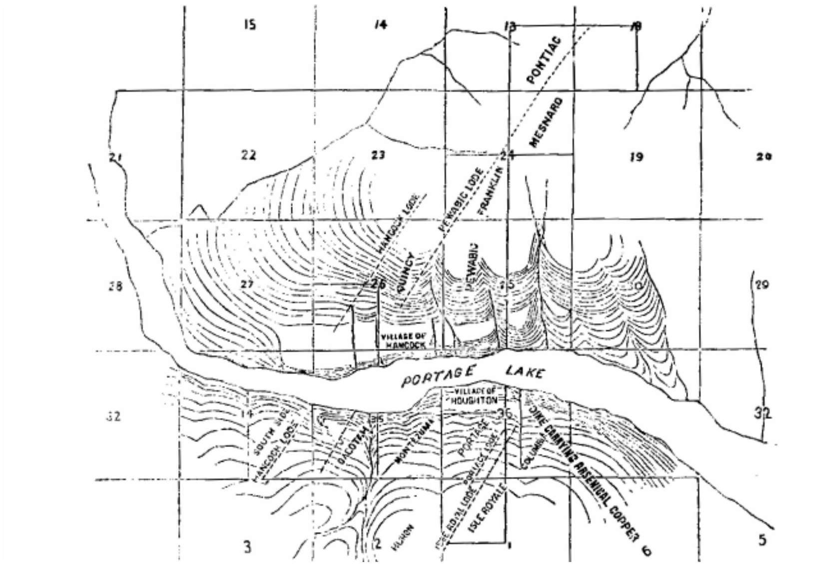
In illustration of these assertions, I wish to draw attention to a field in which I have been more especially engaged, and to the topography of which I have devoted more or less study, viz.: The Lake Superior copper region.

The Lake Superior copper region has in accordance with the centers of mining industry, been divided geographically and politically into three sections, namely: " The Point," " Portage,"and" Ontonagon" districts, situated respectively in Keweenaw, Houghton and Ontonagon Counties, and although the districts are situated on the same continuous mineral range, they are separated by large comparatively unexplored territories. This division into three sections is by no means accidental, but is the result of the topographical features of the region, as indicated both by its geography and the character of its mineral deposits.

In the first section or district you have natural harbors in the very edge of the mineral range; in the second the range is intersected by a lake which affords transportation directly to the mines; and in the third the mouth of the river, which drains the district, has been made the common commercial centre.

Upon examination, the topography of the range and character of the deposits will be found equally various.

The main features of the coast line of Lake Superior is the great point projecting far out into it from the southern shore. This is the mountain ridge of copper-bearing trap, which has withstood the action of the forces that have worn away the sandstones around it. The conspicuous points of this great headland are Mounts Houghton



and **Bohemian,** peaks of the southernmost of the two ridges, which in this section (The Point) constitute the mineral range. These two peaks, with the ridge connecting them, are a great mass of porphyry, and around them on the north the trap range sweeps with a nearly regular curve from the northeast, where the strata have a bearing of about S. 60 degrees E. and N. 60 W., to the northwest, where they have a bearing of about N. 30 degrees E. and S. 30 W, This latter course is maintained on through the Portage district, and with slight variations on through the Ontonagon district.

In the Point district, the greenstone strata is the most conspicuous belt among the traps, and presents a splendid escarpment towards the south of many miles in length. Its excessive hardness has enabled it to resist the forces which have worn off the other beds, and it is now the great landmark of the explorer. It is a base line from which he measures and numbers the other belts to the north and south.

A careful mapping of this ridge, together with its accompanying and underlying conglomerate, enables the engineer to detect the great displacing fractures which cross the whole range. They seem to possess an approximate parallelism, having a nearly nortli and south bearing, and as the other veins are displaced by them, belong therefore to the most recent class. They have formed the gorges in the ridge, through which the streams have found their way, and afford easy passage for the roadways. Besides these main fissures you find every few hundred feet other veins of a different class and material. Many of these scarcely show themselves in the greenstone ledge, but are much more prominent in the softer strata, and an accurate tracing of these ledges will often detect their presence and displacements. These are divisible into main or mother lodes, which have a bearing more or less radial to the southern porphyritic mountains, and branch lodes which have their beginning and ending in the main lodes.

This, therefore, becomes the distinguishing feature of the Point district, namely, the fracture veins intersecting the stratification at nearly right angles, in which receptacles have been collected to a greater or less extent the objects of the miner's search. Not all of these fractures contain metallic deposits, or at least in remunerative quantities, and it is a question for the most careful study of the mining engineer to determine, not only by the examination of the mineral contents, but also by the topography of the ground, whether these veins cannot be so classified as to be able at once to know the class to which each one belongs, and therefore approximate to its value. Such an examination will also determine the relative ages of the class, and therefore the comparative method or process of filling, valuable data for the mineralogist. I think it may now be safely asserted that the latest made veins of fracture are those which have caused the gaps of the main ridge, and further, that they are for mining purposes valueless.

In order, however, to study these questions in all their bearings, it is necessary to look at the adjoining districts.

In the second, or " Portage" district, the features of the country are entirely changed. The greenstone ridge has sunk down to the general level of the other strata, or perhaps has disappeared, and the summit of the mineral range is comparatively regular and level. The range is marked by no prominent feature, either of elevation, ravine, or change of course, until the deep gorge occupied by Portage Lake is encountered. The explorations in this section, up to the present time, have discovered but few fissure veins, and those only in the immediate vicinity of Portage Lake. No doubt others will be found, but sufficient examinations have been made to prove that they are but few and far between, and further, that they belong to the most recent class, and, as asserted above, are to the miner of no value. The workable metallic deposits of this section are the strata themselves, and we are therefore led to infer that the fissures in the " Point" section have there robbed the strata to such an extent as to make them, with local exceptions, comparatively valueless. This point being ascertained, namely, that the metallic deposits in the fissure veins came directly from the inclosing strata, supplies the geologist with a groundwork for his reasoning as to its original source.

If we now examine closely the gorge of Portage Lake, we will find that its topography opens up other questions of great interest. It intersects the range on a nearly east and west line, the ridge rising on the north side to an elevation of 600 to 650 feet, and on the south side to about 500 feet. The whole slope of the mountain on the north side is covered with the deep deposits of the Drift period. This has been furrowed with deep ravines by the streams which now and formerly ran down the face of the hill. The opposite mountain-side has been scoured clean by the current which must have set through the gorge, leaving the rocks with scarce soil enough for vegetation. The gorge, after passing through the main range in either direction, has a bearing nearly north and south, and it is interesting to follow the hillsides, and notice where the force of the current has either left the rocks bare or allowed the deposition of debris.

About 50 feet above the present level of the lake, in the town sites of Hancock and Houghtou, the ancient shores of the lake are distinctly visible as terraces, extending on the north side from about the middle of section 27 near two miles to the middle of section 25, where the ravines of the mountain-side have made it no longer traceable, and on the south side, from the Dacotah Creek eastward to the east side of section 31, about two and a half miles. The terrace on the north side is higher than on the south (but I cannot now give the difference in elevation), an evidence that a great fracture exists under the bed of the lake. They are not horizontal, as they must of necessity have been at one time, but rise very perceptibly towards the east, an evidence that the mountain range has been subject to some elevating power at a comparatively recent geological period. On the eastern half of section 36, on the south side of the lake, the terrace changes its line of grade, it rising from that point eastward faster than its descent toward the west. This change of grade is a proof of some local disturbance beneath, and it was to me for a long while a subject of conjecture what it could mean. Finally, some few hundred feet from this point of change in grade a dyke was opened which carries arsenical copper in considerable quantities, and upon examining the course of it I found it to intersect this point in the terrace.

This change of grade is not noticeable on the northern terrace, from the fact that it is too much cut up by the ravines to be traceable at the point where the course of the dyke would intersect it. The dyke may not have extended so far, but the fact that some arsenical ore was once found in explorations near the top of the north hill, would lead us to conjecture that it did extend for a long distance in that direction, and if so, it would probably pass between the Franklin and Mesnard mines.

The great main fracture of the range, which exists under the bed of the lake, would most likely be accompanied by minor ones, near at hand, and these we find on the hillsides, cutting through the Quincy, Hancock, and Sheldon-Columbian mines. These, belong undoubtedly also to the most recent class of veins, and have so far proved worthless.

You will thus perceive that the study of the topography of these terraces becomes a valuable clement to the engineer in this district.

After proceeding to the southwest from Portage Lake about seven or eight miles, we enter into a comparatively unexplored region, which extends a distance of many miles before we reach the real Ontonagon district. This unexplored section, if we may judge from the irregularity of the hills—only here and there appearing to form range lines—-is very much disturbed beneath, and much broken by heavy faults.

In the Ontonagon district, there are a number of wide and deep passes in the range, through which flow the rivers Fire Steel, Flint Steel, and Ontonagon, unwatering the country lying to the south. An examination of these mountain ridge *blocks*—if 1 may so designate them—between the passes, will show that at the northeast end of the blocks the strata have a much flatter dip than at the southwest end. Therefore, if we trace a belt towards the southwest, we will, in descending the southwest end of the hill, have to make an offset to the left to find the continuation of the belt on the southwest side of the gap.

This, as it were, oblique elevation, has apparently been the cause of the mixed character of the deposits of this district, since both strata and fissure lodes have been found workable. The fissures, however, do not, as in the Point district, intersect the strata at right angles, but obliquely, and seem more the result of the warping of the strata in the blocks into which the ridge has been broken. The most conspicuous and best known example is that of the section between the Flint Steel and Ontonagon River gaps.

At the north or Flint Steel end of the mountain the rocks dip at an angle of 20° to 25° to the north, and increase gradually until, at the south or National mine, they have attained to 50° to GO^0.

Any sliding motion between the strata which would take place during the elevation, would be apt to be along the smooth surface of the sedimentary or conglomerate and sandstone beds; hence the great contact or conglomerate lode which produced the famous Minnesota mine.

The process of warping of the more rigid beds of trap was most likely the cause of the, oblique fracture known as the North Minnesota lode.

We can easily illustrate this whole case by taking hold of the leaves of an open book by one corner and raising them slightly, the lenticular openings between the leaves will then represent the receptacle or lodes. Viewing the subject in this light caused me, in the year 1859, after having made a close examination of the mine, to express the opinion that they were fust approaching the limits of the deposit, although the mine was then making its largest returns. The end came even sooner than I had expected.

I have now given the leading features, in the topography above and below ground, of the three sections or districts, and have endeavored to show the cause of the variety in the nature of the deposits. In the first we have a series of fissure veins, resulting from the elevating force, being apparently a central and local one; in the second, it seems to have been a uniform raising of the range as a whole, therefore causing no fractures; and in the third, to have been a moving force traversing the range obliquely.

These speculations may be vague and very imperfect, but at the same time may form a sufficient basis upon which to build others when the region has been better explored, and affords more data with which to supply the deficiency. I might enlarge upon the subject by pointing out some interesting local features of the drift deposits, and the elevations and dislocations which took place before and after these deposits; but that would lead me away from my subject, which was to point out the value to the mining engineer of neglecting nothing whilst doing the *preliminary* work in new ground, namely, making the surveys.

THE USE AND ADVANTAGES OF THE PROP SCREW-JACK.

BY E. GAUJOT, M.E.

(WITH FIGURES I-IV, PLATE I.)

IN connection with the question of coal waste and economy in mining, we would call the attention of those interested to an apparatus invented by M. Dernencourt, Superintendent of the Anzin Division of the Anzin Coal Company, North of France.

This apparatus *is* known in France and Belgium under the name of prop screw-jack *(vis botte),* and has been used with good results in the above-named countries for some years past.

M. Ponson gives, in his "Traité de l'exploitation des Mines," a description of it (page 533), but as the description given is old, the work not widely known in this country, and as some valuable improvements have been made since, I thought it might be useful to give a description of it, having seen it in operation in 1867, while in Europe to attend the great Exposition, and on a scientific tour to the mining districts of France, Germany, Belgium, and Italy.

The prop screw-jack is composed of the following pieces:

I. The body or column B, Fig. 4 [Plate (1)], of oak or yellow pine, sawed square, the bark taken off, and any length, proportionate to the vein. The smallest are 10 inches diameter at the base, and 9 inches at the top, the height being from 12 to 15 inches less than the size of the vein. In the axis of this column, and at the top end, is a cylindrical opening or hole, C, 2 3/4 inches diameter, 10 inches deep, for the screw, S.

II. Two wrought-iron rings, R R, to strengthen the two extremities of the column ; the rings must be put on hot.

III. A cast-iron washer, E, with hole in centre a little larger than the screw, to be put on the top of the column, and on which the nut is to rest; the top side of this washer must be faced on the lathe, also the bottom of the nut, to prevent friction.

III. The screw, S, having a total length of 12 inches and a diameter of 2 1/2 inches (for very high veins this diameter may be in creased to 3 inches), and has on its top a wrought-iron plate, T, 5 by 10 inches, and 1 inch thick; the screw *must* be made of first-cl'ass hammered charcoal-iron.

V. The nut, X, also of the same iron.

VI. A plank, P, about six feet long, 1 foot wide, 2 1/2 inches thick.

VII. A piece of plank, P', 12 by 12, and 2 1/2 inches thick.

VIII. The independent ring, O, 2 1/2 by 3/4 inch iron; the inside diameter must be 1/2 inch larger than the base of the column.

IX. The wrench, W, to work the nut.

To bring the apparatus in use you work as follows:

The column being placed perpendicularly to the roof, receives the washer, E; the screw with the nut on it is placed in the opening, C, the nut resting on the washer, E ; the miner turns by hand the nut while holding firm the screw, which brings the screw towards the roof, a space being left to receive the planks P' and the plank P, which is firmly tightened to the roof with the wrench. See Fig. 1.

The screw-jack, once in place, holds the roof more firmly than the usual way of timbering.

The loose ring, O, is used to take down the apparatus.

The pressure of the roof is so great that it required three or four men to unscrew the jack; to overcome this, M. Dernencourt puts a dirt mattress or cushion under the column; the loose ring is slipped down, and holds the dirt under the base of the timber. When the jack is to be taken down, the ring being lifted up, the dirt will run out, or can easily be removed, and the apparatus is loosened without any screwing, jerking, hammering, etc., etc.

It is understood that this apparatus cannot be used in gangways or permanent openings, nor in a vein pitching more than 40°.

Figure 2 shows how they are placed in a flat vein and long wall.

Figure 3 shows how they are placed in a vein pitching at 30°.

The advantages are incontestable for all workings where they can be used, particularly in long-wall work, where you fill up behind you; the filling or stowage, where the jacks are used, is safer, better, and done quicker than with the common timbering, as it leaves the whole space open, having no props in the way.

M. Fayes, at the mines of Bernissart (Belgium), after having used them for several months, gives the following account: " The econ-omy realized during the month of April is 1 franc 25 centimes per miner per day. In the ordinary way of timbering, the miner spent one-fifth of his day in preparing the timber and putting it in place; by this new method, it is reduced to one-tenth ; therefore one-tenth more of his time can be employed in cutting coal."

M. Cornet, the well-known director of the mines of Sars Long-champs (Belgium), read the following before the Société des Inge-nieurs du Hainaut: "The use of the prop screw-jacks does away with timbering in all veins below 40° pitch. The economy varies according to the quantity of timber used in the ordinary way, and increases with the opening of the vein. At Sars .Longchamps it is 1 franc per day per miner; but, with the direct results, we must not forget the indirect ones, which are of some importance, as the filling up can be done better, closer, more compact than when props are left. From this will result more safety for the galleries, less room for the accumulation of gases, and therefore a better ventilation. With it the miner furnishes more coal per day and enjoys more safety ; as the prop screw-jacks arc put in place and taken down quicker, without any hammering, falls arc nearly impossible. It docs away with the hauling of timber in the gangways and shafts, by which considerable time is lost. At Sars Longchamps (where both methods of timbering are in use in different gangways) the results have been to furnish the coal from the chambers with prop screw-jacks, one-half hour sooner at the bottom of the shaft than the coal from chambers in which the old way of timbering is in use. To conclude, I would say that experience has shown, in the apparatus invented by M. Dernencourt, the following advantages : economy in timber, greater security for the miner, to lessen the quantity of rubbish to be extracted, to give the miner more time for cutting coal."

TROY MEETING,

NOVEMBER, 1871.

THE ATTAINMENT OF UNIFORMITY IN BESSEMER STEEL.

BY DR. THOMAS M. DROWN.

THE means relied on to attain uniformity in Bessemer steel may be enumerated as follows :

I. The appearance of the flame. II. The appearance of the slag.
III. The spectrum of the flame.
IV. Examination of the steel itself.

At present, I wish briefly to bring forward a few considerations with reference to the last two mentioned, namely, the conditions favoring the employment of the spectroscope and examination of the steel.

From the amount of careful investigation which has been devoted to the examination of the Bessemer flame by the spectroscope, both on the part of scientists and practical metallurgists, one might reasonably expect some results definite and satisfactory in their nature, first, as regards the nature of the flame, and second, as to the practical value of the spectroscope as a guide in conducting the process. We find, in fact, however, that uncertainty and confusion still exist. In Germany, where this subject has received the greatest attention, it is now very generally conceded that manganese is the cause of the well-known groups of dark bands that characterize the Bessemer spectrum. Nor is it easy to see how we can avoid accepting this conclusion, when Wedding and Von Lichtenfels have produced the manganese spectrum and found it to correspond closely with that shown by the Bessemer flame.

But it is evident, on a moment's reflection, as Roscoe has recently brought forward, that manganese cannot be the only cause of the Bessemer spectrum, for we notice the characteristic bands quite as plainly when English pig-iron is blown, which does not, at the beginning of the operation, contain as much manganese as the German pig-iron does when the blow is completed, and the dark bands have completely disappeared from the spectrum.

Roscoe considers the bands to be due to carbon, which is known under different circumstances to present different spectra. Whatever may be the truth of the matter, one thing is certain, that the disappearance of the lines from the spectrum is coincident, or nearly so, with the disappearance of carbon from the iron.

The question of the practical use of the spectroscope in the Bessemer process is, however, fortunately independent of any theory that we may hold regarding the causation of the spectrum, although we must admit that the idea of the lines being caused by carbon, or carbonic oxide, the disappearance of which from the spectrum coincides with the disappearance of carbon from the iron, has in it something attractive, affording, as it does, a common standpoint for theory and practice.

It is solely to the practical side of the question that I wish to draw attention now, and endeavor to reconcile, if possible, the conflicting statements made regarding the value of the spectroscope as a guide for stopping the blow.

The clue to the difficulty is to be found, I think, in the fact, that the reports from Germany are almost unanimous as regards the practical advantages to be derived from the use of the spectroscope, whereas in England it is looked upon mainly as an instrument of scientific interest, which although it indicates promptly when to stop blowing, yet is no more accurate in its indications than is the flame itself to the unaided eye of an experienced workman.

The most emphatic indorsement of spectroscopic observations of the Bessemer flame, that we have noticed from England, are the statements of Mr. Snellus of Dowlais, and Mr. Bragge of Sheffield, both quoted by Mr. Roscoe in his paper on "Spectrum Analysis" recently read before the Iron and Steel Institute of England. " Mr. Snellus has informed me," writes Mr. Roscoe, "of the result of a series of experiments, which go to prove what appears to me to be a very important point, and that is this : not only does he agree with me in finding that the point of decarbonization can be accurately reached by means of the spectroscope, but he believes that it is also possible at the beginning, or in the course of the blow, to predict how long the blow will last—that is to say, he predicts in the middle of a blow, that the blow is going to last, say, for 18 minutes; and he finds that it does actually last 18 minutes. He then predicts in another case, 24 to 25 minutes ; and he finds that it really lasted 23 1/2 minutes. He then predicts 32 minutes in another blow, and finds that it did take 32, and so on through thirty experiments, which were made both at Dowlais and Ebbw Vale."

When we consider that a few seconds more or less blowing materially affects the character of the steel produced, the practical advantage of the use of the spectroscope cannot be said to have received much support from these experiments, although in themselves of interest and value. The report of Mr. Bragge, also quoted by Mr. Roscoe, is to the effect that the spectroscope is daily used in the Atlas Works for determining the point of the disappearance of the carbon, and that to a certain extent they are satisfied with the result, especially in the case of new metal.

In Germany, on the other hand, as is well known, there are many Bessemer works where the spectroscope is relied on exclusively for stopping the blow. So plain arc its indications found, that in Zwickau in Saxony, for instance, it is used by uneducated workmen with complete success.

That there must be a cause for the difference of opinion existing in England and Germany on this subject, independent of the love of the Germans for scientific research in practical matters on the one hand, and the excessive conservatism of the English in established manufactures on the other, must be conceded, for the practical failure of the spectroscope to aid the Bessemer process in England is the result of fair trial by scientific and practical men.

When one first observes the Bessemer practice in Germany, after being familiar with the English method, he is struck by the fact, that the duration of the blow is much longer, as *a* rule, and the heat of the charge much greater.

The cause of the greater duration of the blow must be either that there is more to oxidize in the German pig-iron than in the English, or that the rate of oxidization is slower. By comparing the two pig-irons we find that the English usually contains more silicon, the German more manganese, and also, as a rule, slightly more carbon, but the difference is not sufficiently great to account for any marked difference in the duration of the blows.

We must look for the cause then in a diminished rapidity of oxidation, which is dependent on the pressure of air and the number and diameter of the tuyeres. The pressure employed is very generally the same in all countries, as the height of the iron in the converter is generally uniform, but the number of tuyeres employed is very variable.

I regret that I have not been able to collect more data on this subject, but the following examples will nevertheless show clearly the difference of the English and German practice in this respect:

	Capacity Converter.	No. of tuyere-holes.	Diameter.	Total area, in sq. in.
Königshütte,	3	49	¼ in.	2.40
Neuberg,	3	49	1/3 in.	4.27
Zwickau,	3	42	2/5 in.	5.12
Heft,	2	42	1/3 in.	3.66
Crewe,	5	144	3/8 in.	15.50
Dowlais	5	156	3/8 in.	17.22

If we reduce the number of square inches in each instance to the standard of 1 ton capacity we have for—

Königshütte,	0.80
Neuberg,	1.43
Zwickau,	1.71
Heft,	1.33
Dowlais,	3.44

In this country, at Harrisburg and Troy, we have 120 tuyere-holes of 3/8 in. in 5 ton converters, making a total area of 13.25 square inches, or 2.65 per ton capacity, which is about a mean between the German and English practice.

From these examples it will be seen, that the amount of air forced into the converter in a given time in England is nearly double what it is in Germany, and we can thus see why it is that the duration of the blow should be so much longer in the latter country. What may have been the original cause of the adoption of a smaller number of tuyeres in Germany, I do not know, but that this fact has an im-portant bearing on the use of the spectroscope will be evident on a moment's consideration. The spectroscopic indication of the complete decarburization of the iron is the disappearance of the charac-teristic lines from the spectrum. If, in the last stage of the process the oxidation of the carbon is effected very rapidly, as in England, the disappearance of these lines may be almost instantaneous, and afford no better indication of the conclusion of the blow than the dropping of the flame, with which it is coincident. If, on the con-trary, the oxidation proceeds comparatively slowly, as in Germany, the lines fade away gradually, and it is from the degree of distinctness of the lines that the degree of decarburization is judged.

It requires but comparatively little experience to enable one to estimate with very great nicety the extent of the decarburization by the degree of distinctness of the characteristic bands in the spectrum. Although a practiced eye will often unaided be as correct in its decision as one provided with a spectroscope, yet in the long run there can be no doubt that greater accuracy and simplicity of working *is* attained by relying exclusively on the indications of the spectrum, provided that the rate of oxidation is not too rapid.

The employment of an excessive number of tuyeres prevents, too, the nice adjustment of the amount of air to the amount of carbon and silicon towards the end of the process. It is readily conceivable that when the amount of these elements remaining is very small, that they may not be able to preserve the iron from oxidation in presence of a large amount of air.

Whether the heat of the charge has anything to do with the reliability of the spectroscopic indications cannot be definitely stated, but it seems reasonable to suppose, that the higher the temperature the more satisfactory the observations will be. The only evidence bear-ing on this point is from Bleichsteiner of the Maximilian's Hütte in Bavaria, who has observed that with hot charges, with much smoke, which accompanies highly manganiferous pig-iron, the Bessemer spectrum disappeared before the complete decarburization of the iron had taken place, whereas with cold and non-smoking charges, the disappearance of the spectrum and complete decarburization were coincident.

I have already mentioned the fact, which I think will be generally admitted by those conversant with the subject, that the heat of the charge is, as a rule, greater in the German practice than in the English. This fact I have noticed particularly at Zwickau, where the flame in the last stage of the blow is so intensely bright, that colored glasses are almost indispensable to protect the eyes. The cause of the higher temperature attained in Germany is somewhat obscure.

In general, the sources of heat in the Bessemer process may be enumerated as :

1st. The initial heat of the metal in the converter, which depends on the temperature of the pig-iron as it flows from the cupola, and the temperature of the converter.

2d. The heat resulting from oxidation of the silicon, which is equal, according to Jordan, to 6382.4 units for every kilogramme oxidized by atmospheric air to silicic acid.

3d. The oxidation of iron, equal to 757 units per kilogramme of iron oxidized to protoxide.

4th. The oxidation of manganese to protoxide, equal, according to Jordan, probably to the same amount as in case of iron.

5th. The oxidation of carbon to carbonic oxide, in which case only 475.2 units are available in the process per kilogramme of carbon.

The main source of the increase of heat during the process is due, therefore, to the oxidation of silicon, which is much more largely present in English pig than in the German. Not much influence can be attributed to the manganese, as it merely replaces iron in the slag, and we have assumed the thermic effects of the oxidation of manganese and iron to be equal.

I have thought that it might be possible in those instances where the English practice is followed of blowing with a large number of tuyeres, that some air might pass through without having all its oxygen absorbed. When we consider that the depth of iron in the converter would be only 12—14 inches in height, were it in a state of rest, and that it is tossed about by a current of air with such violence as to be often ejected, in part, from the mouth of the converter, such a condition of affairs seems not improbable. If it is ever actu-ally the case, a loss of heat would, of course, be the consequence.

The only experiments which bear on this point, as far as I know, namely those of Snellus of Dowlais, do not, however, support this view. He examined the gases evolved from the converter during a blow of 18 minutes at 2, 4, 6, 10, and 12 minutes after the commencement, and found no free oxygen present, showing that it had been completely absorbed.

But as the experiment was not tried primarily with a view of determining this point, it may be, that the conditions with reference to pressure and amount of blast were not as we have supposed.

The more rapidly the oxidation proceeds, other things being equal, the higher, of course, will be the resulting temperature. If it should be proved, therefore, that the limit of tuyere area has not been exceeded, and that the oxygen of the blast is completely absorbed, even in the extreme cases which have been mentioned, then the English practice of blowing ought to be more favorable to the production of a high temperature than the German.

Apart from these considerations, it is undeniably true, that there are many great advantages resulting from a very high temperature in the converter, one of the most important of which is the opportunity afforded for testing the steel before casting. In spite of accumulated experience gained in conducting the Bessemer process; in spite, moreover, of the great assistance we may derive from the use of the spectroscope, it must, nevertheless, be admitted, that absolute certainty with regard to the quality of the steel produced can only be gained by examining the steel itself.

In Zwickau, where the process is performed without the usual addition of spiegeleisen or other form of pig-iron, the blow is suspended when the spectrum indicates that the decarburization is sufficiently complete. A long rod of iron is then inserted into the converter, to which a quantity of slag adheres, through which are dispersed beads of metal. The rod, after removal, is at once plunged into water, and allowed to remain till cold. The metallic beads are then separated from the slag and tested by hammering as to their hardness and malleability. According as the result of this test is satisfactory or otherwise, the steel is poured into the ladle, when sufficiently cool, or the converter is turned up again and the blast continued for a second or two longer. By this system perfect uni-formity of product is obtained.

That this result is rendered possible by having a temperature in the converter much higher than is simply necessary for casting, shows the practical value of high heats. Whether the advantage of uniformity of product would be considered more than counterbalanced by the shorter duration of the converter lining, is a matter to be determined from an economical standpoint, which it is not my purpose, at present, to discuss.

THE SMELTING OF ARGENTIFEROUS LEAD ORES IN NEVADA, UTAH, AND MONTANA.

BY 0. H. HAHN, M.E., ANTON EILERS, M.E., AND R. W. RAYMOND, PH.D.*

THIS paper will treat of such works only as beneficiate ores directly in the mining districts. And when it is said that more than twenty

* This paper was prepared by combining the notes of Messrs. Halm and Eilers, and presented by me in their names at the Troy meeting. I have added my own name to theirs, not to diminish the credit of their authorship, but to relieve them in some degree from the responsibility of my editing, which has involved extensive changes in arrangement of materials, and some modification of opinions expressed. I believe that as the paper now stands, however, both its original authors will accept it.—R. W. RAYMOND.

furnaces exist in Utah, about as many in Nevada, five in Montana, and four in Cerro Gordo, Inyo County, California, it is obvious that a business so extended deserves attention. Wide apart as these different works are located, they have nevertheless to deal in nearly every case with the same or very similar circumstances and conditions, so that, with very few exceptions, virtually the same system of smelting is followed in all these establishments. This is the so-called method of reduction and precipitation in blast-furnaces.

As the principal reasons for the employment of a blast-furnace process are to be considered: the low percentage of lead in the ores, the high price of the only available fuel, charcoal, and the exorbitant rates demanded for labor. The reasons why the reduction and precipitation process is preferred to a roasting, reduction, and precipitation process arc the high prices of labor and materials, and the preponderance of oxidized ores over sulphurets, though in some cases the latter are quite abundant.

The weight of these reasons will be better understood when the character of the ores to be treated and the object of the smelting are more minutely stated. The ores are in nearly all cases a preponderating mass of oxidized lead ores, such as cerussite, anglesite, and leadhillite, in which nests and nodules of undecomposed galena occur. Associated with these are: in Eureka, Nevada, arseniate of iron and arsenical pyrites, hydrated oxide of iron, quartz, and calcareous clay ; in Little Cottonwood Canyon and American Fork, Utah, iron oxide, and in some cases a combination of antimony, the nature of which I have not ascertained ; also dolomite and quartz in widely varying proportions; in Bingham Canyon, Utah, only quartz and comparatively little oxide of iron, or iron sulphurets; in Cerro Gordo, California, oxide of iron, iron pyrites, antimonial compounds, copper ores, and, as gangue, carbonate of lime and quartz. In Argenta, Montana, occur, besides the above-named lead ores, pyromor-phite, and molybdate of lead. The preponderating gangue of the Argenta ores is quartz, and there is here a larger proportion of galena than elsewhere in the West. In most of the localities named, the lead ores themselves contain sufficient silver to render its separation from the ore the main object of the smelting; but in some of the dis-tricts, and especially in Montana, the lead ores serve only to furnish the extracting agent for the silver of true quartzose silver ores, which at the same time contain a sufficient percentage of lead to make amalgamation Impracticable. They are therefore beneficiated by smelting, although the lead itself has no market value.

As there is more or less sulphur or arsenic present in all these ores, none of which are submitted to a thorough preparatory roast-ing, the formation of matte, or speiss, or a mixture of both, is of course unavoidable; and as silver has not only great affinity for lead, but also for sulphur, much of this metal goes with the matte. In most works the latter is not roasted before adding it to a subsequent charge, if it is at all treated further; and the extraction of the silver from it is, therefore, in this case, only possible after it has passed the furnace quite often, very little of the sulphur being driven off in the upper parts of the blast-furnace at each smelting. In Eureka, a mixture of matte and speiss, the latter predominating, is formed, the contents of silver and gold in which hardly ever surpass §12 to the ton; and this amount is at present not considered worth extraction in that locality. The speiss, or "white iron," as it is there termed, is therefore thrown over the dump.

The marketable product which the smelt ing-works produce is argentiferous lead, with the exception of the works at Argenta, Montana, which cupel the lead and ship the silver only. As a general rule it pays best in the mining districts to produce argentiferous lead bars or crude bullion, the contents of which in silver and gold vary from 860 to 8500 in the different districts. The main reason for not cupelling the lead in the West is found in the increased rates and risk of freightage for bullion; but the separation of the silver and lead, and the refining of the latter, can also be accomplished at much less cost in the Eastern centres of trade than in the mining districts. There are of course exceptions, as, for instance, in Montana, where the smelting-works are located so far from the railroad that the price obtained for the lead would not even cover the cost of smelting and freight, and where only the silver is therefore shipped, the lead remaining in the furnace-yard in the form of litharge. Part of this is used over again in smelting such silver ores as are naturally too poor in lead; but the greater portion remains to await cheaper reduction and railroads.

A few remarks in regard to the present tendency of metallurgical ideas, as far as smelting is concerned, may be here in place.

Formerly the blast-furnaces used for lead-smelting usually had an oblong rectangular cross-section, the size of the hearth being rarely larger than 20 inches by 2 1/2 feet, and frequently they were drawn together at the top. The capacity of such a furnace, with one or sometimes two tuyeres, was about six to eight tons per twenty-four hours. But of late years essential improvements have been made, the aim of all of which was a higher production, and less loss of metal in slags and by volatilization. This has been reached by a complete alteration of the shape of the furnaces, by increase of size, and the introduction of proportionately more compressed air through a larger number of tuyeres. In regard to their shape, and the results obtained, two furnaces have come into especially prominent notice. These two are:

1. The *Raschette* furnace. It has an oblong rectangular cross-section, and the form of an inverted truncated pyramid. Numerous tuyeres, cooled by running water, arc placed in the long sides, in such a manner that the opposite currents of air pass each other.

2. The *Piltz* furnace. It has a hexagonal, octagonal, or circular cross-section, and the shape of an inverted truncated pyramid or cone. Many tuyeres are placed radially around the furnace centre, the breast alone being without them.

Both of these furnaces are furnaces with open breast, and both have the two most important principles in common,—*the application of more compressed air in a comparatively smaller space than in old style furnaces, and a widening of the shaft toward the top.* The first secures a more perfect and rapid combustion, and hence a more rapid fusion; the second causes the smelting zone to commence lower down in the furnace than formerly; the charges, lying firmly upon the slanting sides, force the gases and heat to pass through the whole column above, and while the wider section above decreases the velocity of the upward current, volatilization is to a great extent prevented.

But quite recently experience has taught in this country that a combination of the form of the Raschette and Piltz, so to speak, produces still better results, the capacity of the furnace being thus increased, while the management is less difficult. Last spring two new furnaces were built at the works of the Eureka Consolidated Company, in Nevada. In order to test the comparative merits of a combination furnace and the Piltz, Mr. Albert Arents, the metallurgist of the works, concluded to construct one furnace with elongated hearth, 3 feet wide by 4 1/2 feet in depth, and 6 1/2 feet diameter at the top. The furnace was provided with ten water-tuyeres, four in each side and two in the back wall. The other furnace was a Piltz, of 4 feet diameter in the hearth, 6 1/2 feet at the top, and provided with twelve tuyeres placed radially around the centre. Both furnaces were 10 feet high above the tuyeres, and worked admirably, but the combination furnace was found to smelt from one-fifth to one-fourth more ore than the Piltz, under the same circumstances. The same experience has been arrived at in the Hartz districts in Germany, where the best results are obtained with a circular furnace of 5 feet diameter at the top, having a hearth 20 inches wide and 3 1/2 feet deep, and seven tuyeres. In this furnace the loss of lead in the slag (although the same charge is used as in the other furnaces) disappears almost entirely, being only 1/2 per cent., while in the other furnaces it is from 2 to 4 per cent.

The best proportion of the hearth-area to the throat-area may be accepted as 1: 2 1/2 for a height of from 10 to 12 feet. It is rarely necessary, in the western districts, to give a greater height to the furnaces. There is at present in existence only one which exceeds this height. This is situated in Bingham Canyon, Utah, and has to smelt very quartzose ores.

Before proceeding further, a general statement of the elementary principles of metallurgical operations will be here given. It is true that the current text-books cm metallurgy cover a good deal of this ground ; but it is important to introduce this plain and practical resume for the benefit of those who cannot easily consult the best, large works upon the subject. Many of these are in foreign lan-guages, others are both dear and scarce, and all, it may be presumed, arc more or less difficult of access in our remoter mining regions.

Minerals containing the useful metals in such quantities and in such a chemical combination as to make their extraction profitable, we term " ores," while their earthy portions we designate as their " matrix" or "gangue." In regard to subsequent metallurgical treatment, we can make the following practical classification :

1. *Smelting ores,* viz., ores containing base metals in notable quantities.
2. *Dry ores,* viz., ores containing noble metals and no base ones, or only in limited quantities.

Those pertaining to class 1 will here be particularly treated.

Ores and gangue are always more or less intimately mixed. For the utilization of the metals, it is, therefore, necessary to separate them from their gangue by artificial means, which are either of a mechanical or chemical nature. A mechanical separation alone is not sufficient to produce a merchantable product; it can only serve as preparatory to the chemical processes, among which that of smelt-ing will be here specially considered. Smelting is a conversion of solid mineral or mineral and metallic masses into the fluid state by means of heat and chemicals, and the subsequent separation of the metallic from the earthy ingredients by means of their specific gravity. Although there are a great many methods in vogue for utilizing lead ores by smelting, there are only two which have found application and justly claim attention in the mining regions of the Great Basin: (A) the English process of smelting in reverberatory furnaces, and (B) the blast-furnace process.

The former has some marked advantages over the latter: the possibility of using raw fuel; its exemption from the necessity of using blowing-engines, and the consequent saving of power; an casier control of manipulations, and the production of a lead of better quality in which the precious metals arc concentrated. Its general application, however, is greatly impaired by the fact that only comparatively pure ores can bo treated successfully. Thus, ores con-taining a considerable percentage of other metals besides lead, as, for instance, zinc, copper, antimony, etc., or more than 4 per cent. of silica, are unfit for the reverberatory process, silicate of lead, which impedes the process of the operation and gives rise to the formation of rich residues, being formed in the latter case. In the former there is, besides loss in rich residues, also a large one by volatilization. In England the lead ores subjected to this process contain about 80 per cent. of lead, the gangue generally being car-bonate of lime. The English process in its unaltered form can, therefore, only be recommended for pure galenas with calcareous gangue, an ore not often obtained in the Western mining districts. There is only one establishment in operation where ores are treated by this process, that of Messrs. Pascoe & Jennings, near Salt Lake City. Another one of this kind, that of Messrs. Robbins, is idle for want of the proper ores. A more minute description of this process may, therefore, be here omitted.

Compelled by the high prices of labor, transportation of materials and products, lack of cheap mineral coal, etc., the lead-smelters of the Great Basin have almost unanimously adopted the blast-furnace process of smelting. By its means they are enabled to obtain a salable product in the shortest possible time, and with the least expense, the residues being so poor that they can be thrown away.

To insure success in smelting lead ores, as all other ores, it is nec-essarv to know their mineralogical character, as well as the chemical properties of the gangue in which they occur. A perfect separation of the ore from its matrix by hand being impossible, and a concen-tration by water being, in most cases, in the West impossible, on account of the insufficient supply of this liquid, the gangue accompanying the ore must be converted into a fusible compound, termed *slag*. Quartz, we know, is infusible by itself; so is lime; but if we mix both in the proper proportions, and expose them to the necessary heat, the result will be a fusible compound. It has been found by actual experience that not the single compounds of silica and lime, or alumina, magnesia, etc., but double compounds of, say, silicate of lime and silicate of alumina, are the most fusible ones. Replacing one of these bases by alkalies, or the protoxides of the heavy metals, as, for instance, iron and manganese, we increase the fusibility of a slag within certain limits. The fusibility of a slag depends principally upon the proportion of silica to the bases contained in it. Mineral substances which serve to liquefy others not fusible by themselves we call *fluxes.* Under favorable circumstances an ore may contain all the slag-forming ingredients in the proper ratio, but only in a very few instances has nature graciously permitted such a coincidence, as, for example, in Eureka district, Nevada.

According to the ratio between silica and the bases, we discriminate four classes of fusible slags:

1. *Trisilicates,* in which the silica contains three times the amount of oxygen present in the bases. As there is over 50 per cent. Of silica in such slags, they require too high a temperature for their formation to be thought of in lead-smelting.

2. *Bisilicates,* containing 50 per cent. of silicic acid and 50 per cent. bases, in which the amount of oxygen in the silica is twice as large as in the bases.

3. *Singulosilicates,* with 30 per cent. silicic acid and 70 per cent. bases, the silica containing as much oxygen as the bases.

4. *Subsilicates,* with 20 per cent. silicic acid and 80 per cent. bases, the amount of oxygen in the silica being less than that in the bases.

In the latter two the bases are predominant over the silicic acid, therefore they are termed " basic slags," while the first two are termed " acid slags." Chemists have taken the trouble to establish complicated formulae derived from accurate analyses of various slags; but, as they are rarely constant compounds, these formulae have hardly any practical value for the metallurgist; he is content to know the percentage of silica and the quantity of the useful metal which he is endeavoring to obtain. An experienced smelter must be able to draw bis conclusions from the appearance of his slag in both the fused and solid states.

The most desirable slag for lead-smelting is the singulosilicate, or a mixture of bisilicate with the former, with protoxide of iron prevailing. The singulosilicates run with a bright-red color, and solidify very quickly with turgescence. The bubbles, after bursting, frequently discharge blue gaseous flames.

These slugs have a vitreous, metallic lustre, and a higher specific gravity than the bisilicates, and arc, therefore, more liable to entan-gle metallic particles. If lime and alumina are the prevalent bases, the heat required for their formation is much higher than in the case mentioned before. Such slags are generally pasty, run short, and form incoherent lumps. After solidification they have a honey-combed, stony, or pumicestonelike appearance, grayish-green color, and radiated, or lamellar-crystalline texture. An earthy singulo-silicate is really almost the least desirable slag for a lead-smelter.

Bisilicates require a higher temperature, and consequently involve a larger consumption of fuel for their formation than singulosilicates. They flow slowly like syrup, solidify very gradually, without crack-ing or bursting, and are not liable to form accretions in the furnace, like basic slags. They appear vitreous after chilling, have a con-choidal fracture, and generally a black color. Being saturated with silicic acid they corrode the furnace-lining much less than basic slags. Their specific gravity is lower and admits of a clean separation of metallic particles; but on the other hand they are apt to take up a large percentage of oxide of lead, and so cause a loss of metal. Furthermore, for their formation it is necessary to have the ore reduced to at least pea-size, which condition is not fulfilled in Western smelting works, where crushers are generally used for breaking up coarse pieces of rock.

Subsilicates are entirely out of the question, as they are only detrimental. If protoxide of iron is their principal base, they run in a thin stream, like fluid litharge, congeal very quickly, and easily form accretions in the furnace-bottom. Having a high specific gravity, they do not allow a clean separation from the metal. By their corrosive action on the lining, and their tendency to form accretions in the furnace, they shorten a campaign or run to a few days; hence, their production must be avoided.

As *fluxes* the following substances are used :

1. *Acid slags*, for their capability to take up bases, and as solvent agents.

2. *Basic slags*, for their capability of saturating themselves with silicic acid, and as diluting agents.

2. *Ironstone* is a very efficient agent to slag silicic acid, *i. e.*, quartz,

being reduced in the furnace to protoxide of iron, which has a Strong affinity for silicic acid, and forms an easily fusible slag. Its price varies in the Western districts, according to local circumstances, from $5 to $25 per ton. The best quality for our purposes is hematite or magnetite. Hydrated iron ores are too easily reduced to metallic iron, and ought to be burned before use. If free from quartz and slag they may be thrown into the furnace in pieces of fist size. Iron ores are also used as desulphurizing agents.

4. *Soda* is even better than the above as a solving agent for quartz, but it can only be had in a few localities at reasonable rates, the general price being from $60 to $80 per ton.

5. *Lime*, as a partial substitute for ironstone in solving quartz. It is best used in pieces of pigeon-egg size. From the theoretical standpoint burnt lime would be the best form, but as this is generally in a very fine state, it will partially be blown out at the top of the furnace or roll through the interstices of coal and ore, and thus be prevented from uniting with the silica in the desired proportion. Lime cannot be used by itself as a slagging agent for quartz. Lime-slag is smeary, not very liquid, and deranges the furnace very easily by clogging. The metal separates only imperfectly from it, which is the reason that so much metallic lead is wasted by being thrown away with the slag in some of the limestone districts.

6. *Clay* is only used on a very small scale as a partial substitute for quartz. It must be applied very cautiously, as it often arrives raw at the bottom of the furnace in the shape of dry, incandescent lumps, which stick to the walls and hearth.

7. *Salt* is used by some smelters of Utah who have a very indistinct comprehension of fluxes. Although they allege that it renders the slag liquid, this is an illusion. Any assayer knows that the salt does not enter into a chemical combination with gangues, but forms a slag by itself, which, on account of its lesser specific gravity, floats on the top of the other slag. I noticed slag of this kind at Mr. Easton's furnace, Salt Lake City. Besides its inefficiency upon earthy matters, salt acts injuriously upon the metal by forming volatile chlorides of lead and silver.

8. *Iron pyrites* has been ignorantly used as a miraculous Port of flux. To the skilled metallurgist the effects are obvious, viz., the production of a brittle, sulphuretted metal, or of matte, no action upon gangues, and a clogging up of the furnace.

9. *Quartz,* in the form of coarse sand. It is used to furnish the acid for the slag in cases where the gangue of the ores is basic.

In addition to the fluxes enumerated above, some metallic products are occasionally used for various purposes :

1. *Iron,* in the shape of tin scraps, pieces of wrought-iron, cast-iron, etc., is used to decompose galena, thereby forming sulphuret of iron *(iron-matte),* and metallic lead. Owing to the high price of iron in Utah and Nevada, it is cither replaced by the less efficient iron- stone, or rendered unnecessary by a previous roasting of the ores.

2. *Litharge* was intended to be added to poor lead ores at Ogden, Dunne & Co.'s works at Eureka, Nevada, in order to prevent the precious metals from being carried into the iron-matte. Owing to the heavy expense of cupelling, and a change of the ore for the better, this purpose was abandoned.

3. *Cinders,* semifused matter from previous smelting to extract the metals.

Fuel.—The only fuel used at present by the lead-smelters of the Great Basin is charcoal, the price of which ranges from 15 to 34 cents per bushel of 1.59 cubic feet, according to locality. The lowest rates are paid at the American Fork and Tintic districts, Utah, where timber is abundant; the highest at Little Cottonwood, Utah, which gets its coal from Truckee, California, by rail, and at Eureka, Nevada. In the latter place the enormous demand has materially influenced the price. The five furnaces of the Eureka Consolidated Company, for instance, consume alone 4600 bushels daily. The charcoal is chiefly burned from cedar, quaking aspen, mountain mahogany, and nut-pine wood. Nut-pine coal is considered the best, and generally contracted for. The coal-burners make their pits of various sizes, according to circumstances. A pit of 100 cords of green wood burns out in about fifteen or twenty days, and yields from 2500 to 3500 bushels of charcoal. The best coal is made about Eureka, Nevada, by experienced Italian coal-burners, the poorest in some places in Utah. The latter is generally made of small timber, and is full of brands and dross. The waste often reaches 15 per cent. As one ton of good, hard coke approximately produces the same effect as 200 bushels of charcoal, it would be a great benefit for the Western smelters to use it. But the blast-engines used do not yield a sufficient pressure for a perfect combustion of coke, as experiments at the Eureka Consolidated have shown. The price of char-coal being steadily on the increase, there will be a time when smelters will have to replace the former by coke. It may be reasonably expected that after the Utah Southern Railroad is finished, the development of those fine beds of mineral coal in the southern part of that

Territory will tend to the springing up of coke industry, and so give a new impetus to smelting.

Blast-engines.—The only blast-engines in use in Nevada and Utah ' are the different sizes of Sturtevant's fan and Root's pressure-blower; the latter, yielding a much higher pressure, is better for lead-smelting, and may possibly compete with cylinder blast-engines, where coke is used in smelting. The only advantages the former have over the latter are their cheapness and the small amount of power they require. A Root's blower No. 8, yielding sufficient blast for three large-sized furnaces, does not require more than twenty horse-power.

Building Materials.—Rubble-stones arc used for building the foundations, and sometimes the outer casings of furnaces. The latter are generally made of common brick or dressed stone to present a handsomer appearance. Those parts of a furnace, however, which arc most exposed to an intense heat and the corrosive action of ore and slag, must be constructed of *refractory* or *fire-proof* materials. Of such we have—

Certain *sandstones*, free from alkaline matter and metallic oxides. A small percentage of iron oxide is less detrimental than alkaline earths or feldspar. An excellent sandstone is found on Pancake Mountain, a series of low bills between the Diamond and White Pine Ranges, distant about twenty-five miles from Eureka, Nevada. Sandstones of the same age—the carboniferous—are also found in the Diamond and White Pine Mountains, but their physical proper-ties, and hence their behavior in the furnace, are different and not satisfactory. The Pancake sandstone has a very fine grit and a light yellow color, and does not crack or fly in the fire after seasoning. Green sandstones of ever so good a quality, and defective ones, viz., such as show flaws or nodules of foreign matter, are not fit to be placed in the furnace. The Pancake sandstone is known to stand for months in a furnace without needing to be replaced. It sells for §20 per ton at the quarry, and §12 additional for hauling.

The coarse-grained reddish sandstones and quartzite of Utah are not to be compared with those before mentioned, and had better be used for outer casings only.

Granite does not often answer the requirements of a fire-proof material, and is mostly used as bottom-stone only. In Argenta, Montana, however, a very quartzose granite is used in the furnaces, and it stands campaigns of three weeks' duration.

Instead of the natural fire-proof stones the majority of smelters use artificial ones, viz., English, Pennsylvania, and Colorado *firebricks*. Sun-dried bricks or adobes, moulded of various proportions of good clay and coarse quartz-sand, are too expensive, and there-fore have gone out of use. They were used in the White Pine Smelting Works.

The *clay* used about a furnace ought to be refractory, or nearly so, and plastic at the same time. These qualities arc combined in the Eureka and the Camp Floyd (Utah) clay ; that of Camp Douglas (Utah) is too lean, and that Of White Pine (Nevada) almost worth-less, on account of its large percentage of oxide of iron.

Lean clay serves well enough as a mortar, but is unfit for a great many other purposes, as will be seen below.

Good fire-clay contains from 50 to 70 per cent. of silicic acid, and from 30 to 50 per cent. of alumina.

As a *mortar* for the foundation-walls and the outer casings, a mixture of slacked lime and river-sand is used; for the inside, or lining, however, as for all parts of a furnace directly in contact with heat, a mixture of refractory clay with quartz-sand or ground sandstone has to be used. The clay, of course, must be ground and sifted. Lime-mortar in this instance is unfit for use, as it crumbles off in the heat, and allows the slag in combining with it to creep through the joints.

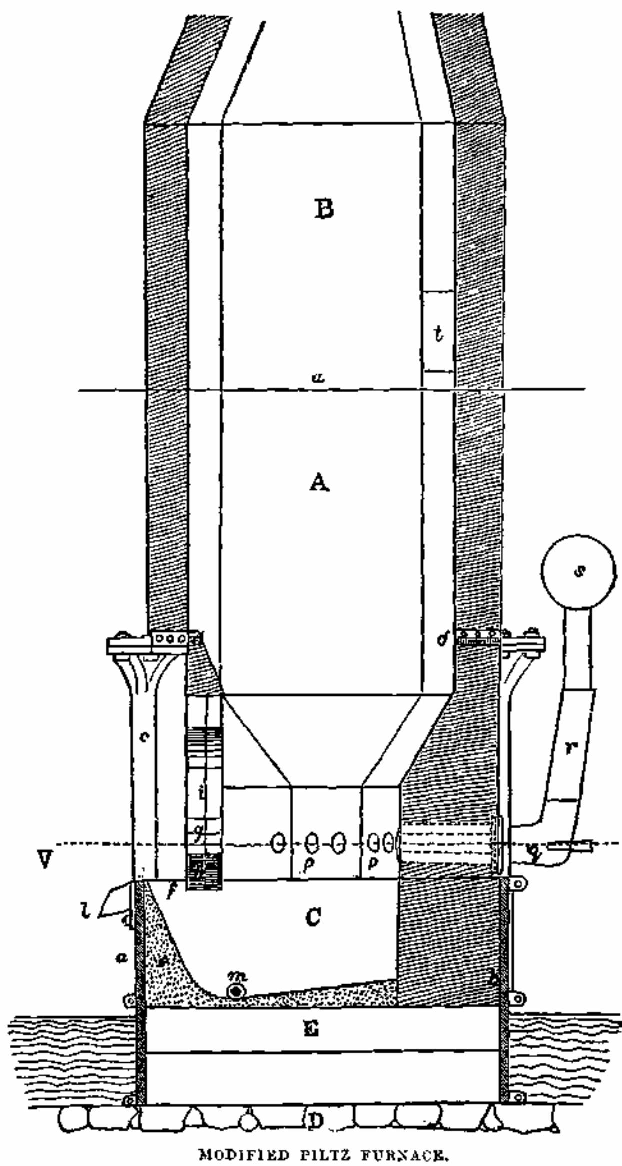
The annexed sketches show the construction of an improved blast-furnace for smelting lead ores, such as are now in use in Eureka, Nevada, and have given great satisfaction :

The longitudinal section (Fig. 1) is made along the line H Y, in Fig. 2; and the cross-section (Fig. 2) is along the line T V in Fig. 1. A is the shaft of the furnace; B, the chimney; C, the hearth ; D, the foundation; E, the bottom-stone; *a,* the dam-plate; *a* and *b,* hearth-plates of cast-iron ; c, cast-iron pillars, on which the flange *d* rests ; *e,* dam ; /, fore-hearth lying outside of the furnace ; *g,* bridge; *h,* tymp-stone, or front made of clay; *i,* breast; *k,* slag-spout; *l,* matte-spout, or iron-spout; TO, siphon-tap; *n,* tap-hole; *o,* lead-well; *p, p^1, p^2*, etc., tuyeres through which the blast enters the furnace; *q,* nozzles (made of galvanized iron); *r,* wind-bags (of leather or canvas); *s,* induction-pipe; *t,* charging-door, or feed-hole; *u,* throat.

The wall in which the breast lies is called the front wall, the one opposite to this the back wall; the adjoining ones the side walls.

This furnace is called an *open-breasted one.* In foreign countries, furnaces with a *closed breast* and without fore-hearth, which have only an opening for the exit of the slag, are often used. Such furnaces are termed "crucible furnaces." Notwithstanding the many advantages they have over the open-breasted ones, they do not

FIG. 1.



MODIFIED PILTZ FURNACE.

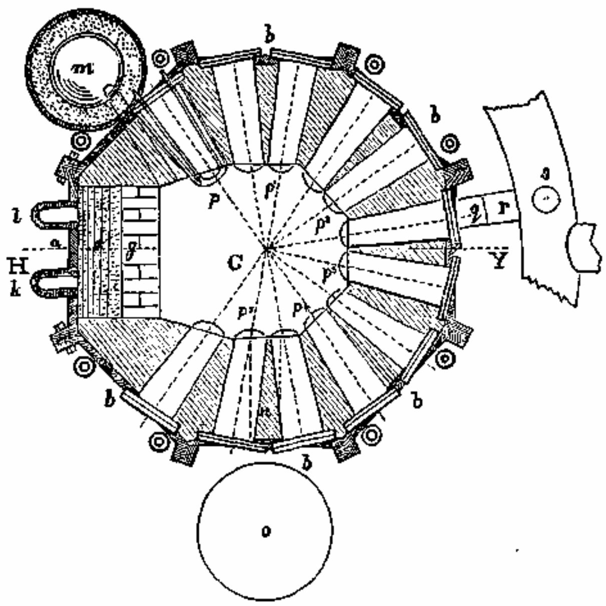
permit the detaching of accretions in the furnace, and are, therefore, not suited for our purposes. The mason-work, especially the lower part, of all rectangular furnaces, is strongly bound together by 1 1/2-inch tie-rods of wrought-iron laid in the outer walls. Each pair of them, lying in the same vertical plane, passes through a wooden, or, better, a cast-iron brace, which is screwed tight to the wall. Round furnaces are tied either by means of iron rings passing around the outside, or by complete shells of boiler or sheet-iron.

The height of shaft-furnaces ranges from 8 to 20 feet above the centre of the tuyeres. Low furnaces are necessary for basic ores, especially such as carry a great deal of oxide of iron (White Pine district), to prevent the reduction of metallic iron. High furnaces are of good service for refractory ores, *e.g.*, argillaceous or quartzose ores (Bingham Canyon), and where a bisilicate slag is desired. In high furnaces a higher temperature is attained with a less amount of fuel than in the low ones. But a low furnace is easier manipulated when deranged than a high one. Where the character of the ores changes frequently a low furnace is preferable. The standard height in this country is 10 feet above the centre of the tuyeres. On the top of the furnace is an iron, or, better, brick smoke-stack, high and wide enough to carry off the fumes.

The manner of charging or feeding is of importance, as it affects the working of a furnace materially. Furnaces of small dimensions generally have a feed-hole a few inches above the throat, on that side of the furnace directly opposite the front wall. The proper proportion of fuel, either by measurement or weight, is introduced first, and on the top of that the ore, which may be scattered all over the area of the furnace, leaving an empty space only at the front wall (Jackson & Roslin furnaces, Eureka; Salt Lake Valley, Stockton, etc.). More capacious furnaces require two feed-holes, which are situated at nearly right angles to the breast, *i. e.*, in the side walls (Eureka Consolidated Company's and Utah Silver Mining and Smelting Company's new furnaces). The ore is not spread over the area of the throat, but charged round the tuyere-walls, leaving a core of coal in the centre.

To insure regularity in charging, the throat of a furnace is frequently provided with a funnel, the opening of which can be kept closed by a sheet-iron box let down from the top while charging. As soon as it is time to charge the furnace, this box is raised by means of a counterpoised lever, and the charge drops down. After emptying the funnel, the box is lowered again. This arrangement at the same time protects the workman from noxious vapors. Where no condensation chambers are used, this box runs out into a pipe, which is movable in the stationary smoke-stack (Richmond furnace, Buel & Bateman's furnaces).

FIG. 2.



MODIFIED PILTZ FURNACE.

The number of tuyeres and the manner of placing them are really not of so great consequence as is generally assumed, if the proper quantity of air is introduced into the furnace and divided well in the hearth. The majority of smelters in this country place the tuyeres only six inches above the level of the slag-spout, and point them down-ward. This is very faulty in lead-smelting, as it tends to concentrate the heat too far below, volatilizing much metal. Placing the tuyeres too high above the slag-hole is entirely wrong, as in that case the metal in the hearth below cannot be kept sufficiently hot. Before the tuyeres the furnace-temperature is highest. There the separation of the metal from matte and slag, according to their specific gravity, takes place. Below the tuyeres the temperature decreases again. If the tuyeres are, therefore, inserted too high above the slag-spout, the molten masses will stiffen, and even solidify, below. A furnace in White Pine once had the tuyeres three feet or more above the slag-hole. The consequence was a congealing of the fused masses in the hearth, and an entire clogging up of the furnace. The correct way is to place them horizontally, all on the same level, and from 10 to 18 inches above the slag-spout (Eureka Consolidated Company's and Phœnix Company's works). All vertical dimensions are understood to be measured from the centre of the tuyeres. For every 1 1/2 square feet of hearth-area, a tuyere of 2-inch nozzle is required.

Since the introduction of cast-iron or wrought-iron tuyeres cooled by water, the working capacity of lead-smelting furnaces has been greatly increased. Formerly, only sheet-iron, clay, or simple cast-iron ones were in use, giving rise to much inconvenience. In order to protect the furnace-walls from the influence of the reverberated heat, the tuyere had to be provided with a nozzle of clay, or a very acid slag, protruding into the furnace. But, to keep this nozzle or nose of a certain length, and to prevent it from growing or melting off, it had to be constantly watched by attentive and experienced men. During the last century an attempt was made, on the Hartz Mountains, to increase the production by constructing a large-sized furnace with fourteen tuyeres. It failed, on account of the difficulty in keeping the tuyere-walls from burning out. Even the first Raschette furnace, built in 1864, on the Hartz, was provided with sheet-iron tuyeres. But they had to be replaced so often—which always necessitates a stoppage—that it was found expedient to try water-tuyeres, which, indeed, gave entire satisfaction. The best ones in use in this country are wrought-iron ones of the Keyes patent. The lowest point of the hearth is from 36 to 40 inches below the centre of the tuyeres, the latter figure being the maximum. If made deeper, the lead will get too cold.

In selecting a furnace-site a great many things have to be taken into consideration in an economical as well as a technical point of view. To answer the latter three conditions are necessary—a suffi-ciency of water, a spacious ore-floor, and a convenient slag-dump. The lack of one or all of these conditions puts a smelter to great inconvenience, and may even cause a financial failure. After having graded off a suitable location for a furnace at the side of a gently sloping hill, if such a one is convenient, a square or rectangular excavation is made in the ground to receive the foundation. The area is generally 8 by 10 or 10 by 10 feet, the depth depending upon the condition of the subjacent ground. If the same be directly on the bed-rock, as in the instance of the Eureka Company's furnaces, no foundation is required, and a depth of 3 or 4 feet is sufficient to receive the furnace-masonry proper; but if it be moist or in gravel, a depth of from 7 to 14 feet is judicious. The foundation is made of undressed rocks which are laid in lime-mortar, or, better, in cement. The largest ones are used for corners, and the joints must be filled up with spalls. The topmost course, on which the furnace is to be built, ought to consist of dressed stones, well seasoned, and sandstones, if possible. The joints must he perfectly tight. In some instances it is desirable to make provision for draining oft the surface-water by arched channels, as the furnace-bottom ought to be absolutely dry.

If the furnace is intended to be provided with hearth-plates, like the one described, those, as well as the cast-iron pillars, arc to be put in place now. Then the inside of the hearth-plates is carried up of sandstone blocks 2 feet wide by 1 foot thick, leaving sufficient room for the tap-holes and an open space at the dam-plate. In Eureka, as soon as the mason-work has progressed to 7 inches above the plates, the tuyeres are placed in position and walled in with firebrick or sandstone. Three feet above the dam-plate the arch over the breast is started and the masonry continued to a level with the top of the pillars. Then the flange which is to bear the upper port of the furnace is put in its place and well bolted to the pillars. The flange is 2 inches thick. The part of the furnace above this flange may con-sist of inferior sandstone or even common brick, 1 foot or 18 inches thick, as it is less affected by the heat and corrosive action of the ore. About 6 inches or one foot above the charging-floor the chimney for carrying off the fumes is started and continued to a height of from 12 to 15 feet, leaving out spaces for the feed-holes 3 feet wide by 2 1/2 feet high at two opposite walls. The chimney ought to have a sufficient opening—say 3 feet—at the top to prevent the smoke from issuing through the feed-holes into the charging-room. The use of sheet-iron smoke-stacks is objectionable, as they always get red-hot in the operation of lighting up and blowing out a furnace, and then rapidly yield to the corroding action of the oxygen of the air.

To keep the mason-work from spreading it is braced by *a* sufficient number of wrought or cast-iron uprights, which are sustained in position by wrought-iron bands passing over them. The latter are bolted together. The first bands are laid round the furnace about 2 feet above the dam-plate, and then follow one another in spaces 1 foot apart. At the Richmond and Winnamuck Company's furnaces the upper part of the furnaces is bound by an iron shell.

.Now, the foundation is covered with soil, made firm by pounding, to within 3 feet below the upper edge of the plates, and a track is made for the slag-trucks. After having connected the tuyeres with the water-tank by wrought-iron pipes of convenient size (3/4 or 1 ¼ inches), the work of seasoning commences. A fire of billet-wood is kept slowly and steadily increasing in the furnace for about two weeks. During that time the bolts ought to be loosened to prevent the stones or bricks from being cracked by the escaping moisture. As soon as the furnace-walls get warm outside and no more moisture is perceptible in the joints, the furnace is ready for use. The fire is withdrawn and the furnace cooled down enough to allow a man to work inside. The bottom-stone, previously put in, is now provided with a thin coating of clay or brusque (a composition of powdered charcoal and clay in varying proportions), which is rammed in with a wooden stamper, after wetting it until it just coheres in lumps. The dam is made in the same manner, but of very good fire-clay, and taking care to make it extremely hard. It has a steep pitch toward the bottom. The tap-hole is made by pounding clay into the space left for that purpose and turning a pointed stick on the outside round a central axis, thus circumscribing a cone. The tap-hole may be in the front plate, which is best, or in a side of the furnace. Generally a large furnace has two tap-holes on opposite sides, and at right angles with the front plates. One tap-hole is at the deepest point of the bottom, the other one a few inches above, it. Thus the metal may be tapped high or drawn off entirely, according to the circumstances. Mr. Arents, of the Eureka Consolidated works, recently made an attempt to do away with the inconvenient mode of tapping hitherto in use, and his efforts have been crowned with such success that there is not a single furnace in Eureka without this peculiar contrivance, termed the "siphon-tap" or "automatic tap." It consists of a sheet-iron cylindrical shell, which is bolted on to one of the cast-iron plates, in which formerly one of thetap-holes would have been located, and 6 inches below the top of the plate. Through a hole in the side of this shell toward the furnace passes a 3-inch wrought-iron pipe into another hole in the furnace-plate, and obliquely down to the lowest part of the hearth inside. The highest point of the pipe lies in the middle of the shell, and a foot or more below its upper rim. This cylinder is rammed full of fire-clay, the pipe being meanwhile closed by a plug. A basin, 18 inches in diameter, is then cut out and the plug withdrawn. The rim of the basin is on a level about 1 inch lower than the lowest level of the matte-spout, which is from 3 to 4 inches

below the level of the slag-spout, so that the two can be drawn off separately. During the running of the furnace the lead stands always as high in this basin as in the crucible inside of the furnace. It is proved by the actual working results, since this improvement was introduced, that 1. The furnace runs more regularly than before.

2. The lead obtained is purer.

3. "Sows" arc prevented.

4. The work of the smelters is lightened.

These results agree entirely with the theories bearing on the sub-ject, and it win be shown that a fifth beneficial result might be added, namely, saving of fuel.

When the usual method of tapping a lead-furnace is followed the blast is stopped and the tap-hole in the bottom of the crucible is opened (sometimes with great difficulty, when metal hits cooled in it at a former tapping). The lead, matte, and slag run out into the kettle, the hole is stopped again with clay, or a mixture of elay and coal-dust, called "stübbe" or " brasque," and the blast is turned on and smelting resumed. With the cleaning of the crucible, building up of fore-hearth, etc., this part of the smelting often takes considerable time, and the temperature in the furnace is reduced, so that much fuel is burned to make up the lost heat. Irregularities in the running of the furnace arc frequently directly traceable to this cause; and the first commencement of the formation of "sows" occurs also in nearly all cases during the stoppages, when the small doughy masses of reduced metallic iron have an opportunity to stick to the bottom of the crucible, which is no longer protected by a liquid mass. It is well known to every metallurgist that whenever the foundation is laid for a "sow" it is extremely difficult to prevent its rapid growth ; and even if the larger parts are broken or chiselled out at every tapping the iron will continually gain on the smelter.

By the employment of the automatic tap the first formation of "sows" is evidently prevented. Even if there be much iron from the charge reduced to the metallic state, the lumps will not come in contact with the bottom, but will always swim on the lead-bath. Being here exposed to the oxidizing influence of the blast they will be carried into the slag.

Furthermore, this arrangement for tapping carries the molten lead out from the *bottom* of the blast-furnace as fast as the metal is reduced inside. At the same time the lead smelted from the charge above remains in the crucible long enough to give the molten ingreclients the required time to react upon each other and separate according to specific gravity.

The lead obtained must be purer, because it is taken from the bottom of the crucible, where the purest (heaviest) metal gathers, and because the foreign (lighter) metals, as iron, zinc, etc., are kept longer under the influence of the blast, and thus are, mostly oxidized and slagged. The work of the smelters is, of course, considerably lightened, because, in addition to the tapping, the hard work of removing "sows," loosening the charge in the crucible after tapping, etc., is dispensed with.

It seems that this invention is one of the first importance for lead and copper smelting. For copper-matte the pipe must be of clay.

When a furnace is blown out the last of the lead is of course drawn off through the lowest tap-hole, into a basin of 40 inches diameter and 18 inches depth, at the side of the furnace opposite the automatic tap, in the same manner as this has always been done.

As soon as the bottom is made the breast must be put in. About 6 inches above the front plate a straight arch, called the " bridge," is started of firebricks. In accordance with the thickness of the breast desired, they are laid lengthwise or edgewise. At Eureka the breast is made 9 inches thick, although 4 inches would be sufficient. A fire is now started in the hearth, siphon-tap, and lead-well to dry them. In the hearth the fire is continued till it gets red-hot. This is done by filling the hearth with lump-coal and kindling it. After it is all burned down the ashes are withdrawn and a fresh fire is started. These operations are continued till the desired end is accomplished, which generally takes two clays.

Ores.—The majority of smelting ores with which the smelters of Utah and Nevada have to deal are galena and the carbonates, sulpho-carbonates, and antimoniates of lead.

According to the quantity and quality of the gangue we may classify them as—

1. Ores containing all the slag-forming ingredients (oxide of iron, silica, lime) in the proper proportions, or *neutral* ores (Eureka Consolidated Company's mines).

2. *Basic, ores,* with lime and oxide of iron or manganese, and no silica, or not in sufficient quantities (White Pine, East Canyon, American Fork, Cottonwood, Eureka, Nevada).

3. *Acid or hard* ores, with silica and clay prevailing (Bingham Canyon, Stockton, Tintic? Humboldt?).

Provided the slag-forming ingredients alone be present, *galena ores,* when passed through a blast-furnace, do not yield metallic lead at once, but a mixture of metallic lead with sulphuret of lead *(lead-regulus, matte),* and other sulphurcts, if such be present—an article that finds no market. In order to produce metallic lead galenas may be smelted with an addition of metallic iron (5 per cent. or more, according to circumstances), or after roasting.

In the first case the iron unites with the sulphur of the galena to form a sulphuret of iron, called *iron-matte,* and metallic lead is set free. This reaction is, however, not complete, as a considerable quantity of sulphuret of lead, and with it silver, is retained by the iron-matte, necessitating another roasting and smelting operation. The iron-matte being lighter than the lead, floats on the top of the latter, and thus can be easily separated from it after cooling.

The combined *roasting* and *smeltiny process* is preferable to the *iron-reduction* process. The galena is first roasted in heaps, stalls, or reverberatory furnaces. Roasting in heaps and stalls is cheaper, as the ore may be used in lumps, and no expensive apparatus is required ; but it is more tedious and incomplete, and only suited for galenas containing a large percentage of sulphurets of iron or copper. The latter prevent the ore from smelting together and so stopping the roasting process, and their sulphur furnishes the necessary fuel.

The roasting in reverberatories is by all means the best preparation of galena ores for smelting. In this country it is generally done in small Mexican furnaces, called *galemadors* (a corruption of " ga-lenadorcs"), of the shape given in Küstel's "Nevada and California Processes." After the roasting operation is finished the heat is so increased that the ore is converted into a slag, principally *silicate of lead,* which is drawn out of the furnace, cooled, and broken up into large pieces, of convenient size. The agglomerated ore is then passed through the blast-furnace, with the proper quantity of fluxes (Cerro Gordo, California; Big Cottomwood, Corinne). The quantity agglomerated is 10 tons in twenty-four hours, at a cost of about $4 per ton.

Before smelting, the ores ought to be reduced to the proper size. Some of the Eureka ores, yielding a very basic slag, may be thrown into the furnace in any size without disturbing the smelting operations (Richmond Company's ore). But silicious and calcareous ores ought to be reduced to pea-size in a battery. Unless this is done no furnace can be run without sledge and bar.

Ores carrying much oxide of iron, like the White Pine ores, ought to be agglomerated in conjunction with quartz in a reverberatory furnace. Hereby the oxide of iron is slagged, and cannot be so easily reduced to metallic iron by subsequent smelting in a blast-furnace. Metallic iron, not finding heat enough in a lead-furnace to keep it sufficiently fluid to run out with the slag, congeals in the hearth, and forms what smelters term "sows," "bears," "horses," or "salamanders."

Very fine ores ought to be agglutinated by milk of lime, or agglomerated in a reverberatory, as they either escape from the top of the furnace or roll through the charge and arrive raw before the tuyeres, thereby forming nozzles and deranging the furnace.

The *Eureka ores* are principally bog ores, with argentiferous and auriferous carbonates of lead interspersed. The iron ore is chiefly in the shape of hydrated oxide of iron ; but streaks of pittizite, arse-niate, and sulphate of iron arc frequent, and phosphates of iron probably occur, although they have not yet been observed. The principal lead ores are cerussite, mimetite, and galena, in pockets. But wulfenite (molybdate of lead) has been found very frequently in cavities, beautifully crystallized. Owing to the presence of arsenic and sulphur in these ores no reduction of metallic iron need be feared, as this metal is carried off in the shape of a mixed sulphuret and arseniuret of iron, termed "matte" or "speiss," a very fusible compound.

The percentage of gold in these ores decreases with the rise in the percentage of lead. The reverse (Ruby Hill ores) is the ease with the silver. There arc, however, zones of.lead ore, which do not carry gold at all, and only about thirty ounces of silver per ton (Bull-whacker mine). The average contents in lead of the ores delivered at the smelting works of Eureka arc probably about 25 per cent., value of gold and silver varying. Formerly even ores with only 8 and 8 per cent, of lead were smelted in one establishment, along with dry ores. The resulting lead was very rich, sometimes running up as high as $1500 in gold and silver, but the matte was also rich, assaying about $70 in gold and silver. As matte requires additional expensive operations to extract the useful metals from it, it is, at present, better to make it as poor as possible and throw it over the dump. To do this we have to observe the metallurgical principle,—-the more lead in the charge the less of the noble metals will go into the by-products.

In the front rank of the works at Eureka, Nevada, are those of the Eureka Consolidated Company, at the north end of the town. This company have five furnaces, of a capacity of 150 tons of ore per day.

The motive-power for four Sturtevant blowers, No. 8, an 8 by 10 Blake's crusher, and a 6-inch pump, is furnished by a 40 horsepower engine, with two boilers, one being always in reserve in case of repairs.

Furnace No. 1, having five tuyeres of 2 1/2 inches nozzle, was built after the pattern of the Orcana furnaces, similar to a north-of-Eng-land slag-hearth. Its present dimensions are 2 1/2 by 3 feet in the hearth, and 2 by 4 feet at the top, with a height of 12 feet from the centre of the tuyeres to the feed-hole. Capacity, 21 tons of ore per day.

Furnace No. 2, with three tuyeres of 3 inches nozzle, is of the same pattern and capacity.

Furnace No. 3 is six-sided, with five tuyeres of 2 1/2 inches nozzle, and otherwise of the same dimensions as the last, except as to height, which is 10 feet. Capacity, 23 tons.

Those three furnaces derive their blast from two blowers.

Furnaces Nos. 4 and 5 arc octagonal, and have ten tuyeres each, four on each side, adjoining the breast, and two at the back. Each furnace has a blower of its own. Dimensions, 3 by 4 1/2 feet in the hearth, 6 1/2 feet at the top, 10 feet high. Capacity, from 35 to 40 tons per day. The blowers are run at a speed of 2100 revolutions per minute, and yield air of a pressure of 1 inch mercury. The cooling-water passes from the tank through a 3-inch supply-pipe, and thence through 3/4 inch pipes, entering the tuyeres from below. The waste-water passes out at the top of the tuyeres into funnels connected with a 3-inch waste-pipe. The latter leads to a large collecting-tank outside of the building, whence the water, after cooling, is pumped back into the supply-tank. Owing to the inadequacy of the supply-pipe, and the temporary insufficiency of water, only four furnaces can be run at a time. As the water is very muddy, the cast-iron tuyeres are very rapidly destroyed, on account of the accumulation of sediment inside. It is therefore contemplated to use only wrought-iron tuyeres, which, though costing nearly twice as much as cast-iron, last much longer.

The nozzles, connected by leather hose (wind-bags), with corresponding reducers in the main induction-pipe, are 4 inches diameter at the outer end, tapering down to 2f inches towards the mouth. They are pushed tightly into the tuyeres, to prevent the escape of wind. At the outer end or elbow a 1 1/2 inch projection is attached to the central axis of the nozzle. This contains the eye-hole, which is closed with a wooden plug. The latter is removed occasionally, to inspect the condition of the tuyere.

To illustrate the manipulations at a furnace, they will be described from the commencement of a campaign, viz., from the blowing-in.

The hearth and furnace having been dried in the manner described above, the furnace is gradually filled up to the throat with coal, care being taken to keep it blazing. The fore-hearth and the apertures of the tuyeres are left open during this operation, to facilitate the draught. The filling up takes from four to five hours in a large furnace like Nos. 4 and 5. As soon as the coal at the throat has reached a dark-red heat, the blowing-in proper commences. Previous to putting on the blast, however, the front is put in; that is, the space *h* under the bridge *g* is closed up with bricks of stiff clay, rammed in tightly, and reaching a few inches below the dam-plate. Then the fore-hearth is also covered with clay, pounded down tightly. All the tuyeres, except the four nearest the front, arc closed with clay stoppers; their respective wind-bags arc tied up with strings, to prevent the escape of wind. The nozzles of the four tuyeres named are now placed in position, and the blast is allowed to blow with full force for three-quarters of an hour, a long flame issuing all the time from the pipe of the siphon-tap. When the latter is red-hot, the blast is shut off by a cut-off in the main pipe. The clay balls are now removed from the closed tuyeres, and all the nozzles are put into the tuyeres. The blast is turned on again, and the charging commences. About three tons or more of lead are put into the furnace through the feed-holes, in the proportion of two scoops (1.2 bushels each) of coal to 250 or 300 pounds of lead. This is done to heat the hearth properly, and prevent the accretion of slag or cinders, which might seriously interfere with the good working of the furnace. About 250 bushels of coal arc used in all the foregoing proceedings. After all the lead is melted down, the feeding of the ore commences. First, six scoops (1.2 bushel = 18 lbs. each) of coal, are scattered over the furnace, three from each feed-hole; on the top of this, but close to the walls, eighteen shovels of fine ore (15 lbs. each) nine through each feed-hole, and four shovels (17 lbs. each) of slag = 25 per cent, of the weight of ore. This makes 1 pound of coal to 2.5 pounds of ore, or 3.1 pounds of smelting-mixture.

Every charge is marked by moving a peg on a tally-board for the convenience of the superintendent.

As soon as the lead has entered the pipe of the siphon-tap below, which may be observed by the disappearance of the flame emanating from it up to that time, the basin is covered with live coal and kept so all the time. Simultaneously the clay is removed from the fore-hearth. About two hours after the first charge, the slag, entering from below the breast, rises in the fore-hearth to the level of the slag-spont, viz., 3 inches below the top of the dam-plate. A cast-iron pot of conical shape, 26 inches deep, 15 inches upper, 6 inches lower diameter, is now placed under the slag-spout by means of a truck, and the exit of the slag is urged by detaching the crust along the dam. For the first half hour the slag is somewhat stiff, and only red-hot, from impurities, and from the fact that the furnace has not attained the proper temperature; but in the course of time it increases in fluidity and incandescence. The corners of the fore-hearth have to be frequently cleared from hard accretions, to prevent them from growing. After the lapse of a few hours the blast is shut off and the front removed by means of a sledge and bar, in order to clear the hearth and tuyeres from adhering cinders. If there be a hard crust on top it has to be broken up and pushed out of the hearth. During the. Stoppage the tuyeres are closed up to protect the work-men from the escaping carbonic-oxide gas, and to economize the heat in the furnace. No new charge is introduced during this. time. As soon as the hearth is clear, lump-coal to the amount of about two bushels is thrown over the fore-hearth, and a new front is made. The latter has to enter into the slag; if this is not observed, the blast will come through, not only exposing the furnacemen to lead-fumes, but at the same time chilling the fore-hearth. The front must be made of plastic clay; lean clay does not answer. After having closed the front, the noxzles arc adjusted and the blast is turned on again. Hitherto the furnace has been running with a blaze at the top, indicating too high a temperature in its upper portions, which gives rise to great loss of lead by volatilization, and also injures the feeder's health. If the slag is gaining in fluidity, and the tuyeres remain perfectly bright, not even showing the least black ring, two shovels of slag may be replaced by two shovels of ore, but this must be done with the utmost caution, and at intervals of from four to six hours. At last a point will be attained when the blaze at the top disappears and the throat gets perfectly dark, discharging only black smoke. The normal charge has now been reached. In twenty-four hours 180 charges of smelting-mixture are run through with 1260 bushels of coal. The normal charge for fine carbonate ore is thirty-four shovels of ore and two of slag, corresponding to 46 tons of ore in twenty-foul" hours; for coarse ore it is 26 shovels of ore and 2 of slag, corresponding to 35 tons per twenty-four hours. When the furnace has been in operation for a week, it will even take more than this for a time, probably because it has then assumed the most favorable shape for smelting.

The furnacemen have to watch everything about the furnace very attentively in order to be always ready to apply the proper remedies. The slag has to run almost constantly while the blast is on. As soon as it becomes smeary and sticky, and emits a spray of sparks, which rise in parabolic curves, the matte-spout is opened and the matte run into a cast-iron pot, lined with clay. It is of smaller dimensions than the slag-pot. Care must be taken to keep wet or even cold tools away from matte or metal to avoid explosion. When the matte ceases, and in its stead slag begins to flow, the matte-spout *is* closed again with a clay stopper. The matte-spout is 3 inches lower than the slag-spout, and inclined a little towards the outside, while the latter lies horizontal. Thus it is possible to keep slag and matte separate.

Meanwhile the siphon-tap requires some attention. The pipe must be kept clear from accretions by pressing a rod-hot bar through it from time to time, because it is very difficult to open it again after it is once closed up. The basin is kept nearly full, and the lead is ladled out as it accumulates. The lead-moulds, which are in bar-shape, hold about 120 pounds each. From every fifth bar a sample is taken by means of an iron spoon. The samples from all the furnaces obtained during a certain time (usually twenty-four hours) are melted together to obtain the average sample.

The tuyeres must be kept clear by introducing a bar from time to time, to detach obstructions. If there should be any sign of darken-ing, the charge must be decreased by two shovels, and the result waited for. If the charge be still too heavy, another decrease of two shovels is ordered, until the tuyeres resume their normal condition. If they should at any time get long black nozzles, the blast must be stopped and the hearth cleared out immediately. The reason of this occurrence may be an overcharge, or a preponderance of silica in the charge, *i. e.*, a faulty mixture. If under normal charges ore arrives raw before the tuyeres and the blaze bursts out at the top, an irregular sinking of the charges or their detention on wall-accretions is indicated. These have to be removed. To do this the charge is allowed to descend half way in the shaft of the furnace, and only wood is applied as a fuel. By its blaze the wall-accretions are partly melted down. The balance is removed with chisel-pointed bars, worked through the feed-hole. During this operation the blast is, of course, shut off. Then the furnace is filled up again with coal, and the smelting proceeds as usual. Under ordinary circumstances the hearth is cleaned once in eight hours.

If wall-accretions have increased to such an extent that they cannot be removed without the greatest difficulty; if the charges descend irregularly, in spite of being decreased; and if the furnace walls show unmistakable signs of destruction, it is advisable to blow out the furnace. The charge is allowed to go down to the tuyeres, the furnace emitting thick lead-fumes and a blaze. As soon as the charge has arrived at the tuyeres, the blast is shut off, and all the loose masses are drawn out of the furnace. Then the tap-hole is opened with a sharp-pointed bar, and the liquid contents of the furnace arc discharged into the lead-well or basin, which has been previously heated. The congealed matter remaining in the furnace, consisting of slag, ore, etc., is detached with bar and sledge. The breast is only removed when needing repairs. After cooling, which usually takes thirty-six hours, the furnace is freed from wall-accretions, and the injured places are repaired. The hearth and boshes are relined with English fire-bricks, and a new dam and bottom arc tamped in. In thc siphon-tap only the basin needs repairing. The inside of the tuyeres must be cleared from sediment before they are ready for service again. A furnace, if badly burned out, can be in running order within a week's time.

Furnace No. 5 was lighted up for the first time on May 31, 1871, and made three runs of respectively twenty-six, forty-five, and fifty days, together one hundred and twenty-one days, without ever being repaired. It was only blown out in consequence of repairs not connected with the furnace.

In the three small furnaces the proportion of coal to coarse ore is as 1: 3.75; to fine ore as 1: 4.6 by weight. The quantity of ore run through in twenty-four hours is, for coarse ore, 20 tons, for fine, 26 tons, with an average consumption of 33 bushels of coal per ton of ore. The four furnaces constantly in use smelted in the fall of 1871 115 tons of ore per day, yielding from 14 to 24 tons of lead. They consumed on an average 4000 bushels of coal. The ore assayed on an average $27 in silver, and $35 in gold. The lead assays have been discontinued as being unimportant. Daily 120 tons of ore were delivered by teams from the company's mines.

The ore is dumped in front of the feeding-floor. The coarse pieces are picked out and run through the crusher, while the fine ore is wheeled directly to the furnaces. Generally, charges of coarse and fine ore are given alternately; only when the furnace is deranged the latter are given in preference.

The charcoal is piled up in the open air in a place elevated some distance above the roof of the feeding-floor. Trestle-works with ear-tracks connect the latter with the former. Every furnace has a compartment of its own for the coal. It is conveyed from the pile in cars holding 20 bushels, and dumped into chutes leading to the bins. There is always a thirty days' supply, viz., 120,000 bushels, kept on hand. The dross and waste of the coal is about 10 percent.

The laboring time at a furnace is divided into three shifts of eight hours. The crew for one shift consists:

I. At a large furnace (Nos. 4 and 5) of 1 smelter, at §4.50 per day; 2 helpers, at $4 per day; 2 feeders, at $4 per day.

II. At a small furnace, of 1 smelter, 1 helper, 1 feeder.

Two foremen, at $6 per day, have the immediate supervision of the furnace hands. They change every twelve hours. Two machinists at $5, under the supervision of a chief engineer at $8, take care of the engine. Besides, there is a blacksmith and outside foreman, and a number of roustabouts adequate to the wants of a large establishment. At the head there is a metallurgist, who reports to the general superintendent.

The products obtained in smelting are:

1. *Silver-lead,* generally called base bullion, with from $250 to $400 in gold and silver, about one half of the value being gold. As it is not advantageous to treat it any further on the spot, it is shipped to Newark, New Jersey. The expenses of shipping to San Francisco, thence by sailing-vessel to Newark, and the cost of parting, amount to $69 gold.

There were produced at the Eureka Consolidated Company's works, during the time from January 1 to October 1, 1871, 3800 tons of bullion from 17,000 tons of ore, at a cost of about $39 per ton, all told.

2. *Matte,* or rather a mixture of matte and speiss, that is, sulphurets and arseniurets of iron, with 60 per cent. of iron, and from $12 to $15 in gold and silver. It is thrown over the dump as worthless under the present circumstances. Its color is yellowish-white, like that of marcasite, with a blue tint at the surface; its texture is radial; specific gravity, 4.02. It is produced in the proportion of 2 to 4 bullion. Sometimes this proportion is larger.

3. *Slag.*—It is a mixture of singulo with subsilicates. It shows only traces of gold and silver by either crucible or scorification assay,

and has a specific gravity of 3.6. About 10 or 12 per cent. is used over again, the rest is thrown over the dump.

Its composition is shown by the following analyses:

	I (thin).	II (thick).	III.
Silica,	=20.12	37.50	30.20
Protoxide of Iron,	=52.80	50.70	
Oxide of Lead,	=2.79	8.00	
Alumina,	=5.80		
Lime,	= 12.00	2.80	
Magnesia,	=		6.90
	99.51	99.00	100.51

I and II are analyses made by Arents from recent slags; III by Küstel from former ones.

Wall-accredions, principally sulphurets of lead and arsenic, with about $10 in silver and traces of gold. These are thrown over the dump. They crystallize in small cubes, and have metallic lustre and blue color.

Hearth-accretions and *furnace-scrapings,* semifused slags, etc., are likewise thrown away.

Dust, assaying about the same as the ore, is a mixture of coal-dust with the finest particles of ore. Its percentage is considerable, but cannot be accurately ascertained without attaching dust-chambers to the furnaces. It would be well for a large company like the Eureka Consolidated to do this.

The principal loss, however, is not in the dust, but in the matte and in some of the slag. The yield of precious metals is 93 per cent. of the fire-assay reduced to dry ore.

The theory of this smelting process is easily explained. Under the influence of heat the carbonates first lose their moisture and carbonic acid. The remaining oxide of lead unites with the silica present to silicate of lead. The limestone also loses its carbonic acid, thereby becoming a base which has a stronger affinity for silica than oxide of lead. The oxide of iron is reduced to protoxide by means of heat and the reducing power of carbonic oxide from the fuel. The consequence is, that we obtain silicate of iron and lime, and oxide of lead, which yields to the reducing action of carbonic oxide, and forms metallic lead. If there is an excess of limestone or oxide of iron, a portion of protoxide of iron, being a weaker base than lime, will remain uncombined, and then will be reduced to metallic iron. Sulphuret of lead in contact with oxide of lead (according to the formula $2PbO + PbS = 3Pb + SO_2$) forms metallic lead, while sulphurous acid is disengaged. In the presence of oxides of iron a portion of the latter is reduced to metallic iron, which, in its turn, decomposes with the sulphuret of lead to sulphuret of iron and metallic lead. These reactions with sulphur and iron are less complete in the presence of silver than of lead alone, owing to the great affinity between silver and sulphur, which causes more or less silver to remain in the matte or iron sulphurct, though the greater affinity of lead for silver takes the most of the latter into the metallic lead.

Arseniates of lead and coal, acting upon each other in the heat, yield arseniuret of lead, arsenious acid, carbonic acid, and metallic lead. The arseniuret of lead is again decomposed by metallic iron, forming an arseniuret of iron, or speiss and metallic lead.

The next important works at Eureka arc those of the Richmond Company, lately passed into English hands, at the southeastern end of the town. They were originally erected by Messrs. Ogden, Dunne & Co., for the purpose of doing custom-work. But the searcity of real lead ores offered for sale induced these gentlemen to abandon this scheme and consolidate with the owners of the Richmond, a very valuable mine adjoining those of the Eureka Consolidated Company on Ruby Hill. The ores resemble in their character those of the latter company, being bog ores, intermixed with gold and silver bearing lead ores. On an average, they yield by fire-assay $40 in gold and silver, and produce, when mixed with about 7 per cent. of quartzose silver ore (milling ore), a bullion of $250 per ton, which is shipped to San Francisco for parting at a cost of $35 per ton. At present the company have a circular furnace of the Piltz pattern, with seven 2-inch tuyeres, mechanical feeder, and siphon-tap, running; but there are two more large furnaces, designed by Mr. Avents, in the course of construction, each of which will re duce 50 tons of ore per day. In addition, there is a German eupelling-furnace of ten feet diameter, a softening or calcining furnace, and a bullion-melting furnace, which are out of use at present. The steam-engine is a vertical one, of 35 horse-power, with one boiler only. It drives a No. 7 Sturtevant blower, a Blake's 10 by 12-inch crusher, a Howland crusher, and a Harrison burrstone mill. The Blake's crusher is intended for breaking up the coarsest lumps of ore. The Howland crusher and the Harrison mill are only used for sampling purposes and grinding sandstone, clay, etc. The former reduces the material to pea-size, after which it goes to the mill to be ground to a fine pulp.

The arrangement for getting coal to the smelting-1 substantially the same as that at the Eureka Consolidated works. There is a magnificent ore-floor, built of stone, attached to the works, where the winter supply of ore is piled up. The feeding-floor is spacious, and contains a number of bins to keep different ores separate.

Lately the charge was as follows :

17 Lange shovels of charcoal,	= 90 pounds, about 5 bushels.	
24 Shovels of **Richmond** ore, at 15 pounds,	=	360 pounds.
2 Shovels of milling ore, at 12 pounds,	=	24 pounds.
		384 pounds.
2 Shovels of slug, at 17 pounds,	=	34 pounds.
		418 pounds.

This is at the rate of 1 pound of coal to 4.6 pounds of smelting-mixture, or 4.2 pounds of ore, or 26 bushels of coal to 1 ton of ore. There arc passed through the furnace 150 charges in twenty-four hours, equal to a capacity of 28.8 tons of ore. The ore, smelted during the month of October, worked $64 dollars per ton. Run, from three to four weeks. The proportion of matte produced along with the bullion is about the same as at the Eureka Consolidated Works. The wall-accretions are more troublesome than in the former works, as the mechanical feeder prevents their detachment. The slag is basic, and resembles No. 1, heretofore described.

The works of the Phœnix Company do not present any new feature. They have a small Raschette furnace, of 25 tons capacity, built by Charles Liebenau, running, and another one in the course of construction. The company's mines are in three different ore-zones, viz:

1. That of the bog ores (Jackson mine, mines on Ruby Hill).
2. That of the dry or milling ores (mines on Adams Hill), auriferous silver ores, with little or no lead.
3. That of the lead ores (Bullwhacker mine). The latter are rich in lead, with a moderate yield in silver, and no gold.

The ores of the variety No. 1 are very basic, and require an admixture of quartzose material for smelting. This is accomplished by adding the ores of the varieties Nos. 2 and 3.

The bullion yield is four tons per day, assaying $210 in silver, and $40 in gold per ton. There is no, or very little, matte produced, owing to the lack of sulphurets in the ore. Wall-accretions do not occur. The furnace looks perfectly clean after blowing out, but the slag is of a more basic character than No. 1 of the Eureka Consolidated Company's works, hence the walls round the tuyeres are very rapidly destroyed. Run, 21 days.

Besides these establishments there are a great many smaller ones in Eureka district, which run, however, only at intervals.

In White Pine district the first impetus to a perfect smelting mania, was given, it is reported, by Colonel Charles S. Bulkley. Waiting in vain for the completion of the White Pine Smelting-Works, at a fixed date, he started himself to manufacture a lot of lead, necessary for calking the pipes of the White Pine water-works. For this purpose he built a little brick furnace with a grate inside, in the town of Hamilton, the apparatus being about as high as a German elbow-furnace. Then he purchased several tons of good gray carbonates from the Miser's Dream mine, from which he reduced the lead by throwing it into the furnace, alternating with dry billet-wood. The lead ran into a bowl in front of the furnace. The simplicity of these operations, and the bright shine of the lead-bars produced, which, by the way assayed $36 in silver per ton, gave rise to the erection of an almost unlimited number of furnaces. "Every miner his own smelter," was the word. Mexicans erected atmospheric or draught furnaces, which, on account of their small cost, were soon copied by the miners, and Welshmen built the more expensive blast-furnaces. But a collapse was soon to come. The small capacity of these furnaces, and the low grade of the lead produced, were out of proportion to the general costliness of the necessaries of life. Other difficulties were associated with these circumstances, and rendered smelting impossible for people of small means. The completion of the Pacific Railroad encouraged other parties to engage in smelting. The first one was a San Francisco corporation (the White Pine Smelting Company), who, in June, 1869, built works at an expense of $36,000, with a view of depending entirely upon custom-work. As the business was considered to be very profitable, the Alsop Company and private individuals offered, competition, and this was the beginning of the end. One party was overbidding the other in the purchase of ores, to drive their opponents out; finally they had exhausted their resources and ceased work. Just at this time another capitalist stepped in, expending large sums of money for new works. Before fairly getting to work he had to stop, however, because the prices for ores, coupled with the difficulties of smelting them, seriously impaired a financial success.

The smelting-ores of White Pine may be classified as follows :

1. *Lead ores* proper, principally cerussite with occasional nodules of galena and red copper ore (Cu_2O), carrying from $5 to $35 silver per ton. The purer carbonates form solid masses, and have a peculiar gray color; therefore they are called " gray carbonates." The majority of the carbonate ores, however, are mixed with the oxides of iron and manganese, which give them a black or brown appearance. They are pulverulent, and yield readily to the pick. Both varieties fill cavities in the Devonian limestone, and are confined to a particular branch of the White Pine Mountains, called the base-metal range (Miser's Dream, Mollic Star, Jennie A., and other mines).

2. *Copper-Lead Ores.*—They are, according to their chemical composition, a mixture of arseniates of copper and lead, with the carbonates of copper and pockets of galena, and assay on an average $60 per ton. They form either large pockets in the limestone, or impregnate the same. For this reason they are not as easily mined as the real lead ores. There seems to be an abundance of them on the western slope of Treasure Hill (Elko, Erie, Russian, and Imperial mines).

As may be inferred from their occurrence, these ores are of a very basic character; the former class being very ferruginous, the latter calcareous. To flux them, clay, clay-slate, and a very silicious sand from the vicinity of Shermantown were used in default of quartz, which could only be procured with greatest difficulty. Besides, most of the works had no means to crush it. Purely quartzose ores only occur on the White Pine Mountain proper; but the cost of transportation and the high prices compelled smelters to desist from getting them. Occasionally small lots of quartzose silver ore from outside districts, or quartzose tailings, could be bought, but not enough to avoid those incessant troubles and vexations arising from a want of fluxes. Iron sows were a daily occurrence. Another source of trouble was the lining. The insufficient quantity of quartz added to the ore caused the latter to corrode the lining in order to saturate itself with silicic acid. English firebrick, pancake sandstone, in fact every kind of lining, would be destroyed in the course of a few days. The commonest lining was a sun-dried composition brick, made at great expense, of kaolin and common clay. But, owing to its not inconsiderable shrinkage, it would soon present to the slag points of attack, which kept the mason busy repairing. Notwithstanding these difficulties, runs were made at the White Pine Smelting-Works and the Alsop furnace of four and six weeks.

The most ridiculous feature in smelting at White Pine was the practice of some smelters to roast or burn calcareous ores of class 2 in a sort of limekiln to get rid of the sulphur. Instead of smelting these galeniferous copper ores in their raw state, perhaps with an addition of galena in admixture with carbonate ores, with a view to produce a tolerably pure lead and copper matte, those ores were subjected, to the above operation, and a mixture of lead and a semi-sulphuret of copper was obtained, which was not salable in San Francisco, and in the East only at a great loss.

The carbonate ores ought to be agglomerated in a reverberatory furnace with silicious ores, and then, to curich the bullion, passed through the blast-furnace with raw copper-lead ores and galenas. The result would be silver-lead of a good grade and argentiferous copper-matte. The latter could be roasted and smelted for concentrated matte or black copper. To insure financial success, however, a company ought to have works of a large capacity in a central location, and own mines of their own. Custom-ore cannot be relied upon, as it takes capital to develop mines so that they can keep a large establishment supplied. This most of the miners do not possess. The furnace at the White Pine Smelting-Works had a capacity of 15 tons per day, and consumed from 26 to 30 bushels of coal per ton of ore. The latter required an addition of from 15 to 20 per cent. of quartz. If quartz-tailings were used, they had to be mixed with clay, and formed into bricks. Raw tailings being very light, and in a fine state of pulverization, are either carried out of the chimney by the. blast, or roll through the charge into the hearth without entering into combination with the ore. The bullion produced from the carbonate ores alone yielded from 18 to 30 ounces of silver per ton; from mixed ores (carbonates, copper-lead ores, and dry ores) 130 ounces and upward.

There are many other promising smelting districts in the State of Nevada, but the smelting operations carried on there do not differ materially from those already described.

Most of the lead ores of Utah differ in this particular from those of Nevada, that the prevailing gangue is quartz. Calcareous ores are, however, also found in considerable quantities in East Canyon, Little and Big Cottonwood Canyons. Bingham Canyon offers the most striking instance of the occurrence of quartzose ores. They lie in a disintegrated quartzite, which intersects a stratified limestone, probably pertaining to the Devonian age. The great bulk of them are the carbonates, and sulphocarbonates of lead, carrying from 15 to 30 grains of silver, with streaks of galena varying in silver contents. A large portion of the ores show traces of gold. Of accessory minerals, small quantities of sulphurets of iron, oxide of iron, and clay ironstone may be named.

There are at present two smelting establishments in Bingham Canyon, that of Messrs. Bristol & Daggett, and that of the Utah Silver Mining and Smelting Company, limited, both of which work ores from their mines, and also do custom work. The former is very conveniently located at a hillside below the mine, belonging to the same parties, the Winnamuck, from which the ore is chuted down on a planked ore-floor, forming part of the housed feeding-floor. The different classes of ore delivered to the works are thrown through a screen; the coarser pieces are run through a Brodie crusher and reduced to walnut-size. Previous to smelting the ores are mixed by weight, so as to produce a bullion of a certain standard.

The company's furnace is a circular one of the Piltz pattern, with eight tuyeres of 2-inch muzzle. It is 14 feet high from tuyeres to throat 3½ feet diameter in the level of the tuyeres, and 5 feet at the top. The hearth forms a hexagon on the outside, and is inclosed by six east-iron plates 1½ inches in thickness. The two nearest the dam-plate are provided with slots for tap-holes. The upper part of the furnace, made of brickwork, rests on a cast-iron flange, which is borne by four hollow cast-iron pillars. The part below the flange is of Utah sandstone, 13 inches thick, lined inside with 4 inches of Pennsylvania firebrick. The motive power comes from a 10-inch cylinder stationary steam-engine, with 25 horse-power locomotive boiler. It drives a Brodie crusher and a No. 4 Root's blower. The efflux-pipe of the latter is provided with a safety-valve and a wind-gauge, by which the pressure of the blast is measured in inches mercury.

An open bulkhead adjoining the ore-floor holds about 30,000 bushels of charcoal.

The manipulations at this furnace do not differ much from those anywhere else, only in lighting up the proceedings are a little different. After the hearth is heated up sufficiently, a suitable quantity of lead is introduced through the front; then the furnace is filled up with coal in the usual manner. As soon as the coal has reached to within 5 feet below the throat, slag is charged in portions of one pound of the latter to one pound of charcoal. When the charge is in the level of the throat, the blast is turned on. About 1000 pounds of good, fusible slag, picked out for that purpose, are fed before commencing with light charges of ore.

In the past summer the ores coming to the works for treatment were:

1. Carbonates of lead from the Spanish mine, with from 28 to 30 per cent. of quartz, 55 to 60 per cent. of lead, and $22 silver per ton.

2. Carbonate ores from the Winnamuck mine, with 30 per cent. of quartz, 35 per cent. lead, and about 880 silver and gold.

3. Ferruginous dry ore from Winnamuck mine, with 38 per cent. silica and alumina, 27 per cent. metallic iron, and $65 silver and gold.

4. Same ore, with 45 per cent. silica and alumina, 23 per cent. metallic iron, and $80 silver and gold.

Ore No. 1 was the principal one smelted; occasionally No. 2, which is of the same character, and No. 3, were added; No. 4 was reserved for assorting. The furnace worked well, and without the least difficulty, when the ore was mixed with 40 per cent. of a tolerably pure hematite from Lchi, 20 per cent. of limestone, and 30 per cent. of slag.

The slag produced was stiff, and resembled a bisilicate. A decrease in the percentage of slag added to the smelting-mixture was always accompanied by evil consequences. The resulting slag in that case was dry, short, and would soon stop running. A diminution of the iron ore and increase of the limestone also worked unfavorably, and the more so the less oxide of iron was in the smelting-mixture. Pure silicates of lime cannot be perfectly liquefied by the temperature prevailing in a lead-furnace.

The tapping is done at these works in the old manner, by piercing the tap-hole with a bar as soon as the lead has risen to the slag-spout. The tap-hole is just high enough above the bottom of the hearth to leave a suitable quantity in the latter. After tapping, the hearth is cleared from cinders and other accretions.

The production of matte is not noteworthy.

The normal charge was: 5 scoops of charcoal, at 1.1 bushels or 18 pounds = 90 pounds; 15 shovels of lead ore, at 15 pounds = 225 pounds; 6 shovels of ironstone, at 13 pounds = 78 pounds (partially Winnamuck ore No. 3); 4 shovels of limestone, at 13 pounds = 52 pounds; 3 shovels of slag, at 10.5 pounds = 31.5 pounds—total smelting-mixture, 386.5 pounds.

The proportion of coal to smelting-mixture is as 1 pound to 4.3 pounds, and to ore as 1 pound to 2.3 pounds; 1 ton of ore to 15 bushels of coal.

In twenty-four hours, under a pressure of from 1 ½ to 2 inches mercury, 140 charges were run through the furnace, corresponding to 27 tons of smelting-mixture, or 15 3/4 tons of ore, from which resulted 7 tons of lead, carrying between $60 and $80 of silver per ton.

The lead is shipped to Chicago for parting.

The number of hands required was: 3 smelters, at $5 per day; 6 helpers, at $3 per day; 3 feeders, at $3 per day; 2 engineers at §4 and S3 per day; 1 blacksmith, at $3 per day ; 1 coal-receiver, at $2 per day ; 4 roustabouts, at $2.50 per day.

Three helpers might be saved by providing the furnace with an automatic tap.

The ores of the Utah Silver Mining and Smelting Company, limited, arc of the same character as those of the Spanish mine, viz., very poor and silicious. At the time of a visit of Messrs. Hahn and Eilers to these works nine classes were made, for what purpose could not be learned.

The charge was as follows: 2 baskets of coal, at 2 1/2 bushels = 90 pounds; 6 shovels of ore (chiefly leadhillite) = 90 pounds; 2 shovels of iron ore = 26 pounds; 2 shovels of limestone = 26 pounds; 2 large shovels of slag, about = 30 pounds—172 pounds.

This is at the rate of 111 bushels of coal to 1 ton of ore, or 58.1 bushels to 1 ton of smelting-mixture. This proportion is exorbitant; but it was all that could be done under the circumstances, the ore being poor in lead, and the iron ore, though scrupulously assorted, very silicious. Assuming that 140 charges passed the furnace within twenty-four hours, its capacity would be 6 tons 600 pounds of ore, from which 2 tons 200 pounds of lead resulted. Under a higher pressure of the blast like that at the Winnamuck furnace, the capacity of the latter would probably be attained.

The furnace then running was a six-sided one, with five tuyeres of 2 1/2-inch muzzle, and mechanical feeder. It was supplied with blast by a No. 8 Sturtevant blower. But there was a larger one in the course of construction, an exact copy of No. 5, at the Eureka Consolidated Company's works.

Buel & Bateman's works, at the mouth of the Little Cottonwood Canyon, consist of two circular Piltz furnaces of the same size as the one of the Utah Silver Mining and Smelting Company, limited. They have been running extremely irregularly during the summer, and, as near as could be ascertained from the best authority, at a decided loss. The manipulation of the furnace does not differ materially from that of similar furnaces elsewhere. The ores smelted are those from Little Cottonwood Canyon, which are, with the exception of those from the Emma mine, decidedly basic.

Very good smelting-works have lately been built in American Fork, to smelt the ores from the Miller mine. But at present it is known only that they are Piltz furnaces, with automatic tap. The ore smelted here is decidedly basic.

There are a great number, probably over twenty, other smelting-works in Utah ; but none of these have so far run regularly or with profit.

In Montana, only two smelting-works arc in operation now, and both these are located in Argenta, Beaver Head County. A third establishment, a copy of the Argenta works, is building in Helena.

The smelting-works of Argenta, and especially those of S. H. Bohm & Co., are managed as well as can be expected in that locality. Bohm *& Co.* have had their two blast-furnaces and one cupelliing-hcarth in blast since May, and Mr. Stapleton's works have also been in operation pretty regularly, A third works, the old ones of the Saint Louis Company, are idle, and have been so for several years.

All three are located a short distance above the town of Argenta, on the south bank of the Rattlesnake Creek. The Saint Louis Company's works were built first, at a time when labor and all the materials for building were at the highest price. A natural tendency to save in the cost of materials is therefore everywhere visible, and it is undoubtedly owing to this that the external appearance of the furnaces and buildings is ungainly, rough, and clumsy in the extreme. The works might, however, have answered the purpose very well, if the inner shape and dimensions of the blast-furnace had been suitable. But neither the wide hearth nor its trapezoidal section could give good results with ores as quartzose as those of Argenta. And, furthermore, it appears from the burnt appearance of the inside of the furnace, from bottom to top, that the ore must have been charged into the furnace in large pieces, and the smelting conducted with the flame blazing out of the top, two very serious mistakes which ought never to have happened. The slag, too, on the dump, shows at once that smelting in reality was unsuccessful, whatever large amounts of silver may have been taken from the furnace during the short time of its running. A part of the slag contains very much lead (and undoubtedly silver), while another part is not smelted at all, but was probably pulled out of the hearth with instruments. The German cupelling-furnace, on the contrary, is a very good and substantial structure, and must have done its work well. The establishment is not now in shape to be started up again with little cost, many important parts being entirely missing, and the whole having suffered much from exposure,

S. H. Bohm & Co.'s works, the old " Elsler furnace," are the next above the foregoing. They consisted, up to August, 1871, of two stack-furnaces and a German cupelling-furnace, the blast being supplied by a Root blower, driven by a magnificent water-wheel of 12 feet diameter and 4 1/2 feet breast. The latter supplies also the power for a Dodge crusher. Since August, a third blast furnace and another cupelling-furnace have been added to the works. The blastfurnaces are the high furnaces, with rectangular section and the same area at the hearth and throat as first introduced into this country for copper-smelting, at Ducktown, Tennessee. The inside height above the tuyeres, is 20 feet, the section 24 by 24 inches. The furnaces are necessarily so narrow and high because the ores are extremely quartz-ose. The lining is a quartzose granite from the neighborhood, which stands the heat about three weeks. There arc two common tuyeres in the back of each furnace, which lie horizontally about 10 inches above the upper end of the dam-plate, and have a diameter of about 1 3/4 inches at the mouth. The smelting is conducted with "noses," that is, the melted charge is allowed to cool locally around the interior openings of the tuyeres, so as to form a nozzle or "nose," protecting the tuyere against heat and chemical action, and at the same time conveying the blast well into the interior of the furnace. The hearth is filled with heavy *stiibbe,* or brasque made of charcoal-dust and burnt yellow clay, no white clay being at hand in the neighborhood. This material is reported by the owners to stand very well,

A pressure of about 1 inch quicksilver is intended to be maintained in the blast. The charges vary, of course, considerably, as very different ores are constantly delivered from the mines, but it is intended, and the dump shows that the object is generally reached, to produce a slag ranking between a singulo and a bisilicate. Rather large amounts of iron ore and limestone, both from the vicinity, are used for fluxing the great excess of quartzose gangue in the ores; and only from 2 to 2 1/4 tons of bullion are produced from each furnace per day. The charges contain from $80 to $150 silver per ton, and the base bullion produced assays from $250 to $500. Specific statistics in this connection are wanting at present.

The cupelling-furnaces are exact copies of those used in the German lead and silver works. For the hearth, a very good marl is employed, which is found in the limestone a short distance from Argenta.

Stapleton's works, a little higher up the creek, consist of two shaft-furnaces and one cupelling-furnace, all constructed on the same plan as those just described. These works do not run quite as regularly as Bohm's, principally because the ore-supply is precarious.

Such a cause has, so far, not affected Bohm's works; undoubtedly on account of the superior activity of the managers in securing ores from all quarters in advance, and the larger working capital at their disposal. The prices paid by both works for ore to miners are exceedingly moderate, and leave a large margin for profit, although the cost for smelting must necessarily be very high. Charcoal, for instance, costs from 18 to 20 cents per bushel, and labor from $4 to $6 per day, everything else being correspondingly high. The loss of silver in smelting is claimed by Mr. Bohm to be only from 8 to 10 per cent, of the assay value, though there are no arrangements con nected with the furnaces to condense the dust. This is quite possible, as no ores containing much antimony, arsenic, or zinc appear to come to the works.

The litharge produced in the cupelling-furnaces is, for the greater part, not utilized at all at present, small quantities only being occasionally required for addition to the charges of the blast-furnaces. The bulk of it lies in the furnace-yard, awaiting the time when it can be profitably reduced and shipped.

Much of the lead-ores being carbonates, and such of the galena-ores as contain a sufficiency of iron pyrites to be fit for open heap-roasting, being subjected to that process before smelting, there is only an inconsiderable quantity of matte produced, which, being at the same time poor in copper, is added to the charge without a preparatory roasting. It would, however, be a better plan to save the matte until there is enough on hand to make a roast-heap; as in that case quite an amount of iron ore which must now be purchased at the works as flux might be saved, and the silver and lead would be extracted at once. By the present method, the greater part of the matte passes the furnace many times almost unaltered.

The smelting-works in Argenta will undoubtedly do well, if conducted as at present, as long as there is no competition, either from large amalgamating-works or from smelting-works using the copper ores of Montana for the extraction of silver and gold. But it seems that with either of these they would be unable to compete.

On the whole, very few of the smelting-works in Nevada, Utah, and Montana have been financially successful, and this in spite of the rich ores they usually treat. There are two principal reasons for this. The one is the unprepared state in which the ores are delivered at the smelting-works, the other the fact that but few works can be found which are managed by metallurgists who really are what they claim to be.

In many of the Western mining districts, notably in those of Utah and Montana, there is an abundance of water, which invites a removal of the greater part of the gangue of the ores by the cheap and effective means of dressing. Yet this has never been done, though it is so evident that an enormous saving in fuel and fluxes might be effected by the removal of the gangue before smelting. It is rarely the ease that in the Western lead ores the true silver ores arc found, which would occasion much loss in dressing; the silver is, on the contrary, in nearly all cases, closely allied with the carbonates and galena; and in dressing such ores very little loss need be feared.

In regard to the other reason, it is astonishing that mine-owners will not comprehend that metallurgy is a business which requires long study and practice, and which cannot be successfully conducted by those who know neither the theoretical ground on which it is founded nor the practical details. A noteworthy exception in regard to the last point arc the works of the Eureka Consolidated and those of Bohm & Co. in Montana. These works arc really successful, and might be more so if a mistaken economy did not prevent a still further perfection.

THE ECONOMY OF THE BLAST-FURNACE.

BY PROF. FEED. PRIME, JR.

To an association like the one before which I read this paper, few questions can be more important and constantly recurring than the following, viz.: "What economy can be effected in the manufacture of American iron ?" And it is the one with which I purpose to deal in this paper; premising, however, that my object is merely to indicate the direction in which an answer should be sought for, rather than to give it myself. This subject may be divided into two parts, " Economy in the production of pig-iron," and " Economy in the manufacture of wrought-iron;" but it is to the former alone that I shall confine myself this evening.

Of late years the improvements inaugurated in the Cleveland District have excited the wonder and admiration of the iron world. Instead of 30, 40, and 50-feet furnaces, the iron-masters of this district have taught us to build them of 70 and 80 feet, which last height is, I believe, the greatest yet reached in the United States.

The first object of the furnace manager is, *coefais paribus,* to obtain the greatest amount of metal with the least consumption of fuel. So long as gases are escaping from the furnace-throat of such a nature and temperature as to be capable of reducing the ore being treated, we know that heat, or in other words, fuel is lost. The first point to be settled is, at what temperature each ore commences to be reduced.

Bell has shown that in the Cleveland ore this process begins at 424° Fahr., while he holds that, in general, sesquioxide of iron is dcoxidized at all temperatures between 302° Fahr. and a bright red heat, but that it is never absolutely complete. And he shows that the reduction of ores containing scsquioxidc of iron is dependent not on their chemical composition, but on their molecular condition, and the rapidity of the current of gases passing over them, and the dcoxidation and carbon deposition are at a maximum at about the temperature of melting zinc, 783° Fahr. Now, to ascertain at what temperature the various magnetites, hematites, and limonites of this country commence to be reduced it would be necessary to make a series of experiments on the subject with native ores, in the performance of which no very great expense would be incurred. This having been done, the next step should be to ascertain the temperature and composition of the escaping gases, in order to see whether all the work that was practicable had been performed by them in the way of deoxidizing the ores. This, of course, would vary very much with the different coals and varieties of each. Should it be found, for example, that the gases when escaping at the furnace-throat were still capable of deoxidizing the ore, then the inference would justly be that the furnace was not high enough, and that fuel was being lost, and it would be a commercial question, as I. Lowthian Bell states it, whether the additional expense of enlarging the furnace would be sufficiently paid for by an improvement of the operation or an increase of work effected. Where anthracite is used in the blast-furnace, there need be comparatively but little apprehension of the burden crushing the coal, except by the decrepitation of the latter, and I would call the attention of those persons present who direct such furnaces to the question, whether they have ever instituted comparisons in regard to the economy of anthracite furnaces when both the pressure and amount of blast are increased ? Anthracite, although equal to coke as a fuel in the amount of carbon, requires a much greater pressure of blast for its perfect combustion, which should be equally distributed through a large number of tuyeres, and I would suggest that iron-masters should endeavor to ascertain the fact, whether with such a dense fuel, considerable economy might not.be attained by increasing the height rather than the diameter of such furnaces. We have in this country many open burning coals, which either do not coke at all, or else afford a very tender coke in ordinary ovens. In Great Britain the Ferrie self-coking blast-furnace has been introduced for the purpose of coking the fuel in the furnaces, and at the same time relieving the coke of a portion of its burden. In order to do this a furnace eighty-three feet high is divided, for a distance of twenty feet below the space required for the cup and cone, into four compartments, by vertical walls supported on arches and radiating from the centre. Both these and the circumferential vails arc pierced with flues, so that a portion of the gases taken from the top can be led down to the level of the bottom of the compartments and—receiving a supply of ah- through gratings in the external wall of the furnace—be ignited and consumed in the flues traversing the partition walls and surrounding the compartments, the draft through these flues being assisted by chimney-stacks at the top of the furnace. Time does not permit me to give any further details, for which I must refer you to *Engineering* of June 16th, 1871, and Volume I of *Journal of Iron and Steel Institute.* Suffice it to say, that in Lanarkshire district, the extraordinary result was obtained of saving a ton of coal to the ton of iron made, and also about 2 1/2 cwt. of ore. I. Lowthian Bell, who at first attributed the entire saving to the increased height of the furnace, subsequently changed his opinion and acknowledged that a portion of it was due to the combustion of the gases in the chambers.

Another point to which I wish to direct your attention is the manner of taking off the blast-furnace gases from the top of the furnace. It is a well-known fact that the gases have a tendency to escape up the sides of the furnace, leaving, in the centre, a column of ore, fuel, and limestone untouched. The common method practiced in this country, where the furnaces are close-topped, of taking off the waste gases at the throat from the sides of the furnaces, tends to increase this difficulty by creating a draught in the direction of the sides. Consequently if the gases are takeu off from the centre of the furnace above the charging-hole, this tendency is more or less counteracted. There can, however, be no doubt that taking off the waste gases from the centre of furnaces tends to prevent the latter from scaffolding, and also to economize fuel. Lurman's patent cinder-tap is probably so well known to you all that mention of it here would be superfluous, although experiments at various iron-works have been made with very contradictory results.

Another point, which I cannot too urgently set before you, is the very insufficient attention paid in this country to the proper comminution of ores. When small and large pieces of ores are thrown indiscriminately into the top of a furnace, it must necessarily work very irregularly, owing to the fact that the smaller portions are reduced and carbonized before the interior of the larger ones has begun to be reduced. The consequence of this is a very irregular yield in the different qualities of iron. This would to a great extent be ameliorated, if not entirely prevented, by bringing the ore to a nearly equal state of division by passing it through some ore-crusher or breaking it with hammers. As regards the calcining of ores, but very little has been done in the United States. It is true that in some places black-band is calcined in open heaps, in order to increase the percentage of iron, while in others, as at Johnstown, coal-slack is intermingled with the impure carbonate of iron on a hillside, and the mass of ore roasted. But the important advantage of rendering the magnetites and red hematites of this country porous, and consequently more easily reduced in the blast-furnace by calcining them in kilns, has, I believe, only been tried at Riugwood, N. J., with what result I do not know; but it is claimed for the Westman furnace, which is the kind built there, and is heated by a portion of the blast-furnace gases, that it renders ores porous, however dense they may be. Of course where the ores contain water a great advantage is gained in thus removing it before it passes into the blast-furnace, where heat is rendered latent by its conversion into steam, causing a decrease of temperature in the upper portion of the furnace, or necessitating the use of more fuel. In many furnaces it would be possible to utilize a portion of the gases now lost in roasting the ores. Of course it is a purely commercial question whether the roasting of the ores would pay, but I am convinced that in many localities it could be profitably done, especially by using coal-slack for this purpose. Experiments in this direction will undoubtedly be made before long, and if coal-slack cannot be directly used, as in the case of anthracite, some method will be devised for converting it into carbonic oxide outside of the calcining-kiln, and, if necessary, a certain proportion of lump coal may be added to the ore in the interior of the kiln. By running the calcined ore, while still hot, to the top of the furnace and passing it into the furnace, the decrease in temperature which always takes place when a fresh charge of cold ore and flux is added, would in a great measure be obviated.

Another point to which I wish to allude is the proper construction of hot-blast stoves. Mr. Bell believes that a very high temperature of blast is not requisite, and that when a temperature of 900° to 1000° Falir. has been obtained, the maximum has been reached. But Durham coke and Cleveland ore are different from anthracite coal and magnetite or hematite, and it seems to me that we have no right to assume, *a priori*, that the conditions which are found to be the best in the Cleveland district will also be the most suitable for the fuels and ores of the United States. I believe that by increasing the temperature of the blast considerably above that actually attained in this country, we shall effect a very palpable saving in the amount of fuel now necessary to produce a ton of pig metal, the temperature to which the blast may be heated being necessarily limited by the power of resistance offered by the iron pipes. The very common practice here, of permitting the hot gases to rise up vertically between the limbs of the U shaped pipes, is a very imperfect method of heating the blast, the gases escaping so rapidly as to be capable of but very imperfectly communicating their heat to the iron pipes, and consequently to the blast. Leaving out of the question the application of the regenerative system as too expensive for us to experiment upon, until the English iron-masters are able to give us some satisfactory answer, let us look at our present pipes, ami instead of conducting the hot gases vertically, cause them to pass in a horizontal direction, and we shall find that considerable economy will in all probability be attained; the blast will be heated to a higher degree, and consequently less fuel will be consumed. Should the hot products of combustion be found to still contain useful heat after passing once laterally through the hot-blast ovens, the} might be made to return in the direction whence they came, through another oven, or be passed under the boilers. "A considerable economy in fuel may be effected by simply arranging the blast-pipes in such a manner that the circles of fusion created by each shall be merely tangential and not intersecting. This may be ascertained by inserting an iron rod through each blast-pipe in suecession for a minute, and when that portion of it situated in the circle of fusion is red hot, the alteration then necessary in the position of the tuyeres is easily accomplished by calculating the space occupied by each circle. The last point to which I wish to allude this evening is the importance of consolidation. Those of you who are acquainted with the British iron trade are probably aware of the enormous capital employed, and the large number of furnaces owned by separate companies-—eight being a very common number, and less than four a rarity. This is one of the means by which they can afford to undersell the American iron-masters when we have no tariff. Another advantage they possess is in the consolidation of their works, which enables them to dispense with a large number of officials otherwise necessary.

My aim in this paper has been morelv to indicate what might be done as regards economy in the manufacture of iron, although some of the ideas appear to be impracticable at present; but before entering upon any experiments, the first and principal question to be asked and satisfactorily answered is: Will the alteration of the furnaces, and other expenses therein involved, *pay* in the end?

THE BROWN HEMATITE QBE DEPOSITS OF SOUTH MOUNTAIN,

BETWEEN CARLISLE, WAYNESBOROUGH, AND THE SOUTHEASTERN EDGE OF CUMBERLAND VALLEY.

BY J. W. HABDEN, M.E.

THE observations here following are the result of an examination made as to the feasibility of extending the South Mountain Railroad from Pine Grove to Waynesborough, and of the commercial value of the ore through which such extension would be made to pass.

The road at present built and in operation has a junction with the Cumberland Valley Railroad, half a mile east of Carlisle, and extends southward to Pine Grove, a distance of 17 1/2 miles. The extension proposed will add to it near 27 miles, making its total length 44 1/2, more than 23 of which will run through, or in close proximity to, beds of ore.

Along the route taken there are a number of openings at which the ore is gotten, of which the Craighead bank, Huntzinger's bank, Lowrey's bank, Wenkoop's bank, the Henry Clay bank, the Fuller bank, and the Laurel bank, between Carlisle and Pine Grove, are examples. These openings produce on an average, each, about 50 tons of ore per day. Some of this produce is smelted at the two furnaces, Whitestown and Pine Grove; the Whitestown cold-blast producing 30 tons of iron per week, and the Pine Grove, hot-blast, producing 60 tons per week. Both are near their respective diggings; the remainder of the ore is exported. The Laurel forge, too, turning out 30 tons of blooms per week, stands on this end of the route.

The ore deposit here alluded to lies along the slopes and valleys formed by the spurs and separated ridges of the South Mountain, as well as of the southeastern edge of the Cumberland Valley, and in association with the clays and sands, to which it once held a much nearer relationship, is the residue of decomposition in the dissolution of the slates and limestones at one time helping to make up the mountain. It is found all along the outlying edges, on the flat slopes, and in the cavities and caves of the underground convexities and peaks of the still existent but slowly changing rocks. In the gorges and narrow valleys, extending a **considerable** distance from the foot of the mountain, linking as we cross the valley with other brown hematite deposits, is the result of dissolution of higher beds of the great limestone formation, the whole belonging to the great Silurian system of Sir Roderick Murchison—of whose death, while penning these lines, we read.*

The ore, though exposed to the surface in many places, has generally a red gravelly covering, varying in thickness from five to twenty feet, evidently a surface wash of subsequent date, local, and always to be distinguished from the one underneath.

The excavation from which Pine Grove furnace is supplied is 300 feet long, further extended by ore uncovered but not gotten, and 150 feet wide. Its depth, as now seen, averages 50 feet, including 15 feet of the gravelly wash above spoken of. Starting at the end and following it round to a close, there is exhibited a working face 900 feet long by 30 to 35 feet deep, or say 30,000 superficial feet of surface from which ore is being gotten, and from which, by the use of gunpowder, 50 tons have been brought down at a time.

In this face we have conditions of ore varying from a soft, greasy,

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* This is literally true ; while my pen was on the line in which the name of Sir Roderick Murchison occurs, the *Philadelphia Ledger* was placed before me, and the first paragraph I read was the announcement of his death.

ferruginous, maroon-colored, impalpable mud (which, if properly mixed for the purpose, would make good paint), to the hardest of hematite ore in rock, projecting from the face. The intermediates being made up of balls, shells, shards, flat pieces and amorphous masses, the whole grouted in with clays and red earth, streaked and marbled in colors varying from white to that of the darkest maroon, and in which every stage of the process of decomposition and reconstruction is to be seen, from the disintegration first begun to the completely crystallized hydrated peroxide of iron we are now discussing.

Allowing liberally for the imbeddings, the mass will consist of upwards of 75 per cent, ore; and, charged with the oxides of a higher level, oxides of ages of production, slowly concentrating, sliding and descending, as their density increases and as the shrinkage *en manse* of the disintegrating slates and dissolving limestones permit, the ore increases both in quantity and quality as the diggings deepen. The average metallic value of that now being gotten is 42 per cent, at the furnace.

But the floor of this excavation is still on the best and hardest of ore, and a bore-hole put down two years ago, 107 feet, was yet in it. The bit of the boring tool broke, and now remains in the hole. The depth of the ore, then, is not proven.

Northeast of these diggings, the South Mountain Iron Company have a continuation of this ore spreading over the slope of the mountain, and in the valley of Mountain Creek to the southwest, it extends some three miles, averaging from a quarter to three-quarters of a mile wide, into which shafts and drifts have been put with varying results, proving the extent and quality of the ore, and that, where the bottom of the deposit is yet unreached in diggings now at work, the densest ore has yet to be gotten.

Continuing the same course over Grave Ridge, after a pause of three and a half miles, at Wolf's Hill, at the head of Birch Run, and again on the Hosack Run, tributaries to the Conecacheague, we are again on the same character of ore on property belonging to the estate of the late Hon. Thaddeus Stevens, from whence it was wagoned to the Caledonia furnace when it was in blast.

Jumping an interval, and in a recess of the slope of Chestnut Ridge, at a point parallel with the Chambersburg and Baltimore turnpike, we find ore in which there has once been a digging. It was abandoned, I am told, owing to occasional inundations from the creek.

Crossing the turnpike, and at the east flank of the Big Mountain, along it and between it and the Little Mountain, we are again on the ore, the synclinal conformation between the two mountains holding the products resulting from the dissolution of nobody knows how much of the rocks down to their present honeycombed and dissolving outeroppings and under-cropping edges.

In front of the Little Mountain the ore is continuous, and has upon it the Caledonia bank belonging to the Stevens estate, and on its flank the Pond banks belonging to the Moat Alto estate.

Nor do we lose sight of it again through the whole length of the route of the proposed extension to Wnyncsborough.

Two beds of magnetic ore also are to be seen in the gneiss of the mountain, both OH the Stevens and the Mont Alto estates, and limestone of better or worse fluxing properties is found along the whole distance, some of it containing from five to ten per cent, of iron. Boulders of it are also dug from the ore-banks.

Five miles east of the latter place, in a gorge of the mountain, whence flow the headwaters of the Antictam Creek, stands the Mont Alto furnace and works. They arc supplied with ore from diggings almost close at hand, and from others within half a mile on the slope of the Big Mountain, in immediate contact with the Potsdam sandstone. Though of a similar character, generally, to that described, the ore at these home diggings is not in so large lumps, and in consequence of its local position has more friable, less adhesive imbeddings, and is tolerably easily worked with the pick and shovel.

An analysis by Prof. Booth gave as follows:

Sesquicxide of iron,	75.00
Alumina,	1.00
Silica,	16.00
Water,	8.00

with a trace of lime remaining.

But as at Pine Grove, the denser and richer ore lies below the level of the present diggings, and at the Pond banks, belonging to this property, a mile to the west, off the slope, and in front of the Big Mountain, the ore is good within five feet of the surface, and where shafts have been sunk the ore was found to be harder and purer as the depth increased.

It was at the Pond banks of this property that in 1864 a mass of lignite was penetrated in sinking a shaft, and it is to a paper on the subject, read at one of the American Philosophical Society's meetings by Prof. Lesley, that I am indebted for the following description of them. Some time before I made my examination of the neighborhood, the workings had been discontinued, owing to water, and their distance from the furnace.

"The Pond banks and Caledonia banks, and the English diggings, are several openings of greater or less size in the upturned belt of slates surrounding the Little Mountain, which rises as an isolated ridge, one or two miles long, from the floor of the valley. The English diggings are behind it, the Caledonia bank before it, and the Pond banks at the south end, in the plain. The ore mass in the Caledonia bank dips towards the mountain, but must certainly rise again upon its flank. The English ore evidently dips away from the mountain. The shape of this vast excavation is that of a crescent with nearly vertical sides, and an irregular bottom. Its total length is about 300 yards, and its depth to the general floor is from 60 to 80 feet. The ore appears within 10 to 20 feet of the surface, at some points, and at others not for 30 or 40 feet down. Mountains of stripping stand beside it to the west; above where the body of the ore turns over a small anticlinal, and buries itself westward beneath undecomposed limestone. The depth of the ore is still unknown. Shafts from 60 to 110 feet have been sunk in it at the sides, and in the bottom of the present excavation. The top of the ore stratum, at the extreme north end of the quarry, is exactly on a level with the edge of the upper Pond bank, which is only 5 or 10 feet above the top of its own ore, into which the mining has descended 30 to 40 feet. The lower Pond bank is on a slightly higher level. The fact is, therefore, that all these three excavations, separated by only one or two hundred yards of interval from each other, and extending in a line about one thousand yards, are sunk in one deposit of ore, or, to speak more correctly, in the broad overlapping margin of the ore-bearing slate deposit, which sweeps round the south end of the Little Mountain in a nearly horizontal, and partly basin-shaped posture.

"In the bottom of these excavations, the ore is reported as uniformly well compacted. In the upper end (north end) of the Caledonia bank, at a depth of say 60 feet from the surface, I saw the top of a body of ore which was as solid as a mass of cellular, brown hematite ore could be. In other parts the ore is distributed through clay. The whole is being worked with pick and shovel."

Of the quantity of ore in this bank he says: " Taking the length and width of the three banks for a basis of calculation, and giving only 50 feet as the average depth of the ore, and deducting 50 per cent, for clay (which is very large), we have 850,000 cubic yards of ore in the ground, from which the extracted ore has been deducted," and "starting with this amount of ore in sight, and applying the calculation to that descending on the west, ascending again on the east, outspreading to the south, and filling the little valley behind the Little Mountain, we get many millions of tons in addition, and under precisely the same conditions."

Traversing the footlands and flats five miles southward between the mountain, and Qnincy from Mont Alto furnace to **Waynesborough,** we have evidences of a continuation of these beds, as rich, and in all probability as abundant as those spoken of by Prof. Lesley on the north. Unshapen masses of ore, weighing from ounces to hundred-weights, are to be seen on the surface, the former in many places covering it to the detriment of cultivation. The fences arc built of it, and every plough turns up a fresh supply—to the farmer a cause of great annoyance. There are places on the foot lands to be seen where ore one day has been gotten; but, as a rule, owners of properties have devoted their energies to the cultivation of the surface, to the almost total disregard of the mute but importuning evidences of the greater mineral wealth beneath.

Taking as a basis of calculation the ore gotten and exhibited at Pine Grove diggings, and corroborated by what we have just read of Prof. Lesley's report on Mont Alto ground, and we have 35 feet depth of ore face in work and 107 feet bored into and not bottomed, together 142 feet. If we say 50 per cent, of this is clay in which the ore is imbedded, but of which large percentage we have met with no example, we have 71 feet of ore, but that we may not exaggerate, reduce this to 60 feet.

As will be readily understood, the weight of the ore varies according to its quality. The specific gravity of a hand specimen we brought away is 3.821, giving 238 pounds per cubic foot; the ore got at the top of the excavation would not be so much. When in the heap it is found to weigh from 112 to 120 pounds per cubic foot. We shall not err, then, after the deductions just made, in calling it 120 pounds per foot when in the bed.

Now we have said the ore overlies the valley and slope of the mountain here, from a quarter to three-quarters of a mile wide, the average of which would be half a mile. Instead of which, and for no other reason than security against overestimation, call it 1000 feet, and we have 15,840,000 long tons per mile, or between Pine Grove opening and Grave Ridge, 55,440,000 tons.

But along the route traversed, we have 13 miles of ore ground, exclusive of that on the Hosack and Birch Runs, and the magnetic ores of Mont Alto and Caledonia, of neither of which are we in the possession of the facts necessary for computing quantities. Leaving these out of the question then, we have without them 209,920,000 tons.

That the value of these figures may be the more readily realized : there are three charcoal furnaces on this route, each producing say 60 tons of iron per week, which with good management they probably would, and it will take 100 such furnaces 330 years to exhaust the ore. Or by the light of things more modern, assume that 250,000 tons of **anthracite** iron arc being made per year, there would be wanted for all purposes 450,000 tons of coal, creating 700,000 tons of freightage. In addition let there be 500,000 tons of ore per year got and exported, and there is produced 4000 tons per day of mineral freightage over the Cumberland Valley and South Mountain Hail-roads for the working days of 205 years.

In making out these quantities, calling the length of ore ground thirteen miles, width 1000 feet, and depth 60 feet, we would not be understood to imply that a continuous trench of these dimensions could be dug, out of which ore might be gotten. The irregularity of dissolution, coupled with the unintelligible noaconformability of the uperopping limestone, will not permit it. Neither will every acre of land of every estate, on the line of assumed width, possess enough of ore to make a digging. At the same time, the overflow-ings, as it were—the outspreadings of ore from the more marked lines of its production, and the doublings, are all evidences favoring the probability that the quantities here arrived at are not overestimated.

All this, however, only deals with the ore as ore. Converted into metal, the neutral character of that at Pine Grove produces an iron of superior quality, commanding a ready sale, and out of which C. S. Pennook & Co., of Coatesville, Montgomery County, make their superior boiler-plate. Of the Mont Alto iron, Prof. Lesley says: " Tested at Washington with three other varieties of iron, it stood as follows:

Tredegar iron sustained	32,000 pounds.
Ullster iron sustained	32,000 pounds.
Glendon iron sustained	34,000 pounds.
Mont Alto iron sustained	34,000 pounds

The test bar being round, and its section equal to a square of three-quarters of an inch."

Within the past twelve months upwards of 600,000 tons of iron, pigs and rails, have been imported from England.

With the ore resources of this country, so vast and so accessible, the facilities for mining and digging it of the easiest character, and ironmaking one of the most profitable industries in which capital can be invested, one is left to wonder, after reading statistics on the subject, that with such home resources there should be such need of importation. Labor has something to do with it, but not all.

Between Carlisle and Waynesborough, on the route of which this paper treats, there are, if I mistake not, twenty-three miles of hematite ore of a good character, and comparatively easy to dig.

Pine Grove, with its one furnace, has made iron for more than a century, and with its 20,000 aeres of woodlands, and an inexhaustible supply, it has yet much to do. Aided by the use of anthracite and an extended and vigorous regimen, with its natural and local advantages, there is before it a largely productive and profitable future.

The average make of the furnace now in blast, taking nine months next preceding April last, was thirty-eight tons per week. Change of management, repairs, and an additional tuyere (it had but one) increased the produce to fifty-two and a half tons per week, and made the average cost of production, as exhibited in the last four months to November llth, $19.19 per ton, made out as follows:

Ore 2 9/20 tons, at $3.08 per ton,	$7 55
Charcoal, 120 bushels, at 7 cents,	8 40
Limestone, one-half ton,	50
Labor at furnace,	1 34
Preparing the ore,	99
Haulage,	29
Oil, &c.,	12
	$19 19

Here the ore is charged at the price sold for in the market, with 10 per cent, added for waste in calcining and screening. Take it at the cost of getting, namely $1.25 per ton, and credit the estate with a royalty of fifty cents per ton, the cost at the furnace for the four months given will have been §15.92 per ton.

But anthracite coal will, sooner or later, play an important part in the ironmaking of this region. Delivered at §5 a ton, and charging the ore with a royalty and the cost of getting as above, adding §1.25

for freightage, and the cost, delivered in Harrisburg, will be $16.27 per ton.

Mr. J. C. Fuller, the President of the South Mountain Iron Com- pany, attributes these favorable results to the regular treatment of the furnace in every particular, and to the manner of preparing the ore for the tunnel head. The lump ore, being from a third to one-half of that used, is calcined in open heaps, and broken into pieces of about three inches cube. The small ore is put through a double screen, the upper mesh of which is a quarter of an inch square, the lower mesh less. By this means much of the sand and dirt which would otherwise go to the furnace is separated and kept out. The wash ore, also, after leaving the washer, being left on the wharf to drain and dry, is then put through the same kind of screen.

The foregoing is only an example of what is done at one of the small establishments now on the route, and exhibits what might be done by others and larger ones, for which there is abundance of space. In the location of industry the district is a desirable one, is easy of access, has good roads, and large and suitable areas for the establishment of works and the settlement of operatives. It is well watered and drained, conditions, I need hardly say, conducive to health and enjoyment, and with the already established means of supplying its home wants, as may be found at Waynesborough and other places on the route, is a district in which labor will seek to dwell.

BLAST-FURNACE SLAGS.

BY KENNETH ROBERTSON, M.E.

THERE is probably less known of this subject than of any other connected with the metallurgy of iron. In all the books that treat of this matter, there are given analyses of slags, their chemical formulae, the loss of iron, etc.; but few, if any, give the character of the iron made at the time; none give analyses and physical characteristics of the ores and limestones used, and they present merely isolated exam- ples from various furnaces, and consequently one is more frequently puzzled than enlightened after reading them.

During two years I have had occasion to analyze the slags and many of the pig-irons from two furnaces, and for this article I have made analyses of all the different grades of pig made by them. A record of these analyses and the deductions drawn therefrom may prove interesting and add a small amount of information on a subject so important to iron men.

A blast furnace is a chemical apparatus, as much as any used in the laboratory ; the reactions which take place in it are entirely chemical and governed by chemical laws; the combustion of the fuel, the reduction of the ore, the formation of the slag and the carburation of the iron arc simply chemical reactions, which take place in accordance with known principles. The slag is a chemical compound ; it is the combination of an acid with various bases, and is as much a salt as the sulphate of alumina and potassa. Its formation is as strictly governed by the laws of chemistry as that of any chemical substance. The silica is the acid, and the lime, alumina, magnesia and the alkalies are the bases.

The ores of iron arc generally silicious; if, when an ore is put into a blast-furnace and smelted, no base is added, the silica, seeking a base and not finding one, will seize on the oxide of iron, combine with it and carry it off as slag. To prevent this, limestone, being a base, is added.

Now a certain quantity of silica requires a certain amount of lime to saturate it, another quantity of magnesia and another of alumina; all of which quantities will vary with their chemical equivalents. Having, then, analyses of all the material of the charge, the proportions of each may be so calculated as to produce a certain slag.

But with slags, as with other chemical compounds, there may be two atoms of base to one of acid, two of acid to one of base, or one of base to one of acid ; and according as this is the case they are called basic, acid or neutral slags.

The acid slags are the most fusible, the neutral next, and the basic the least so. It is obvious that the use of one or the other of these slags involves a question of economy of flux, of the quantity of material to be smelted, and consequently of a saving of fuel. I think it will be admitted, that the slag which is formed at the least expense and at the same time fulfils all the conditions as to fusibility and character of accompanying iron, is the best. To enable us to arrive at a conclusion on this subject, I give a table of analyses of slags from these furnaces.

The character of the iron is given also; those marked with a star have been analyzed and their analyses will be given with those of the other pig-irons.

SLAGS FROM FURNACE NO. I.

Furnace 45 feet high. Pressure of blast 3½ lbs.

No.	SiO_2	S.	Al_2O_3	FeO.	MnO.	CaO.	MgO.	Fe.
1, ...	44.87	0.58	9.14	3.42	0.99	28.87	14.13	2.67*a*
2, ...	45.29	. . .	. . .	2.09	. . .	. . . .	. . . .	1.68*a*
3, ...	39.48	0.73	8.85	3.01	1.94	29 81	13.31	2.34*a*
4, ...	36.59	0.48	8.22	2.12	2.04	39.68	9.25	1.65*a*
5, ...	40.17	0.39	6.59	3.06	3.47	36.10	8 60	2.38
6, ...	43.22	0.59	9.11	1.29	. . .	36.08	7.92	1.01*a*
7, ...	50.10	0.63	8.46	1.08	0.82	27.04	10.40	0.82*b*
8, ...	35.48	0.46	10.26	3.73	2.54	35.79	9.80*	2.90*a*
9, ...	40.51	. . .	11.59	2.16	. . .	36.68	. . . .	1.71*a*
10, ...	39.18	0.55	11.37	1.20	. . .	38.05	8 78	0.93*a*
11, ...	41.28	0.45	8.02	2.16	0.92	37.58	9.01	1.73*a*
12, ...	47.16	0.28	10.41	1.85	0.28	23.80	15.79	1.44*a*
13, ...	48 04	. . .	. . . .	1.25	. . .	. . . .	. . . .	1.05*a*
14, ...	45.98	0.12	10.17	1.85	. . .	25.15	15.99	1.44*a*
15, ...	47.99	. . .	. . . .	3.69	. . .	. . . .	. . . .	2.89*a*
16, ...	47.89	1.05	9.24	2.10	. . .	22.52	15.63	1.48*a*
17, ...	45.98	. . .	. . . .	2.96	. . .	. . . .	. . . .	2.30*c*
18, ...	45.40	. . .	. . . .	3.28	. . .	. . . .	. . . .	2.55*a*

SLAGS FROM FURNACE NO. II.

Furnace 60 feet high. Pressure of blast 6 lbs.

No.	SiO_2	S.	Al_2O_3	FeO.	MnO.	CaO.	MgO.	Fe.
1, ...	42.17	0.64	13.59	1.23	0.27	33 02	8.31	0.96*b*
2, ...	44.29	. . .	. . . .	. . .	. . .	. . . .	. . .	0.82*c*
3, ...	43.07	. . .	. . . .	. . .	. . .	. . . .	. . .	1.28*d*

The letter a denotes the furnace was making white iron ; *b*, gray forge; *c*, mottled, and *d*, gray.

The ores used regularly at the furnaces are magnetites; three of these slags are from a mixture of hematite with magnetite, and will be noticed in their proper places. The magnetic ores are from Morris County, N. J., and have the following characteristics :

The Beach Glen ore is schistose in structure, with much hornblende, mica, free silica, and averages 34 per cent, iron, and 30 to 33 per cent, silica, and is comparatively free from sulphur and phosphorus.

The Millen ore has a columnar structure; the silica exists in an uncombined state, and averages 20 to 22 per cent. It contains about 46 to 48 per cent, iron, and 2 to 3 per cent, phosphoric acid.

The Swede ore contains a great deal of hornblende, no free silica, but little phosphoric acid, and 40 to 45 per cent. iron.

The ores from the Orchard and Mount Pleasant mines are essentially the same in appearance and composition, having a gangue of silicates and free silica. They average 10 to 15 per cent, silica, and 58 to 62 per cent, iron, and do not contain an excessive amount of phosphoric acid.

The Hackettstown limestone is a dolomite containing 6 to 8 per cent, silica.

The calcitic limestone is from Andover, and contains 5 to 7 per cent, silica, about 2 per cent, alumina, and the rest carbonate of lime.

A stone from Montville, N. J., is used at times; it is a dolomite with serpentine as a gangue.

One of the first peculiarities we notice in the preceding table, is the utter disproportion between the iron and the silica. We find with a slag containing 50 per cent, silica, a loss of 0.82 per cent., and again with a slag of 35 per cent, silica, a loss of 2:90 per cent, of iron: this shows plainly that it is not for a want of base wherewith to saturate itself, that the silica has carried off iron. Those slags which contain the most iron have been invariably made from a mixture of ores, the greater part of which was an ore containing hornblende and other silicates of iron: in a furnace 45 feet high these do not have time to be reduced, but get into the hearth, are fused, and pass out into the slag. It will be noticed that in the higher furnace the loss of iron is not so great; the same ores are used, but the furnace being higher, the silicates are reduced before reaching the hearth.

The slag which contains 50 per cent, silica and 0.82 per cent, iron was made from iron ore containing between 40 and 50 per cent, silica, entirely in the state of free silica; but there being more than a sufficient quantity of base in the slag to saturate the silica, and it (the silica) being in an uncombined state, saturated itself with lime and other bases, and left the oxide of iron to be reduced,

So we see by these analyses that, between the limits of 50 and 35 per cent, of silica the amount of iron lost is not due to the amount of silica, but rather to the state in which the silica exists in the ore.

This accounts for the loss in part, but it will be seen that the greater losses occur in the smaller furnace, where the pressure of blast was 3 1/2 pounds, the " stock" in larger pieces than in No. 2 furnace, and the furnace working rapidly and making white iron. It would thus seem to be necessary to submit to a loss of iron in the slag in order to make white pig.

We see also that white iron was made with slags containing as high as 48 per cent, silica with 3 1/2 pounds pressure of blast, and that gray forge was made with a slag containing 42 per cent, silica and 6 pounds pressure of blast. A slag from gray forge iron at Hokendauqua gave 42 per cent, silica, and one from Glendon gave 38 per cent, silica.

Two slags in the preceding table (No. 3 and 4) show severally 39 and 36 per cent, silica and still the iron was white; this can be readily accounted for when we know that the charge, in one case, consisted of 1/2 Staten Island hematite and in the other instance 1/3 the same ore; which ore contained 1.25 per cent, sesquioxide of chromium, the chromium from which went into the iron, making it white and hard. Otherwise, with as basic slags as these were, we would have had every reason to expect a different iron.

We may then safely say that with a slag containing above 42 per cent, silica and a low pressure of blast we will have a white iron, and that with a slag containing less than 42 per cent, we can expect a gray forge or foundry iron, according as the slag is more or less silicious within the limit.

It may be asked whether it is not possible to make a gray forge-pig with a slag containing more silica than those quoted. It is a question which can only be answered by experiment; but I think it is likely that the furnace working "hot," and with as great a pressure as 6 pounds, there would be a strong probability of the silica being reduced, and the silicon passing into the pig, making it unfit for mill purposes. The following determinations of silicon in pig-iron will serve to confirm my impressions.

I. Si. 0.78 per cent, made with a charge of 7 cwt. ore to 3 1/2 cwt. stone.

II. Si. 2.10 per cent, made with a charge of 7 cwt. ore to 2 1/2 cwt. stone.

III. Si. 0.95 per cent, made with a charge of 7 cwt. ore to 3 1/2 cwt. stone.

The mixture of ores being nearly the same in each case, it will be seen that No. II, containing 2.10 per cent, silicon, was made with a slag more highly silicious than the others, and also that if we make the charge too silicious in working for a gray, we are apt to introduce silicon into the pig, the condition of the furnace being favorable for the reduction of the silicic acid; thus, in making gray forge-iron, we must necessarily have the slag sufficiently basic to prevent this, which involves, of course, an increase of lime in the charge, and consequently, increased cost of the iron. In this, if nothing else, the production of gray iron for rolling mills is attended with greater expense than that of white iron; but when lime is added the amount of material to be melted is increased also, and at the same time the fusibility of the slag is diminished, which evidently causes a greater consumption of coal.

White pig is made with a slag ranging from 40 to 48 per cent- silica, and with a low pressure of blast; this iron contains about 0.40 per cent, silicon. The smallness of this amount can be accounted for by reason of the furnace working rapidly, the blast being at a low pressure, and the charge not being sufficiently long in the furnace to cause the reduction of the silicic acid.

If a good white iron was made with a slag of 48 per cent, silica, it follows that the pig, made from one containing 40 per cent, silica, was made with too groat an expenditure of limestone. The method of charging the furnace without any reference to the slag to be produced, is fully illustrated by the following record of charges and analyses:

NO. I,

Charge,...........6 ewt. ½ qr. Ore
" ....3 " 0 " Limestone

Slage.	Percent.
SiO_2	= 41.28
S	= 0.45
Al_2O_3	= 8.02
FeO	= 2.16
CaO	= 37.58
MgO	= 9.01

NO. II,

Charge...7 ewt. 0 qr. Ore.
" ....2 " 3 " Limestone

Slag	Percent.
SiO_2	= 47.16
S	= 0.28
Al_2O_3	= 10.41
FeO	= 1.85
CaO	= 23.30
MgO	= 15.30
MnO	= 0.28

The same ores were used in each case, but with No. 2 slag they were far more silicious than with No. 1, and yet there was a larger proportion of ore and a smaller quantity of limestone used in the second case than in the first, and the limestones used were also poorer than with the slag of 41 per cent, silica.

Now a white iron was made in each case, and as no complaint was made by the mill manager, it is fair to suppose that there was no fault to be found with either one. Consequently it is evident that the iron with the first slag was not made as economically as that with the second.

Unfortunately no analysis of either iron was made, so nothing definite can be known as to their character; but at all events the only important constituent to have been determined would have been the silicon, and as there was no complaint made, it is fair to believe that no injurious amount was present in either iron. In fact, we have never had a complaint on this account from the mill, except in two instances. Once with the gray pig made from the Haekettstown hematite, which contained by analysis 2.99 per cent, silicon, and the second time from pig bought from the Reigelsville furnaces, which contained 3.48 per cent, silicon, wasted in the puddling furnaces, and made a rotten bar, containing 0.43 per cent, silicon. I think, then, that it will be fair to infer that a white iron, made with a slag containing 47 per cent, silica and with 3 1/2 pounds pressure of blast, did not contain any injurious amount of silicon. As for the phosphorus and sulphur in the pig, the amount of silica in the slag would not influence the quantity of those elements present, since the full amount of phosphorus in the ore is bound to go to the pig, and but little sulphur is carried off by the slag.

We may then say with safety that a good white iron can be made with a slag containing 47 per cent, silica: this is as much as practice shows us ; but the question arises, whether or not as good a while pig could not be made with a slag containing more silica. All of the slags given have more than enough base to saturate the silica, and with few exceptions are about bibasic silicates; that is, there are about two atoms of base to one of acid. Those slags which contain about 47 per cent, silica arc sesquibasic slags, *i. c.,* three of base to two of silica; those containing about 39 per cent, are bibasic; and those with more than 47 per cent, silica more nearly approach the formula of a neutral slag, which has one of base to one of acid. It is evident, from the preceding statement, that it would require less limestone to make a neutral slag than either of the others. Besides this, as the quantity of limestone is decreased the amount of foreign matter to be melted is diminished, and the fusibility of the slag increased. Experiments, alone, can show the effect produced on the quality of the iron, by working for a white iron with the formation of a neutral slag and a low pressure of blast. The probabilities are, however, that with a slag of that fusibility, the furnace working rapidly, and blast at a low pressure, there would be no time for the reduction of silica. The loss of iron in this case would probably be greater than when the furnace worked more slowly ; that is, there would be a greater percentage in the slag ; but a furnace working on a neutral slag would make 1780 pounds slag to the ton of iron, and would require 0.22 tons limestone to do it; running on a sesquibasie slag it would produce 2234 pounds slag to the ton of iron, and take 0.66 tons limestone for the ton of pig. Now allowing the greatest waste of iron in any of these analyses for a neutral slag, viz., 2.90 per cent, iron, we would have 52 pounds iron lost with a neutral slag, to the ton of iron ; and allowing 1.50 per cent, iron lost with a sesquibasic slag, we would have an actual loss of 34 pounds iron to the ton of pig. It will be seen at a glance that the losses of iron and the quantity of limestone are not in proportion, so without taking into consideration the possible saving of fuel, the economy of the neutral slag is apparent; but, should the quantity of coal for each slag be in proportion to the number of pounds of slag made, the saving would be much greater. The only question undecided is, the effect upon the quality of the iron, but this will never be settled, until some iron-master shall be found who will be willing to make the necessary experiments, and not be guided entirely by traditions. The risk to a furnace would be nothing, the slag would be too fusible to engorge the furnace, and the hearth would remain intact, since it is basic slags which corrode the furnace-lining. The charge might be changed gradually until the proper slag should be reached, and meantime the slag and iron could be analyzed from day to day; should the iron deteriorate, it would then be time enough to change the charge. At all events, it would involve the risk of making thirty or forty tons of pig which *might* be inferior, but when we consider the economy which might result from it, this is but a slight risk to incur for the prospect of such a gain.

We must also consider the yield of the furnace in deciding as to the economy of making white pig. The forty-five foot furnace averaged 198 tons pig per week, making white iron; the sixty foot furnace averaged 199 tons per week, making gray forge-iron. This is not in proportion to the size of the furnaces; as the larger one cost more than the smaller one, there will be, of course, a larger sum to be charged to the ton of product as interest on capital invested. If anything, there are more men around the large furnace, and as they are paid by the day and not by the ton, there will be a larger sum to be charged for labor.

To resume, we find that in working for a gray forge-iron, we use a greater quantity of coal and limestone, the furnace works slower, and does not produce as much iron, and what is produced contains a greater amount of silicon than white iron; and the following analysis will show that they contain more carbon and less iron than white pig.

PIG-IRONS FROM FURNACE NO. I.

No.	Character.	No. of Slag.	Si.	S.	P.	Fe.	Mn.	C.
1,...........	White.	. . .	1.32	0.43	0 96	94.50	….	…
2,...........	Mottled.	.. .	1.53	0.21	0.82	95.48	….	…
3,...........	White.	. . .	0.42	0.09	….	95.92	….	…
4,...........	White.	10	0.44	0.19	0.75	96.18	….	2.63
5,...........	Gray.	7	2.99	0.02	0.42	93.19	….	…
6,...........	Mottled.	17	1.34	….	….	….	….	…
7	White.	18	0.56	0.41	1.36	95.65	….	…

Ores Used.—For Nos. 1 and 2 one-third each of Milieu, Orchard, and Mount Pleasant; No.4, one-third each of Swede, Orchard, and Mount Pleasant; No. 5, one-half Hackettstown hematite; No. 6, one-third each of Mount Pleasant and Milieu, and one-sixth each of Swede and Beach Glen; No. 7, one-quarter each of Orchard and Mount Pleasant, and one-sixth each of Swede, Beach Glen, and puddled cinder.

PIG-IRONS FROM FURNACE NO II.

No.	Character.	No. of Slag.	Si.	S.	P.	Fe.	Mn.	C.
1,...........	Gray.	….	2.10	none.	0.59	94.44	….	…
2,...........	Gray.	….	0.99	0.08	0.61	94.65	….	…
3,...........	Mottled	….	1.59	trace.	0.52	94.65	….	…
4,...........	Mottled.	2	1.57	….	….	….	….	…
5,...........	Gray Forge.	3	2.50	….	….	….	….	…
6,...........	Gray.	1	1.85	0.06	0.87	94.50	….	…

Ores Used.—For No, 1, one-sixth each of Swede, Crane, and Beach Glen, and one-quarter each of Orchard and Mount Pleasant; No. 2, one-third each of Mount Pleasant and Orchard, and one-sixth each of Beach Glen and Swede; No. 3, one-quarter each of Orchard and Mount Pleasant, one-third of Beach Glen, and one- sixth Swede; No. 4, one-quarter each of Mount Pleasant and Or- chard, one-third Milieu, and one-sixth Beach Glen; No. 5, one-quarter each of Orchard and Mount Pleasant, one-sixth each of Swede, Milien, and Beach Glen; No. 6, one-third each of Swede, Orchard, and Mount Pleasant.

VARIOUS PIG-IRONS.

Where from.	Character.	Si.	S.	P.	Fe.	Mn.	C.
Reigelsville,………	Gray.	3.48	0 37	0.22	93.88	….	2.45
Andover,…………	White.	0.29	0.34	0.86	96.39	….	2.32
Columbia…………	Gray.	0.78	none.	1.03	94.80	0.27	….
Columbia,	White.	0.24	0.08	1.53	95.71	0.21	….
Glendon,	Gray Forge.	1.00	0.09	0.70	94.10	0.25	3.74

It having been established, then, that white iron is made cheaper, contains less silicon and more iron, the question arises, why is gray iron made for mill purposes?

Since puddling is a process of purification, it would seem that the pig which contains fewest impurities would answer best for the pur- pose. It is universally conceded that a white iron is easier worked and more adapted for forge purposes than gray iron, by reason of the difference of state in which the carbon exists. In spite of this there seems to be a great prejudice in favor of gray forge-iron. For instance, I have seen a gray iron containing 0.61 per cent, phospho-rus piled up for market, while a mottled iron containing but 0.52 per cent, hosphorus (Nos. 2 and 3 from Furnace No. 2), was car-ried to the mill, because, from a sual inspection, the gray forge appeared the best of the two, when in reality it was not. Because a pig docs not break easily, it docs not follow, that it is better than one which does, when one is gray and the other white. No matter how pure a white iron might be, it would break with much more case than a gray iron, on account of its physical structure. And it does not ollow that when an iron is white and breaks readily, that when puddled it will not make as trong a bar as that from gray forge. The tests and standards for a foundry iron seem to be p-plied to a forge-iron, which is manifestly unjust. For a foundry pig the structure is almost everything, since upon it more than upon its chemical composition (within certain limits) its strength depends. But for puddling, where the. entire structure of the iron is changed, and its original form cannot affect the strength of the bar, such struc-ture is unnecessary, and consequently when time, labor, fuel, and limestone are expended in making a gray forge-iron, it seems to be simply a waste of material. There is no reason why, if a gray forge and a white iron, each containing the same amount of injurious matter, are puddled, the white shall not make equally as good a bar as the gray iron; on the contrary, the probabilities are that the white iron would make the best bar of the two, for its conditions of melting are such that there would be much greater chance for the elimination of the substances. Some one may urge the objection to this, that in the analyses of pig-iron the white irons contain more phosphorus than the gray. To this I would answer that they were made with different ores. Unfortunately I have no record of analyses of gray and white pig made from the same mixture of ores. It seems to me sufficiently evident, nevertheless, that if the same ores are used, and in one case a white and in another a gray pig is made, that there will be the same amount of phosphorus in each; or, if there is a difference, it will be in proportion to the carbon absorbed.

The difference between the percentages of iron in white and gray pig ought to make a difference in their value when used in a mill. To illustrate it, take an average of the percentage of iron in gray and white pig, and we have for the gray 94.18 per cent., and for the white 95.55 per cent., which is the same as a gain of 1.37 tons me- tallic iron in buying one hundred (100) tons of white instead of gray forge-iron. In puddling this is not wasted, of course, and so, for a mill using 300 tons per week, there would be a gain of 4.1 tons iron per week, which is 200 tons in the year; and with iron at $30 per ton, amounts to $6000 worth of iron in a year.

From what we have seen, it is evident that it is much more economical to make a white than a gray pig-iron for mill purposes. Iron for foundry use must have a certain structure, which must be attained, no matter at what expense. It is known that iron for foundries cannot be made from magnetic ore alone; the shrinkage of the iron (for an unexplained reason) in the moulds being too great. It is then useless for a furnace, where magnetic ores are used alone, to attempt, to make a foundry-iron. So then we have only to consider the slag for a white iron, which, we decided, might be at least a sesquibasic silicate, and possibly a protobasic or neutral silicate. I shall give in full the method for calculating the former and merely indicate the latter.

Method for Calculating a Slag.—In order to compute the requisite quantity of base to saturate the excess of silica, it will be necessary to have complete analyses of the average ores and limestones ; suppose that we have three ores of the following composition :

		No. 1.	No. 2.	No. 3.
SiO_2	=	21.96	18.61	21.33
S	=	0.14	trace	0.18
PO_5	=	0.19	0.29	3.07
Al_2O_3	=	2.92	3.96	4.00
Fe_3O_4	=	64.06	80.07	65.95
Mn_3O_4	=	0.41	trace	0.25
CaO	=	4.37	1.30	3.71
MgO	=	6.57	0.67	0.62
		100.62	99.90	99.11
Iron	=	46.39	57.98	47.76

Now we decide to use one-third of each of these ores in the charge; one ton of charge so proportioned would contain:

$Si0_2$	=	18.97	per cent.
$A1_20_3$	=	3.29	"
CaO	=	3.13	"
MgO	=	2.02	"
S	=	0.11	"
PO_5	=	1.18	"
Fo_3O4	=	70.03,	"
Mn_30_4	=	0.22	"
		99.55	
Iron	=	50.70	per cent.

It was decided to calculate a sesquibasic slag, that is, a slag containing three of base to two of acid.

Alumina, to form a neutral salt, requires three atoms of acid, so for a sesquibasic salt it would take three equivalents of alumina to six of silica, and the formula would be $3A1_3O_3$, 6SiO2, or what is the same thing, $A12O_3$, $2SiO_2$. So to determine how much silica the alumina in the ore takes, we have the following proportion :

1 equivalent $A1_20_3$: 2 eq. $Si0_2$:; per cent. Al_2O_2 : X
51.5 : 60 : : 3.29 per cent.: X = 3.83 SiO_2

so 3.29 per cent, Al_2O_3 takes up 3.83 per cent. SiO_2.

For the lime we have:

3 eq. CaO : 2 eq. $Si0_2$ :: per cent. CaO : per cent. SiO_2
84 : 60:: 3.13 percent.: X =2.24 per cent. SiO_2^o

so 3.13 per cent, CaO take 2.24 per cent. SiO_2^o

For the magnesia we have :

3 eq. MgO : 2 eq. $Si0_2$: : per cent. MgO: X
60 : 60 :: 2.62 per cent. : X = 2.62 per cent. SiO_2

the 2.62 per cent. MgO take 2.62 per cent. SiO_2^o

Hence we find that:

2.29	per cent.	Al_2O_3	saturates	3.83	per cent.	$Si0_2$
3.13	"	CaO	"	2.24	"	"
2.62	"	MgO	"	2.62	"	"

Silica in ore saturated by bases in ore = 8.69 per cent. $Si0_2$

which leaves 10.28 per cent. SiO_2 to be fluxed by the addition of limestone; this is equivalent to 230.27 lbs. of silica in the ore. The ash of the coal must be taken into consideration. If we make an allowance of 0.8 tons coal to each ton of ore, it will be ample. We assume the ash to be 7 per cent, having the following composition:

SiO_2	=	4.50	per cent.
$A1_2O_3$	=	1.50	"
CaO	=	1.00	"
		7.00	

By the same method as the preceding, we find that:

1.50 per cent.	$A1_2O_3$	take	1.75	SiO_2
1.00 "	CaO	"	0.71	"
Silica in coal saturated by bases in coal		=	2.46	per cent.

which leaves 2.04 per cent. SiO_2 unsaturated in coal or 45.70 lbs. SiO_2 in one ton of coal; but we use only 0.8 tons coal to one ton of ore, so we have for one ton ore:

Free silica in 1 ton ore,	230.27 lbs.
" " 0.8 tons coal.	30.50 "
Free $Si0_2$ with 1 ton ore,	266.83 lbs.

which must be saturated by the bases in a limestone.

Suppose we have a dolomite of the following composition:

SiO_2	=	6.04	per cent.
$A1_2O_3$	=	1.14	"
CaO	=	29.97	"
MgO	=	19.05	"
CO,	=	44.15	"
		100.35	"

By the same method of calculation, always keeping in view the formula of a sesquibasic silicate, we have :

1.14 per cent. $A1_2O_3$ take 1.33 per cent. SiO_2

leaving 4.71 per cent. SiO_2 to be saturated. This will take exactly 4.71 per cent. MgO to do it, so the limestone, after all silica is saturated, is represented by:

CaO	=	29.97	per cent.
MgO	=	14.34	"

One of lime in forming a sesquibasic silicate takes up 0.71 silica and one of magnesia takes up 1 silica; consequently 1.4 lime equals 1 magnesia; but there are 14.34 per cent. MgO, which are equal to 20.08 per cent. CaO. The entire dolomite is then equivalent to

14.34 MgO =	20.08	per cent. CaO
	29.97	" CaO.
	50.05	per cent. CaO

which is equivalent to 1121.12 lbs. free lime in a ton of stone.

There were 266.83 lbs. SiO_2 to be neutralized by addition of lime, then—

$$2 \text{ eq. } SiO_2 : 3 \text{ eq. } CaO :: 266.83 : \text{lbs. } CaO$$
$$60 : 84 :: 266.83 : X = 373.56 \text{ lbs.}$$

It will then take 373.56 lbs. lime to saturate the silica from one ton of ore and 0.8 tons of coal. There were 1121.12 pounds free lime in one ton limestone; so it will take 0.33 tons limestone to one of ore to make a sesquibasic silicate. The ore contained 50.70 per cent, iron, which we may call 50 per cent., so we then will use 0.66 tons limestone to 1 ton of pig made. This would give a slag of the following composition :

SESQUIBASIC SLAG.

		Coal and Ore. lbs.				Stone. lbs.		Total. lbs.	Per cent.
SiO_2	=	501.50	+	44.64	=	549.20	=	47.05	
Al_2O_3	=	100.58	+	8.43	=	109.01	=	9.34	
CaO	=	88.03	+	221.54	=	309.57	=	20.51	
MgO	=	58.69	+	140.82	=	199.51	=	17.10	
						1167.29		100.00	

Formula.—$(R2O_3,2SiO_2) + (10RO,7Si0_2)$

which is as nearly a sesquibasic silicate as can be calculated, using but two places of decimals; the correct formula would be $(R_2O_3, 2SiO_2) + (9RO,6SiO_2)$.

With this limestone and mixture of ores we would use 0.33 tons limestone to 1 ton ore (0.66 tons stone to 1 ton pig), and have 1167.29 lbs. slag with 1 ton ore, or 2334.58 lbs. to 1 ton pig for a sesquibasic slag.

Using the same ores and limestone, and allowing one equivalent of base to one of acid, so as to get a neutral slag, we have 0.11 tons limestone to the ton of ore, or 0.22 tons stone to 1 ton pig. The slag formed will have the following composition :

NEUTRAL SLAG.

		Pounds.		Per cent.
SiO_2	=	519.44	=	58.34
Al_2O_2	=	103.39	=	11.61
CaO	=	161.88	=	18.18
MgO	=	105.63	=	11.87
		890.34		100.00

*Formula.*_$R_2O_33SiO_2 + 5(RO,Si0_2)$.

This is equivalent to 1780.68 lbs. slag, and 0.22 tons limestone to 1 ton pig.

By the same method of calculation, we find that by giving two of base to one of acid, we have a bibasic slag of the following composition :

BIBASIC SLAG.

	Pounds.	Per cent.
SiO_2 =	584.04 =	39.38
$A1_20_3$ =	115.39 =	7.78
CnO =	477.40 =	32.19
MgO =	306.19 =	20.65
	1483.02	100.00

Formula.—$(2R_2O_3,3SiO_2) + 15(2EO,SiO2)$

RÉSUMÉ.

Neutral Slag.—1780.68 lbs. slag and 0.22 tons limestone to 1 ton pig.
Sesquibasic Slag.—2334.58 lbs. slug and 0.66 tons limestone to 1 ton pig..
Bibasic Slag.—2966.04 lbs. slag and 1.16 tons limestone to 1 ton pig.

The economy of using one or the other of these slags is evident at a glance; the only question open being the advisability of having as highly a silicious slag as the neutral one, but this can only be proved by direct experiment. The chances are that it would answer in a small furnace where the ore would not be so long; in contact with the coal, and the chance of reduction of silica be diminished, provided the furnace worked rapidly, with a large volume and low pressure of blast.

Although it may be extraordinary, in this country, for a slag to contain 58 per cent. silica, yet in Percy's Metallurgy of Iron and Steel, page 502, we find analyses of slags from coke furnaces containing 53 per cent. silica, and those from charcoal furnaces with as high as 70 per cent. silica. The slags from furnaces using charcoal as a fuel must be more fusible than using coke or anthracite, and consequently they are more silicious. Because anthracite is a better fuel than charcoal, is that a sufficient reason for giving it more work to do ?

The saving to be made in limestone, fuel, and labor, is sufficient, I think, to warrant an effort being made to determine whether or not it is practicable. As far as economy of material, it is certain there would be no injury to a furnace, and the only question is the quantity of silicon which would enter the pig. But with proper precautions this could not effect much damage, for the charge could be changed by degrees, and the slag and iron watched from day to day.

Till within a few years, it was considered disadvantageous to use a dolomitic limestone as a flux, and even now among many furnace managers it is considered inferior to those containing only carbonate of lime. From what this prejudice originated, I am at a loss to say; probably, in some cases, from the idea that the magnesia in it rendered the slag infusible; but in others that I know of, from the belief that the lime alone played any part in the fluxing of the silica; and so the stone was judged from the amount of lime it contained, which, of course, is less than in a calcitic stone. It is known that substances which by themselves arc infusible or difficultly so, often, by the addition of other substances, become more fusible. For instance, the alloys of some of the metals, *ex. gr.*, Bismuth melts at 270° C.; lead at 322° C.; and tin at 228° C.; but an alloy (D'Arcet's) of bismuth 8, lead 5, tin 3 parts by weight, melts at 96° C; and what is more, this combination corresponds to the chemical formula Bi_3,Pb_2,Sn, which is an argument for having a slag of an exact chemical composition.

So, although a silicate of lime is more fusible than a silicate of magnesia, yet a mixture of the two is more easily melted than either of them alone. Then the objection of want of fusibility is disposed of. Iron-masters appear irrational and inconsequent on the subject. How many of them are glad to get an argillaceous ore to mix with their silicious ores, and yet what is more infusible, *per se,* than a silicate of alumina? But when there is a compound formed containing silicates of alumina, lime, and magnesia, it is far more fusible than either of them alone. The other cause of difference in the general valuation of the stone, viz., the idea that the magnesia does not carry off any silica, is one which is hardly worth noticing, further than to make the following statement:

1 lb. Al_2O_3 takes ....1.74 lbs. SiO_2.
1 lb. CaO " ....1.07 lbs. "
1 lb. MgO "...........................1.50 lbs. "

The above is for a neutral slag, the relative proportions of silica saturated will be kept in any other slag, from which can be seen the comparative saturating power of these bases for silica. Having the analyses of two limestones, their relative value can be determined.

NO. I.		NO. II.	
SiO_2 =	6.04	SiO_2 =	7.55
Al_2O_3 =	1.14	Al_2O_3 =	2.33
CaO =	29.97	CaO =	48.19
MgO =	19.05	MgO =	1.46
CO_2 =	44.15	CO_2 =	39.47
	100.30	HO =	1.00
			100.00

For No. I we find that 1.14 $A1_2O_3$ take 1.99 SiO_2, which leaves 4.05 per cent. SiO_2 free. The MgO equals 26.67 CaO, since 1 MgO equals 1.4 CaO; consequently the stone is equivalent to 56.64 per cent. CaO with 4.05 free SiO_2 in it. This 4.05 per cent. SiO_2 takes 3.78 per cent. CaO, so there are 52.86 per cent, free CaO in No. I.

For No. II we find that 2.33 per cent. Al_2O_3 take 4.07 per cent. SiO_2. This 4.07 per cent. SiO_2 require 3.79 per cent. CaO. There is 1.46 per cent. MgO, which is equivalent to 2.04 per cent. CaO. The stone is then the same as:

CaO	=	48.19
CaO	=	2.04
CaO	=	50.23
CaO	=	3.79 taken by silica.
		46.44 per cent. CaO.

which is the value of the limestone.

No. I contains 52.86 per cent, free CaO.

No. II " 46.44 " "

Since limestone is used for a flux, that stone which contains the greatest proportion of fluxing material would be the best, and when two stones contain unequal amounts, their value ought to be in direct proportion with their percentages of base. Some furnace managers deny this, but when this statement is accompanied by the declaration that a dolomite with serpentine as a gangue (which serpentine is charged into the furnace with the stone) answers as well as either a good dolomite or calcite, the statement is so irrational that we are compelled to doubt their ability to decide, and accept their dictum for what it is worth.

The economy with which pig-iron can be made depends, in a great measure, upon the material consumed in making it. This can only be regulated by continual watching of the ores and limestones, and apportioning each with a view of producing a certain result, both in iron and slag. The ore is almost certain to vary, and although it may require a certain proportion of limestone one month, it does not follow that the same will answer for the next month. The irrationality with which charges are frequently made is shown by the two examples given previously. This same waste is likely to occur at any furnace where a close watch is not kept on all material and some degree of reason exercised in regulating the proportion of ore and limestone. This cannot be done until American iron-masters consent to follow the example of their European brothers, and call in the aid of those sciences which relate to their industry; until which time, it will be a question open to dispute, whether it is the cost of labor alone, which forces the manufacturers of America to have a high tariff in order to enable their products to compete with those of Europe.

N. B.—-The calculations of slags have been made upon the assertion of Fresenius that the formula of silicic acid is SiO_2, and the equivalent of silicon 14,0.

PHILADELPHIA MEETING,

FEBRUARY, 1872.

THE MANUFACTURE OF IRON AND STEEL RAILS.

BY JOHN B. PEARSE,
Superintendent of Pennsylvania Steel Works.

IN order to get an idea as to the strength of steel rails, it will be well to review the tests to which iron rails have been subjected. In England, Mr. Ashcroft found that the best 80 pound rails broke under a 300 pound weight, falling 15 feet. In Germany the Society of Railway Managers determined on and have long applied a test of 1000 pounds falling 10 1/2 feet, as the standard which all first-class iron rails must reach. In this country no inspection nor test is applied, but tests made show that iron rails from our most reliable makers, break under a 6 foot fall of a 1500 pound drop as an extreme test, most of those tested breaking under a far less test; some breaking with less than a 3 foot fall of the same weight.

Everywhere where steel has been used, engineers have come to the conclusion that some test is required to show the regularity and strength of the product. As compared with iron, the tests which steel will stand are wonderful. After numerous experiments partially based on the experience of the rail-mill at Graz, belonging to the Southern Railway of Austria, the Society of German Railway Managers fixed upon a test of 2000 pounds falling 13 1/2 feet. They found that this test represented the steel which suited their necessities, and also found that with steel of otherwise average purity, this test represented about one-half per cent. of carbon, and made it a rule to take no steel containing under three-tenths of a per cent. of carbon, because it was too soft. They expressed a hope that a harder steel could soon be made tough enough to stand the same test. In England, a test was adopted of 2240 pounds, falling 15 to 17 feet on the rail on heavy bearings. This test has been found satisfactory under heavy traffic on average road-beds, and has been invariably retained by English makers, and adopted by American makers. It is an expeditious practical way of ascertaining the qualities of the rail. Experiment in Germany and experience in England pointed out the test corresponding to the proper grade of steel, and the test adopted has been considered the most practical one. The jar from a moderate weight (2240 pounds), falling from a great height, is more sudden than that imparted by a heavy weight falling a small distance, and better adapted to exhibit the toughness of the rail. This latter is the object had in view in all tests, as it would take far too long a time to determine the quality of rails by a treatment approximately similar to that received in the track. An objection of some force has been urged against the English method of obtaining test pieces. They take one rail from each day's rolling, to indicate the quality of the rest. In this way their test becomes a matter of chance, and nothing they have yet done removed this character. Our American practice has been to test every charge, thereby insuring beyond doubt the quality of the rails.

After a short experience with steel mils it was found that their homogeneity is their distinguishing characteristic ; but they unite entire homogeneity with considerable hardness as compared with iron. There are no layers to peel off, no welds to open out, the ends of the rails do not broom out as iron rails do, and the head wears uniformly along its whole length. Not only is the single rail entirely homogeneous, but all the rails made from a single charge have exactly the same qualities. Many experiments on the steel at Seraing, in Belgium, in Austria, and in this country, before and after its conversion into rails, show this to be a fact.

But the hardness is a most important point as regards wear. Some first-rate English rails have been found too soft for roads with heavy traffic. Therefore, a rail is wanted which will be hard enough to stand abrasion and wear, but strong enough to stand all the strains to which it is liable. The railroad engineer's idea of hardness is that quality which imparts durability without brittleness. Hardness is sometimes erroneously associated with brittleness because some hard bodies are brittle, but in steel brittleness arises from causes entirely different from those which produce hardness. The steelmaker's idea of hardness is a composite one—one that results from considering the effects of physical structure or grain of the steel, and the effects of carbon, phosphorus, and manganese. The effects produced by the presence of these elements far exceed any brought about by change of physical structure. Phosphorus and manganese occasion brittleness, while carbon in excess is seldom present, as the processes through which the rail passes have a constant tendency to reduce it. The state in which carbon is present in the rail is, however, remarkably influenced by mechanical treatment and the resulting physical structure. Those modes of reduction which work quickly and forcibly exert a strong influence to retain the carbon in a combined state, while the slower methods, on the contrary, permit some of the carbon to separate as graphite. These facts have been observed by Gruner and Caron, and have been corroborated in Austrian practice, as the following analyses of steel will show:

(a) Steel made for heads of steel rails at Graz, and rolled into shape without hammering:

Combined carbon,	0.38
Graphite,	O.C5
Silicium,	0.05
Manganese,	0.07
Sulphur,	0.05
Copper,	0.08
Iron,	98.57
	99.85

(6) Steel made at Neuberg and hammered into shape:

Combined carbon,	0.234
Graphite,	none
Silicium,	0.033
Phosphorus,	0.044
Sulphur,	traces
Manganese,	0.139
Copper,	0.105
Iron,	99.445
	100.

Both these steels were soft Bessemer steel, and from observation I made at the two works on the respective quality of their metal, I see no reason to doubt their correctness. A remarkable point in the matter is that the iron at Neuberg was much more graphitic than that used at Graz. At Neuberg they tapped direct from the blast furnace, and their "blows" averaged about thirty minutes, some running up to fifty minutes. At Graz they remelted their iron in an air furnace, and their " blows " were much shorter. The iron each works used was then of substantially the same character, made by charcoal from spathic ore. Neuberg made its own iron, while Graz bought its iron largely *from* Mariazell and Eisenerz, furnaces not far from Neuberg.

Now, at the Pennsylvania Steel-Works, we have a quite graphitic mixture for conversion, but we find scarcely any graphite at all in the rails—in fact none. Out of many tests we have only one, an apparently abnormal one, in which the graphite amounted to 0.08 per cent., it being generally present in too small quantities to be estimated.

Speaking within the limits of steel manufacture, it is safe to say that brittleness has nothing to do with the mechanical treatment, yet by this treatment the state of the carbon may be controlled and the specific gravity and consequent density of the steel increased. Rails arc brittle when too cold-short from the presence of phosphorus and manganese. The proper proportion of the former forms the most delicate point in steel-making, and must always be kept within safe limits. No good steel rail has ever yet been made with more than one-fifth of one. per cent. of phosphorus, and half that is considered too much by Bessemer. In regard to manganese, our experience is not yet fully ripe. Its action, however, is far less dangerous than that of phosphorus, and in small quantities is beneficial.

We have thus a definite idea of the important qualities of steel rails and the proper tests to show their uniformity. The tests made on the steel preclude possibility of brittle steel being used, and it is evident that those methods of reduction which unite the greatest hardness with the necessary strength are to be preferred. In general terms, a steel rail is wanted to last a lifetime, and to be strong enough to stand all accidents of wear.

Railmaking begins with the Bessemer ingot. This is a block of highly crystalline metal, the tensile strength of which is low, and which contains some blow-holes or bubbles formed by the carbonic oxide retained by the liquid steel. The inner surface of these bubbles is generally oxidized, and they are apt to be more numerous near the surface of the ingot.

The first steel rails made ten years ago were treated like cast-steel. Until 1863 they were made from ingots seven to eight inches square and four and a half feet long in four heats. In the first two heats the ingot was hammered down to size, one end at a time, and swaged in dies to the shape of the first pass of the rolls. Then the bloom, by this time eight feet long, was rolled in two heats through twelve passes into a finished rail.

This process was excessively crude, wasting everything a steelmaker cares to save, and as the rails were found deficient and their weak points tested, it was found that the small size of the ingots and the little work done on them caused a great number of imperfect rails and a very poor quality in the steel. At this time the expressions of want of confidence in Bessemer steel took shape. We have now, however, surmounted all difficulties, and produced a reliable uniform quality of steel in enormous quantities considered in the light of former capabilities of production. We now use very large ingots, which necessitate thrice the work formerly applied. In 1867 the ingots were raised in England to ten inches square, and in 1870 to twelve inches square, which is the size in general use. In America we have had exactly the English experience with small ingots, the efforts to use them to advantage having entirely failed.

Seeing, then, that large ingots weighing three-quarters of a ton, and making two rails, have been found necessary, it has become a question as to what mode of working them up gives the best results. I think that hammering furnishes the preferable product, and my present experience goes to justify the opinion. Rolling is preferred by some makers because it is thought cheaper, but I think the better wear of a hammered rail is a strong point in its favor. Rolled rails are generally softer than hammered rails, for the reason I have given, namely, because their carbon is apt to be partially separated as graphite, and their density is less.

There have been, in the history of iron metallurgy, two noted contests between rolling and hammering, in one of which the hammer came off victorious, in the other the rolls. I refer to the manufacture of hammered iron and to that of armor plates. Hammered iron is a necessity for smith work, and the qualities imparted to it by continued piling and hammering are wonderful as compared with ordinary iron. The reputation of the Low-Moor and Yorkshire iron tires and plates is world-wide, and the steel tyre had in the Low-Moor tire for some time a formidable competitor. In this case the benefits are produced by a better texture of the iron and greater ductility developed by the work done. The cinder is thoroughly expelled in the blooming and first piling, and may be left out of the question. In the other case the object was to get as soft and wax-like an armor plate as was consistent with the strength necessary to resist the impact of the shot. As the work done by the shot generally used represents in foot pounds the effect of one (gross) ton falling a mile and a half, it will readily be acknowledged that there is little similarity between the case of an armor plate and a steel rail, which has to stand a ton weight falling only 17 feet.

In my own experiments on the effects of the two processes, I compared ingots of the same steel with an average area of respectively about 75 and 110 square inches, average section, as they were the only moulds I had at the time to compare. I found that the rails made of blooms, hammered from the ingots of the latter section, stood over 100 per cent, more than the rails made direct from the ingot. The bloom was hammered to the size of the ingot, and each rolled in two heats, one of them a wash heat, into the same kind of rails. I tested in this way 31 different charges. Weight used was 2000 pounds, bearings 2 feet apart. The rails from ingots stood 21½ feet fall of this weight, showing 1 6/10 of an inch deflection without breaking. The rails from the blooms stood a 43 foot fall of the same weight without breaking, and showed a deflection of 3 9/10 inches. This leaves a surplus of 50 per cent. in favor of the hammered mil, deducting 50 per cent. for amount due to difference of area of ingots. To show the connection, on a manufacturing scale, of these tests with the actual result, I would remark that we made 13,285 rails out of the ingots of 75 square inches average area. Of these there were rejected by the railroad, for insufficient strength after delivery, 178 rails, or 1⅓ per cent. Of the larger ingots we had made up to the fall of 1870, 34,320 rails, and had rejected for all causes, after delivery, only 18 rails, or 1/20 of one per cent., or a quantity only 1/26 as large as before.

We, therefore, continued to hammer, but now use an average section of 150 square inches; doing two-thirds the work under the hammer, and only one-third in the rolls. Our rails thus produced stand a ton weight falling 17 1/2 feet, and leave an ample margin of reserved strength. We have had recent tests, in which the rail stood what was equivalent to a ton weight falling 70 feet without breaking, but have not yet got up to the armor-plate standard of a mile and a half. Out of a lot of 1200 tons of 58 and 60 lb. rails, not a single rail, out of the 439 tests given, broke under a ton weight falling 16 1/2 feet. We have since had many similar series.

The bubbles in the ingots give some trouble in the subsequent working, sometimes occasioning cracks in the ingot requiring to be chipped out. This we do, as we hammer the ingot down, without hindering the hammer in its work. Rolls are apt to laminate these bubbles instead of forcibly compressing them like the hammer, and it sometimes happens that the bubble breaks out on the surface of the bloom, and causes a long streak where the metal is not sound. These streaks are especially noticeable in the head of the rail. In order to obviate the cracks resulting from these blowholes, a hammer must be associated with the rolls to chip out bad places; and this renders the rolling process more complicated than it would appear at first sight. I do not see why it is not simpler to do all the work under one tool, namely, the hammer.

The objections to hammering, on the score of cutting sharply into the metal, are not, in my opinion, of weight, as our experience agrees with the English, that you can hardly have too heavy a hammer for steel. We can strike two full blows of a 12-ton hammer on the same place without deforming or injuring the bloom in any way, or making a mark on it deeper than 3/8 inch each time. As showing what steel will stand, I will say that I have seen, in Vienna, Haswell's hydraulic press reducing ingots from 10 inches thick to 2 inches at one squeeze, without injuring the steel, which was from Neuberg. It is thus surely idle to talk of a hammer as injuring steel in any way. The stroke of a heavy hammer works uniformly through the bloom, drawing the interior as much as the surface. We want to make a hard and tenacious bloom, and the concentrated blow of a heavy hammer is well adapted to that end. We lose practically nothing in ductility as compared with the rolls, and have ample room within the limits of our strength. The chemical composition controls the brittleness of our rails, and as long as we keep that right, we can make a comparatively hard rail well adapted to wear.

In regard to the amount produced *by* the two methods in the same time, the hammer compares very favorably with the rolls. A blooming-mill turns out about 55 tons of blooms a day from ingots. We do as much as that daily under a 12-ton hammer, and have done much more than that for a considerable time, so that the relative capacity of the two is hardly decided as yet. In five to six minutes we can hammer down, chip, and cut in two, and carry away, a large ingot, reducing it to one-third its former size; and in thirty-five to forty minutes do the whole work of getting a heat of 5 ingots hammered complete into finished rail-blooms, requiring no subsequent hand-chipping. For three months this hammer did an average of about 70 tons of rail-blooms per day, turning them out sound and well chipped.

As *a* matter of interest, it may be well to refer to the fact, that at Neuberg, in Styria, they use a 19-ton hammer on steel, and according to published statements, produce under it in a week only 65 tons out of 2 furnaces in 11⅓ turns. They hope, by using 4 furnaces, to get up to 130 tons a week. It shows well the spirit of American work to compare our product with this. We do now over three times as much as they hope to do, and do it under a hammer of under two-thirds the weight. The weight of ingots is about the same.

I have explained above my reasons for preferring hammered rails, all derived from experience capable of easy verification. In practice we have found, as far as we could compare hammered with rolled rails, that the former stand the treatment they have to suffer better than the rolled rails. From experience with rails of different making, rolled and hammered from ingots of the same size, I am enabled to say that the hammered ones have far less rejections on all accounts than the rolled ones, and that their strength against sudden jar is greater.

I believe, therefore, that the hammered rails arc superior to the rolled in very important characteristies. I do not deny that rolling may be improved so as to equal a hammered rail. That is not impossible, nor improbable. It has not done it yet, in my opinion, but when it docs, I shall be most happy to change my opinion.

In order to show the relative endurance of iron and steel rails, I would like to mention a case that may be regarded as furnishing an American experience of steel rails, equalling that had on the English railroads, and especially on the London and Northwestern. The Philadelphia, Wilmington, and Baltimore Railroad laid, in their yard in Philadelphia, steel rails on one side of the track, and iron rails on the other. The steel rails were hammered rails, and were, with the iron, laid in 1864. The steel rails wore out some 17 sets of the iron rails, and then the company stopped the experiment, laying steel on both sides.

On a curve of 525 feet radius, steel rails have lasted intact since 1865, and are as perfect as when laid, where iron rails had before lasted only from three to six months.

None of the rails of the Pennsylvania Steel Company, nor of any other company in this country, have ever been worn out by traffic or shifting work, so that, after a five years' experience of American makes, I have reason to believe they will last at least a generation, under the hardest service.

PILLARS OF GOAL.

BY S. HARRIES DADDOW, PRACTICAL MINER.

THE INSUFFICIENCY OF PILLARS OF COAL FOR THE PURPOSES DESIGNED—THE FRUITFUL CAUSE OF DANGER, EXPENSE, AND WASTE—THE PROOF OF INSECURITY—SUBSTITUTE FOR PILLARS OF COAL—PILLARS AND PANELS COMPARED.

PILLARS of coal, which are designed and left in our mines as the means of supporting the overlying strata of our coal-beds, and securing protection to the miner, are not only insufficient for these purposes, but the most objectionable means of providing the desired security to life and property. Though such pillars are left at a great sacrifice to the owners of collieries and mineral lauds, loss to the resources of the commonwealth, and ultimate privation to the public, they defeat the very ends for which they are designed, and not only do not secure life and property, but arc as fatal to the one as ruinous to the other.

Propositions.—It is eminently desirable that the resources of the commonwealth—particularly our mineral wealth in anthracite coal, which is limited—should be carefully utilized and made available, not only to ourselves but our posterity. Yet, speaking as an anthracite miner, we are wasting our resources of coal with a recklessness which will bring ruin in the end, unless checked, not only to the iron manufacturing interests of the East, whose chief protection, in competition with the iron-masters of the interior, lies in a cheap and abundant supply of anthracite furnace fuel, but to the best interests of the State. It is, consequently, not only desirable, but necessary, that we should realize every ton of coal from each colliery, and every acre of coal area, in order that our resources may not be wasted at present, to breed want in the future, and to realize the greatest present benefit to the mine, the miner, and the public.

It is not possible, however, to secure these ends, if we continue to leave, as we do at present, from one-third to one-half our resources in anthracite as pillars in our mines. But our sad bills of mortality, our abandoned collieries, and our yawning mountain-sides, present ample evidence that even this enormous waste of coal, though left for the purpose of protecting life and property, is as totally inadequate for the one as it is for the other. We may, therefore, ask: If one-third, or one-half our anthracite coal-beds must necessarily be lost as pillars, without securing adequate protection to life and property, shall we continue to waste our resources, sacrifice our lives and property, as we are now doing, or shall we increase the waste by leaving still larger pillars in order to try if this may secure greater immunity from danger?

Pillars of Coal.—I propose to demonstrate that even a greater proportion of coal, if left as pillars, would not secure the ends and aims desired. Therefore, it is of no consequence in this connection to the argument whether one-half or one-third of a coal-bed is actually left, if even a still greater proportion would be inadequate, unless such ruinous wastefulness is unavoidable.

I leave out of the question surface mines, or those of inconsiderable depth, merely remarking that no coal should be mined near the surface, if future injury might result from "caving," because no one can estimate how large a pillar would be required to provide permanent security, particularly where air, gas, percolating water, and other causes may be. constantly reducing the strength of the pillars, and decomposing the excavated or hanging strata.

But there must be some limit to the depths at which this prohibition should cease, because the coal below would be worth far more than the surface above. It would be difficult, if not impossible, to estimate to what depth the strata may break when supported on pillars; but, by the best methods of mining, in which pillars of coal are not left for this purpose, experience demonstrates that one hundred feet is the maximum thickness, or depth of the strata from the surface, at which mining should cease in large coal-beds (of twenty to thirty feet thickness), and from twenty to fifty feet in ordinary coal-beds, independent of the soils or surface wash. This can be safely estimated, however, as will be demonstrated in another connection.

It has been stated, publicly, that laws should be enacted enforcing the miner to leave adequate pillars to support the surface, in view of the fact that towns and cities are in danger from their present insufficiency to support the surface. Indeed, the Governor of Pennsylvania, in his late message, states:

" It should, therefore, be made unlawful to remove the coal supports without supplying their places with others of substantial masonry, or something equivalent."

The "something equivalent" is the saving clause, because we know that masonry is out of the question, and were we compelled by law to leave still *larger* pillars of coal, the towns and cities built by the coal and supported by its extraction from beneath and around them, would only tumble into ruins the sooner. They grow on its strength; they thrive on its nourishment, and they will decline when it is exhausted. The term of their existence depends, as far as human foresight can determine, on the duration of their coal deposits. Indeed, the present and future wealth and prosperity of Pennsylvania, if not the manufacturing interests of a great portion of the East, depend largely on the pent-up energy stored in our resources of anthracite.

The Strength of Pillars.—The strength of adequate pillars and their dimensions would depend—other considerations, gas, etc., left out of view—on the depth at which a pillar of coal would crumble beneath the strata it is designed to support. We know with what care the engineer selects his foundation-stone, to support structures only a few hundred feet high, and yet, here we have a foundation of brittle, crumbling coal, not only to support a column of a thousand feet, more or less, of its own size, but one from two to three times its dimensions. We not only take away from one-half to two-thirds of the base, but expect as much security from one-third of the coal-bed as pillars, in a thirty feet bed, as in a five or ten feet bed. In our pillar methods of mining we have no rule to determine the relative diameter of the pillar in proportion to its height.

A pillar 30 feet high may be 20 feet in diameter at its base, and 30 feet in diameter on top, while the chamber may be 30 feet wide at the bottom and 20 at the top, or arch. Thus, one-half the coal is really left as pillars, in our large beds, while less than a third is available in supporting the overlying strata. This, we think, expresses the best results, rather than the average. There are always the gangway, airway, and other large pillars 40 to 60 feet wide altogether, in addition to the chamber pillars in a lift of 300 feet. Besides which, in many of our large beds, the upper stratum, or many feet of the upper coal stratum, remain as the roof of the chamber. Yet in the best and most solid coal-beds of great dimensions, these prove inadequate to sustain the strata in large areas or deep basins. In proof of which we have had some notable examples.

But in most of our deep mines, large volumes of carburetted hydrogen are produced, and in these, this gas is continually struggling to escape from the coal, which tends to weaken and crumble the pillars. In other cases, the beds rest on fire-clay, from which the gases also escape, and which water and air tend to decompose; while the ever increasing weight of the superincumbent strata, while mining operations are continued to increase the mine area, also crumbles the roof or the coal in the pillars, causing ultimate destruction.

It is true this general result is not yet noticeable, where only a comparatively small area is extracted by each colliery; but when many square miles and entire basins of strata arc resting on pillars without *side supports*, their inadequacy will be more generally apparent. The larger our coal-beds and the deeper our mines may be, the more evident and disastrous will be the result. We need not turn to the deep mines, and the experience of English miners for facts. There are five examples within a radius of less than five miles from the writer's chair. But, if the coal miners of England proved this matter thirty years ago, and found, by sad experience, that *half the coal*, even in their small beds, were entirely inadequate as pillars to support the strata and protect the mine and the miner, we ought to profit by their examples, and learn how much more difficult is the case in our large anthracite coal-beds; because if pillars of coal are insufficient in small coal-beds to promote the end for which they are designed, they will be less efficient in large beds.

The late Nicholas Wood, an eminent English mining engineer and colliery proprietor, and for many years president of the North of England Institute of Mining Engineers, records the following evidence:

"The ordinary mode of working the coal seams, in the early days of coal mining, was to get as much of the coal as could possibly be done, leaving pillars just sufficient to support the superincumbent strata, so as to secure the safety of the men working the seam; and, when practical, to take out all the coal. When pillars were left, attempts were afterwards made to work off a portion of the pillar, or "robbing" as it was technically termed, which generally resulted in producing a " creep," or a thrust, and so destroying the remaining coal almost entirely, or so crushing it as to render it unprofitable to work.

"The late Mr. Buddie, perceiving the evil effects of this mode of working, commenced removing the pillars entirely, simultaneous with working the whole coal as a system ; thus leaving no support for the roof, which immediately fell, and thus relieved the pressure from the adjoining pillars. . . , By this system all the coal of the entire coal-field can be obtained," Mr, Dunn, one of the early government inspectors, in describing the pillar method of mining in England, states:

"In the deep collieries of the Newcastle district, before the mode of managing inflammable gas was as well understood as at present, the working of pillars was not contemplated ; therefore the attention of viewers and managers of that day was directed to the procuring as much coal as possible by the first working, leaving so much in pillars as would support the roof and no more. With this view, in all the valuable Wallsend collieries, the quantity of coal taken away varied between *one-ha/f* and *one-third,* leaving-, respectively, in pillars, from one-half to *two-t!iirds* of the whole mine,"

These clear statements, from the best authority, present conclusive evidence that it is impossible to obtain even half the coal from beds four to six feet thick, in deep mines, by the pillar method, while the method itself is shown to be radically defective.

Inclining Coal-beds.—The simple question is as to the use of pillars of coal as permanent supports, I design to prove that they are not only defective but worse than useless, for the purpose designed, and that all the coal may be obtained from our great anthracite beds without the use of pillars; I mean the permanent pillars which are now lost, as well as all the coal from the smaller beds of England and other countries. The objections, or the chief objections urged against any innovation to our present system of pillars, are the *size* and *irregularity* of our coal-beds. We need not demonstrate further that pillars of coal are less efficient in large beds than in small ones; because that would be arguing as to the relative strength of short or long pillars, and the evident conclusion must be, that larger pillars, and consequently more coal, are required in large beds than in small ones, in proportion to the available coal, or that which may be obtained by the pillar method.

It is equally evident that the inclination or variation of dip, prevalent in the anthracite regions, cannot be of any advantage to the use or strength of pillars; on the contrary, we may justly conclude that any variation of dip is a disadvantage to the relative strength of the pillar. Consequently, we must conclude that the pillar method is more objectionable in beds of high inclinations and large size, and offers less security than in comparatively small beds of low inclination.

Examples.—The fact, however, that the use of pillars in large and inclining beds is more objectionable than in small and horizontal coal-beds, would only increase our misfortunes, were it not possible to remedy the difficulty by adapting the better systems of mining, which have been so long and successfully applied in older mining communities where the panel and long-wall methods, or a combination of both, have been in use from twenty to one hundred years, in coal-beds which vary in *depth*, thickness and inclination as much *as* those of the Anthracite regions.

In the Manchester coal-field, England, the beds vary from three to six feet in thickness, and the dip ranges as high as 45° or 50°. Near Oldham the long-wall method has been in use since 1812—how much earlier we do not know—and now, both long-wall and panel, or board and pillar arc in exclusive use. The pillar method as still practiced by our anthracite miners and the miners of South Wales, with some variation, was in use in the Newcastle mining districts exclusively, as late as 1836. At that date, a writer—who was also a practical long-will miner of Oldham, in Lancashire, by the name of Marlow-—compares the pillar method of Newcastle, then defended by Mr. Dunn, formerly quoted, with the long-wall method of Oldham. Mr. Marlow was then considered very unpractical by the Newcastle miners—just as the present writer may be considered unpractical *by* many of his contemporaries of the anthracite mines, but the sequel proved his correctness.

The thick coal, or "ten-yards" coal-bed of the Dudley coal-field, England, dips at all angles of inclination, and yet this great bed is successfully mined without the use of pillars, by a special panel method, in which all the coal is obtained.

In some of the Scotch coal-fields the beds vary from three to twenty feet in thickness and from horizontal to 45° of inclination. Yet both the long-wall and board and pillar or panel methods of mining are in successful operation, w*e* think exclusively.

In the great coal-bed of Blanzy and Le Crenzot in France, which averages from thirty to forty feet in thickness, and ranges from horizontal to perpendicular in dip, all the coal is obtained by a special method and no pillars are left; and yet though the coal is extracted to within one hundred feet of the surface, beneath a cultivated valley, the operations of the miners who delve one hundred or one thousand feet below, do not interfere with the farmers who plough the soil above. We might multiply these examples, but the foregoing will be sufficient to prove that pillars—as used in the anthracite mines—are not the adjuncts of clip or dimensions, or the necessities of successful mining, however large or steep the coal-bed may be.

Substitute for Pillars of Coal.—Whether the long-wall, board and wall, or any other system of mining be employed, which is based on the principle of extracting all the coal, a substitute is necessary and always provided, to take the place of the coal extracted, and provide that protection to the surface and security to the miner and mine now vainly sought for, or attempted by our miners at the sacrifice of half our resources of anthracite.

Of course, "pillars of masonry" would be too expensive for use, and could only afford temporary and partial security at best. Fortunately, they arc not required, because the coal is *permanently* replaced by a substantial stratum of rock. As fast as the coal is extracted, its place is occupied by the overlying roof-slates which break and fall soon after the coal on which they rested is removed.

We know that nearly all our workable coal-beds arc accompanied by an overlying stratum of slate, shale, or comparatively soft material—except in a few localities where the "roof-slates" have been displaced, and the heavy rocky strata rest on the coal.

These "roof-slates" arc of variable consistency, but never in a massive stratum. They are always stratified in their beds—sometimes tough and clastic in fracture, but generally brittle and easily broken, and frequently friable and crumbling.

To keep these roof-slates from foiling is the main object of pillars between our chambers, as now used; consequently, a " good top," or strong roof-slate is a desirable quality in a coal-bed, when mined by the pillar method,

But, by the other methods, which we will term panel, for convenience, where pillars are not used, the quality of the roof is of much less importance.

Indeed, a very strong roof is much more objectionable than a very weak one, because in the panel method it is desirable that the roof-slates shall fall soon after the coal is removed; but should the top fall immediately, the coal can be obtained with greater security to the miner than would be possible by the pillar mode, as we will show in another connection.

The panel* method, in this respect, is the *reverse* of the pillar method, because in the latter the effort is directed to keep up the roof-slates; but, by the former, the effort and design is to bring them down in a broken condition in order to pack or fill the place of the coal as early as possible. We can calculate closely how much broken

* We wish to state expressly, that we do not confine ourselves to the panel or long-way methods, because special methods are often necessary in large beds of variable dip, or great inclination.

strata would be required for this purpose, when the thickness of the coal removed, and about the average dimensions of the broken pieces of slate are given. Thus, a coal-bed 10 feet in thickness, might require 15 or 20 feet of overlying strata to fill the space of both; and a stratum of 25 to 30 feet of broken rock, would consequently become a substitute for the coal, and a solid permanent pillar. Thus, this simple substitution of the broken roof-slates, by the most easy and natural process, becomes the most acceptable and available pillar that could be desired or suggested. It affords permanent protection to the surface, and permanence to the mine, while it also provides the greatest security to the miner. It enables the miner to obtain all the coal, saves the expense of timber, and otherwise reduces the cost of mining; while ample facilities arc also provided for the rejection of the impurities of the coal-bed, because they can always be thrown among the broken roof-slates, and thus left in the mine, instead of being loaded in the mine cars, paid for at the rate of pure coal, broken into a hundred small pieces in the breaker, and then picked out at great expense, or sold to consumers.

It was stated in the beginning of this paper that it is possible for the mining engineer to calculate how near the surface a coal-bed may be safely mined by this process, when the dimensions of the coal-bed and the character of the overlying strata are known. It is not necessary that we should further explain how these data may be obtained or made available, because it must be clear to the mind of any practical man, that the breaking process would be arrested at some ascertainable limit. The broken strata could not be packed again in their original dimensions. Falling promiscuously, they would naturally occupy one-third more space than they required when *in situ.* The actual increase in bulk would depend, to a considerable extent, on the character of these roof-slates or overlying strata, and the manner in which they would break, fall, and pack; but, in the same bed, and the same method of mining, there would not be much variation in the form of breakage or the limit at which it would be arrested; consequently the data to make the calculation, would be available in all classes of coal-beds. Over the 30 feet Mammoth vein the breakage would be arrested within 80 or 90 feet, or generally below the Mahoning or Mammoth sandstone. Any depression of surface below that Would be gradual, and not dangerous, except beneath heavy buildings or streams of water.

The character of the slates overlying the Mammoth is favorable to this sort of mining, because the slaty stratum is generally more than double the thickness of the coal, while the great sandstone above this stratum is so massive that it will settle down, if it moves at all, gradually preserving the overlying coal-beds from injury.

Working Double Beds.—Double beds are of frequent occurrence in many localities within the anthracite fields, owing principally to the habits of coal-beds B and E, which frequently divide, forming two or three beds each; but there are other beds, also, which are sometimes close together, and yet too far apart to be mined as a sino-le bed.

To illustrate such cases one example may be sufficient, and we select the Mammoth and "Seven Feet," at St. Clair, which are there divided by from 5 to 20 feet of slate, as an instance, perhaps of the greatest **difficulty** in the present methods.

If the upper bed is mined first, by our present or pillar method, and the weight of the roofs drawn on the pillars, it becomes exceedingly difficult to work the Mammoth, which may be from 5 to 20 or even 30 feet below, because, while an increased pressure is induced in limited localities, this pressure is, moreover, concentrated on the pillars, whose bases may rest either partially or wholly on the roof slates of the Mammoth chambers below; and when this happens, as it frequently does, in spite of the care supposed to be taken, in locating one pillar directly under the other, but little coal can be obtained from such chambers. The best that can be done is to abandon them and open other chambers, directly under the corresponding chambers above. We have noticed cases of this kind in other regions, and in one particular instance, where a new colliery, or set of workings had been opened beneath an abandoned mine to which there was no access, and consequently no means of locating the chambers and pillars of the bed, which was 20 feet below. The result proved that it was impossible to mine the lower chambers, unless they were squarely located beneath those above, and this proved a most difficult matter, because the old works were extremely irregular.

There is no difficulty, however, in the " panel method," because the upper bed may be mined in advance any length of time, provided only that the dividing strata are of sufficient thickness to fill the place of the lower bed on the principle set forth, without breaking through to the bed above. In fact, on this principle it would be possible, and indeed practicable, to mine the extreme local enlargement of the Mammoth, where this great bed is often 40 to 60 feet in thickness, and in a few cases, nearly 100 feet thick !

Twenty feet of the top may be mined, and the roof let down on the remaining coal which may be subsequently mined from beneath the broken slates, which would not be so difficult as it may appear. This method, however, is not new, because it has been successfully and satisfactorily practiced elsewhere, as, doubtless, many of our mining engineers are aware.

Method.—We do not intend to enter into the details of mining by the panel method, because that would involve the discussion of long-wall, board and wall, the Dudley "ten yard" special mode, the Blanzy, and perhaps a few others, which have proved successful and advantageous in coping with local peculiarities. But, whatever mode is now adopted by practical mining engineers in older mining communities, *all the coal* must be extracted, and no system is perfect that docs not admit of this consummation.

It may be noted that the British commissioners, appointed to investigate the duration of their coal-fields, estimated only 10 percent, as the probable loss. We may be permitted, however, to give an opinion, regarding the most suitable methods for mining our deep coals. The surface coal in the anthracite regions is nearly all exhausted or abandoned, a far greater amount being abandoned or lost than has been vended. Consequently, the deep coals concern us most, and to develop them the skill of the engineer is absolutely necessary to insure success.

We have used several methods in our own experience, and have had the opportunity of studying and investigating both long-wall and board and wall, personally, in the mines; and while we have had no practical experience in the Dudley method, our acquaintance with intelligent miners who have worked in the Dudley and Staffordshire "thick coal," enables us to speak intelligently in regard to these various methods.

Board and Wall.—For most, if not all of our bituminous coal-beds, and the horizontal or slightly inclining beds of the anthracite region, the board and wall, as originated by John Buddle, could be used with great advantage over our present method of pillars, and by this mode all or most of the coal can be obtained. This method may be properly termed right-angled long-wall, or even right-angled panels, because it differs from long-wall chiefly in the fact that the long-walls (board and wall), are parallel with the dip, instead of the strike. The only disadvantages in comparison with long-wall, *per se*, being that the pillars below the lower level must be heavy and partially lost; while in long-wall, as most extensively used, these pillars may be extracted with the coal above them.

But the advantages of a larger production, and the gain of time in opening the mine to its full capacity, would fully compensate for this loss. This method, however, cannot be recommended, where the dip is too great to admit the use of horses or mules, in conveying the coal from the chambers. But by this system, or by the long-wall system, the capacity of a colliery is limited. A shaft may develop a body of coal 500 yards on the dip, and yet the production Would be limited to the number of "walls." or levels which might be operated at right angles to the gangway (lower level), in one case, and parallel with it in the other.

This right-angle method, however, is the simplest possible departure from our present pillar system. The only material change necessary, is the contraction of our breasts or chambers to some absolutely safe dimension, merely as the means of approach and for the conveyance of coal, if it would not be entirely safe to increase this area ; but this decrease in the size of the breast is proportionably made up, by the increased size of the pillar. By the old method of breast, all the coal is obtained in advancing while the pillars are lost, but by this method little coal is obtained in driving up, yet all the coal is obtained in withdrawing, and no pillars are left.

Board and Pillar.—We stated that, " pillar " and " panel " systems are the reverse of each other, and it might be inferred that pillars are dispensed with in this method, but the reverse is also true, because by this mode the *whole coal* is left as a pillar, except the small opening, through which the miner approaches—where he is sure of security and a safe retreat—which provides ventilation and through which the coal is conveyed. The operations of the miner are carried on through the solid coal, or galleries through the. panel or long-wall systems, while the breast and pillar mode requires all this to be clone through the excavated parts, between pillars which are always reduced to their smallest possible dimensions, and under the hanging roof, supported by decaying props.

There are, therefore, two radical and material improvements in the panel over the pillar mode. The first substitutes the roof-slates for pillars in the abandoned mine, thus turning a difficulty to an advantage—coaxing them to fall instead of trying to prop them up, with whole forests of timber, and at the sacrifice of half our resources in coal—which, at fifty cents per ton (its worth in improved collieries), would pay our National debt, thrice told !

The second substitutes almost the whole coal for pillars in the industrial departments of the miner.

In regard to the board and pillar *per se,* we shall have little to say. It differs chiefly from board and wall and long-wall in dividing the "walls," into pillars and the entire mine into panels. It seems to have all the advantages of the other methods and none of their disadvantages. It is, however, not so applicable to beds of great inclination as the long-wall, and for this reason we have advocated a combination of both long-wall and board and pillar, and in our large beds the "10 yard" method, slightly modified to meet this combination. For the sake of convenience, or for want of a better term, we propose to call this method long-wall panel.

This is designed for all angles of dip, but chiefly with reference to our large, inclining beds, great depths and large collieries.

The design is to operate from two to four levels (though more may be used) from the same shaft or slope. Sweeping out the upper levels in advancing on the long-wall principle, and the coal of the lower levels in returning on the same plan.

Thus, while a large production may be realized from the start in the upper levels or lifts, the lower ones are being opened and ready for withdrawing when those above are worked out.

In order to use this method two levels are necessary ; more may be used, however, if needed. The upper one is abandoned, however, as fast as the coal is exhausted, while the coal is conveyed through the whole coal of the lower level to the gangway, and the air courses in the same direction to the return airway, below the gangway. There are, consequently, always provided, permanent avenues of approach and transit, until the entire body of coal is exhausted, whatever may be its length or breadth. No pillars need be left or coal wasted.

Ratio of Danger and Production.—The figures are not available at this time to make a relative comparison between chief mining districts of the world in regard to the production *per capita* per annum, or the ratio of danger, nor have we the space for such a purpose, but in order to contrast pillar and panel we will cite a few prominent cases, which we think exhibit a fair comparison.

TABLE *for three years, ending* 1869, *showing the number of deaths, amount of coal in tons mined, per death from all causes ; ratio of safety*—100 *being most safe; arid number of tons mined per capita per annum.*

Localities.	Systems.	No. of Deaths.	Tons per Death.	Safety Ratio.	Tons per Capita per Annum.
North Durham and Cumberland,	Panel.	249	133.310	80	387
South Durham, ...	Panel.	279	163.698	98	
South Wales, ...	Pillar.	533	51 536	30	310
Manchester District (chiefly), . .	Long-wall.	218	94.821	56	271
Schuylkill, Pa. (one year), 1870, .	Pillar.	112	38.000	25	250*
West Scotland, ...	Panel and	120	153.475	92	285
East Scotland, ...	Long-wall.	135	166.321	100	291
Yorkshire (chiefly), ...	Pillar.	595	48.746	29	262

DISCUSSION.

MR.. COXE remarked that at Blanzy, the old, so-called Blanzy method of exploitation has been abandoned and a new system introduced, the peculiarity of which is the filling up of the excavated spaces with rock from outside the mine carried in for this purpose. The cheapness with which this can be done in that locality is surprising. The steep, thick bed is worked out in layers from the foot-wall, each new layer having the rock packing as a foot-wall. With regard to comparison of the safety to life of different systems, he remarked that the ordinary tables of casualties are scarcely a fair basis. What is needed is a carefully prepared table from which all accidents are omitted that are not in some way connected with the system pursued; men run over by cars, or falling down shafts, or in any way injured by reason of their own carelessness or that of their employers, should not be counted in such a comparison, unless the system of working involves the cause of accident or renders it more likely to occur. Mr. Coxe then sketched the system employed in the KÖnigshÜtte mine (Silesia), which produces 3500 tons of coal daily, extracting, by a system of chessboard chambers, nearly or quite all the coal. Among the difficulties in American mining, the first is the inadequacy of capital to lay out the work properly. Again, our miners are not miners; many of them barely know enough to make a hole, put powder in it, and fire it without killing themselves. It is difficult to make them accept or understand, to say nothing of efficiently carrying out, any but the rudest system. Another difficulty in the way of abolishing the pillar system is the

* Approximated as the highest figure. The ratio for the Schuylkill anthracite regions this year is rather more favorable.

fact that in the Lehigh region the overlying rock to many veins is exceedingly hard. In some cases several acres of it will stand after excavation, refusing to fall for a long time and then come down all at once.

MR. RAYMOND described the Bruchban followed in Zwickau (Saxony), a species of long-wall retreating, which requires large capital to lay out the field in advance, but presents the maximum of production, safety, convenience, and economy. The settling of the surface, due to this method of mining, has not been found to cause much damage. It is in most cases imperceptible, though now and then a chimney or brick wall shows it.

ON THE IMPORTANCE OF SURVEYING IN GEOLOGY.

BY BENJAMIN SMITH LYMAN, C.E.

THE importance of topography to geology is so commonly underrated as to deserve to be pointed out again and again. The relation of topography to the different branches of geology may be seen best by a glance at them all.

Geology is well understood to consist of the observation of facts about rocks as materials of the earth (geognosy), and the explanation of those facts (geogeny).

The facts to observe are:

I. GEOMETRICAL, as (1) *structure,* including the dip and strike at different points, the size, shape, and position of basins and saddles; (2) *vertical section,* that is, the thickness of rock groups and of their parts; (3) *horizontal* or geographical *position.*

II. PHYSICAL, such as *texture,* whether sedimentary or crystalline; and, if crystalline, whether granitic, porphyritic, amygdaloidal, globular, or concretionary ; whether *compact or granular ; coarse or fine; pervious or impervious; hard or soft; firm or tender; with cleavage or without; massive or thin ; the microscopic structure; also whether magnetic or not; soluble or insoluble; fusible or infusible ;* and the *constituent minerals.*

III. CHEMICAL, that is, the composition of the rocks and of their minerals and their affinities.

IV. PALÆONTOLOGICAL, as what kind of fossils are in the rocks, whether (1) *salt-water;* and if so, whether *(a)* deep-water; (6) shallow-water ; or (c) lagoon ; (2) *fresh-water ;* or (3) *land.*

Knowledge of this general character about the fossils is all that is needed of them for geological purposes, for understanding the nature of the rocks and the successive changes the earth has undergone. The special fossils that may be found in different beds of rock may be of great interest in the history of life in the world, or of organisms (palæontology), and may sometimes give more or less trustworthy aid in determining practically the relative age of such beds. But in general it is rather the position of the beds that determines the relative age of the different groups of animals or plants whose remains arc found in them; and geology gives to palæontology far more in value than it gets in return. It is absurd, then, for palæontology to assume to be geology, or the chief part of geology, as so often happens nowadays. Pahæontology in truth only helps to a knowledge of a very few of the many physical and chemical facts about the earth's materials, and those few perhaps seldom of very great importance. The explanation of the changes from bed to bed in the general character of the fossils, as salt-water, fresh-water, or land, deep-water or shallow-water fossils, depends, of course, on physical or chemical laws.

The facts that were just now called geometrical are, of course, in one sense, merely physical; for they only concern the size, shape, position, and general composition of rocks or groups of rocks. The explanation of such facts must always be of a physical or chemical nature.

It is plain, then, that both the facts of geology and their explanation are always either physical or chemical, with the not very important exception that the general character of fossils is shown by physiology.

The facts learned by measurement, though they can scarcely be separated wholly from the other classes of facts, do not yield to them in importance. The questions, where a rock of a given physical or chemical nature is found, what is its extent, and what is its position relative to other rocks, and to the sea level, are at least as important as the physical and chemical facts themselves, both in theoretical geology and in practical mining. Indeed, the geometrical facts of themselves would sometimes show some of the most important physical facts; as, for example, the shape of the surface of the ground very often shows the relative hardness of the rocks that underlie it, and in a limited region show by that means what beds of a known series underlie given points, such as a coal-bed marked at its outcrop by a terrace, or a hard bed of rock marked by a ridge. For a thorough understanding of geology, of course, an intimate acquaintance with the laws of physics and chemistry would be needed ; but for most practical and even theoretical purposes only that common knowledge of them is wanted which almost every man has, and geometrical measurements become the sole and all-important requirement.

The necessity of some sort of geometrical representation of some of the most important geological facts has been acknowledged almost universally by the use of maps, and of more or less rudely made sections. But it is perhaps the very imperfection of such methods, as have been commonly employed, that has brought this branch of geological work into the undeserved contempt in which it seems generally to lie; and such geometrical representation has at best almost always been used solely to set forth geological facts, seldom as a means of finding them out. Very often, indeed, the map is merely to show the geographical distribution of different groups of fossil animals and plants. Even when hills or mountains are shown, it is only by vague shading or indefinite hachure lines with all traces of geological structure left out. The cross-section, with its exaggerated vertical scale and distorted dips, would commonly seem rather to impress the eye with the varying height of surface than to show how the rocks lie, the true aim of a geological section. The map and section not only give the geological facts so very imperfectly, but are almost useless as an aid in working out the geology, from the bare, disconnected facts observed in the field, and in correcting or verifying the guesses made there.

A geological map should be a geometrical construction on paper of the earth's features on the surface and below, and should show as fully as possible the shape of the surface, marked with the places of the observed rocks, and should give the position of the rocks, or of some of the chief beds of rock below the surface as well as on it; and should be accompanied by a section, to show the thickness and sequence of the rock-beds, as well as by a cross-section of the region, to show the dips and basins of the rocks.

The relative position of points on the ground is found, of course, by the measurement of horizontal distances and angles; the height of points is found by levelling, that is, the measurement of vertical distances. The points of reference on the surface are well enough mapped by any of the ordinary methods, but the shape of the surface is far better shown by contour lines (or lines of equal height) than by hachures (lines of greatest steepness) or shading (dark according to the steepness). Where the map is on a large scale, the contour lines may be ten feet apart in level, or even less, and show many details. But even in maps of large regions on a small scale, contour lines, although 100, or as much as 250 feet apart in level, or even more, so that many details must be left out, still give very much more information than hachures or shading, and show, roughly at least, the height of mountains, besides their course and steepness; and on comparatively level ground, where hachures and shading have nothing whatever to say, contour lines show not only the height, but the direction of the slopes and their steepness.

Shading aims only to show the steepness of the ground, and at the very best can do this only very roughly indeed. Hachurcs aim to show the steepness and its direction ; but can show the steepness no better than shading, and to show well even the direction of greatest steepness, would often need far greater delicacy of touch and of eye than either is capable of. Neither shading nor hachures give even a rough idea of the relative height of the ground at different points. Contour lines, on the other hand, show with more or less exactness the height of every point on the surface, besides giving with great nicety both the direction of greatest steepness and its amount. There is, indeed, no comparison between the merits of contour lines and those of either of the other two methods; and the only plausible explanation of the fact that contour lines are comparatively so seldom used is, that they are definite in their statements, they expect for their preparation a more definite knowledge of the shape of the ground, or at least a clearer idea of it, and consequently greater labor. Shading and hachnres furnish a vague language that is fitted for expressing with ease vague information; what contour lines tell, they tell with precision. If the information at hand be imperfect, contour lines will still express with clearness the best opinion or guess that can be given by the mapmaker, whose guess even may be of great value to those who have not had his means of forming an opinion. The uncertainty of the information should at the same time be shown by the wording of the title of the map, or by a note upon it, or by dotting the contour lines. Indeed, any desired degree of vagueness can be given by leaving the distance apart of the contour lines indefinite, or only more or less approximately uniform. The advantage of contour lines over hachuring has been well insisted on in Lesley's *Manual of Coal and its*

Topography, 1856, but cannot be urged too often, until it is generally acknowledged and they come into common use.

It is very easy to give the appearance of relief to the map by thickening the contour lines, on one side of the hills, and by altogether leaving out half of them on the other side, so that the hills may look as if they were lighted by the sun on one side, and in the shade on the other. But some confusion might arise in reading the map, because this very effect of dark shade is also given by the mere closeness of the contour lines which marks steepness of the ground. A dark shaded part may seem steeper than it really is, and a really steep place on the sunny side of a hill may, from the omission of half the contour lines, seem only half as steep as it is. It is, perhaps, better to give the relief effect by mere shading; heavy shading on one side

of the hills, and light shading, or none at all, on the other side, leaving the contour lines of uniform thickness, to show the steepness of the ground by their closeness. Confusion would especially be guarded against by making the contour lines of a different color from the shading.

As contour lines give the best means of showing on paper the shape of the surface of the ground, so they give likewise the best means of showing on paper the shape of the surface of a bed of rock. It is seldom that the surface of a bed of rock is laid bare for any great distance by nature, so that it can be mapped like the surface of the ground; but it often happens that this can be done in mines. In other cases it is necessary to map the bed, and draw its contour lines with more or less certainty from the exposures that happen to be visible. Not only may the actual exposures of the bed itself be regarded, but as the beds above and below are more or less exactly parallel, its position can be reckoned from an observation of theirs. At each point of observation the strike and dip of the rocks must be taken as well as their level, just as in making observations for mapping the surface of the ground; besides taking the level of a point, the contour lines near it are at least sketched; that is, the direction of a level line, and the steepness at right angles with it, are more or less exactly taken. If such observations on the rocks are made at points enough, a perfect geometrical representation of any bed of rock can be made. Even if the observations are too few for that, they may yet be enough to form a reasonable conjecture as to the position of the bed, with more or less certainty. The very putting down on paper with precision, in proper relation, what is known of the position of the rocks, aids immensely in completing a geometrical construction of them, and gives a vast deal of information beyond what can be guessed at in the field. The eye takes in readily such mapped observations, and sees their bearing upon each other, when the biggest head, with the same facts, but without a map, would be at fault, and merely muddled.

The known or conjectured shape of the surface of the bed can be shown on paper better by contour lines than in any other way, and is generally so much more regular than the shape of the surface of the ground that the contour lines of one will not be mistaken for those of the other, even if they be drawn in the same color on the same sheet; and sometimes even several different beds may be drawn without confusion. The points where the contour lines of the bed meet the same contour lines of the surface, show the position of the outcrop of the bed, one of the most important features to map, whether for practical or for theoretical purposes. It is, in fact, the geometrical construction itself, that commonly shows the position of the outcrop through most of its length, very often where it would not otherwise be suspected.

If the dips are very steep it will often not be well to make the contour lines of a rock-bed (the underground contour lines) as near together in level as those of the surface; they may be a hundred feet apart in level instead of ten, and yet show perfectly well the shape of the bed. Sometimes it is shown very well merely by the outcrop and a single contour line, that, for example, of the drainage level of the region, or the course that a drift for drainage would take on the bed in question. With surface contour lines and underground contour lines, the depth of the bed below the surface at any point can readily be known; and this is highly important in sinking a shaft or reckoning the yield of a bed above a given level.

With such a complete geometrical representation of the shape of a bed as contour lines would give, it is only needful to make a full section of all the beds with their thickness to show the position of every bed of rock at every point. The thickness of each bed in its order must be measured, of course, at right angles with its surface ; and a drawing of the whole series made to show them all on the same scale. It is plain that the whole series need not be measured at one point, but the different parts can be taken wherever exposed. The geometrical construction of the map will help very much to show their relation, and the gaps between them, if any.

Having the surface of the ground and that of one or more rock-beds shown by contour lines, and a section of all the rock-beds with their thickness, it is easy to draw a cross-section of the country in any direction, so as to show the profile outline of the ground and of each bed. Such a section across the average strike of the rocks or across the axes of their basins and saddles is especially useful; the next most useful section is commonly one along the axis of a basin. Of course the vertical and horizontal scale of such a section must be the same, otherwise the rock structure, the chief object of the section, would be greatly distorted. In making an undistorted cross-section before the underground contours are drawn, facts often come to light that would otherwise be unknown, such as the identification of beds exposed only at distant points, and the steepness of the dip at points where there is no exposure. Sections of this kind are, therefore, often a very great help in making the map itself.

Such maps and sections, then, show completely all that is known (or conjectured) of the geometrical facts of the beds of rock, the thickness, extent, position, and present shape of each bed, its position with reference to each of the other beds; the shape, size, and position of the basins and saddles, what part of each bed still remains underground, and what part has been worn away to form valleys, what part is above the lowest drainage level of the region or any other given level, and what below it; and the very process of making the maps and sections is a very valuable aid to gaining such knowledge, and often teaches as much as could be learned by very costly digging or mining. These facts are not only of the highest importance themselves, but they lie at the base of very much (if not most) reasoning towards the explanation of the purely physical and chemical facts of rock-beds.

Simple and clear as all this seems, yet it was so long overlooked and is still so much disregarded, that maps showing with the least completeness the geometrical facts of the surface and of the rock-beds were never seen thirty-five years ago, and are extremely rare even now. Pennsylvania, in fact, can claim for itself or for its citizens the credit of doing nearly all that has been done for the progress of this branch of geology, whose early history (in America at least) is but part of that of the Pennsylvania State Geological Survey, and whose later history is found in the geological work of the chief topographer of the survey, Professor J. P. Lesley, followed by that of others who have learned more or less directly from him. To him alone, in fact, belongs the credit of almost all the advances that have been made in this line of work, as well as of having first established its most essential principles. Some of its earlier hitherto unpublished annals, learned by inquiry of him, deserve to be recorded before it is too late.

The Pennsylvania Survey, under Professor H. D. Rogers, began in the year 1836, and soon discovered a very intimate relation between the surface features and the structure of the rock-beds below, a relation that is perhaps more striking in this State and Virginia than in most countries.

Early in the spring of 1839, one of the assistants of the survey, James D. Whelpley, finished in lead-pencil at the end of two years' work, all his own, the first topographical map. It embraced all the anthracite region except the Wyoming Valley.

In 1840 Alexander McKinley finished a sketch map of the Wyoming Basin.

Between the spring of 1839 and fall of 1840 Andrew A. Henderson (now Surgeon in the United States Navy), made a beautiful map of the Juniata region, partly copied into Lesley's *Manual of Coal and its Topography* (page 137). At the same time the country north of that was also mapped by McKinley.

In 1839 J. P. Lesley, who had just joined the survey, made in Whelpley's style a map of the country south of the anthracite region and north of the North (or Kittatinny) Mountains.

In 1840 and 1841, Lesley was occupied in completing Whelpley and McKinley's maps by putting in the surrounding country.

At the end of 1841 all the materials of the whole State where any mapping had been done went into Lesley's hands, and in 1841 and 1842 he made up the State map and its cross-sections.

In all these maps no contour lines were used, but great attention was paid to elevation for the cross-sections, and the maps were made with the sections before the eye as a guide in making the hachures, and Dr. Henderson was especially successful in this.

In the winter of 1846 and 1847, Lesley made a second copy of the State map and of all the sections across the State.

In 1851 he made a great map of the Shamokin anthracite region for Mr. Rogers, a private undertaking. The country was cross-barred with section-lines staked at short intervals ; and the map was made with hachures on a peculiar system of Lesley's invention, equivalent to contour lines.

In 1852 Lesley spent the summer in the field in making (for the State survey again) a great sheet of the Pottsville anthracite region. The country above ground was cross-barred with lines three-quarters of a mile apart, and the outcrops were run by parties under charge of

John Sheafer; while underground surveys were also made by parties under P. W. Sheafer, and Lesley did the mapping. Contours were drawn only to determine the depth of the hachures, which were all short, showing the slopes, with eight or ten systems on a single mountain-side. The outcrops in the gaps were marked by a peculiar system of hachures that showed the dip. Every outcrop of every coal-bed and every rock outcrop were laid down. The map was between twenty and thirty feet long, and has gone out of sight, but no doubt still exists among the papers left by Rogers at his death, since the State law made all the materials of the survey his private property.

At the end of 1852 it was finished only, from near Donaldson and Tremont to within six or seven miles of Tamaqua, and embraced the Mine Hill basin and the plateau of the Broad Mountain. It was intended to carry forward and finish the map the next year; but the corps was broken up, and in 1853 A. A. Dalson with one assistant was employed to extend the sheets. Without parties he could not do it in the same way, and Rogers had him make out of all the materials extant the reduced copy of the map of the anthracite region (with hachures), published in the State Report under Lesley's and Dalson's names; but Lesley never saw it until it had been printed. It should be called Dalson's map, as the preface to the Report does call it.

This and the great map of the State with its cross-sections, are all that was ever published of all this work.

The first contouring for geological maps was done in 1853 and 1854, in a great map of Lesley's for the Pennsylvania Railroad Company, of the country from Johnstown to Greensburg, in Western Pennsylvania, covering parts of Westmoreland, Fayette, and Indiana Counties. It was eight feet long and four feet wide, and was covered with fine contour lines twenty feet apart in level, and with intermediate ten-foot lines for relief, and shading on the southeast side of the hills. I myself saw this map about 1856 or 1857, and can bear witness that it was a very wonder of topographical labor and skill. It would seem years ago to have disappeared from existence, but it is incredible that so valuable a piece of work should be destroyed.

In 1855 and 1856 Lesley mapped Broad Top Mountain with contour lines; and the survey was so minute that there were over eleven thousand stations levelled. None of this has ever been published, and it would be an extremely valuable contribution to another State survey.

In 1856 he published his *Manual of Coal and its Topography,* in which he set forth most admirably the relations of topography to geology, and made public the principles of the art to which he himself had first given form. The book contains many beautiful little topographical maps and sketches by way of illustration. From that time to the present (owing partly to the increased ease of reproducing maps by the help of photography and photolithography), he has published many specimens of his work, especially in the Proceedings and Transactions of the American Philosophical Society, as well as in the pamphlets of private owners of mineral lands; and much remains unpublished. The maps cover many points in the Appalachian region from Cape Breton to Georgia, but particularly in Pennsylvania, and arc sometimes in contour lines, with or without shading in addition, sometimes only in shading. The position of beds (say, of coal or iron) is shown on them by laying down their outcrop and the course of a level upon the bed, for example the lowest water-level of the tract or region. The maps are sometimes colored and sometimes not. They show not only very great topographical and geological knowledge and experience, but high artistic taste and skill.

In 1866 and 1867, the feasibility of using underground contour lines, to give the shape of rock-beds (sometimes of three or four above one another), was proved on some Southwestern Virginia coal, iron, and lead maps of my own ; a photograph of one of which was shown to the meeting of the American Association for the Advancement of Science, in 1867, at Burlington. A number of such maps have been made since that, but the only printed ones are in my *Report on the Punjab Oil Lands, Lahore,* 1870. They were all drawn with special reference to the requirements of photography.

In the last three years, and especially within the last year, contour lines have come a little more generally into use for geological purposes, no doubt solely through Lesley's example and teaching. R. P. Rothwell, J. W. Harden, S. F. Emmons, A. Hague, T. B. Brooks, J. F. Blandy, and perhaps others, have published good works of this kind ; not all of them, however, marking the position of the beds of rock even by an outcrop line, still less by a level.

*THE METHOD AND COST OF MINING THE RED SPECULAR AND MAGNETIC ORES OF THE MARQUETTE IRON REGION OF LAKE SUPERIOR.**

BY MAJOR T. B. BROOKS.

THE iron ores of the Marquette region arc mostly extracted in open excavations; hence the process is more properly quarrying. Several attempts at underground work have been made, which have not, on the whole, been successful. The Edwards mine has been almost entirely wrought by candle-light. The slate ore pit, No. 1, of the New England mine, is now worked in the same way, as is also the Pioneer furnace pit of the Jackson mine.

The Champion mine was opened systematically for underground work, with two levels, 60 feet apart, and three shafts at distances apart along the bed of 200 feet; but this idea has been practically abandoned, the greater part of the ore in that mine being now taken out in open pits.

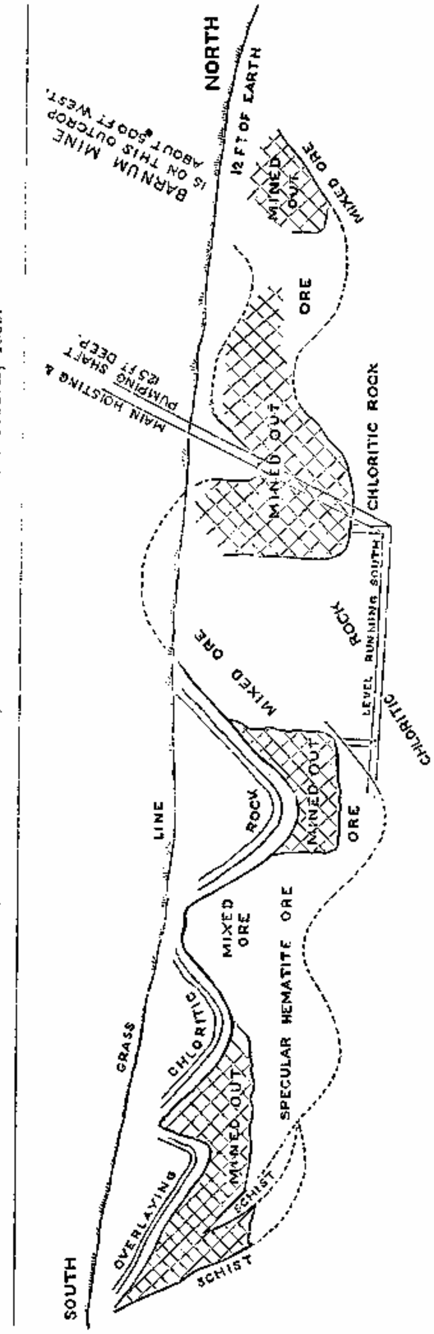
Several other mines have occasionally worked underground stopes, but only temporarily; if such slopes could not be opened out today-light, they have usually been abandoned. In brief, it may be said that no considerable amount of ore has as yet (1870) been extracted underground in the region, and of that so mined very little has been taken out at a profit; and I may add that it seems to be the belief of the most experienced mining men that this state of things will hold for some time to come for reasons which will appear.

Nearly the same remarks may be applied to the mines of the Iron Mountain region, Missouri, the ores of which are very similar in character to those of Marquette. Some of the New York and New Jersey magnetic deposits are wrought open, but this is the exception, underground mining there being the rule.

The following brief sketch of the geological structure of the Marquette deposits will indicate some advantages of the method of mining employed. The iron-bearing (Huronian) series of rocks, are stratified beds, the principal ore formation being overlaid by a quartzite, and underlaid by a diorite, or greenstone. This ore formation is made up, first, of pure ore; second, of "mixed ore" *(i. e.,* banded

* A second part of this paper was read before the American Society of Civil Engineers. Both papers are embraced in Chapter IX, Part I, Vol. II, Geological Survey of Michigan.

SECTION (PARTLY IDEAL) OF LAKE SUPERIOR MINE, 1869.



Approximate scale, 75 feet to 1 inch.

jasper and ore); and third, of a soft, greenish schistose rock (probably magnesian), which occurs in lens-shaped beds which alternate with the ore, thus often dividing the formation into two or more strata of ore, separated by rock. Usually the beds of both ore and rock thin out as they are followed from a centre of maximum thickness, producing irregular lentiform masses. Since its original deposition, if we may assume they were laid down under water, the whole series, including the iron beds, has been bent, folded, and corrugated into irregular troughs, basins, and domes, which often present at the surface their upturned edges of pure ore, standing nearly vertical. A cross-section, finely illustrating this structure, can be seen on the west side of the great southwest opening of the Lake Superior mine. It is locally known as the " Big W," which letter is plainly suggested by the sharp folding of rock and ore. (See Figure.)

This structure involving sudden changes in the amount and direction of the dip, from horizontal to vertical, would evidently necessitate in the case of underground work, constant changes in the plan of attacking the ore, as well as in the mode of supporting the roof.

The magnetic iron deposits in the Eastern States may also be regarded as true beds, but are far move regular in strike and dip, extending downward at a high angle to an undetermined depth, and appearing more like veins. If folds exist, they are much deeper and more regular than in the deposits under consideration. The Marquette ore deposits are often very thick, 50 feet being not infrequent, which makes ordinary timbering difficult, if not practically impossible; while the Eastern deposits, so far as my observations have extended, are seldom over 20 feet, and average considerable less than that thickness.

The " pinch and shoot" structure, suggesting what are termed "chimneys" or "courses of ore" in some metalliferous mines, and which is very apparent in the New York and New Jersey mines, (practically dividing the ore into pod-shaped masses, the axes of which " pitch " in the planes of stratification in a direction quite different from the dip), has not yet been observed in the Marquette region; but greater depth may reveal it. The intervening barren streaks—" pinches "—where the hanging and foot walls come near together, and which therefore divide the shoots, form excellent supports to the overlying rocks, and give the mine great security, as all who have mined the New Jersey magnetic ores will testify.

The soft schist already mentioned as frequently bedded with the Marquette ores, often constitutes the hanging wall in parts of the mine, but does not possess the requisite strength to make a good roof. It is impossible to support such rock with occasional timbers or pillars, for it will scale off between the supports, demoralizing the men, if not actually endangering their lives. Even when the works reach the solid quartzite, which, as has been stated, is the true overling rock of the ore formation, it is sometimes not safe; particularly near the surface. These facts make open workings a practical necessity at the start, and the great economy of breaking ore from high stopes with heavy charges of powder, induces a continuation of the method even where the rock covering has attained a thickness of many yards, and underground work would seem to be advisable. It is indeed hard to say what thickness of solid rock a Marquette mine-superintendent would hesitate to remove if it covered a large deposit of ore. Forty feet of earth and nearly as many of quartzite (as hard as granite) have been "stripped," and the thickness of rock is daily growing greater as the beds of ore are followed on their underlay in depth.

It may be said, and I do not know but that it is a canon of mining, that all mines which sooner or later have to be wrought underground, should be systematically opened as mines at the start, but this is not Marquette practice; and I have undertaken to describe, and so far as I am justified, defend the methods there employed. It would be difficult to convince our people that having a large deposit of pure ore before them of unknown form and size, covered often by but little earth, and backed by, perhaps, a small amount of money in the company's treasury, it is best to incur the delay and cost, incident to sinking and drifting to open ground, thus already opened by nature and ready to win. Wrought as open quarries, several mines have paid their way from the start, while, had they been opened on a regular system of mining, it would have required an investment of $50,000 in plant and improvements before shipments could have begun, and at least one year's time. Such facts settle such questions with American capitalists,—and with the uncertainties which attend the opening of new mines in new districts, the high rate of interest in this country and uncertainty of tariff legislation regarding iron, it may be a question whether this hand-to-mouth, quick-return, let-the-future-take-care-of-itself view of the question is not in a certain degree defensible.

The appearance of our mines is anything but pleasing. They consist of several (sometimes of ten or more) irregular elongated pits, often very large and generally more or less connected, having usually a general easterly and westerly trend imposed by the strike of the rocks. Everywhere are great piles of waste earth and rock, which are often in the way of the miner, and which in some instances have been handled over three times.

There are two principal advantages in open works. First—the preparatory work is all reduced to the simplest and safest kind of pick-and-shovel, hammer-and-drill, horse-and-cart business, such as can be let to the common run of mine contractors. On the other hand, underground mining involves sinking, drifting, timbering and elaborate machinery, all of which require skilled labor and large investments. In an isolated cold country like Marquette, the *quality* of the labor demanded is an important consideration. The second advantage already mentioned, is the great economy in cost of drilling and explosives which high stopes in open works permit. These elements of cost arc important items in all mining when hard ores are encountered. It is believed that they have been reduced to a minimum in the Marquette mines; holes two inches in diameter are sometimes sunk 22 feet, and 15 feet is common. Such holes are not fired directly with the blasting charge, but are "shook" several times first, that is, fired with small charges, which produce cracks and cavities about the bottom of the hole; when these are large enough to hold a sufficient amount of powder the lifting charge is put in, and the great mass thrown down. Twenty kegs of powder, of 25 pounds each, are sometimes fired at once, and from five to ten kegs is a common charge for a stope-hole.

By this method, five thousand tons of materials have, in some instances, been removed at one blast, and one-third of that amount is quite common at some of the mines. In this way the entire cost for labor of drilling and explosives has been reduced for a single blast to less than three cents per ton. The average cost is of course much greater, being at some of the mines 50 cents per ton of ore for all drilling and all powder consumed in the mine, about one-third of which is for block-holing the large masses thrown down by the stope-holes, which are often so large that they have in turn to be broken by powder. The cost of powder and fuse for the hard-ore mines, it is believed, does not exceed 10 cents per ton. In some of the New York and New Jersey mines which are worked underground I am informed that these items cost much more. In the Persberg mines, Sweden, the drilling and explosives cost 65 cents per ton of ore in 1870.

It may be inferred from the above description, that Marquette iron mining does not differ essentially from ordinary excavation on public works, being work that may be let by the cubic yard or ton to the common run of contractors. Until quite recently this has been very near the truth, the difference being in the skill and care required in separating the ore and rock which are often mixed together in the mine. But these palmy days arc rapidly passing for most of the mines now worked. An increase of water and greater cost of handling incident to increased depth, and, what is still more costly, the increase in thickness of the rock covering, will soon require, in fact docs now require, more expensive plants, different methods, and more skill.

The transition from the present system of quarrying to the future method of underground mining, which will have to be made in this region, will be a critical period, and will present great interest as affording a solution of a mining problem, such as may not yet have been presented anywhere. Attempts at its solution have already been made, but, as has been remarked, very little ore has as yet been extracted at a profit under ground. To recapitulate ; the system adopted will have to meet the case, 1st, of beds of ore, varying, often abruptly, in thickness from 0 to 50 feet. 2d, of beds varying in dip from nearly vertical to horizontal, and passing by a curve of small radius from one inclination to another; 3d, of beds varying in character of the hanging wall from a solid quartzitc, which will stand with ordinary supports, to a soft schist, which can only be kept in place by a continuous support, or actually filling in—"remblais." Again, the axes of the folds are not horizontal, but sometimes " pitch " at angles of 30 degrees or more in the direction of the strike, producing a fourth troublesome feature. Now, when we consider that the dressed ore *is* expected to yield 65 per cent. in the furnace, and is not worth at this time (1870) on the average over $4 per gross ton on the cars at the mine, including royalty, the general character of the problem will be understood.

In New Jersey, with perfect regularity in the dip, better hanging walls, thickness within the limits of easy timbering, cheaper fuel and labor, and ores which break easier than those of Lake Superior, the ores of several well-known mines, I am told, cost fully this amount.

Steam machinery for hoisting and pumping, which has cost from six to not less than fifty thousand dollars has been erected at ten out of the thirteen mines in the region, and one of the exceptions, the Washington, has driven an expensive tunnel in order to do away with the necessity of engines, which has cost as much as a heavy plant of pumping and winding machinery. At the present time (1870) not much more than one-half of the entire ore product of the region is handled by steam, and much less than this proportion of all the material, the balance of this kind of work, being done by horses. From this it may be inferred that while the cost of breaking ore may have been reduced to a minimum, by the system of mining employed, not much can be said in favor of the methods of handling the ore from the miner's hands to the cars. The expensive horse and cart, swing derrick and whim, are in too general use, and the roads over which the loads arc hauled arc often not above criticism as to grades and surface.

In order to more intelligently follow the methods of working the Marquette mines, we must classify the various items of cost under appropriate heads, and assume some absolute cost per gross ton, as near the actual fact as possible, as a basis of comparison of these items with each other, and with other mining regions.

No discussion of the question which leaves out the cost, would possess much practical interest; but, all who have undertaken to obtain such costs for publication, know the difficulty, and will form their own judgment as to the accuracy of what follows. $2.64 per gross ton will be assumed as the entire cost of mining the hard ore and delivering it in the cars ready for shipment; but this sum does not include interest on capital, expense of selling, royalty or mine rent, nor depreciation of the mining property.

Before dismissing the subject of *mine rent* or *royalty*, which does not appear in this estimate, I will make a few remarks. Marquette mines are generally owned and worked by the same parties, hence royalty does not enter directly as an item of cost, but it exists in substance, and may be called *depredation of the mine,* an item in the cost of ore often not sufficiently considered. One of the best organized and successfully operated iron companies in Eastern Pennsylvania place this item at fifty cents per ton of ore. That is to say, every ton of ore sent from a New Jersey mine which they own, is charged with fifty cents over and above its cost, as shown by the mine accounts, and a like sum is credited to the capital stock account or to a sinking fund. This fifty cents stands for the original cost of the ore in the ground, and is all the more real, that it was paid in advance in the price of property and improvements. Any mining company which fails to recognize this principle is doomed some day to serious disappointment. Whoever has had experience with charcoal blast-furnaces, which so rapidly sink their capital by burning up their wood, will be fully alive to the importance of this matter. It is a delusion to suppose that our mines will not eventually be exhausted; iron ores do not grow; a ton shipped from a mine is gone forever, and the property has one ton less remaining, and is therefore worth less money. Continued shipments will eventually exhaust any and all mines. Abandoned pits, in which no ore can be found, now exist at several mines, and in this class arc some pits that two years ago were the best.

The Andover Mine, New Jersey, once presented as good opportunity to break ore, as any pit now worked in the Marquette region ; but about 150,000 tons aggregate product exhausted the mine, and to-day the owners do not know where to find a ton of merchantable ore on the property. I do not wish to be understood as predicting the exhaustion of the whole region; I think Marquette will produce iron as long as that article is wanted. New deposits of rich ore will be found, and leaner ones which now have no value will be worked; the old deposits will be followed deeper; but this implies new mines, the building up of new locations, new railroads, new men, and more capital. What I wish to say is, that unless present holders of average Lake Superior iron mining stocks are receiving fair interest on their investments, and in addition are being paid back the capital they have invested at the rate of not less than fifty cents per ton of ore sold, they are not doing a good business.

Therefore the $2.64 assumed above should be increased by this amount, making it $3.14. Commission for selling, interest and exchange, insurance and expenses of the general office of the company (including salaries), will increase this sum to at least $3.50, which will more truly represent the actual cost per gross ton of ore on ears and sold. This, from the amount assumed before as selling price, leaves fifty cents per ton for interest on all fixed capital invested.*

There may be no better place than in this connection, to speak of another fruitful source of the disappointments which are sometimes experienced by mine stockholders. I refer to those delusive " permanent improvement accounts," better named permanent disappointment accounts, which are too often kept open, and in which are too frequently placed awkward sums, which should properly go to current expenses, and be paid for by the pig-iron, ore, lumber, or whatever

* In exceptional seasons when the demand is far in excess of the supply, like some that have passed since the above was written, the margin is much greater.

is produced. After the necessary real estate is bought, the mining or manufacturing plant built, and the business of production actually commenced, the improvement account should be closed forever. Some kinds of business, in some places, under some managements, may permit an opposite course, but the above is the only safe rule. If in any particular year an extraordinary expenditure is made which is not likely to be repeated, a part of it may properly be held in some open account, in order that it may be distributed over more than one year's product. But this is a different thing from piling up a permanent account under the delusion that the property is enhancing in value.

There are few kinds of business in which there is more danger from this cause than in iron mining; for not only is an iron ore property depreciating from the exhaustion of the ore, but at any time it may be still more depreciated by unfriendly tariff legislation, for which the ironmaster must be prepared.

To return to our subject, the mining work and costs sketched above, amounting to $2.64 may be conveniently classified under the following five heads:

1st. *Dead Work* or all that is preparatory to getting ore. This includes finding the ore, making all roads, shafts, drifts, etc., which will enable the miner to attack it, removing the earth and rock covering, together with such improvements and appliances as may be necessary from time to time for the proper handling of the ore, or conveying it from the miners' hands to the cars. Rock and earth excavation is all done by the cubic yard or fathom, the contractor often finding his own teams. Shafts and drifts are always done by contract. This dead work, according to our estimate, costs 74 cents per ton, equal to 28 per cent, of the whole cost of the ore. I estimate that about 62 cents is for labor, and about 12 cents is for supplies of various kinds.

2d. *Mining proper,* locally termed "breaking ore." This embraces all drilling and blasting, sledging, sorting out rock, and loading the rock and ore into the vehicle which is to carry it away. This labor is almost entirely performed by contract, the contractors being paid from 60 cents to §1.60 per ton of ore, with sometimes an allowance per ton for rock. The contractors find their own powder and fuse, and pay for the use of tools. Such contracts are sometimes let to one man, who hires his own help, but the common way is to give the job to a party of men jointly; a new price is often made each month. In a few instances contractors take long jobs, do their own stripping, breaking the ore and delivering it in the cars. $1.05 is the estimated cost of this part, which is all labor; it equals 40 per cent, of the whole, and is the largest single item. The fact that the cost of this work varies so widely in different parts of the same mine, and in the same part at different times, makes organized strikes difficult. There can be no common grievance, no watchword. One "pair" (two or more men working in common) may be losing money at 75 cents per ton and be disposed to strike, but their neighbors who are receiving S1 in their pit are making money and have no sympathy with the strikers. Usually the unfortunate "pair" stick it out until the end of the month, and then get a better price or go away.

3d. Mining *material* and implements. The items embraced here may be subdivided into explosives, tools, and repairs; the miners' term " mine-costs," embracing them wholly or in part. As has been stated, miners working on contract have to pay their own " mine-costs," which amount is usually from 13 to 17 per cent, of the whole amount they receive for their work. About 31 cents per ton, or 12 per cent. of the whole, is regarded as the cost incurred under this head, 10 cents of which is for labor, chiefly of blacksmiths, and about 21 cents for supplies,

4th. Handling the ore from the miners' hands to the cars, and freeing the mine from water. As has been stated, mining contracts usually go no further than to load the ore in the cart, skip, or bucket. All the costs from this stage to the cars are embraced here.
as well as the *pumping,* which is usually performed by the same machinery that hoists, hence cannot be well separated. Until recently no pumping has been necessary, and the handling has been done by horse and cart. It is estimated that this work cost heretofore over 41 cents per ton, or say 16 per cent, of the whole. About 27 cents of this would be labor, largely of drivers, and 14 cents supplies, in which forage is by far the largest element.

5th, *Local management,* office expenses, taxes, etc. This is not intended to include the selling of ore, nor salaries of officers who do not reside in the mining region. About 12 cents per ton, or less than 5 per cent, of the whole cost, is placed opposite this item, over one-half of which would be for salaries.

DISCUSSION.

MR. RAYMOND remarked that Major Brooks's paper, in its complete and thorough analysis of mining costs, and its recognition of the great truth, that a mine is constantly destroying its own capital, offered a very good model for the study and imitation of engineers. The question of the cash value of a producing mine, is one capitalizing an annuity of limited period; and yet many persons seem to suppose that a rough estimate of costs and profits, guessing at everything, and then dividing by 2, "to be perfectly safe, " and a simple calculation of a sum upon which 10 per cent, dividends could be paid out of the profits so determined, constitute a reliable determination of value. The error is almost universal, of valuing a mine according to the amount it has produced. In fact, the ordinary mining risk is such as fairly to require 40 per cent, annual profit in the Far West, and 30 per cent, in the East. If a mine is not doing as well as that, the stock ought not to be worth par. Exceptions may be made in cases where the assured prospect for the future is so much better as to influence the value of the stock, or where much of the mining risk is removed, as in the case of coal-mines on regular beds, in well-known basins. Here the exact extent and duration of the deposit, and its gross and net value, can be reasonably determined beforehand. But it is remarkable that coal and iron mines, the value of which can be closely ascertained, sell on the whole cheaply, while gold and silver mines, on which the discount for risks should be larger, are generally held at inflated prices. The favorable "general opinions" of experts arc used to bolster up these high valuations. Engineers ought to discourage this, and to insist that their opinions shall not be so misused.

ROLLING VERSUS HAMMERING INGOTS.

BY A. L. TROLLEY, C. E.

IN order to put sufficient *work* on steel ingots for rails, they must be reduced from about 12 inches square. As this cannot be done at one heat, they are first drawn down to about 7 inches square, and then reheated and rolled into rails. This first reduction or " blooming, " is usually done in this country in a 30-inch 3-high rolling-mi11, with movable rolls, so as to get several reductions in each set of grooves. The first of these mills has been running at the Troy Steel-works above a year, with great success. Another at the Cambria Iron-works has been running above six months, and has produced 140 tons of rail blooms from 12-inch ingots in 24 hours. The mill was not then fully employed, the limit of capacity being a single Siemens heating furnace.

The practice is now being introduced of rolling long 12 by 14 inch ingots, instead of short 12 by 12 inch ingots, thus producing three-rail blooms at one rolling, instead of two, and saving largely in labor and fag-ends. As the handling of the piece at the rolls, and indeed its charging and discharging at the furnaces, arc performed by steam power, the large ingot requires no more men than the small one. The capacity of a blooming-mill rolling 3-rail ingots may be safely put at 200 tons per day.

In England, and also at the Pennsylvania Steel-works at Harris-bnrg, the rail ingots arc reduced to blooms by hammering, usually under 10 to 15 ton hammers. The 13-ton hammer at Harrsisburg is a first-class tool and the practice with it is unusually good. Its maximum production is about 75 tons of blooms per day, or much less than half that of a rolling-mill which costs, with its engine, about the same money. A smaller number of men and less skilled and high-priced men arc employed at the rolling-mill. By the use of Mr. Fritz's feeding-tables, the labor at the rolls is reduced to little more than directing the operations of the machinery.

Three-rail ingots cannot be advantageously handled under a hammer.

The impression has heretofore existed among railway men, that the quality of what they call hammered rails is superior to that of rolled rails. The use of the *rails* has not developed this impression so far as can be ascertained. The impression is founded on the fact that *iron* is improved by hammering and that the highest-priced steel—such as tool steel—is hammered rather than rolled.

It is true that the pressure of the hammer is greater and more concentrated than that of the *light rolls usually employed,* and that the hammer may expel more cinder, in the early stages of the *iron* manufacture. The real reason why the hammer is used, in iron-mills, however, is because it will work large and hard puddle balls and piles for which there is no adequate rolling machinery at hand. That rolls are preferred to hammers, even for iron, in the most improved practice, is shown by the introduction of very heavy squeezers instead of hammers, for reducing the large puddle balls of the Bank's furnace.

The hammer certainly increases the density of an iron or a steel bar, as compared with rolling. The rolls crowd the fibres back, as well as towards the centre; the action of the hammer is exclusively towards the centre. This is conspicuously shown in treating large ingots. The velocity of the hammer is greater than that of the periphery of the roll, hence the effect of its impact is greater on the *surface* of the ingot, while that of the rolls is more distributed throughout the thickness of the ingot. It would therefore be supposed that the hammer would *draw* the surface of the ingot so much as to leave concavities in its ends. The rolled bloom is cup-ended, *although* it is more uniformly condensed than the hammered bloom. The result of this must be, and the fact is, that the rolled ingot is less dense; it weighs less per cubic inch, but at the same time it is more uniform in structure. Now this density does not promote toughness in steel, whatever it may do in iron, while uniformity *does* promote toughness, and this is the quality to be most carefully looked after in the steel rail manufacture. Nearly all steel rails are hard enough for waring purposes, and their hardness can be increased by chemical moans, with the greatest uniformity and convenience—indeed the trouble is to sufficiently keep down phosphorus, silicon and other hardening agents.

It is stated that the carbon in hammered steel is chemically combined, while that in rolled steel is graphitic. If this is the fact in regard to rails, it is a strong argument in favor of rolling. As we have just observed, steel-makers, with the irons they have, find difficulty enough in making their rails mild and tough, without being subjected to the additional embarrassment of chemically combined carbon. It is well known that the tool-makers' process of hardening is simply combining the carbon, while *annealing*—that safety process to which boiler-plates and forgings are subjected to give them toughness—consists in simply rendering this carbon graphitic—the same thing that rolling is said to do.

But, in fact, rail-makers are not embarrassed by the hardening process imputed to hammering, because there is no such thing as a hammered rail, or as a structural condition of rail due to hammering. Whatever the condition of carbon in a hammered *bloom,* it is graphitic in the rolled *rail.* The reheating of the bloom, and its subsequent treatment by rolling alone, probably leave the physical condition of the steel substantially the same as if it had been rolled rather than hammered *before* reheating—excepting only the condition before mentioned, due to the character of the pressure—the rolled steel is less dense, and is more uniform. This uniformity is further increased by the fact that the temperature of a rolled ingot is practically the same at each pass, while the hammered ingot is reduced at varying temperatures.

A very large number of experiments have been made, at Troy and Johnstown, on rolled and hammered ingots from the same steel, and although the results confirm the above reasoning, rather than contradict it, the difference in the quality of the rails is not very marked. In fact, a large number of rails rolled direct from 9-inch ingots, are wearing as well, so far (three years), as rails made from cither hammered or rolled 12-inch ingots. In making *complete* tests—tests to destruction—it is unnecessary to say that the size of the ingots experimented on by the hammer and the rolls should be the same. A test in which rolled 9-inch ingots are compared with hammered 12-inch ingots, has no value.

The use of hammers or rolls for blooming seems to resolve itself, then, into a question of cost of product, as it has been impossible to establish, so far, any marked difference in quality—certainly none in favor of hammering.

We have shown that the rolling-mill has over twice the capacity for a given cost, and that it employs less labor. Another advantage of the rolls is, that their collars bold up the corners of the bloom, thus reducing its cracking, and making sounder rails, as well as a larger number of first quality rails from a given number of ingots. Rolled blooms are of exactly uniform cross-section, while hammered blooms must vary considerably. Hence the crop ends of the former may be reduced to a uniform minimum, while a large allowance must always be made in hammering.

USES OF BLAST-FURNACE SLAGS.

BY PROF. T. EGLESTON.

IF *we* may characterize the aim of metallurgists twenty years ago by any one point towards which their efforts were especially directed, we should say it was the idea of adapting "waste products" to some useful purpose, while the energy of to-day seems rather to take the direction of so arranging processes as to have no "waste products. " The iron-master of this decade no longer speaks of the *waste gases* of the blast furnace. The supply of combustible material from this source is a part of the regular working, and is depended upon to such an extent that in many cases it is doubtful whether the iron could be profitably manufactured without its use. This is an economical age, and in large works the same care that looks after the saving and utilizing of material not hitherto available presupposes, as a general thing, skill in the manufacture of the product. There is hardly a point in the whole range of metallurgical detail where more or less successful attempts have not been made to economize, *by* the use of " waste products," and no one thing upon which greater skill has been lavished and so much money spent. The operations are so large, the capital involved so great, that a comparatively small saving will often justify even the abandonment of one process for another, as was the case in the introduction of Patinsonage in place of the costly process of enrichment by Cupellation, and the substitution, recently, in many places in Europe, of the Zinc process for Patinsonage.

In the metallurgy of iron the most cumbersome, expensive, and useless product is the blast-furnace slag. The variety and ingenuity of plans proposed to make use of it, or in some way utilize the heat it absorbs, or even to get rid of it, is only equalled by the persistent want of success which these efforts have, until within a few years, attained. The amount of slag which flows from an ordinary blast furnace in twenty-four hours may be calculated at very nearly twice the production in iron by weight, and five to six times by bulk. The amount of heat absorbed by and radiated from this mass of material, if it could be transformed into horse-power, would make very 5mportant changes in our present methods of manufacture, and materially diminish the cost of the iron. Besides the large amount of heat lost in the slag, it is a constant source of inconvenience, accumulating near the furnace, as a hot viscous mass, difficult to handle, requiring special tools for its removal, and necessitating the investment of a large amount of capital in land on which to pile it, which brings no return of any kind. The labor spent upon this unproductive substance is often equal to the whole of the productive labor of the furnace. Hence the amount of skill lavished first to make use of it and then to get rid of it.

The first attempt, and for a long time the only one to use it was in making roads, for which it was simply broken up by hand, and then used like any other stone. Though in itself excellent road-making material, this form of slag is not well suited for it, and hence, as this is the only use generally known, we find enormous slas-heaps, which are often over one hundred feet high, served by special engines and cars, in the vicinity of many of our blast furnaces. Happy the company who, like the Hudson Iron-works, can use their slags to fill in shallow bays, and thus by an actual production of lands turn all their slags to profitable account.

In some parts of Europe where stone is exceedingly scarce this is the only material for road-making that can be procured in large quantities. Hence, in such countries as Silesia, every effort has been made to make the only material they have as well adapted for the purpose as possible.

The great objection to the use of slags is their brittleness. Hence very early attempts were made to devitrify them at a small cost. This necessitates a cheap fuel, which is generally an exception, and hence the most successful attempts at devitrification have been the accumulation of the slag in large masses, allowing it to cool slowly under considerable pressure. Tin's is the case at Tarnowitz in Silesia, and elsewhere where the ground around the furnaces is incumbered for days together with large accumulations of slag, a foot or eighteen inches in thickness, which are left to cool. This method is necessarily imperfect. Only the lower half of the slag is devitrified, but imperfect as it is it furnishes an excellent material for paving, and the traveller would generally be astonished to learn that the pavement over which he rides is nothing more than an imperfectly devitrified blast-furnace slag. As only a very small portion of the slag can be used in this way, slag-heaps in Silesia would be quite as prominent a feature of the landscape, as they are in the Lehigh Valley, if the furnaces were as numerous. The benefit in this case is on the side of the road-maker rather than on that of the iron manufacturer.

The necessity of having building-stone in certain countries of Europe, where it is very scarce, led to a long series of experiments, which, after a multitude of failures, resulted in the manufacture of a very useful product for certain kinds of construction. These experiments began at a charcoal blast furnace, the slag from which was taken out of the fore-hearth with a ladle, compressed into a mould, and cooled slowly. In order to keep the slag in the hearth from becoming cool it was covered over with charcoal. A small quantity of the powder of the charcoal became mixed with the slag, and effected a partial devitrification in the moulds. The attempt to apply this exceedingly simple process to a coke-furnace failed entirely. The bricks became too porous from the evolution of gases resulting from the admixture of coal-dust. Sand and coke-dust were then substituted, but as the bricks were still fragile they are now annealed in furnaces. This process is applied in Konigshutte in Silesia to the manufacture of building material of which some of the important constructions of the works are built. The slag is run from the furnace into a hemispherical basin on wheels. The bottom of this basin is covered with sand or fine coke-dust to the depth of about 3 centimetres. The wagon is then drawn to the point where the bricks are to be made. The slag and sand are mixed together with a curved iron tool until most of the gases have escaped, and the mass is about the consistency of. dough. It is then drawn with the same tool into a mould with a hinged cover, and punctured several times to let out the gas. The cover, which fits into the mould, is then turned down, and the slag becomes compressed. By the time three or four moulds have been filled, the first slag brick is sufficiently solid to be removed. This is done by raising a clamp, which allows the mould to separate. The red-hot brick is now drawn into a kiln covered over with powdered coal and left to anneal. Each kiln eontains 1000 bricks, and is from three to four days in cooling. Four men can make 500 of these bricks in three hours. The loss in the manufacture from breakage is about 20 per cent. The cost of annealing is about two thalers the 1000. These bricks arc rough on their surfaces, but on account of their larger size do not require more mortar than an ordinary brick. They do not readily absorb moisture, and for that reason are extensively used in the construction of foundations. The pillars supporting the main wind-pipes at Konigshiitte are built of this material. In Silesia these bricks cost 25 per cent, less than ordinary brick.

A brick much inferior to these in every respect is made in the Hartz Mountains out of the lead furnace slags, which are silicates of iron. These are moulded and compressed, and are used for buildings. As the bricks are very brittle, the constructions in which they are used are generally covered with a coat of mortar. The buildings of the immense mechanical preparation works of Clausthal are built of this material.

Mr. Sepulere, a Belgian engineer, was one of the first who successfully transformed the slag into a stone which could be generally used. This he effected by causing the slag-channels to terminate in an excavation whose sides had an inclination of about 30°, and whose capacity varied from a half to ten cubic metres. The very steep inclination of the sides causes the section of the pits to increase very rapidly, and this allows the solid crust, which forms on the surface of the liquid slag, to rise with it without becoming attached. The slag must flow continuously into the excavation, and if, for any cause, there is an interruption, the crust must be raised to allow of the liquid material flowing underneath. In this manner the whole mass of slag in the pit is sure to be all liquid, and will solidify from above and under pressure. After the excavation is full it is left for five to ten days to cool, the only precaution required being to cover the top with ashes or sand to a sufficient depth to prevent the mass from cooling too rapidly. The stone so produced grows hard on exposure to the air. When first made it can be easily broken into any required shape, but after exposure for a period more or less long, it becomes so much harder as to require double the number of tools to work it.

All kinds of slag arc not suitable for this manufacture; those which contain too much lime fall to pieces on exposure. In general, it may be said that they should contain from 38 to 44 per cent, of silica, and that the furnace should be working well.

According to experiments made at the Conservatoire des Arts et Metiers in Paris, this stone, when made from slag while the furnace was running on white iron never became fissured under a pressure of less than 242 k. the square centimetre, and was crushed at a pressure of 886 k. as a minimum. When made from gray iron they do not crush under a pressure of less than 405 k., but they have fissures at a pressure as low as 222 k., or a little less than the white iron slags. This material is, therefore, stronger than the best marble.

One of the Belgian furnaces, which produced 2500 tons of slag in thirty days, made from it 1177 cubic metres of stone. The expense of manufacture was $820. The material sold for $1600, making a profit of $780 in thirty days; 70 per cent, of the slag produced was profitably used. In order to introduce it the price was put 25 per cent, lower than ordinary stone.

In certain parts of Germany, and during the late war in our own country, basalt and certain volcanic rocks were used in the manufacture of glass. But little is wanting in certain blast-furnace slags to make them of the same composition as basalt, and this fact suggested their use in the manufacture of glass. The experiments which were made with slag were so successful that in some parts of Belgium, sonic of the glass-makers have contracted with the blast-furnaces to furnish them a certain amount of slag every week. One furnace, producing 30 tons of cast-iron in 24 hours, that I visited, during the last summer, furnished one clay's run of slag per week to the glass-makers. To prepare it for this use the slag is run out on cast-iron plates, and cooled with water.

Attempts have been made in some parts of Europe to use the heat evolved *by* the slags for domestic purposes. The most simple and the most practical one is the employment of the heat of the slag by the men for cooking, or heating their food already cooked. Attempts have been made to use it for heating the house, near the furnace, by allowing it to run into iron moulds and placing them in a drum, but the expense attendant upon it and the trouble of constantly changing the slags probably cost more than the saving of fuel, and undoubtedly kept the unfortunate persons who were subject to this expensive economy in an uncomfortable state both of mind and body.

Mr. Minary, director of the Franche Comte Iron Company, conceived the idea of using the slags by granulating them as they flow from the furnace. To do this the trough through which the slags run is made to terminate in a stream of water, which has sufficient velocity to carry the. grains of slag into a pit prepared for it, from which it is charged into wagons, without further expense, by an endless chain with buckets. The engine for this purpose is run by the gases of the furnace, and requires scarcely a horse-power. In these works, which consist of five blast-furnaces, each producing 20 tons in 24 hours, the introduction of this improvement resulted in a saving of the wages of 20 men occupied in charging the slags, and of 5 blacksmiths who repaired their tools. Much larger wagons were brought to the furnace, which, *as* the granulated slag can be discharged at any height by the endless chain, were for the most part railroad cars. No one is now employed to look after the slags, as the whole of the work can be done by the founder and his assistant. The saving thus effected amounts to 5 to 6000 francs a year, while the cost of granulation does not exceed $0.07 the ton of slag. This rendered the slag portable by the ordinary methods of transportation, did away with all the special tools formerly used, and reduced the labor of getting rid of the slags to almost nothing.

The granulated slag was first" used as gravel in the works and to make the bed of the casting-house. It was found that from such a casting-bed the pigs came out clean and bright, and were preferred by the puddlers even to those cast in iron moulds. This method of using the slag is now of almost universal application in the Siegen district in Prussia, where most of the furnaces run on Spiegel. The grains of iron which the slag contains were formerly separated by stamping. They are now separated by granulation, and are caught in a receptacle for the purpose, while the light porous slag is carried off by the water, thus avoiding the expense of crushing and washing, to which all the furnaces were subjected before the method of granulation was introduced. It is also extensively used in some parts of France and Belgium.

The extremely clean pigs made in this casting-bed of granulated slag suggested its further use. The fine dust was sifted out and used to sand the moulds for fine castings. It was found that such eastings were much more easily cleaned, and that the iron was quite bright. The result was a better and cleaner easting and considerable saving in the item of cleaning them.

As these uses consumed but a very small part of the slag, it was offered as ballast to the railroad companies on condition that they should remove it themselves. As the size of the grain can be easily regulated by the velocity and direction of the water, the railroad companies were not slow to avail themselves of these conditions, and soon were glad to pay for it, thus furnishing to the furnace company a revenue from what had previously been a source of expense. The granulated slag weighs 1200 k. the cubic metre. Its cost in France, where it is used, is less than half the price of sand. It is exceedingly porous, so that it retains very little moisture and yet packs sufficiently; the result is, that it will bear transportation long distances, as it is much cheaper than ordinary gravel and better adapted to the purpose of ballast.

The substitution of the granulated slag for sand in construction suggested itself at the outset, and its use has been attended with excellent results. It was found that some of the slag mortar which had been left over after some repairs where it had been used, became solid after a short time; this suggested its use in the preparation of concrete, and in the construction of foundation walls. A number of experiments were made to ascertain the exact nature of the sand, and it was found that 100 grammes of granulated slag digested in 100 grammes of water containing 0.15 g. of lime in solution absorbed in 48 hours 0.052 g., the water at the end of this time retaining only 0.098g. of lime in solution.

The manufacture of bricks from this material immediately suggested itself. Persons who have been in the habit of travelling on the Rhine will probably have noticed in the vicinity of Neuwied long rows of white bricks of all shapes, pipes, and more or less complicated pieces for building purposes, piled drying in the sun. This material is manufactured from a granulated pumice, which is found here at a depth of a few inches from the surface. It is simply mixed with lime, pressed and sun-dried. It is very extensively used on the Rhine and in its vicinity. It is of this material that the interior arch of the roof of Cologne Cathedral is said to be constructed. This pumice resembles the granulated slag. The proprietors of the Georg-Marien Hutte, in Hanover, adopting the suggestion, commenced the manufacture of this kind of brick from slag, and are so well satisfied with it, that they use it in the place of bricks for the construction of their buildings. The bricks there, at the time of my visit, were made at some disadvantage with imperfect machinery, yet they cost much less than ordinary brick. Once out of the machine the bricks are simply sun-dried, and can be very quickly used in construction. They give a light, cheerful air to the buildings, and make a warm and exceedingly comfortable house at a very small cost. It is remarkable what can be done when the necessity exists. I saw at Kreutznach on the Rhine, and in the Siegen district, bricks made from ordinary coal ashes mixed with lime and sun-dried, which had stood during several years of exposure with no sign of deterioration. The manufacturer assured me that there were seven or eight large establishments for the manufacture of this coal-ash brick in Germany.

In some parts of Europe there is a demand for bricks covered with an enamelled surface. By coating the surface of the unburned brick with granulated slag and then burning it, out of the direct contact of the coal, it was found to produce an enamel of different colors varying with the composition of the slag; and it is suggested that such bricks as these can be made without any extra cost, by simply replacing the ordinary sand with which the men cover the tools to prevent the adherence of the clay, with the granulated slag sand. It might be used to advantage in the manufacture of tiles, drain-pipes, and coarse pottery generally.

By mixing a certain proportion of this granulated sand with clay, it was found that the articles so manufactured were capable of undergoing sudden changes of temperature without breaking. This suggested the use of a certain amount of the artificial sand in the manufacture of firebricks; and after a certain number of preliminary assays in a blacksmith's forge, a furnace for melting brass was constructed, in making the firebricks for which, the calcined sand was replaced by granulated slag. These bricks were quite as serviceable as any others, and underwent no alteration after three months' trial. It is proposed now, after a sufficient number of assays shall have been made, to use this material in the manufacture of bricks for the puddling furnace.

Another application of the granulated slag is its use for agricultural purposes. The important part which carbonic acid plays in rendering soluble the different mineral substances which plants require for their growth is well known. It was found that by digesting 100 grammes of granulated slag in water charged with carbonic acid, for a period of forty-eight hours, 1.6 g. had been disolved. This renders it probable that it can be very profitably used on calcareous soils, while the large quantity of lime contained renders it likely that it will prove equally serviceable on silicious soils. The very fine state of division to which it may be reduced at a very small cost is favorable to its decomposition in the soil.

Blast furnace slags gelatinize in acids, and they arc, therefore, very suitable for the manufacture of cement. Pelonse and Fremy, in the last edition of their work on general chemistry, cite them as being eminently fit for tin's purpose. The possibility of having them in such form as granulated slag reduces the price of the pulverized material to a sum so small, that in certain parts of Germany an artificial cement, equal in every respect to the best Portland cement, is manufactured at a price so low as to yield a large profit, and yet very much undersell it. Very large works for the manufacture of this artificial cement are, during this year, to be constructed, on the results of experiments, lasting over several years, at one of the large German iron-works.

Considerable attention has been paid in Belgium and Germany to the use of the slags for the manufacture of chemical products. These were first salts of alumina, then salts of lime *as* an incidental product, and lately the use of the silica extracted for the manufacture of soluble glass. This of course necessitates the location of the blast-furnaces at some point near a large acid manufactory. It does not seem likely that this method will ever be used on a large scale in this country, where material containing a much larger percentage of these substances can be had almost as cheaply as the granulated slag, which must, of course, be used to bring the manufacture of chemicals even within reach of probable profit.

In certain conditions of the furnace the slag is spun by the blast into fine fibres, and makes a substance which is sometimes called " furnace wool." This material is a very bad conductor of heat, and it has recently been proposed to use it as packing, to prevent loss of heat about boilers, etc.

I have thus rapidly sketched some of the uses to which this hitherto worse than useless material may be put. But few of these are likely to find any application in this country. The manufacture of paving-stone where good material for that purpose is wanting may be carried on successfully. It requires but little care, but the slags must be of very nearly constant composition, and must not change their form after cooling. The material when properly made wears well, and has been laid in some of the cities of Europe under severe tests for several years. I have a number of such blocks in the metallurgical collection of the School of Mines, taken up after seven years' use, at my request, from the streets of one of the largest cities in Europe.

The manufacture of the granulated slag bricks, when wood for building purposes is cheap, is not likely to come into use. But in every case where brick or stone is to be used, it is cheaper and preferable, and the manufacture once started, it is more than likely that if such bricks will stand our severe climate, and there seems no reason why they should not wear here, as well as in the large establishments where I saw them used, they will be adopted for these constructions. The use of the slag in the place of sand will follow as a matter of course when it is granulated, and also its use for agricultural purposes.

The most valuable of all the uses, however, is that of cement. I have seen cement equal to any of the best Portland cement made at a very small cost, and this from any slag, no matter how the composition varies. The great advantage of having a suitable substance for the manufacture of cement, in such a condition that at very small cost it can be reduced to an impalpable powder, is apparent. This manufacture of cement is not to be confounded with the adulteration of cement by slag, which is said to be carried on, on a large scale, in England. The slag, before it is manufactured, will of course deteriorate the value of the cement with which it is mixed, though it is a better adulteration than ordinary sand, and may perhaps be honestly undertaken in the belief that the pulverized slag alone has some of the properties of cement. The construction of a large manufactory, after several years' experiment, in one of the largest works of Germany, seems to be a guarantee that we may hereafter use cement in construction more freely, and be able to procure at a small cost a better article, than we now have.

NEW YORK MEETING,

MAY, 1872.

THE METALLURGICAL VALUE OF THE LIGNITES OF THE FAR WEST.

BY A. ELLERS, M.E.

No one who has visited our Western mining districts, and studied the economical part of the beneficiation of the ores occurring all over that vast extent of country, can underrate the high importance of the above subject.

By far the larger number of the districts which contain smelting ores, *i. c.*, argentiferous and auriferous lead, or copper ores, are situated in the Great Basin, that great plateau between the Rocky Mountains on the east, and the Sierra Nevada on the west, almost the whole of which is comprised at present in the boundaries of Nevada, Utah, and part of Arizona.

This region is essentially a barren country. The extreme dryness of the atmosphere permits but a scanty vegetation in the plains; and even in the detached mountain-chains running through it—generally from X. to S., or from N. W. to S. E.—there are no trees found except dwarfed pines and mahogany, at the head of sheltered ravines, and a few cottonwoods and willows, which fringe the insignificant streams, before the water sinks in the arid plains.

Nearly all the mountain-chains in this region are rich in silver ores. That class of these ores which is adapted to amalgamation, and rich in silver, has been worked with profit for more than ten years. But before the advent of the transcontinental railways, mining was restricted to these ores alone, and the consumption of fuel could be met with the scanty supply of forest trees in the immediate vicinity of the mining districts. Since, however, the Union and Central Pacific Railroads have brought the Great Basin nearer to the commercial centres of the East and the Pacific coast, thus reducing the expenses of freight and labor materially, other silver deposits, containing poorer ores in greater abundance, have been rapidly taken up and worked. During the last year this industry has so expanded, that the State of Nevada alone has been able to show a production of over $22,000,000 in silver. But not alone are the poorer grades of amalgamating ores now worked profitably, aided, as the metallurgical process is, by such excellent inventions as that of the Stetefeldt and the Bruckner roasting-furnaces, but the working of smelting ores has also been largely entered into. If I say largely, I do not only mean to say, that smelting works are now scattered widely over the Great Basin, but that some of these conduct their operations on a really grand scale. In Eureka, Nevada, for instance, there are twelve furnaces in operation, producing, during the last year, 5665.5 tons of base bullion, worth $2,035,588, although only a small part of them ran regularly. Four of the Eureka furnaces have each a capacity of from 35 to 40 tons of ore per day. Three of these belong to the Eureka Consolidated Company, who have also two smaller furnaces. Nearly throughout the year this company have kept four furnaces running at a time, and one idle, and the daily consumption was 120 to 140 tons of ore and 4000 bushels of charcoal. At this rate of smelting, the wood for ten miles around Eureka has been used up in a little over a year, which is not a strange statement, when we consider, what I said before, that there is very little wood in these regions anyway. Thus the question of fuel becomes at once a very important one, for the price of 33 cents per bushel of coal, which is now paid at the works, cannot rise much without threatening the very life of the industry.

In Utah, where over 20 furnaces were built and had been partly in operation, in the fall of last year, some of the works have been compelled to pay as high as 30 cents per bushel for their charcoal, and very few are so favorably located as to get their coal for less than 18 cents per bushel. Many more smelting works have been erected since the time spoken of, and the addition of every one of them must inevitably tend to raise the price of fuel. Even the most fortunate ones, those located high up in the mountains, where timber is comparatively plenty, cannot hope to escape, in the next few years, the danger of an enormous rise in the cost of wood and charcoal.

And almost every smelting and amalgamating works in the Great Basin, finds itself in precisely the same position. While the masses of poor ores are growing on their hands, fuel has a continual upward tendency.

Now there are two means, by the combination of which this threatening danger can be averted. The first is the building up of a network of narrow-gauge railroads along the principal valleys, which will connect the mining districts with the Central Pacific Railroad ; and the second is the employment of the vast stores of lignites occurring in the Rocky Mountain region, for metallurgical purposes. The utilization of this coal for the purpose named, has not yet been attempted successfully, and I propose, therefore, to-night, to say a few words on this subject.

According to a late lecture of Professor Newberry, these lignites underlie not less than 50,000 square miles in the Great Basin, and along both flanks of the Rocky Mountains. The principal beds now opened and wrought, I have had the good fortune to visit during the last summer. The mines arc located at Carbon, Rock Springs, and Evanston, all three stations on the Union Pacific Railroad, and along the eastern slope of the Rocky Mountains in Colorado. The coal in these localities, though from different beds, hardly varies in external appearance; but analysis has established a somewhat differing composition. It has a black color, resinous lustre, a brown streak, and is very compact, the wood-structure, which is found intact in so many lignites, being almost totally obliterated.

The Carbon seam, 140 miles west of Cheyenne, is 8 to 10 feet thick, and had been extensively worked for over a year, when the unfortunate fire broke out in the latter part of 1870, which caused the whole mine to cave in. At the time of my visit, in the summer of 1871, work was progressing rapidly to reopen the mine, and regular operations have since been resumed. The coal in this bed is distinguished from that in the other beds by many small patches of resinous matter, very similar in appearance to amber. An analysis of this coal, furnished me by Mr. Wardell, the Superintendent of the Wyoming Coal and Mining Company, gives: water 6.80, ash 8.00, volatile matter 35.48, fixed carbon 49.72.

The Rock Springs seam is opened in the midst of the Bitter Creek Desert. It is 10 to 12 feet thick, and a smaller seam lies close above it. This coal contains also some resinous matter, but not so much as the foregoing. The analysis shows: water 7.00, ash 1.73, volatile matter 36.81, fixed carbon 54.46,

The Evanston seam is by far the largest. It is from 22 to 26 feet thick, but the coal is not as good as that of the last locality. According to analysis it contains: water 8.58, ash 6.30, volatile matter 35.22, and carbon 49.90. This bed presents also the great disadvantage in mining it, that innumerable joints ran through it at right angles to the strike and dip, undoubtedly resulting from great pressure, and that the coal is very hard and brittle, so that in undermining only slow headway can be made, and a very large proportion of waste results.

In regard to the Colorado beds, now open, I cannot give any details, as I was prevented from visiting the mines.

The coal-mines along the Union Pacific Railroad have furnished a considerable product since they were first opened in 1868, viz.:

There were mined by the Wyoming Coal and Mining Company:

In 1868,..	tons,	8,755
" 1869,..	"	54,723
" 1870,..	"	84,356
" 1871,..	"	93,348
Total..		241,182 tons.

By the Rocky Mountain Coal and Iron Company:

In 1869,...	tons,	2,437
" 1870..	"	18,187
" 1871,...	"	53,869
Total, ...		74,529
Altogether, by these two companies, up to the end of 1871, ...		315,711 tons.

The capacity of the mines of the Rocky Mountain Coal and Iron Company has been much increased lately, so that in the first three months of 1872 this company has been able to mine and ship 24,933 tons.

Almost all this coal has been used up by the two great railroad companies, the Union Pacific and the Central Pacific, the quantities shipped to San Francisco and other points being insignificant.

Here, then, is an almost inexhaustible source of supply for the pressing wants of the metallurgical works of the Great Basin and the Pacific States and Territories generally.

But if you suggest the use of these lignites for metallurgical purposes to the superintendents of works in those regions, you receive the unanimous answer, that they are not fit to be employed for the production of high temperatures. You are told that the main difficulty in using the coal is the fact, that it breaks into small pieces as soon as it is exposed to the. heat; that in the fire-box of the reverberatory the draft cannot after that penetrate it, and that in the frequent stirrings which are necessary, the small pieces fall through the grate half burned, while, on account of the frequent opening of the fire-doors for the purpose of stirring the fire, a great part of the heat produced is lost. In the blast furnace, it is claimed, the blast cannot penetrate the fine coal and ore, and thus the necessary temperature is unattainable.

Such and similar opinions, in regard to this coal, arc held by almost every one connected with mining and reduction in the Far West. It is considered a settled affair, that this coal cannot be used to advantage in metallurgical operations.

Now, let *us* see whether this is really the case; and to do this, we must first examine the experiments by means of which people have arrived at such a conclusion.

As to the experiments for the use of this coal in reverberatories, there are two unsuccessful ones on record, one in Colorado, the other in Utah. In both cases, the grate used in the. common fire-box was the horizontal grate, and the supply of air was provided by the draft of the chimney only. In both cases the coal broke up into small pieces, and could not be burned rapidly enough to produce the required temperature.

In blast furnaces these lignites have been frequently tried in different localities in the West, But no smelting temperatures could be attained, and the furnaces would come near chilling. This effect was also rightly attributed to the cracking and breaking up of the coal, and its use in blast furnaces in the raw state is now virtually given up. I should mention here that the blowing engines used in the West are ventilators, with which you can produce no pressure, and Root's blower, with which you can reach a very slight one.

Then it was proposed to first coke the coal. To look at the analyses of these coals, there appears to be no good reason why it should not be possible to make good coke of them. But it is the unanimous verdict of everybody, who has tried the experiment, that no serviceable coke for smelting purposes can be produced from them. Specimens which I saw last summer at various places along the Union Pacific Railroad, are certainly not calculated to encourage the idea, that the existence of the lignites in this region is a guarantee for the perpetuity of the mining industry in that barren country. The coke is not at all coherent, in fact so soft, that a slight pressure of the hand crumbles it into a thousand fragments. How could such material resist the pressure of the superincumbent mass in a blast furnace? It is evident that it could not be used at all, for the powdered mass would give the blast less chance to penetrate than the raw coal.

It would seem, then, at first sight, that the existence of these lignites brings no relief to a threatened industry. At least this appears to be the conviction of the majority out West, and we do not now hear of further experiments.

Yet what have those already made proved ? They have proved that, under the conditions given in the various trials, the Rocky Mountain lignites cannot be used to advantage in metallurgy, and nothing more.

But there is a great number of devices in modern metallurgy, by which this fuel can be made to do effectual duty. I do not intend to discuss these at length this evening, but I wish to point out a few ways in which I am confident the desired end may be easily reached.

As to using this lignite in its raw state in the common fire-box and on the common horizontal grate with natural draft only, it might have been expected that a material containing 8 per cent, of hygro-. scopic, and certainly from 12 to 20 per cent, of chemically bound water, would fall to pieces, and thus render the production of a high heat impossible, especially as so much heat is inevitably consumed in converting the water into steam. On the locomotives of the railroads, where no very high temperature is necessary, a sufficiently rapid combustion cannot be reached except through the increased draft by means of the exhaust; and even with this improvement the engineers on the Union and Central Pacific Railroads complain continually about the difficulty of keeping up steam.

But the whole difficulty can be overcome, as far as reverberatories are concerned, by using this coal in gas-generators instead of in the common fireplace, and by doing the metallurgical work with gaseous fuel instead of the solid. I could adduce numerous examples where lignites, far inferior to those of the Rocky Mountains, are used to great advantage in this way, and some, where even the high temperatures necessary in iron-works are thus produced. According to Tunner, gases from good lignites are capable of producing a temperature as high as 2600° C.

The lignites of the West are eminently fitted for use in gas-generators ; for the very fact that they break up into small pieces when exposed to the heat, is an advantage, because it will be much the easiest this way to convert *all* the carbonic acid formed in the lower part of the generator into carbonic oxide, as a very large surface of glowing carbon is thus presented. They arc *not* bituminous, and their contents in ash are so small that they will not interfere. It may be, indeed, necessary, and it is certainly highly advantageous, to use a blast under the grate in order to further a rapid development of the gases, but this has also the advantage that the danger of explosions will be lessened. It is my opinion that generators, with stair-grates and under-blast, will be found the most advantageous, and if still higher temperatures than can be produced by this means should be required, an increase can easily be obtained by using hot wind, both under the grate and for the combustion of the gases.

But the use of the lignites in blast furnaces is of far higher impor- tance to the Western mining districts than that in reverberatories. Experiments so far have proved unsuccessful—principally. I am sure, because with the blowing engines in use the required pressure could not be attained. To burn that material in the blast. furnace, cylinder-blasts are required, and perhaps it would also be necessary to close the tops of the furnaces, in order to smelt under a high pres-snre, which may be regulated by the dumper in the flue. The ex-traordinary results thus attained, in producing high temperatures, by Bessemer, are too new, to require recalling. Nothing of this kind has, however, yet been tried in the West, but I hope that during the present year this subject will be thoroughly investigated.

The coke produced from the lignites, by the simple method em-ployed, is, as I have said before, not fit for the blast furnace. Bat the coal used was, as far as I am aware, of the inferior kind occur-ring in Colorado, and in the Wahsatch, near Coalville. The Rock Springs coal, which is by far the best lignite, has not been tried. And if, instead of trying to coke this material in imperfectly con-structed beehive ovens and in pits, more perfect apparatus, like the Belgian oven or Appolt's oven, had been used, I think the result, even with the poorer qualities of Rocky Mountain lignite, would have been more encouraging. The Rock Springs coal, I am confi-dent, will make coke in good apparatus, and if it should not be quite as firm as required for the blast furnace, its hardness might be increased according to experiments, which I learn, have been made in the West several years ago, by coking it under pressure. To produce this pressure in the coking ovens, the escape of the gases need only be regulated; and the ovens themselves must be con-structed with the special view of resisting a pressure from within. Success in this direction would, of course, be of the atmost moment; for, even if we assume as a settled fact that the lignites can be used in the blast furnace, with the proper blowing machinery, in their raw state, their high percentage in water will always be fatal to the production of very high temperatures, and their maintenance. It is, besides, much more agreeable and economical to use coarse fuel than fine tuff, as every smelter well knows.

Finally, I wish to draw your attention to the importance which these lignite beds have in regard to the vast magnetic iron ore deposits near Laramie, and the hematites of Rawlins. The latter arc very pure and rich in iron, and the former also contain nothing deleterious, except a little sulphur, the precise amount of which I have forgotten. If a method is found in which good coke can be made from the coal, there is, of course, nothing in the way of the railroad companies of making their own rails; but if this should not be the ease, it seems to me highly desirable that the late experiments of Siemens and Ponsard, for the purpose of making wrought-iron and steel directly from the ore, and so avoiding the blast furnace, should be continued with a special view to the utilization of the iron ores and lignites of the Far West. It is true that the. respective means employed by these two gentlemen though technically successful, have not been so economically. There are, however, at the present time, experiments going on in this country with apparatus different from from used by the English and French engineers, which are very likely to solve this problem favorably, it being the special object of these experiments to produce large quantities of iron in a given time, and with the greatest possible economy in fuel. *At* a future meeting of the Institute, I hope to be able to lay the results of these experiments before yon.

DISCUSSION.

MR. PECHIN said that the Johnstown Iron Company some years ago tried to make coke in beehive ovens from a four-foot vein of coal; but the coal was friable, the amounts of pyrites and slate enormous, and the result was that the coal was not even heated through. By washing their coal and using Belgian coke ovens they made coke of excellent quality, and have now put up washing-works. He asked if similar operations would not succeed in the West.

MR. BRITTON had some knowledge of the lignite of Arkansas; traced it over some square miles above and below Camden, and along the Ouachita River, and had seen the same in limited quantity in Mississippi and Louisiana, and heard of it in Texas. The seams in Arkansas were some of them six feet thick, lying nearly horizontal, and in places cropping out from the hills. When first mined it was dark, nearly black, but after exposure to a drying atmosphere soon got lighter, and became friable, and when in such condition could be easily ignited. A pile of it, of more than 1000 tons, had been accidentally set fire to by the emptyings of a pipe of one of the miners, and quickly burnt, leaving behind only a light, somewhat bulky ash, which, tested between the teeth, was found to be almost wholly free from sand or grit. When burnt in a stove with a strong draft the flame would heat the pipe ten feet high. He had roughly analyzed it, and found some 20 per cent, of water, and as much as 14 per cent, of crude oleaginous matter, which congealed at about 80° F.; thought it would not answer to transport for fuel, though he believed it could be utilized in the Siemens regenerative furnace. It would not coke.

He judged from his analysis that it was identical with some of the lignites of the Far West. Both contained, variously disseminated, a yellowish, resinous substance, sometimes called mineral amber; some pieces of which, larger than peas, he had distilled, and obtained as the product an oil similar to what he found in the lignite.

MR. RAYMOND thought, from the description, that this coal was quite different from the lignites of the West. He had seen coke made in Utah and Wyoming; it was not good, lacking the lustre, and a certain degree of firmness.

MR. ROTH WELL asked for statistics of coal-washing.

MR. PECHIN replied that the cost of a machine for working many tons daily was about §3000, and that the operation, being altogether mechanical, must be very cheap. The coke from washed coal, though not equal to the best Connellsville coke, was very good indeed. The Belgian coke-ovens were 2 1/2 feet wide, 5 feet high, and 20 feet long.

PROF. BLAKE thought the Belgian oven would succeed, and, observing that pressure as well as heat entered into the process of meta-. morphizing coal, asked if pressure did not have something to do with coke-making.

A discussion arising on Rhode Island coal, Prof. Blake said he had used it in the New Jersey Zinc Works for mixing with the ore, but it was a failure.

MR. NEWTON said it is now used in various manufacturing works in Providence, and the mines are giving some coal.

MR. DADDOW thought there was no true coal west of Omaha, but there being coal at Fort Dodge, Iowa, of exceptionably good quality, he was of opinion that the Eastern beds came up to the surface there.

MR. PECHIN did not think the Fort Dodge vein true coal. When he saw it there was a three-foot vein opened, above it another seven-foot vein, and above that a two-and-a-half-foot vein of cannel had been discovered. The coal seemed to be semibituminous, and spotted with lignite.

MR. DADDOW repeated his opinion that the Fort Dodge field was an outlying basin of true coal.

THE PRESIDENT said that though the geological horizons which we have East may continue West, it is not necessarily a consequence that the coal-beds do also. There is nothing which should lead us to suppose that, because the Eastern strata dip toward the West, we shall find them coming up again in any place. In reference to Western coals we cannot talk about the sintering or fusion of carbon. It has never been done even by the greatest effort. Nevertheless coke has an appearance which indicates that the coal has been softened or melted. It is not merely the skeleton of the coal, but a skeleton *plus* sintering. There is good ground for believing that high temperature is important, more important than high pressure in coking light coals. In the West there is a great variety of coal, semianthracite in New Mexico, and good coal in Southern Utah. When we consider the cost of bringing charcoal 500 miles, and carting it 10 or 12 miles, added to the first cost of 25 cents for 15 to 20 pounds, we see how important the utilization of Western coal is.

INDIANA BLOCK COAL IN COMPETITION WITH RIVAL FUELS.

BY JOHN S. ALEXANDER.

DURING the past few years the block coal of Indiana has been talked about and written upon to such an extent, that almost every one at all interested in such subjects, has been made acquainted with the area and geographical position of the field, the quality and peculiar properties of the coal, the thickness of the veins, the manner of mining, etc. The writer, therefore, taking for granted that to those present all this is familiar ground, desires more especially to call attention to the position this coal takes in the market, and at those points of consumption where it is brought in direct competition with rival fuels.

Chicago, thus far, has been the chief consumer of Indiana block coal, the distance from the mines at Brazil, *via* Terre Haute and the newly opened Chicago, Danville and Vincennes Railroad, being 203 miles. This distance will, however, be considerably reduced by the opening of the Indiana North and South Railroad, now in course of construction.

In the blast furnaces, rolling-mills, and Bessemer steel-works recently erected in or near Chicago, an opportunity has been offered to give this new fuel a thorough and severe test, and the almost unanimous opinion of all who have given it a trial is, that it will eventually displace Brier Hill coal in that market, as it has been found equally to be relied upon, whether in the furnace or rolling-mill, and can be supplied with more regularity and at a much lower price. The greatest iron manufacturer in the West, after witnessing its behavior in the blast furnace, unhesitatingly pronounced it the best iron-smelting coal in the United States. The sincerity of this opinion is evidenced by the fact that he is now one of the very large consumers in Chicago.

The old Carondelet furnace, and the two large furnaces of the Vulcan Iron-works at Carondelet, near St. Louis, are now using Indiana block coal, one mining firm at Brazil having a contract for furnishing these furnaces with 150 tons per diem. The distance by rail from the mines at Brazil to East St. Louis, on the Illinois side of the river, is 185 miles, which, being a shorter distance, gives St. Louis an advantage over Chicago in freight.

The St. Louis iron-men have persistently endeavored to use Big Muddy, or Grand Tower coal, to the exclusion of the Brazil coal, and last fall one large consumer asked to be released from exceedingly favorable contracts made at Brazil, in order to use Big Muddy coal, which, it is claimed, can be supplied more cheaply; within a few months, however, the Brazil contracts have been renewed, and it is evident that Indiana block coal now occupies a better position in St. Louis than ever before.

In conversation with the superintendents of these furnaces, the writer found them prepared to admit that they preferred the block coal to any fuel they had yet tried, but gave, as the chief objection to its use, the irregular supply, on account of inadequate and badly managed railway transportation. This difficulty, in time, will doubtless be remedied; nevertheless it is the opinion of those who have examined the subject that St. Louis will be more economically and conveniently supplied from the southern portion of the Indiana coal-fields, from which locality the projected Indiana Mineral Railway will, when in operation, be able to place superior block coal upon the Ohio River at a point 128 miles below the Ohio Falls, at Louisville, by less than 15 miles of railway transportation. The distance from this point to Carondelet, by water, is 413 miles, which can be accomplished at a comparatively low cost.

The two ably and successfully managed furnaces of the Vulcan Iron-works at Carondelet arc now producing, by the use of block coal, pig-iron of a very superior quality, equal to any manufactured in the United States, for Bessemer steel purposes. These furnaces arc 60 feet in height, and the diameter at the boshes is 14 feet. Each is provided with a bell top, and the gas evolved by the combustion of the fuel is more than sufficient to heat the boilers and the blast ; the temperature of the blast is 750°, and the pressure at the tuyeres is two and a half pounds. These figures were furnished by Mr. D. E. Garrison, Secretary of the Vulcan Iron-works. The yield of these furnaces is very large, the writer having scon an eight-hour •cast made at furnace No. 2 which reached 18 tons, and the product of this furnace for the twenty-four hours preceding his visit was reported by the superintendent, Mr. J. P. Withrow, to have been 47 tons of No. 1 foundry pig; this large yield being due, of course, to the use of 66 per cent. Iron Mountain ore.

The five successfully operated furnaces at or near Brazil, and the one at Terre Haute, add their testimony to the favorable reputation Indiana block coal has acquired as a reducing agent, at Chicago and St. Louis.

According to the analysis of Prof. E. T. Cox, the State Geologist of Indiana, No. 2 pig-iron, made at the old Brazil furnace, contains—

Silicon,	1.770
Carbon, combined,	0.700
" graphitic,	2.200
Phosphorus,	0.076
Sulphur,	slight trace
Iron, by difference,	95.254
	100.000

A recent analysis of No. 1 pig, from the same furnace, shows a large increase of both combined and graphitic carbon; the phosphorus, however, is reduced to the merest trace. Both these specimens were made from Iron Mountain ores. The fuel charge, in furnaces using Iron Mountain magnetic ores and Indiana block coal, is 2 1/4 tons of 2000 pounds, the temperature of the blast usually ranging from 650° to 800° Fahr. It is confidently believed, however, that, by increasing the size of the furnace and raising the temperature of the blast to the high points reached elsewhere, 4000 pounds of this fuel will be ample for the production of a ton of 2268 pounds of No. 1 foundry pig.

The Staab coal of Spencer County, Ind.—which in the opinion of Prof. J. W. Foster is the finest block coal yet discovered in the Indiana series—from its extreme hardness and density and its remarkable freedom from deleterious substances—the sulphur in its composition being but 0.93 and 0.97, according to Booth & Garrett of Philadelphia, and the phosphoric acid but 0.3 per cent., according to Delafontainc of Chicago—would, no doubt, prove peculiarly valuable as a fuel for furnaces of a great cubical capacity. By the use of such a fuel, one of the great advantages of large furnaces—the increased carbonization of the product—would be obtained without the, to some extent, corresponding disadvantages of an increased absorption of sulphur and phosphorus, during the necessarily long contact of the iron with the fuel.

At the Vulcan furnace, at Carondelet, where block coal from the Coal Brook mines, near Brazil, has been, and is now largely used, it is found advantageous to mix Connellsville coke with th block coal, this mixture being more easily managed in the furnace than the coal alone; it is not claimed, however, that the product is thereby improved. In the Brazil region, the expense of obtaining coke interferes with its general use in connection with block coal, although it has been tried to some extent, and with success, so far as the working; of the furnace is concerned.

In the different rolling-mills located at Indianapolis, Ind., Decatur and Chicago, 111., the puddlers who have tried it, all pronounce themselves better pleased with Indiana block coal than any fuel they use, claiming that the time and labor expended is less, and the quality of the iron superior. The rolling-mills, of which a large number have been erected throughout the West, are among the best customers the Brazil operators have upon their books.

The statistics of the American Iron and Steel Association show that, in 1871, the mills of Illinois rolled 40,026 tons of rails, of which 2800 tons were steel, and re-rolled 51,152 tons, making a total production of 91,178 tons, which places Illinois next to Pennsylvania in the manufacture of railway bars.

Although the more interesting to the scientist, the demand for this coal for the purposes of metallurgy has, thus far, been secondary to the requirements of railroad companies and manufacturers, who consume it largely as a steam generator.

Western railroad companies have, heretofore, as a general thing, used wood in their engines, the use of which is not only expensive upon the prairies, but compels long and frequent delays at wooding stations, and besides, docs not produce the economical results which follow the use of coal, especially in moving freight trains. Many Illinois roads, such as the Illinois Central, and the Chicago, Burlington and Quincy, traverse the region of the inferior Illinois coals, and have largely made use of the sulphurous coals mined along their roads—to the great injury, however, of all those parts of the engines with which the burning fuel comes in contact. The development of the Indiana coal has supplied a much-needed want in this direction, and as rapidly as the change can be brought about, coal-burninp; engines are displacing wood-burners upon all the important roads accessible to this coal-field, and the block coal is even driving the inferior coals out of the engines of many of the Illinois roads.

Mr. C. It. Peddle, late General Superintendent of the St. Louis, Vandalia, Terre Haute and Indianapolis Railroad, gave a certificate, which the writer has seen, setting forth that the entire length of the western division, from Terre Haute to East St. Louis, 165 miles, has been run without the fireman being required to clean the grate-bars, the runs being accomplished with one tender, or 6000 pounds of block coal. The Jeffersonvilie, Madison and Indianapolis, the Indianapolis, Cincinnati and Lafayette, the Michigan Central, and many other roads, have had block coal in use for many years, and always with most satisfactory results.

For use under the boilers of saw, woollen and grist mills, water-works, etc., this coal is shipped to the large Western towns in all directions, shipments being made as far north as Milwaukee and Kalamazoo.

The Chicago Tug Association was induced, last season, to give one-half its fuel contracts to a Brazil firm, the other half being filled from the vicinity of Pittsburgh. This season, however, of the forty-five tugboats in service at the port of Chicago, thirty-eight are using block coal, which is a sufficient evidence of the success of the experiment. Many of the large lake propellers are also using it, and so great has this lake trade become, that the Illinois Central Railroad Company has appropriated extensive docks for its accommodation. The facilities thus afforded for the transfer from car to vessel, and the low rates offered by returning ore craft, have induced some block-coal shippers to seek a market among the blast furnaces of the Lake Superior iron region. When the block coal of Spencer County, Ind., is placed upon the Ohio River, an immense market will be opened up. The river steamboats have almost entirely abandoned the use of wood, and the introduction of block coal as a substitute for the indifferent and sulphurous coals they are now compelled to use, will be gladly hailed by the river men.

It might be mentioned as an interesting item in connection with the Chicago trade, that during the month of February last one firm shipped to that city, from Brazil, 3811 tons, or within a fraction of one acre of coal. To move this mass, 316 gondola cars of 12-ton capacity each were required.

In conclusion, it is safe to make the statement that during the five or six years Indiana block coal has claimed the attention of consumers in the great West, no matter to what use it has been applied, it has never failed in a fair trial to fulfil all the requirements of a first-class fuel, but on the contrary, in every case within the knowledge of the writer, it has far exceeded the most sanguine expectations.

DISCUSSION.

MR. ALEXANDER stated in response to inquiries, that mining on these coal-veins had not yet been reduced to a system, but is still ' rather roughly done. Most of the miners have been brought from Youngstown, Ohio, and the system is the same as that pursued there. Shafts are not sunk, the veins being opened in those situations which permit drifting. It is pillar-and-chamber work, with subsequent removal of pillars. The chambers are 12 feet wide, and the pillars 12 feet thick. The roof is weak and apt to fall. The veins are nearly level, having but a slight dip, which is southwest. The coal deteriorates by standing in pillars. Each foot in thickness gives 1000 tons to the acre, or 4000 tons to the acre for the main seam. In Brazil County the lessees pay 28 cents for the main seam, and 15 cents for a lower one. In one case the lower seam was found the best. One dollar a ton is about the cost of mining, and there is 23 to 75 cents for administration. The work is done by the pick, the miners objecting to machines. There are two veins separated about 30 feet, one 4 feet, the other 3 1/2 feet thick.

THE PRESIDENT inquired about the leases.

MR. ALEXANDER replied that the leases are mostly for a long time, and the royalty covers only the coal sent to market.

THE PRESIDENT, in continuation, said that this reminded him of many of the Pennsylvania leases, made on similar terms, and open to the serious objection that the lessee had no incentive to good mining. However wasteful he might be, it was the owner of the land and not the worker who suffered. Leases should be so drawn that the lessee would bear his proportion, at least, of losses by bad working.

MR. PECHIN said that Pittsburgh heard a great deal about its " rivals." Every now and then something came up that was sure to undermine the prosperity of Pittsburgh. But, in his opinion, while they could mine Connellsville coal for 28 cents per ton, and coke it for 50 cents more, he thought he could go to sleep very comfortably on that bed, and let rivals who had to pay §1 a ton for mining do their worst. Their coke cost less than Indiana coal, and contained only 0.08 to 0.12 per cent, of sulphur.

MR. ROTHWELL said that in West Virginia the men made 15 per cent, better wages working long-wall, and the company also got its coal cheaper. He thought that was the system for the block coals. Other members expressed the same opinion.

MR. ALEXANDER said that the sulphur exists in the form of small flakes of pyrites, sometimes very difficult to find.

MR. ROTH WELL read the following analyses of the Alabama coals:

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Sulphur,...	050	0.95	0.52	0.86	1.04	0.43	0.63	3.00	0.56	0.52
Fixed carbon.	66.22	62.62	63.04	63.68	64.54	64.91	62.20	59.64	66.53	66.81
Ash, ...	4.62	3.20	2.02	2.20	2.47	1.63	2.28	5.59	1.09	1.21

The water varies from 1.4 to 2.13 per cent.; and the specific gravity averages 1.12. These coals are from the southern portion of the Cahawba fields.

MR. BRITTOX spoke of the necessity of taking innumerable samples in analyzing coals, in order to obtain average results. He thought many published analyses at fault for commercial use, in having been made upon small pieces.

DR. HUNT said that in analyzing Nova Scotia coals he had been in the habit of crushing a great quantity and averaging this sample. He found a very decided difference between such analyses and those made upon hand specimens. The method suggested by Dr. Storer, of Boston, gives satisfactory results; in this the oxidation is effected by potassium chloride and nitric acid. The sulphates of alumina, iron, and magnesia, are just as prejudicial as pyrites, because they are reduced in the furnace to sulphides; but the calcic sulphate passes unchanged into the slag.

THE PRESIDENT said that manganese probably tended to preserve the sulphates from reduction.

DR. HUNT thought that manganese was not necessary with calcic sulphate, unless, possibly, with a very acid slag. With a slag properly basic there is no danger of reduction.

THE PRESIDENT said that anthracite and the Alabama coals are not the real rivals of the block coal, because of their geographical position. The Indiana coal is geographically opposed to coals which it is very easy to surpass, but were the conditions of transportation altered, its superiority might not be unchallenged.

MR. ALEXANDER said that he was indebted for the expression " rival coals," to Captain Ward, of Detroit, who told him that he had found the block coal superior to any of its rivals. The Indiana coal makes excellent Bessemer steel-iron, which he believed had never been attempted with Connellsville coke.

THE PRESIDENT pointed out that any good fuel would make Bessemer pig, provided the ore was right. The Pittsburgh men certainly had a fair chance of holding their own so long as they could make iron with a ton and a quarter of coke, while three tons of Indiana coal were required, and each ton cost more than Connellsville coke.

MR. MAYNARD remarked that Grand Tower pig had been used in the Troy Bessemer works, and 35 to 40 per cent. gave excellent results. It came by New Orleans, and was cheaper than the English iron. The phosphorus amounted to 0.068 per cent. The iron made at St. Louis from the same ores and coal had the same amount of phosphorus.

MR. FIRMSTONE said that anthracite was used in making Bessemer pig from Cornwall ores.

MR. BRITTON remarked that in the blue ore of Cornwall he had found from 3 to 4 per cent. of sulphur, but this could be eliminated by the roasting furnaces in use. The pig-iron produced, he understood, was used successfully for making Bessemer steel at the Pennsylvania Steel-works and Cambria Iron-works. The chemists at those works, he was informed, had found the pig practically free from sulphur, but not always from copper.

He further remarked that within the last three years he had made a great many analyses of iron rails, a very fine collection of samples of which had been furnished by officers of the Pennsylvania Central, Philadelphia and Reading, and Philadelphia and Baltimore roads. The samples were composed of some of the best wearing, some of the worst, and some of medium quality. The object was to ascertain, if possible, the cause of the difference in the wearing qualities. The work had been laborious, and alone he had been unable to complete it—the American rails were made up of so many different irons. The results were conflicting, and he could not, from those he had obtained, arrive at any important reliable conclusions. He could say, however, that in rails made in South Wales, which had been in use for more than thirty years, and which had not split, cracked, or crushed in wear, but had worn out by abrasion only, the average of some fifty analyses showed about 0.32 per cent, of phosphorus, 0.06 per cent. sulphur, something more than 0.30 of silica, and some 0.06 of carbon. These rails had been made by piling, and not, as was stated, from a single bloom—there had been much work on them. So good and strong was the iron, that when taken from the track, the old rails were worked up into car-axles, bridge-rods, etc. In the heads of some very good-wearing American rails, he had found an excess of phosphorus, but in the necks and flanges the foreign matter he found variable; sulphur was present nearly always.

He had also carefully examined 17 samples of rail-heads of Bessemer steel containing 0.21 of phosphorus and 0.31 of carbon; the metal had proved practically worthless. And other steel (so called) in which he found over 0.14 of phosphorus and 0.19 of carbon, he was told proved unexceptionable.

MR. MAYNARD thought that sulphur was no great bugbear. Four to five per cent. are easily roasted out in Sweden, and we have one similar furnace in America. The Cornwall iron is used at Johnstown.

MALLEABLE CAST-IRON.

BY E. H. TERHUNE, M.E.

THE enormous production of pig-iron, together with the many difficult and interesting problems with which its manufacture is fraught, has secured to this industry the exclusive attention of scientists with reference to the chemistry of iron, while some of the minor departments of its metallurgy have suffered neglect. Particularly is this true of the manufacture of malleable castings, an art, nearly a century discovered, and yet without any history or literature. When cast-iron is exposed at high temperatures to oxidizing substances, a portion or all of its carbon is removed, depending upon the following conditions: the degree and the continuity of the heat; the richness in oxygen of the compound which supplies it; the physical condition of this oxidizing agent, and the facility with which it yields its oxygen for the purpose of reduction.

The process, therefore, is the reverse of cementation and "case-hardening," operations by which carbon is *imparted* to iron by exposing the metal at high temperatures to charcoal or organic substances, producing steel or steely iron. In the present stage of the manufacture of malleable castings it is sought to climinate a *single* element only, while in the puddling of iron and the production of steel in the Bessemer converter it is sought to remove all foreign matter—magnesium, potassium, carbon, silicon, sulphur, phosphorus, etc., the common ingredients of pig-iron. In the one case, solid iron is enveloped in a solid oxidizing agent; in the latter two, melted iron is perforated with streams of air, or exposed by mechanical means to the action of the atmosphere, as well as solid substances which afford oxygen. In the converter and puddling furnace, the conditions of perfect combustion exist, and those of purification are good, as the fluid metal enables the lighter solid products to rise to the surface, and thus separate from the bath. In a casting, in the annealing process, it is obvious that the only products of combustion which are removed are the gaseous; the solid, if any are formed, must remain in the iron, injuring it, as silica, lime, etc. These, then, are the cardinal distinctive features of the two processes; the one which is our subject must be described, to such as are not familiar with it, before theoretical considerations are possible. In order to obtain practical data, it was necessary to visit some typical works. These I have found in the establishment of Messrs. Harrison & Kellogg, Troy, N. Y. It is the oldest firm in the country, and foremost in the application of science to a novel and legitimate field. They use charcoal-iron exclusively; for some unexplained reason the best coke and anthracite irons have not proven available; numbers 3 and 4 are the usual numbers, although from number 1 to number 6 have been used. Fusion is effected in a cupola, or the common air furnace, having a low hearth and very long flue; in the cupola, the charge is 1400 ibs., with one-fifth its weight of Lehigh coal; in the air furnace the charge is 2400 lbs.

with half its weight of Cumberland coal, and crude petroleum. **In** the latter practice, contact of fuel and iron is of course avoided, which may compensate, in case of sulphurous coals, for the greater amount of fuel. Whenever the fusion is effected, the iron is maintained in the melted condition, in the air furnace, for about an hour; the object being to secure a white, hard, and homogeneous iron; the quality of the metal at this stage is determined by the fracture of small ingots cast at intervals ; sound is also a guide to hardness. The operation of casting is simple and ordinary; patterns for moulds are often of brass or iron, and chilling pieces are introduced at the thick parts, to secure a uniform product. For annealing, the articles are placed in sectional *cylinders,* two feet in diameter, for convenience of packing and removing, with alternate layers of forge scale, which is driven into all the interstices, to secure an intimate contact with the metal to be decarburized The packed cylinders are provided with luted covers for the exclusion of air, but more especially carbonic oxide (which, by its presence, would entirely vitiate the process), and are placed in furnaces, about 7 feet square, 5 feet in height, with arched roof, and flues in the walls and hearth to secure a proper distribution of heat. Eight days are required for conversion into the malleable iron of commerce, and the *quality of the product is always doubtful; the apparent precise conditions which one week produce a superior article, will again result in worthless brittle castings.* It is this fact that commends this department of metallurgy to the student as an interesting and, perhaps, profitable field of inquiry, and affords to the manufacturer convincing evidence of the inadequacy of empirical knowledge to the perfection of the art, or to give a plausible explanation of contingent phenomena. The reasons that the cheaper coke and anthracite iron cannot be used, as reported, can only be chemical ones. The object of the prolonged fusion in the air furnace, in a reducing flame, practically secured by causing it to issue 15 feet from the flue-bridge, is not very apparent. The iron, theoretically, should be white and homogeneous, the carbon should exist in the combined state, and the metal must be as free as possible from sulphur, phosphorus, and silicon. The reducing flame employed would not eliminate any of these elements, except by volatilization, although prolonged fusion would change the state of the carbon. It has been suggested that the removal of graphitic or mechanically diffused carbon from the finished casting in the process of annealing, would leave cavities throughout the mass, and possibly the imperfect change in the chemical state of this carbon, may be one of the mysterious causes of frequent failure. On the other hand, if too small a percentage of foreign elements be present, it would not answer for casting. Phosphorus would produce fluidity, as docs graphitic carbon in foundry iron, but the objections to both are apparent.

Hence, in the selection of iron, a variety must be chosen as poor in foreign matter as is consistent with the *production of a casting.* We might infer that the oxidation of silicon, etc., was coincident with that of carbon, and that the *oxides* in the iron would be sources of weakness. If the oxidizing agent was inferior, if it agglutinated, which is the objection to pulverized iron ores, the carbon itself might not be attacked; forge scale is free from this objection, but the restoration of its oxygen with chloride of ammonium, after use, may be imperfect. Various durations of exposure in the furnace should be tried, with the hope of obtaining a product akin to steel in amount of carbon. There are produced annually in the United States about 25,000 tons of malleable castings of a great variety of small articles requiring cheapness, tenacity, and an intricacy of form unattainable by any other known method. The increase of this produce will doubtless be commensurate with the growing substitution of iron for so many other materials in the arts, and, although it is true that the present depth to which iron can be decarburized by this process is slight, it is not fanciful to say that large masses may yet be toughened throughout, giving them value for economical engineering. Analysis of material and product is a fundamental need; by it the changes in each stage will be learned, and perhaps a clue offered to the causes of loss and uncertainty.

DISCUSSION.

DR. T. M. DROWN remarked that, until comparatively recently, the process for making malleable castings has been restricted to very small articles, owing to the fact that the decarburization is effected gradually from without inwards. A piece of iron of large size might, therefore, be completely decarburized on the surface, and still contain a core of unaltered pig-iron. In the McHaffie process for making *direct steel,* so called, the annealing or softening is said to be effected uniformly to a considerable depth, so that large pieces of machinery can be made in this way. The process, as I recently saw it carried out at Lamokin, near Chester, Pa., consists in melting English white pig-iron in a cupola with certain *chemicals.* The nature of these chemicals is kept a profound secret, but the success of the process is considered impossible without them.

The castings are made direct from the cupola, and have the appearance and properties of brittle white cast-iron. These are then annealed in the usual way in ovens, and afford a product that can be readily worked with tools, possesses great strength, is said to be entirely homogeneous, and corresponds in its character to a high steel.

MR. FIRMSTONE said he had seen it stated that red hematite ores were used in England to make malleable castings, up to the time when they came into demand for Bessemer pig. "Chilling" irons are said to be necessary for malleable castings. This is probably the reason why coke or anthracite irons are not used, since they chill badly or irregularly, doubtless on account of the impurities (chiefly silicon) which they contain.

DR. T. STERRY HUNT, in explanation of the theory of the production of malleable castings, alluded to a method of producing malleable iron, devised by Tunner, the celebrated German metallurgist.

In this process, plates of cast-iron, from one-half to three-quarters of an inch thick, are packed in boxes of quartz-sand, so arranged as to permit the passage of air, and exposed to a glowing red heat for several weeks—at the end of which time the metal is found to be decarbonized, and converted into malleable iron. The impurities which form fusible slags, appear in this method to be separated in a liquid form, sweating out, as it were, from the pores of the iron.

In this process, unlike that for making malleable castings, the decarbonization is effected by the oxygen of the air, instead of that of the iron-oxide. In both cases, however, the permeability of the ignited metal to gases (as shown by the experiments of H. St. Claire Deville) explains the seemingly mysterious process by which the solid metal is changed throughout.

The working of the Ellershausen process for malleable iron, which, when properly applied, certainly gives a very superior product, illustrates both of these modes of decarbonization. In this method, as first practiced by the inventor, ingots made by mixing coarsely pulverized iron ore with molten pig-metal were heated on the hearth of an ordinary puddling-furnace, when, if the heat was judiciously managed, the mass, without melting, became changed into malleable iron, with the separation of a portion of liquid cinder. It might appear that in this process, as in that for the production of malleable castings, the mingled iron-oxide was the sole agent in decarbonizing and effecting the conversion of the metal; but in subsequent experiments the proportion of oxide of iron was reduced much below that required by theory to produce the change, with satisfactory results. A mixture of charcoal with the ore was then tried, and at last experiments made with charcoal alone, without any addition of ore, were equally successful. A process which involved decarbonization and oxidation was thus effected through the addition of carbon. The explanation of this seeming paradox is to be found in the fact, that the intermingled charcoal is soon destroyed by combustion, and there remains a porous mass of cast-iron, permeable to air, which then becomes rapidly decarbonized under the influence of the air alone, as in Tunner's method. Undoubtedly, when iron ore is also present, it contributes to the process, both by furnishing oxygen and by supplying oxide of iron to form a silicate with the silica resulting from the oxidation of silicon; thus exemplifying, at the same time, the two modes of decarbonization.

DR. HUNT then proceeded to show that on theoretical grounds it was desirable to select for the manufacture of malleable castings such iron as contained, other things being equal, the least silicon ; since from the oxidation of this element must result a portion of silica or of silicate of iron, which, remaining diffused throughout the mass, must impair its homogeneousness and strength. He further called attention to the account given by Bauermann, of the production of objects in what is called *run steel.* These are malleable castings, the exterior of which, by a process of cementation in charcoal powder, is converted into steel. In this way it is possible to produce a bar, the centre of which is cast-iron, the surface blister steel, and the intermediate portion malleable iron.

MR. PECHIN said, we have produced at the Dunbar Works, near Pittsburgh, a good chilling iron with coke, at high temperature and strong blast.

DR. HUNT said, phosphorus had apparently little to do with the "chilling" property. Iron made from ores containing, he thought, 0.5 to 2 per cent, of phosphoric acid, is used in Canada for car-wheels; yet other irons, equally prized for chilling, contain no phosphorus.

THE PRESIDENT called attention to an allusion in Mr. Terhune's paper as to the effect of graphitic carbon in increasing fluidity, and inquired whether this was a generally recognized fact.

DR. DROWN : The notions of iron metallurgists with reference to graphitic and combined carbon, and the transformation of the one variety into the other, seem to me to be unnecessarily vague. In the first place, it is clearly a mistake to speak of graphitic carbon in molten cast-iron. In this case the carbon must be completely in combination or in solution, whatever may be the character of the resulting pig-iron. Again, the separation of the carbon from the iron, in the form of graphitic scales, is, as far as we know, a mere question of time; the longer the metal takes to solidify the more graphite will be separated. Now the time of cooling is dependent, first, on the fusibility of the metal; and second, on the means employed for hastening or retarding its solidification. It is well known that carbon and silicon in combination with iron increase its fusibility ; consequently, iron containing one or both of these elements in large quantity, will solidify slowly, and allow the greater part of the carbon to separate as graphite. The fact, so often noticed and stated, that silicon causes carbon to appear as graphite in pig-iron, finds thus a ready explanation. In the use of chills, the solidification of the metal is hastened, and the carbon not having time, it may be, to separate, is retained in the combined form. The difference noticed in pig-irons with reference to the amount in depth of chilling is, therefore, solely a question of fusibility. If silicon and carbon are both largely present, the probability is, that the iron being very fusible, will resist the cooling influence of the chill sufficiently long to allow some graphite to separate, and there will be no visible chilling. Again, if silicon is present in a very small amount, chilling may take place in spite of a large amount of carbon, When the amounts of carbon and silicon are both small, it is possible to carry the chilling throughout the entire mass, and white pig-iron results. It is to be regretted that we do not know the limits of carbon and silicon requisite to produce any definite result. Spiegeleisen is, of course, from its composition, excluded from the foregoing considerations.

THE DETERMINATION OF COMBINED CARBON IN STEEL BY THE COLORIMETRIC METHOD.

BY J. BLODGET BRITTON,
Of the Iron-Masters' Laboratory.

IN the Journal of the Franklin Institute for May, 1870, there is published a description of a Colorimeter, together with a modification of the method proposed by Professor Eggertz, for determining combined carbon in iron and steel.

An instrument of the kind there described, but of a little higher range, though in other respects not differing materially from the one originally made and used in the Iron-Masters' Laboratory, I now submit to your inspection ; and I propose, also, to make some determinations with it for the purpose of showing how quickly they may be made, and enabling you to form some judgment of what reliance can be placed in the results.

Professor Eggertz proposed only a single standard, and the solution to be tested should be diluted to exactly correspond in color with that of the standard, and the per cent. of carbon calculated after carefully noting and making allowance for the measures of water used in diluting.

In practice, difficulty was found in bringing the color of the normal solution down to the exact shade of the standard ; also other difficulties were met with in conducting the process, causing delay and interfering with the accuracy of the results.

To materially overcome these, and after numerous attempts, an instrument such as is now before you suggested itself to me; and also I concluded to use a larger quantity of metal than directed by Eggertz, and, in addition, to filter the solution from its insoluble matter before making the comparison ; and, more recently, to use an acid of just such strength as would completely dissolve the metal without the application of heat. Experimenting with these changes from, the original method I obtained reasonably good results.

The instrument, you will observe, consists of a series of tubes, sixteen in number, two and a half inches long, and about half an inch in diameter, standing upright, and securely fastened in a light) portable, walnut-wood frame, but separated one from the other so as to allow just sufficient space between to place for comparison the tube containing the solution to be tested. The tubes are filled with water and alcohol colored with roasted coffee, and hermetically sealed. The solutions have been accurately standardized; the one in the tube to the left has its color to correspond exactly with one produced by one gramme of iron containing .05 per cent, of combined carbon dissolved in fifteen cubic centimetres of nitric acid. The solution in the tube next to it has its color to correspond with one produced by the same quantity of iron dissolved in the same measure of acid, but containing .07 per cent, of combined carbon; and so with each of the other tubes increasing .02 per cent, of carbon, colored in regular succession to the right, the last reaching .35 per cent., as indicated by the figures on the upper rail of the instrument.

On the back of the instrument strong pure white paper is tightly stretched for the purpose of screening and diffusing the light, and making the difference in the shades of color more apparent.

The process of making a determination is exceedingly simple, and may be completed in thirty minutes. One gramme of the metal finely divided is put into a tube of about an inch and a half in diameter and eight inches long, with fifteen cubic centimetres of chemically pure nitric acid of 1.42 specific gravity, and two parts water. The solution is then filtered into a small tube of four inches long, and of precisely the same diameter as those in the colorimeter, and as soon as the temperature has become reduced to that of the atmosphere, the tube may be placed in the instrument, the comparison made, and the per cent. of carbon at once read off.

While conducting my experiments I found that with three determinations there was usually no perceptible variation, though sometimes there was as much as .01 or .02 per cent. due mainly to some of the metal remaining undissolved. I consider it important, however, that the operator should make his determinations always with a uniform weight of metal and measure of acid, and under like circumstances, and the same as when he made his standards. The acid used should be invariably of the same strength. A very strong acid acts imperfectly on the metal; one not quite so strong acts too violently, and causes too much loss of color, while, on the other hand, a very dilute acid leaves much of the metal undissolved. I have obtained good results from one of the strength already indicated. From twenty to twenty-five minutes is usually sufficient time to dissolve the metal, and from three to five minutes more to filter. The metal should be in moderately fine division, and passed through a sieve of about twenty spaces to the inch to insure a pretty uniform size of particles, and about the best suited for being acted on by the acid.

The solution, which always becomes quite warm from the action of the acid on the metal, should be allowed to cool to the temperature of the atmosphere, and the color to become fixed before the comparison is made; the cooling may be hastened by immersing the lower end of the tube in cold water; but a considerable time should not be lost, for after some hours, and sometimes less, a change occurs, and a gradual loss of color becomes apparent, and for this reason a nitric acid solution of metal cannot be used for a standard.

I think that by observing these precautions the operator can, after a little experience, obtain results by the method described, and with the so-called mild steels sufficiently accurate for all ordinary metallurgical purposes, and, by using a number of tubes at the time, make more than a dozen determinations in an hour.

The speaker then proceeded, in the presence of the members, to make three determinations according to the method he described. When the solutions were filtered and ready for comparison, some of the members were asked to make the comparisons and declare the results. The solutions were found to be alike in color, and to be between 15 and 17 of the instrument. The amount of carbon in the metal had previously been accurately determined by another method, and found to contain a little over 0.16 per cent.

The speaker concluded his remarks by stating that he had carefully tried several of the combustion methods, but had found the one known as Ullgren's, with some modifications, to afford the most constant and reliable results, and he preferred it, in his own practice, when a high degree of accuracy was necessary.

ECONOMICAL RESULTS IN THE TREATMENT OF GOLD AND SILVER ORES BY FUSION.

BY JOHN A. CHURCH, M.E.

AT a time when the treatment of gold and silver ores by fusion, in opposition to the mill-process, is attracting so much attention in this country, it may be useful to consider what is done in a well-conducted foreign work. For this purpose I will ask the reader to accompany me to Lend, in Austria, a small but thoroughly organized establishment. It is situated in the Salzburg Alps, and receives its ore from mines at Rauris and Boeckstein. The former, lying 8200 feet above the sea, is said to be the highest mine in Europe, some of its openings being made in glacier ice. It was worked by the ancients, who have left the contracted and tortuous workings peculiar to them. The ore differs in no way, unless in extreme poverty, from countless mines in the West. It consists of gneiss, quartz, and clay-slate, containing the sulphurets of iron, copper, lead, zinc, and antimony, besides arsenical pyrites, gold, and silver. The gold is found in two conditions, free gold and gold alloyed with silver. This alloy for the year 1866 was composed, on the average, of 15.33 gold and 84.67 silver, which gives a specific gravity of 11.28. Mercury has a specific gravity of 13.6, and as the amalgamation of gold by the Austrian method is looked upon as a proceeding entirely mechanical, the separation being effected solely by the superior gravity of gold over mercury, this alloy, which is lighter than mercury, cannot be amalgamated.* Such is the lesson of long practice, the free or fine gold being extracted from a part of the ore, at least, by amalgamation, while the tailings are smelted to obtain the alloy. The following table will show the proportion of fine to alloyed gold, and also exhibit the extreme poverty of the ore. To the Rauris and Boeckstein ores I have added those from Zell in the same part of the Alps. The ore from this place is not now worked, the point of poverty having apparently been reached at which the auriferous rock ceases to be an ore.

	Rauris.	Boeckstein.	Zell.
	In 2000 pounds troy ounces.	In 2000 pounds troy ounces.	In 2000 pounds troy ounces.
Fine gold,	0.32 to 0.48	0.098 to 0.113	0.090 to 0.097
Gold and silver alloy,	1.40 to 1.47	0.570 to 0.660	Unimportant.
Iron pyrites, copper pyrites, galena,	8 per cent.	4½ per cent.	Unimportant.
Value of silver and gold in American coin,	$13.49 to $16.92	$5.91 to $8.49	$1.86 to $2.00

As in 1866 Boeckstein delivered 63 per cent. of the ore, and Rauris 37 per cent., the average value per ton for the year was $10.16,† or 0.004 per cent. gold, and 0.034 per cent, of silver. This

* See Rittinger's Aufbereitung (ed. 1867, page 469).

†Unscientific as the method is, I feel compelled to give these values in American coin, since that is the only expression known to the workers in our mines.

does not include the value of the copper and lead, which form, respectively, 2 and 1 per cent. of the ore. The former is extracted; the latter is not sufficient to supply the waste of the process, and lead has to be bought for the works. Even in Europe these ores are considered extremely poor. I am not aware that ores from veins so poor as these have ever been worked in America, but if they have they must have owed their value to the fact that the gold was all fine, and could be amalgamated.

TREATMENT OF THE ORE.

The ore is first sorted to six varieties for the furnace, and one for amalgamation. The former comprise quartzose ore, rich, medium, and poor, compact pyrites, galena, and antimonial ore.* The ore sent to amalgamation is the poorest kind of pyritifcrous rock. It contains merely traces of pyrites, and is amalgamated, because in that process it undergoes concentration.

Amalgamation.—The ore for amalgamation is crushed under stamps of 220 pounds weight (total), through sieves of 1.5 millimetres (0.06 inch), the battery-box having a sieve on each side to secure the most rapid discharge of the slime. Two methods of treatment are employed for the slime: first, it is first concentrated, and then amalgamated, or, second, it is first amalgamated, and then concentrated. With ore that contains much pyrites the former is best; with ores very poor in pyrites, the latter.

Amalgamation takes place in pans, there called " mills." They are 24 inches in diameter at the top, 1.6 inches at the bottom, and 9 inches high, and made of cast-iron, one-eighth to three-sixteenths inches thick. They are not directly conical, but the side forms a step 3 inches wide. In this pan mercury is poured an inch deep, and a wooden block shaped like the pan, and 1 to 1½ inches less in diameter, is suspended over it. The upper part of this block is hollowed out like a hopper, with its discharge in the centre, and the under side has small pieces of sheet-iron placed radially in it, and which just clear the mercury. When this block is revolved, and a stream run into the hopper-like depression on its upper surface, the slime is carried over the mercury from the centre to the circumference of the pan, the whole apparatus acting like a "centrifugal"

* A collection exhibiting these ores, and a full suite of furnace-products, can be seen at the School of Mines, of Columbia College, New York.

pump. This is the Austrian gold-mill so often described.* Great care is taken to prevent too rapid a motion of the stream, which would not allow the gold time to settle and would carry off the mercury. Twelve to thirty-two revolutions a minute is the speed given, depending upon the fineness of the ore, thickness of the slime, and amount of gold present. These mills extract by one operation 75 per cent. of the fine gold, and 15 per cent. more by repeating the process. Each mill passes about one ton of ore in twenty-four hours. Compared with blankets this system does not appear to present any advantages in the first handling of the ores; but I should think the Austrian mill might be substituted with gain in the place of many other amalgamating arrangements now used after the blankets. Compared with the Colorado methods these mills extract 20 per cent. More† than the Colorado amalgamators, though this yield necessarily depends upon the proportion of silver in the gold. They require little watching, except when used immediately after the stamps, when the accumulation of gold might require their cleaning up every two or three days.

Smelting.—For four years the ores delivered for fusion were in the following proportions:

	From Rauris.	From Boeckstein.
Quartzose ore,	6.50	24.11
Compact pyrites,	0.06	0.48
Sulphuret of antimony,	1.41	0.41
Slime from amalgamation,	28.03	38.00
	37.00	63.00

About 66 per cent. of the smelting ore has, therefore, been amalgamated.

From 70 to 75 per cent. of the ore is worthless rock, and this must be removed before adding lead, which would suffer serious loss if charged with so much quartz. The operations are, therefore, as follows:

1. Fusion for raw matte.
2. Roasting of raw matte in stalls.
3. Fusion (without lead) for a more concentrated matte.
4. Roasting of second matte in stalls.
5. Fusion with lead.
6. Cupellation of rich lead.

* Rittinger's is the best account. See his Aufbereitung.

† See Mr. Hague's Report on Mining Industry of the Fortieth Parallel.

The First Fusion.—Eleven years' experience has proved that the most efficient slag is one approaching the composition of a bisilicate. The following is an average analysis:

Silica,	51.02
Alumina,	2.16
Oxide of iron,	19.75
Lime,	15.40
Magnesia,	8.57
As. Mn. Cu. Zn. S. (by dif.)	3.10
	100.00

Each year the matte resulting from the previous year's fusion with lead is roasted, analyzed to ascertain the amount of oxide of iron present, and charged in the first fusion as a flux for the quartz; or, if containing above 35 per cent. of copper, it is treated for copper.

The furnace is not new, and contains none of the late improvements, but it does good service. Its dimensions are as follows:

Height	24	feet.
Diameter of hearth,	3	"
Diameter of boshes,	4.5	"
Diameter of throat,	2	"
Number of tuyeres,	2	
Pressure of blast,	½ to ½ inch of mercury.	

From 100 to 120 bushels of charcoal are required to warm the furnace, and then regular charges of 5 cubic feet, or 3 bushels, are made. In " blowing in," the quantity of mixed ore and flux added to this charge of coal is, at first, 56 pounds; then 112 pounds; and when the furnace is thoroughly hot the full charge of 203 pounds, which is the constant burden, to 3 bushels of charcoal. This is usually reached in the first twenty-four hours. Four hours after the first charge of ore and flux, the blast is turned on, at first with a pressure of one-third inch and then one-half inch of mercury; or one-sixth and one-quarter of a pound to the square inch. After eight hours the slag begins to flow. The furnace is, of course, worked with a black throat.

The first matte forms 40 to 45 per cent. of the charge, the difference between this proportion and the 25 to 30 per cent. afforded by the ore being made up by roasted matte from the previous year. Its average composition is—

Iron,	55.1
Copper,	4.3
Zinc	3.7
Lead	2.1
Nickel, cobalt, arsenic, and antimony,	4.5
Sulphur	27.9
	97.6

It contains 30 to 40 ounces troy of auriferous silver to the ton of 2000 pounds; or, in American valuation, $100 to §150 in coin. From the fact that the ore is unroasted and the metals are so well "covered" by sulphur, the loss amounts to only 0.25 of 1 per cent. About 38 bushels of charcoal are used to the ton of charge, and 9.75 tons are smelted in twenty-four hours.

The Second Fusion.—The first matte is roasted three times in stalls containing 28 tons, the roasting not being thorough, but carried only so far as to leave about 40 per cent, of unroasted matte. It is then re-smelted with quartz and silicious slag ; and to avoid the use of too much of the flux, a basic slag is made containing about 22 per cent. of silica. This requires very great care in managing the furnace, for the least irregularity of working causes the formation of sows. To secure proper working, whenever the furnace is tapped, the hearth is examined by means of a bent bar. If lumps are felt, the front wall is broken out and they are removed; if the sole is slippery, the presence of reduced iron is indicated. A rough, hard, even sole is the proper one.

The pressure of blast is now reduced to one-sixth of an inch, or one-twelfth of a pound to the square inch; the hearth is made 10 to 12 inches larger in diameter than before, and the charge is increased to 222 pounds to three bushels of charcoal. These changes have for their object not only the prevention of iron sows, but also of speiss, a compound of arsenic with all the other metals present, and very difficult to utilize. The same precautions are used in blowing in as before. About 30 bushels of charcoal are used to the ton of ore and flux, and 13.5 tons are smelted in twenty-four hours. The second matte contains 52.67 ounces of auriferous silver to the ton, and is worth about $200.

Fusion with Lead.—The second matte is roasted as before, but now 50 to 60 per cent. of unroasted matte is left. A stronger roasting would so enrich it that two fusions with lead, instead of one, would be necessary. The slag is again basic, and to keep the heat as low as possible, the pressure of blast is reduced to one and a half lines of mercury, while the charge is increased to 277 pounds of matte and flux to 4 bushels of charcoal. In order to keep the lead in contact with the matte as long as possible, as well as to decrease the heat, the crucible is made a foot deeper than before. The new slag has an average composition of—

Silica,..	27.45
Oxide of iron	56.52
Lime, ...	10.19
Magnesia, ...	3,48
Alumina, ...	1.25

The loss will not exceed 2.5 per cent, of the lead. When the hearth is full of melted matte it is tapped, the products running into a basin, where they are well stirred with poles. The matte is then partially taken off, the lead remaining until 600 to 700 pounds have collected.

For a perfect extraction of the silver it is necessary to charge 120 to 130 pounds of lead for each pound of silver and gold. With this proportion 75 per cent. of these metals is extracted in one operation, and the matte ought not to contain more than 0.75 per cent, of lead. The extraction of 75 per cent. of auriferous silver, means that more than 90 per cent, of the gold and 73 per cent. of the silver have been obtained. A second operation removes so much more that, including amalgamation where the loss is very great, more than 90 per cent. of the silver and 96 per cent. of the gold were obtained. This second operation takes place only when the matte is worked for copper. At other times the gold and silver are obtained by charging the matte back in the first operation. The absolute loss in smelting is but 0.10 of 1 per cent. From 14 to 16 tons of matte and flux are smelted in twenty-four hours. A certain amount of lead-matte is obtained, and is charged back in the same operation. If the third matte is rich enough it now undergoes a second fusion with lead, but usually it is so poor that it is treated at once for copper. If, however, it contains less than 35 per cent. of copper, it is roasted and returned as a flux to the first fusion for raw matte. At Lend the conditions are such that this takes place every other year, copper being made one year, and only matte the next.

Cupellation is performed in a German furnace, with movable hood, made very low, so that the heat from the fuel is thoroughly utilized.

Inasmuch as none of the side products are sold, and there is no need of having them in great purity, there is, beside the fire-bridge, only one opening to the hearth, through which "abzug," "abstrich," litharge, and smoke, alike escape. From 6000 to 7000 pounds of lead are charged at once, and more is gradually added until about 21,000 pounds (the entire make of a year) have been melted. The blast is slow, and the litharge consequently flows rather cold. Refining follows the brightening of the silver, and metal of .985 to .995 is produced. Usually the loss of lead falls between 4 and 6 per cent., while that of silver and gold seldom reaches 0.10 of 1 per cent. About three tons are cupelled in twenty-four hours.

TABLES OF THE OPERATIONS.

The following tables will give at a glance all the foregoing particulars, and also exhibit the amount of material handled. The two fusions without lead are combined in one table.

Table of the First and Second Fusions, **1866.**

	Weight in tons.	Ounces of gold.	Ounces of silver.	Per cent. of copper.
Charge:				
Ore, ...	81.15	21.00942	1333.4058	. . . . . .
Matte and rich scraps, . .	89.61	19.29186	2216.6406	. . . . . .
Flux, { basic 7.41 tons, . . silicious 50.88 tons,	58.29	. . . . . .	. . . .	. . . . . .
Total, ...	229.05	40.30128	3550.0464	. . . . . .
Products:				
First matte, ...	61.38	18 71928	1612 7324	5
Second matte, ...	30.87	20.47698	1806.7302	10
Scraps,.	10.25	0.68238	95.0922	. . . . .
Total, ...	. . . .	39.87764	3514.5548	. . . .

Labor: Thirty-nine 12-hour shifts, 5 men to each shift = 195 days.
Charcoal: For warming furnace, bushels, ...291
Charocal: For smelting, bushels 6,820

7,111

Labor: Per ton of ore,* days 1.8
Charcoal: Per ton of ore,* bushels,...65.2

* In calculating this, it is to be remembered that 28 tons of matte from the previous year were smelted, which must be counted as ore, in calculating the expense of charcoal and labor.

Table of Third Fusion, 1866.

	Tons.	Lead, pounds.	Copper, per cent	Gold, troy ounces.	Silver, troy ounces.
Charge:					
Containing gold and silver:					
Rich quartzose-ore, . .	1.96	. . . .	. . . .	0.9610	59.5404
Roasted second matte, .	30.87	. . . .	10	20.4769	1806.7202
Scraps, ...	2.09	. . . .	. . . .	0.1474	23.0778
Containing lead:					
Lead-matte, ...	3.71	741	6	1.9440	175.9600
Litharge, ...	10.81	17,722	. . . .	. . . . .	66.1500
Hearth, ...	3.30	3,304	. . . .	. . . . .	42.4700
Flux:					
Scoria from first fusion,	10.99	. . . .	. . . .	. . . . .	. . . . . .
Quartz, ...	2.04	. . . .	. . . .	. . . . .	. . . . . .
Total, ...	66.77	. . . .	. . . .	23.5294	2175.9184
Products:					
Lead, ...	10 51	21,030	. . . .	21.5442	1283.8320
Third matte, ...	15 59	. . . .	. . . .	. . . . .	624.5200
Lead matte, ...	3.70	741	20	1 9440	174.9600
Scraps and flue dust, ...	4.06	. . . .	10	0.2430	46.9900
Total, ...	. . . .	. . . .	. . . .	23.7312	2130.2920

Labor: Ten 12-hour shifts, 5 men in each shift = 50 days.

Charcoal: For warming furnace, bushels, ...	100
Charcoal: For smelting, bushels, ...	1,710
	1,810
Labor: Per ton of ore,* days, ...	0.46
Charcoal: Per ton of ore, bushels, ...	16.6
Lead charged per ton of ore, pounds, ...	218

Table of Cupellation, 1866.

		Quantity.	Lead, per cent.	Gold, ounces.	Silver, ounces.
Charged:					
Lead, ...	tons, .	10.06	100	21.5442	1283.8320
Products:					
Fine silver, . . .	ounces,	1208.58	. . .	21.5292	1186.9560
Litharge, . . .	tons, .	10.12	82	. . . . .	64.9080
Hearth, ...	tons, .	2 53	50	. . . . .	31.9860

Loss in gold, ...	0.1476
Gain in silver, ...	0.0180
Labor: 26 days = per ton of ore,* days, ...	0.24
Wood: 7.52 cords = per ton of ore, cords, . . .	0.69
Charcoal: 40 bushels = per ton of ore, bushels, . . .	0.37

* In calculating this, it is to be remembered that 28 tons of matte from the previous year were smelted, which must be counted as ore in calculating the expense of charcoal and labor.

Table of cost per ton of Ore in Units of Labor and Material.

	Labor, days.	Charcoal, bushels.	Wood, cords.	Lead, pounds.
First and second fusions, ...	1.8	65.2	. . . .	. . . .
Third fusion, ...	0.46	16.6	. . . .	8.0
Cupellation, ...	0.24	0.37	0.69	9.7
Total, ...	2.50	82.17	0.69	17.7

To this must be added a small quantity of wood, or refuse charcoal, and labor used in roasting the matte. The above is the cost for ores of the richness above given. With richer ores there is more matte to treat, and the expense of fuel, labor, and lead is therefore greater, and the cost per ton is more ; but *proportionately* richer ores are cheaper to treat than poor. The following table gives the relative cost for various ores, the poorest being taken as unity :

Auriferous silver in 2000 pounds.	Value in American coin.	Proportionate cost, poorest ore = unity.
0 to 14.5 ounces, ...	$0 to $61	1.00
14.5 to 29 "	$61 to 122	1.10
29 to 58 "	$122 to 244	1.31
58 to 116 "	$244 to 488	1.73

The Lend ore falls under the first class. The milling ore of Colorado is worth from $15 to $30 a ton, and comes under the same category. The Colorado " smelting ore" so. called is probably mostly in the second and third ranks.

Losses.—By reference to the above tables it will be found that the following is the loss and gain of the year:

	Loss.		Gain.	
	Gold.	Silver.	Gold.	Silver.
1st and 2d fusions,	4.24 oz.=1 per cent.	35.50 oz.=1 per cent.	....	....
3d fusion, . . .	....	45.63 oz.=2.1 per ct.	2.02 oz.=0.86 per ct.	....
Cupellation, . .	0.15 oz.=0.07 p. ct.	....	....	0.02 oz.=0.0015 p. ct.
Loss, ...	4.39 oz.=1.07 p. ct.	81.13 oz.=3.1 per ct.	....	....
Less gain, . .	2.02 oz.=0.86 p. ct.	0.02 oz.=0.0015 p. ct.	....	....
Leaving loss,	2.37 oz.=0.21 per ct.	81.11 oz.=3.1 per ct.	....	....

These amounts are, however, so small that it is impossible to say whether the assayers' errors do not amount to more than the reported loss and gain. Dr. Turner's opinion, founded upon years of experience, and comparing the analyses of the ore with the yield by amalgamation and fusion through several years, was, as I have said, that he could count upon extracting more than ninety per cent. of the silver and ninety-six per cent. of the gold by the two processes of amalgamation and fusion. The loss of lead was nine per cent. of the amount charged.

The cost of all the operations at Lend, in 1366, was §883.88, and the balance-sheet shows a profit of $1355. The expense was proportioned as follows: Labor, 17; materials, 43; direction, 40; total, 100.

I have dwelt thus particularly upon the minutiæ of each operation in order to indicate the means by which such excellent results are obtained. In our own country the losses in working silver ores by fusion arc so great (frequently from twenty to thirty per cent. in the West) that we can ascribe them only to very rude working. But even in works more pretentious in expense than the somewhat incomplete establishments to be found in the Territories, and which base upon long experience a claim to skilful treatment, we find such reckless application of heat and careless handling of valuable ore as must and docs cause great loss. At the works which I present for consideration all avoidable causes of loss have been eliminated, or their operation reduced, with the greatest care. Two analyses a year determine the proportions of the charges and the composition of the scoria. Larger establishments would require more analytical work, but there is no reason why the largest works should not be conducted with equal care. The cost of the laboratory would not be more than §250, and the work would consume only a few days in each month.

Great care is necessary at Lend, because, with so small a quantity of ore, any disregard of proper precautions would hazard the profits of the works. In 1866 only 83 tons of ore, worth less than §6400 in gold and silver, and containing a ton and a half of copper, were treated. And yet this small quantity, together with the ore which is treated by amalgamation at the mills, keeps alive two mining districts and a smelting work. Beside the miners, an engineer, two smelters, and four assistants have to be supported for the whole year, though the work of smelting occupies only twenty-seven days of twenty-four hours. Of course, such a state of things can be maintained only by low prices, and we find the Austrian workmen paid at rates varying from 27 ½ to 22 cents (coin) a day. Charcoal is 3 1/7 cents a bushel, and wood §1.17 a cord. In this country we have larger supplies of ore, sufficient to cany on the largest works on a correspondingly economical scale. The nature and higher value of our ores would enable us to work with less expenditure of labor and material to the troy pound of silver and gold than at Lend.

In considering the results given in this paper for guidance in using a similar process at the West, it is evident that the American ores contain nothing to prevent the application of this method. Antimony, arsenic, and zinc, the bugbears of the smelter, are, with the exception, perhaps, of zinc, quite as prevalent at Lend as in Colorado. Our ores contain more pyrites than those we have been considering, and there would be no necessity of a fusion for raw matte—an operation which has no object but to remove the gangue. Whether there ought to be a fusion for concentration depends upon the richness of the ore and its adaptability to concentration by machinery. A mixture of rich "smelting ore " and concentrated tailings, such as is now worked up by the smelters, could be roasted and immediately fused with lead. One more fusion with a fresh quantity of lead, if there were silver enough left in the matte to pay for the work, and cnpellation, would complete the process. We should then have a process divided as follows :

1. Concentration of poor ore.
2. Roasting of concentrated and rich ore.
3. Fusion of roasted ore with lead.
4. Roasting of matte.
5. Fusion of matte with lead.
6. Cupellation.

The present imperfect concentration of tailings in Colorado is said to cost $6 a ton. A perfect concentration would cost no more. The other expenses would be—

	Days' labor.	Charcoal.	Wood, cords.
Roasting in piles,	0.4	....	0.029
First and second fusions,	1.8	65.2	....
Roasting matte,	0.2	....	0.001
Third fusion,	0.46	16.6	....
Cupellation,	0.24	0.37	0.69
Total,	3.10	82.17	0.72

Mr. Hague says the millers expect to get 1 ton of concentrated pyrites from 6 tons of tailings, which seems to indicate a pretty heavy loss. At that basis, however, the theoretical expense would be—

Concentrating 6 tons to 1,	$6 00
Smelting 1 ton, 3.10 days' labor, at $3,	9 30
Smelting 1 ton, 82.17 bushels charcoal, at 25 cents,	20 54
Smelting 1 ton, 0.72 cords wood, at $8,	6 00
Total,	41 84
Mining at $ 10,	60 00
Total cost of treatment, 6 tons,	101 84
Cost of one ton,	16 94

The expense of charcoal ought to be somewhat less than this, for in consequence of the small quantity of material treated at Lend, no less than 2.5 bushels per ton of ore are expended in heating the furnace. If we add one-half more for loss in blowing out, we have the very large proportion of 3.7 bushels—a quantity which would be lessened to 1 bushel if 500 tons of ore were smelted in one campaign. With proper management this could be very much exceeded, so that the expense of charcoal for blowing in and blowing out would be too little per ton to be worth reckoning.

It now remains to consider the adaptability of this process to Western ores, and I will take those of Colorado as an example, for the reason that Mr. Hague's report on the mines of that Territory offers the best data for the calculation. He gives commercial assays of ores from various lodes, which prove their value to be as follows:

	Gold, ounces.	Silver, ounces.
First-class ore:		
Consolidated Gregory,	5.6	20
Illinois,	4	20
Gardner,	3.5	11.5
California,	3	18
Burroughs,	6	12
Average,	4.42	16.3
Milling ore:		
Burroughs (1340 tons),	1	4.5

The coin value of the first-class ore is therefore $ 91.36 for the gold and $21.03 for the silver; total, §112.13. By roasting the ore so as to leave one-third raw matte, and smelting with 180 to 195 pounds of lead to the ton, we ought to extract 90 per cent. of the gold,* or 4.05 ounces, worth $83.71; and 73 per cent. of the silver, or 11.90 ounces, worth §15.35, or §99.06 in all. The cost of this would be about as follows :

Mining one ton of ore,		$10 00
Roasting : 0.04 day's labor at S3,	$1 20	
0.029 cord wood, at $ 8,	23	
8 months'int. on $10, at 12 per ct.,	80	
		$2 23
Smelting: 1.5 day's labor,	4 50	
8 pounds lead, at 5 cents,	40	
46 bushels charcoal, at 25 cents,	11 50	
		16 40
Total for roasting and smelting,		18 63
Total for mining, roasting, and smelting,		28 63

If our ore contains no copper, and the matte will not pay for further treatment, and we proceed at once to cupellation, we have in addition:

Cupellation : 0.24 day's labor, at S3 .	$ 0. 75	
0.37 bushels coal, at 25 cents,	09	
0.69 cord wood, at $8,	5 52	
9 pounds lead, say at 5 cents,	45	
		6 81
Total for mining, roasting, smelting, and cupellation,		3544

Profit, $ 99.06 — $35 = $63.62.

We have remaining a matte containing $13.07, and probably a certain amount of copper. Let us see whether this will pay to work , by itself. The cost will be :

Roasting: 0.30 day's labor,† at $3,	$0 90	
0.02 cord wood, at $8,	18	
		$1 08
Smelting: 0.60 day's labor, at $3,	$1 80	
27 bushels coal, at 25 cents,	6 75	
5 pounds lead, at 5 cents,	25	
		8 80
		9 88

* It will be observed by reference to the table of the third fusion that *all* the gold was extracted by one operation at Lend in 1866. I have, however, adhered to Dr. Turner's general estimate in making the above calculations.

† A certain correction has to be applied, because the amount of matte is taken as larger than at Lend. I have assumed it to be 50 per cent. more.

This would cause a loss; for calculating 4 per cent. loss on gold and 10 per cent. on silver in the original ore, we have only §7.50 which can be extracted from the matte. The loss would therefore be 83.38, and unless the matte were worked for other products, as for copper, it probably could not be utilized **at** present, though in many cases it would be required as a basic flux in the first fusion. Considering the present state of the West and proportion of copper **in** the ore, the process would probably consist of three operations—first, roasting the ore; second, fusion; and third, cupellation, the copper matte being sold.

Accepting the Burroughs milling ore as an average of the second-class ore, we have for this, one ounce gold, worth $20.67, and 4.5 ounces silver, worth $5.81; total, §25.48. The cost of treating it would be:

Mining 6 tons,	$60 00
Concentrating 6 tons to 1.	6 00
Roasting and smelting 1 ton,	18 63
Cupellation,	6 81
Add for roasting,*	2 00
Cost of treating 6 tons,	93 44
Cost of treating 1 ton,	15 57
Yield at 90 per cent. of the gold,	$18 60
Yield at 73 per cent. **of** the silver,	4 24
Total yield,	22 84
Cost,	15 57
Profit,	$7 27

This would leave a matte containing $1.86 in gold and silver, and perhaps some copper.

The above calculations are of course theoretical, so far as they relate to works which have never yet been established in the Territory. There may be errors in the prices assumed for labor and materials; but there is no reason why the amount of labor and material expended per ton should be more than at Lend ; that part of the calculations is not theoretical. Undoubtedly in establishing such works some difficulties would be experienced, but with a railroad to the foot of the mountains, and the improved facilities for

* Fine ore requires a more expensive roasting than coarse, for which reason I have added 50 per cent. to the cost. Roasting in furnaces, Mr, Hague says, costs $5 in Colorado.

communication, the difficulties in the way cannot compare with those which have been overcome in establishing the milling system.

A chief drawback to extracting the precious metals in the Terrii-tory, instead of concentrating them in a matte to be exported, is thought to be the lack of lead ores, since the Georgetown mines have not fulfilled their promise as lead-mines. Let us see how much is required for works treating 25 tons of ore a day, a capacity which is considered to be quite respectable for a mill; and it is to be remembered that these 25 tons are concentrated ore, representing several times that quantity of ore as it came from the mine. The loss amounts to about 1.77 pounds of lead per ton, or less than one per cent. Of galena ore yielding, say 70 per cent, lead, one ton daily suffices for, say 70 tons pyrites, or 21,000 tons yearly; two tons daily suffice for, say 140 tons pyrites, or 42,000 tons yearly; five tons daily suffice for, say 350 tons pyrites, or 105,000 tons

If each ton of smelting ore represents 6 tons of ore from the mine, we have more than 600,000 tons of ore treated with 1500 tons of galena ore. Even if the mines of Georgetown and Argenta are unable to supply this amount, it could easily be bought in, and brought from Utah, at rates which would at least pay its own cost. My object, however, is not to urge any process upon the attention of Western miners, or prove by full figures its applicability. I offer the Lend process as one which deals with ores precisely similar to those of Colorado, and leave it to those who are interested in the mines of that Territory to work out its adaptability.

DISCUSSION.

MR. CHURCH, in reply to a question, said that nearly all the gold ores of Colorado contained enough lead to supply the waste of the process. A certain stock of lead, or lead ores, would have to be supplied in the beginning, and the lead in the ores treated would then supply, or nearly supply, the waste. The Lend ores did not contain more than 2 per cent. of galena, while the Colorado ores often have 4 and 5 per cent. The product of the lead mines is small, but it is probably enough to supply such works as those proposed. The difference between the Lend method and that of Professor Hill is, that the former is a shaft furnace process, and the latter uses a reverberatory. In the shaft the lead is more thoroughly reduced and saved, while the oxidizing action of the reverberatory tends to slag the lead. Professor Hill, however, concentrates his ores to a copper and lead matte, and produces no gold or silver. The proportion of useful mineral is larger in the ores of Colorado than of Lend; otherwise the Lend ore is almost the counterpart of the ores in Colorado, consisting of sulphides of iron, copper, lead, and zinc, with a gangue partly silicious and partly basic; and it was this similarity of ore that attracted his attention to the operations at Lend.

REMARKS ON THE HUNT AND DOUGLAS COPPER PROCESS.

BY T. STERRY HUNT, LL.D., F.R.S.

THE essential principle of this new process, now in operation in Chili and in North Carolina, for the extraction of copper from its ores, is the dissolving of the oxides of copper by a hot solution of protochloride of iron and common salt. In the action which takes place, the protochloride of iron is converted into peroxide, while the oxides of copper are changed into protochloride and dichloride, the latter of which, though insoluble in water, is readily soluble in a hot strong brine. From the solution thus obtained, metallic iron throws down the copper in a metallic state, regenerating the protochloride of iron; which is then ready for the treatment of a fresh portion of oxidized copper ore. In the case of slimy ores, the contact of the bath with the ore is effected by agitation in tubs; but when the ores are granular, lixiviation in large vats is equally efficient and simpler. The hot solutions, charged with chlorides of copper, are digested in tanks with scrap-iron, or better, are made to flow through covered channels containing the scrap-iron, and in their passage lose the whole of their copper; the reaction at the same time evolving so much heat as to keep up the temperature of the liquid. In order to prevent a certain loss of chlorine, which otherwise takes place from the production of some basic ferric chloride in the reaction between the ferrous chloride and the oxides of copper (both protoxide and dinoxide being generally present in calcined ores), a portion of sulphurous fumes from the roasting is made to pass through the regenerated bath before adding it to fresh ore. This has hitherto been effected by injection, with the aid of a jet of steam.

The advantages of this method of extracting copper over other wet processes, are that, with proper management, there is no consumption of chemicals, except a little salt, to supply unavoidable losses, and that the proportion of metallic iron required is much less than by any other; the large amount of dichloride of copper obtained in the process yielding two equivalents of metallic copper for each equivalent of metallic iron consumed. By a simple expedient, which may, in some localities, be advantageously resorted to, the whole of the dissolved copper may be converted into dichloride. To this end it is only necessary to cause the hot copper solution to filter (out of contact of air) through a layer of three or four inches of coarsely ground copper-regulus, or of purple or gray copper ore. The copper from this is rapidly taken up by the protochloride of copper, which is thereby converted into dichloride. In virtue of this solvent power of the protochloride of copper, small portions of sulphuret remaining in the roasted ore are dissolved during the lixiviation. This same reagent effects the chlorination and solution in the bath of any silver compounds present in the ore. The dissolved silver may then be precipitated, either by metallic copper, or, according to Claudet's method, as an iodide of silver.

In practice, in North Carolina, it has been found that the raw pyritous ores, rich in sulphur, should be ground so as to pass through a sieve of twenty or twenty-five meshes to the linear inch. They are then calcined in three-hearthed reverberatory furnaces, the object being to secure oxidation, but not a dead roast. Each such furnace, with three hearths, eight by sixteen, will roast from two and a half to three tons of such ore in twenty-four hours, with a consumption of one-third of a cord of wood to the ton. The treatment of the ores in stirring-vats occupies about five hours, and the residues from a five per cent. ore retain from one-third to one-half of one per cent. of copper. The consumption of metallic iron for precipitation averages less than seventy per cent. of the fine copper obtained in the form of cement copper; which, being thrown down from neutral solutions holding no persalt of iron, is unusually pure.

The only practical difficulty as yet met with in the working of the process, has been the gradual augmentation of the bulk of the bath, and its dilution by the washing of the residues and the injection of steam with the acid fumes, as already mentioned. This will be remedied by dispensing with steam, and driving, by means of a blower, a portion of the hot waste gases from the flues of the roasting-furnaces through the regenerated bath, which will thus be supplied with acid fumes, and at the same time reduced in bulk by evaporation.* It may here be mentioned that a similar plan has lately been successfully tried by Mr. R. J. Leckie, at Syracuse, for concentrating brines—a blast of air from a blower being sent through a kind of hot-air stove, and then injected, by means of a system of perforated pipes, beneath the level of the brine to be evaporated.

REMARKS ON THE EXTRACTION OF BISMUTH FROM CERTAIN ORES.

BY T. STERRY HUNT, LL.D., F.R.S.

I HAVE lately had occasion to examine sulphuretted ores of bismuth both from Tudor, Ontario, and Latete, New Brunswick. The former consisted chiefly of bismuth-glance, carbonated at the outcrop, and within associated with some metallic bismuth, iron-pyrites and graphite, in a quartz gangue. In the second locality, where it appears to be present in considerable quantity, the veinstone is also quartz, but the associates of the bismuth-glance are chalcopyrite and galena. The treatment of such mixed ores in the furnace for the extraction of the bismuth could yield only a very impure product, and in view of the high price of the metal I tried with success a wet method for the treatment of the ore, which is based on well-known chemical reactions, and may, in some cases, be advantageously used.

The pulverized ore is dissolved by heat in commercial nitric acid, and the remaining gangue washed by displacement, first with a little strong acid (which is used to attack a fresh portion of ore) and then with a moderate quantity of water, which is added to the first solution. This, if the excess of acid be considerable, may be partially

* This difficulty has since been overcome by a simple expedient, adopted at the works in Davidson County, North Carolina, which consists in keeping the liquors used in washing entirely apart from the strong solutions, and treating each separately with iron for the precipitation of the dissolved copper. In the new works at the Ore Knob mine in Ashe County, North Carolina (where eight furnaces for the treatment of sulphuretted copper ores of twenty-five per cent. are now being constructed, and will be in operation early in 1874), it is proposed to make use of a Gay-Lussac tower, by means of which a portion of the hot sulphurous fumes from the roasting can, if desired, be brought into contact with the regenerated bath or the washing waters, and a partial evaporation of the latter effected.—T. S. H.

neutralized by milk of lime or otherwise, and then, after the addition of a little common salt, the bismuth may be almost totally precipitated by the addition of water, as a dense oxychloride, which by fusion with black flux, or a mixture of carbonate of soda and charcoal, yields at once pure metallic bismuth.

The advantage of this method appears to be that it will permit the extraction of bismuth from mixed ores which cannot be advantageously treated otherwise, and moreover that it effects a separation of the bismuth from such foreign metals as would unfit it for pharmaceutical purposes. The economy of the process will evidently depend upon the cost of nitric acid at the place. It is possible that by a judicious calcination the bismuth ores might be converted into oxide, thus saving a considerable proportion of the nitric acid in the subsequent treatment. I have not, however, tried this modification. When a basic sulphate of bismuth is obtained in admixture with sulphate of lead, the two sulphates may be decomposed by boiling for a few minutes with a solution of carbonate of soda, and the resulting metallic carbonate being washed and dissolved in nitric acid, the bismuth is thrown down by simple dilution with water.

A NEW METHOD OF SINKING SHAFTS.

BY ECKLEY B. COXE.

(WITH FIGURES ON PLATES II, **III, AND** IV.)

I DESIRE to call the attention of the Institute to two deep vertical shafts, which are now being sunk in Schuylkill County, Pennsylvania, about 1 1/2 miles north of Pottsville. These shafts are of interest to the mining engineer, not only on account of the novelty of the method of sinking adopted, which promises to produce a revolution in that branch of mining engineering, but also as examples of the manner in which such work should be undertaken.

GEOLOGICAL SKETCH OF THE TERRITORY TO BE WORKED BY THE SHAFTS AND REASON FOR SINKING THEM.

The Mammoth or E Vein of the anthracite coal-measures in that part of the Schuylkill region near and north of the town of Potts-ville lies at a great depth below the surface, and has, in consequence, never been worked in that locality.

The Mammoth Vein itself is about twenty-three feet thick, but, as is shown in the following sections, it is overlaid by the Seven Feet Vein, which is separated from it by from 4 to 30 feet of rock and slate, so that the two together form a vein of about thirty feet in thickness.

BEECH WOOD COLLIERY.

Seven Feet Vein, . . .	8'.0" coal,	Seven Feet Vein,
	0'.3" slate,	Coal, 17'.0" } 17'.9"
	6'.8" coal,	Refuse, 0'.9" }
	0'.6" slate,	
	2'.4" coal,	
	10'.0" coal,	Partition slate.
Mammoth Vein, ...	6'.0" coal,	
	0'.7" slate,	Slate, 1'.4"
	7'.6" coal,	Coal, 23'.4"
	2'.4" coal,	
	0'.9" slate,	Total, 24'.8"
	2'.6" coal,	
	5'.0" rough coal.	

RECAPITULATION.

Seven Feet Vein, ...	17'.0" coal.	0'.9" refuse.
Mammoth Vein, ...	23'.4" "	1'.4" "
Total coal, ...	40'.4"	2'.1"
Total refuse, ...	2'.1"	
Total, ...	42'.5"	

AT PINE FOREST SHAFT COLLIERY.

Seven Feet Vein, ...	6'.0" coal.
Slate, ...	15'.0" to 20'.0"
Mammoth Vein, ...	20'.0" coal.

North of "Deep Shafts" the slate separating the Seven Feet and Mammoth Veins varies from 10 to 30 feet in thickness.

AT HICKORY SHAFT COLLIERY.

Seven Feet Vein averages, ...	6'.0" to 8'.0" coal.
Slate, ...	10'.0" to 10'.0"
Mammoth, ...	20'.0" to 24'.0" coal.

Section of Seven Feet (called No. 2 Vein) and Mammoth Veins, near Shenandoah.

SHENANDOAH CITY COLLIERY.

No. 2, or Seven Feet Vein,	Top slate and rock:	
	coal, 4′.0″	
	slate, 0′.2″	
	coal, 3′.0″	
	slate, 1′.0″	Dip 20° S.
	coal, 2′.4″	
	slate, 1′.0″	
	coal, 2′.0″	
	13′.6″	
	Bottom slate.	

Mammoth Vein, ...	Slate between No. 2 and Mammoth Vein, sometimes rock:
	0′.9″ coal.
	1′.0″ sulphur balls.
	3′.6″ good, bright coal.
	3′.8″ good coal, containing small streak of bone.
	0′.5″ good "charcoal bench," soft, dull, sandy fracture.
	0′.3″ coal.
	0′.1″ slate.
	3′.6″ good, bright coal.
	6′.0″ " " " "5 feet bench."
	0′.8″ slate.
	3′.0″ good, hard, bright coal, "3 feet bench."
	0′.8″ bone.
	7′.4″ very fine coal, "7 feet bench."
	1′.0″ coal, bone and sulphur, "sulphur bench."
	31′.10″
	Bottom slate.

PLANK RIDGE COLLIERY.

Mammoth Vein, ...	1′.0″ coal.	Not worked.
	0′.5″ sulphur balls.	Not worked.
	2′.0″ good coal, a little rough.	
	3′.5″ very good coal.	
	2′.2″ good coal, a little rough.	
	0′.5″ bone and slate.	
	1′.4″ good, bright coal.	
	1′.4″ "charcoal bench."	
	5′.6″ good coal, cubical fracture, "5 ft. bench."	
	0′.7″ bone and slate.	
	3′.0″ very good coal, "3 feet bench."	
	0′.7″ bone.	
	7′.5″ very good coal, cubical fracture, "7 feet bench."	
	29′.2″	
	Bottom slate.	

No. 2 Vein, ...	4'.8"	very good coal.
	0'.6"	bone.
	2'.8"	good coal.
	5'.0"	" "
Mammoth Vein, ...	1'.1"	slate.
	2'.8"	good coal.
	0'.6"	slate.
	6'.0"	good coal.
	0'.3"	bone.
	4'.9"	good coal.
	0'.6"	charcoal bench.
	3'.6"	good coal.
	6'.0"	" " "5 feet bench."
	3'.6"	coal with several seams of bone, "3 feet bench."
	0'.6"	bone.
	8'.0"	splendid coal.
	51'.1"	
		Bottom slate.

The Philadelphia and Reading Goal and Iron Company own a large tract of land in that vicinity, which was formerly the property of two companies, in which the Philadelphia and Reading Railroad Company owned a controlling interest; within a year it has passed into the hands of the former company, which is really a department of the Philadelphia and Reading Railroad Company.

Fig. 1, Plate II, is a cross-section of the property to be worked by the shafts at the point where they are to be sunk. Although the section may not be strictly accurate, the general structure of the basins is correct. Engineers familiar with the locality do not agree as to the exact position and number of the veins above the Mammoth Vein. There are three principal basins, E, C, and D, Fig. 1, to *be* reached by these shafts; they are separated by the two anticlinal axes or saddles A and B, the first of which, A, deepens to the west, and the other, B, rises for a certain distance to the east, and then sinks so that it is probable that gangways or levels through which the water will drain to the shafts, can be driven in coal from C into the two basins E and D. It is proposed to sink to the bottom of basin C, and in this manner an area of the Mammoth Vein will be opened 1500 yards wide, and at least 4 miles long, provided it should prove economical to extend the workings so far.

Mr. Franklin B. Gowen, shortly after he was elected President of the Philadelphia and Reading Railroad Company, determined to make this large body of land available for the production of coal, the upper or red ash veins having been worked out, and the land, to a certain extent, abandoned. He saw that it would involve a great outlay of money, and that it would take a long time to open the property, but he also saw that a colliery could be erected capable of producing daily a very large amount of coal for a long series of years. Before beginning operations, Mr. Henry Pleasants, the engineer selected to take charge of the work, made a careful study of the whole problem, the results of which were embodied in several reports to the company. He worked out the geological structure of the ground both by an examination of the surface indications and of the old workings, so that the most favorable position for the location of the openings could be determined. There was no useless delay, but many months were devoted by him to the consideration of the various questions which would be likely to arise, and a large number of surveys, both above and below ground, were made. When the preliminary studies had been completed the work was begun, and has been pushed rapidly to what promises to be a successful completion. This undertaking differs in this respect from most of the mining enterprises that have been started in the United States. We generally begin operations without fully understanding all that is to be done, and then solve as best we can any problems that may present themselves during the progress of the work. The latter mode of proceeding involves, of course, very often, much useless expenditure, and sometimes ends in failure. I think, therefore, that this enterprise is worthy of notice as an example of the way in which such mining operations should be undertaken.

When everything was ready the work was begun with the best appliances, and no necessary expense has been spared to make the operation a success, although there has been no useless outlay. Mr. Pleasants at first proposed to sink a single shaft, to be used both as an upcast and downcast, until another airway could be driven out from the top of one of the anticlinal axes. In the meantime, however, the Pennsylvania mining law was enacted, and, as it requires that any mine, in which more than twenty men are employed at one time, shall have at least two openings, separated by not less than 150 feet of solid strata, it was decided to sink two shafts simultaneously. The depth to which the shafts will be sunk is estimated at about 1500 feet, the distance depending upon the diminution of dip in the strata. If the clip of the Mammoth Vein in the synclinal C, is slight, the depth of the shaft will be less than if its dip is steep. The dip diminishes as the distance from the surface increases. It was finally decided to sink the two shafts (known as the East and West Shafts) about 700 feet apart along the strike of the central basin above the point marked C on the section Fig. 1. Fig. 2, Plate II, is a topographical map showing the relative position of the two shafts A and B, the railroad which is to transport the coal, the configuration of the ground, the slope CD and gangway FD, which is driven in one of the upper veins with a slight rise so that the water will flow from B to D. At the surface the strata is very much inclined, dipping about 70° to the north, but it is probable, as shown in Fig. 1, that the shafts will cross to the other side of the basin, and that the inclination of the strata will decrease. The East Shaft (A, Fig. 2) is intended solely for raising coal; it is 16 feet long, and 13 feet 10 inches wide, outside of the timbers, and will be divided into two compartments. Fig. 5, Plate II, is a section of this shaft showing the timbering below the masonry. Fig. 7, Plate II, is a section of the shaft showing timbering and stonework near the surface. The compartment shown in the corner of the shaft in Fig. 7, is used temporarily for ventilation.

The West Shaft (B, Fig. 2, Fig. 4, and Fig. 6, Plate II) is 25 feet 8 inches long, and 13 feet 10 inches wide, outside of the timbers, and will be divided into three compartments, two of which will be used for raising coal and for hoisting men, timber, slate, rock, etc., and the other will be for some years the upcast of the collieries. A suction fan will be used for ventilating the mines. No provision will, at present, be made for putting in pumps for the following reasons: In this part of the anthracite coal-field very little water is met with, when a depth of 500 feet from the surface has been reached, unless the superincumbent strata have been fissured and broken by mining out the veins below that level, so that fora long time the little water that will be met with in the mines can be raised by the winding engines at night, tanks being substituted for the cages. When the underground workings have reached the tops of the anticlinals, one or more air shafts will be sunk to them, and after they are finished, the third compartment being no longer required for ventilation can be used for the pumps, should they become necessary. There will be ample room in it for pumping machinery of the largest kind.

Fig. 3 is a cross-section of the East Shaft and of the Big Tracy vein, which (as is shown on Fig. 1) will be cut by both shafts about 400 feet below the surface. A slope has been sunk on this vein (see C D, Fig. 2, and also Fig. 1 and Fig. 3) nearly to the point where it will be cut by the shafts. From the foot of the slope a gangway

(D F, Fig. 2) has been opened at that level in the vein, and from it the cross-cuts E A and F B (Fig. 2) have been driven to the points through which the shafts, when sunk, will pass. A hole has been bored in the bottom of the East Shaft to the cross-cut E A, Fig. 2, by the method to be explained further on, through which the water that accumulates in the shaft finds its way to the sump at the bottom of the slope, from which it is raised to the surface by a Cameron pump. A hole is now being bored for the same purpose in the West Shaft to the cross-cut F B, Fig. 2.

Fig. 3 also shows the masonry and brickwork in the East Shaft, and Fig. 3 *a*, those in the West Shaft. In the East Shaft (see also Fig. 7) there is a wall of cut stone 4.5 feet thick and 16.3 feet high built upon the solid rock, and above this a brick wall 4.5 feet thick and 16.8 high. The space (about two feet wide) between the masonry and brickwork and the alluvium is filled with puddled clay, by which the infiltration of the surface-water is prevented and the walls of the shaft protected from its destructive action.

As the strata, upon which these walls are built, arc highly inclined (from 70° to 80°) it was necessary to put in below the masonry four sets of iron girders, such as are shown in Fig. 13 and Fig. 14, Plate III, in order to prevent wedges of rock from being pressed out by the superincumbent weight. The West Shaft, see Fig. 6, is walled up in the same manner, but the brickwork is 43 feet high and 4 feet thick, and the masonry is 8 feet high and 4 feet thick; under the masonry there are seven sets of iron girders similar to those represented in Fig. 13 and Fig. 14.

When the two shafts pass the level of the cross-cuts from the gangway F D, Fig. 2, water-tight troughs, cemented around the sides of the shaft, will be put in, by which all the water entering the shaft above that level will be caught and conducted into the slope and from there raised to the surface. It is not thought probable that much water will be met with in sinking below this level, but that all which will accumulate can be raised in the buckets with the rock, etc.

The two shafts are so located that they will cut the Mammoth Vein at about the same level, not exactly in the centre of the basin, as there is always an advantage in having a certain amount of coal below the bottom of the shafts for sumps, etc.

We now come to the consideration of the most interesting and novel part of the work, *i. e.*, the method employed for blasting out the rock. It was determined to dispense with the use of hand-labor in drilling the holes for blasting, and the diamond drill was chosen as the best instrument for the purpose.

This had already been done in other places, but Mr. Pleasants decided, after careful consideration of the subject, to try a new plan of working with the diamond drill, which had been suggested to him. The plan was to sink the shaft, as usual, down to the solid rock, and then, by means of a number of diamond drills, each driven by its own machine, to bore a series of holes about three hundred feet deep, which should be so arranged as to dispense with further drilling for blasting, until that depth had been reached. Fig. 4 and Fig. 5 are plans of the two shafts, showing the number and positions of the holes in each. In the East Shaft 25 holes are used and in the West Shaft 35. In each shaft one of the holes was bored down as quickly as possible until it reached the cross-cut from the gangway and slope, and in this way not only the water which drained into the shaft from the surrounding strata, but also that which had been used in the drilling, found its way to the slope, and was there pumped to the surface.

DESCRIPTION OF THE MACHINERY NOW USED IN DRILLING.

The bit used in drilling is shown in Fig. 11 and Fig. 12, Plate III. It differs from the ordinary diamond bits in being concave instead of convex. The circular grooves and the small cylindrical holes are for the outlet and circulation of the water, which is forced down through the centre of the boring-rods. The rods are made of gas pipe, one and a half inches in diameter outside. The water takes up the fine sand or pulverized rock, carries it away from under the bit and then rises on the outside of the rods or pipes to the surface. The water is supplied under pressure to the rods either by a common pump or by bringing it from a height (the tops of the shaft, for example), which is sufficient to produce the desired pressure. The machine used for drilling is much more compact and simple than the old diamond drill apparatus. A Root rotary engine has been substituted for the two oscillating cylinders, which turned the drill. The arrangement of the machine is shown in Fig. 15, Fig. 16, and Fig. 17, Plate III.

The main shaft A, Fig. 17, of the rotary engine carries a bevel pinion B, which gears into another bevel pinion C upon the sleeve D, through which the boring-rod passes and to which it is fastened. The lower end of the sleeve has a screw cut upon it by means of which the drill is fed. Upon the upper end of the sleeve D, a key-seat of from four to six feet in length is cut (the distance depending upon the length of the sections of the rod); over this sleeve a pinion M, Fig. 15, also key-seated, is slipped. A key, hanging loosely in the key-seats, causes D and M to revolve together. This pinion M gears into another pinion N, Figs. 15 and 16, which is slipped upon the head of the shaft P, Fig. 16, which has a feather on it. Upon the lower end of P is fastened a third pinion O, that drives a fourth, Q, which forms the nut of the screw of the sleeve D. This nut is so fastened to the machine that it can turn, but cannot move in the direction of the axis of the sleeve. If the pinions M and N are of the same diameter, the nut makes the same number of revolutions as the screw, and the rod does not advance; but if the diameter of N is larger than that of M, the nut makes fewer revolutions than M, and the rod moves downwards. By changing the dimensions of M and N the drill can be fed at any desired rate. The part of the machine which carries the drilling apparatus can, by unscrewing a few bolts, be turned round the shaft of the engine so that it can be used for drilling either vertically, horizontally, or at an angle. It is not necessary to dwell upon the construction of the drilling mechanism, as it does not differ from that of the ordinary diamond drill machines.

Figs. 18 and 19, Plate III, show the apparatus used for drawing up the rods. It consists of a Root engine, D, similar to the one used for drilling, upon the shaft EF of which a small pinion is keyed. This drives, by means of the small cog-wheel B, the grooved drum C, around which is wound a small wire rope that draws up the rod.

The West Shaft has seven rows of five holes each, as shown in Fig. 4, and the East Shaft (see Fig. 5) has five rows of five holes each. The method adopted for boring the holes was the same in both shafts. I shall therefore describe in detail the operation for the East Shaft only. At the points where the boring machines are put to work the cross-section of the shaft is made a little larger than it is elsewhere, so that the machine, can bore the holes in the corners and along the sides of the shaft. Two heavy timbers or sills A, A, Fig. 8 and Fig. 9, are then laid across the shaft about three feet above the bottom, and supported by the upright posts B, B, B, B; upon these timbers are placed three cast-iron bed-plates, C, C, C, Fig. 8 and Fig. 9 (see also on a larger scale in Fig. 10), upon which the drilling machines can be made to slide until the axis of the drill is vertically over the point where the hole is to be bored. The machine is then fastened down by bolts, the heads of which fit in the grooves on the bed-plate. As soon as the first hole has been bored to the required depth the machine is moved to the next. Two or three machines can work at the same time on the same bed-plate. When the five holes in the first row have been bored, the bed-plate is moved to the next row. The operation is continued until all the holes in the shaft are drilled. A large quantity of water is required for drilling, as a constant stream of it, filling a pipe about half an inch in diameter, must be forced down through each of the boring-rods. The water passes through the centre of the rod, takes up the fine sand produced by the action of the machine upon the rock, and carries it up on the outside of the pipe or rod, which is smaller than the hole.

In boring the first set of twenty-five holes, this water was brought from the surface and was returned to it, when it had become dirty, by a steam-pump. Two small Cameron steam-pumps were employed for forcing the water down the rods and raising the dirty water to the surface. After the first hole had been drilled, so as to open a way for the water into the cross-cut from the slope, the water which collected in the shaft and that which had been used for drilling found its way through this hole to the pumps in the slope. When the shaft becomes deeper, the intention is to use the same water over and over again for drilling, by pumping it into a settling-tank, placed from 200 to 300 feet above the bottom of the shaft, in order to get head enough to force the water with the required velocity through the rods. The tank will be divided into two parts, so that the water can be partially filtered in passing from one to the other. It is essential to remove any oil which the water may take up in its passage through the rods or which may fall in it from the machinery, as the oil solidifies or gums and clogs the holes in the bit, through which the water passes out from the centre of the rods. It is not necessary to remove all the fine particles of pulverized rock which the water may bring up, unless it is important to know the exact nature of the strata in which the drill is working.

The average rate of drilling, as shown by the following table, is from 30 to 40 feet a day for each machine.

The machines often work much faster, but, there are incidental delays. Seven machines are at present employed, and as there are no cores to be removed, all the rock being ground to powder and carried off by the water, it is not found necessary to take out the rods very often. Steam is now used to drive the boring machines and the pumps, but preparations are being made to use compressed air in the lower levels, partly because the use of steam would render the shaft uncomfortably warm, and partly because there would be great danger of injuring the men in case any accident should happen to the steam pipes. A fan has also been erected for the purpose of ventilating the shaft.

Statement of Drilling done at East Shaft of. East Norwegian Colliery, on Lands of Mammoth Vein Coal and Iron Company.

No. of Machine.	Date when started.		Date when finished.		Depth of holes.	
					Feet.	Inches.
1	January	17.	February	1.	334	5
2	"	17.	"	1.	318	11
3	"	31.	"	8.	200	8
4	February	3.	"	9.	198	7
5	"	6.	"	12.	200	0
6	"	12.	"	17.	197	2
7	"	13.	"	22.	205	2½
8	"	15.	"	23.	179	2
9	"	19.	"	24.	205	2
10	"	20.	"	27.	205	2
11	"	21.	"	26.	200	8
12	"	23.	"	28.	201	5
13	"	24.	March	6.	312	0
14	"	24.	February	27.	200	4
15	"	26.	March	6.	293	0
16	March	1.	"	7.	254	8
17	"	1.	"	9.	279	0
18	"	1.	"	11.	290	0
19	"	5.	"	14.	295	3
20	"	8.	"	19.	295	0
21	"	9.	"	16.	307	4½
22	"	9.	"	18.	298	0
23	"	13.	"	20.	281	7
24	"	15.	"	23.	295	0
25	"	16.	"	23.	301	2

Greatest number of drilling machines used, ... 7
Average " " " at work, ... 3
Average drilling done per day of 24 hours by each machine, 34 feet.

When all the holes are bored to a depth of from 250 to 300 feet, the machines, pumps, etc., are taken to the other shaft to bore the holes in it. During the boring in one shaft, the rock is blasted arid removed in the other. There is always time to spare, as three hundred feet of holes can be drilled much more quickly than the shaft can be sunk through the same distance in rock. The diameter of the holes is in all cases 1½ inches. On the completion of the holes they are filled to the top with sand, and the work of blasting and removing the rock begins. The operation of blasting is conducted as follows: The miner, by means of a small pump, such as is used with ordinary boring-rods, removes the sand from the holes Nos. 7, 8, 9, 12, 13, 14, 17, 18, and 19 of Fig. 5, to a depth of from three to four feet; clay is then forced into each hole, so as to make a plug from six inches to a foot long, and on the top of this a cartridge of dualin is placed, and the holes are then tamped with clay. The cartridges are connected together by wires leading to a galvanic battery, and they are all fired at once. The explosion is produced by a cap filled with fulminate of mercury. The result of the simultaneous discharge of these nine holes is the formation of a large cavity in the centre of the shaft to the depth of the bottom of the cartridges. The rock loosened by the operation is removed, and the remaining holes are then charged and fired in the same way, those on each side together, but only one side at a time. It should be noted here that powder is not effective in vertical holes. Dualin, dynamite, or some other of the nitroglycerin compounds must be used, particularly where the strata are nearly vertical and to a certain extent fissured. The sides of the shaft preserve their proper form, and no hand-blasting is necessary for trimming them up. When all the holes around the shaft have been fired the miner begins again with the nine central holes, and the work goes on in this manner until the depth to which the holes have been bored is reached; the machines are then set to work again, and the holes a're bored from 250 to 300 feet deeper.

The holes in that part of the shaft which has been sunk preserved their vertical direction until they reached a small vein of coal, where, although remaining in the vertical plane at right angles to the strike, they were deflected towards the floor of the veins, as shown in Fig. 20, Plate IV, the angle of deflection being about two degrees. This deflection is due to the fact that when the drill reached the top of the vein, which dipped at an angle of about 60 degrees, and was softer than the rock, it inclined toward the side offering the least resistance. Thus far the deflection has been so slight that it was only necessary after the nine central holes had been fired to put a larger charge of dualin in the holes on the side CD than in the vertical holes, and a smaller charge in the holes on the side AB. In the first case (CD) the dualin shattered the rock behind it, and it was possible to keep that side of the shaft vertical without resorting much to hand-blasting. In all other parts of the shaft the holes went down in a perfectly vertical direction. The corners of the shaft are exactly where the four corner holes went down, and the sides of the shaft look as if they had been trimmed up, although in reality nothing of the kind has been done. The sides have very much the appearance of a stone which has been broken by a plug and feather. The shaft is timbered as the work proceeds, yellow pine timber 12 inches by 12 inches, placed at first skin to skin, and afterward 2 feet apart, being used below the iron girders. The guides are of Carolina yellow pine, and are put in as the work proceeds. The bucket used for taking out the stuff will be guided as is shown in Fig. 25, Plate IV. Two buckets will be used, and there will be shields above them to catch anything that may fall in the shaft (see Fig. 24, Plate IV), so as to protect the workmen. The bucket is made of iron, holds from one to two tons of rock, and has two trunnions placed opposite to each other a little above its centre of gravity. When the bucket is raised to the surface, a truck (Fig. 21, Fig. 22, and Fig. 23, Plate IV) is run under it on a railroad passing over the shaft, and the bucket is then lowered into the Y-shaped rests. The rests are supported on a turntable which allows the bucket to be revolved in a horizontal plane, and, by means of the lever A, the bucket, being suspended nearly at its centre of gravity, can easily be overturned and emptied. This apparatus is simple, and works admirably. By having several trucks and buckets the stuff can be hoisted and disposed of very quickly.

In the East Shaft with eight machines, the 25 holes can be bored in about one month. In the West Shaft, with from 8 to 10 machines, the 35 holes can be drilled in about six weeks. The East Shaft was sunk from April 15th to May 15th of this year (1872), seventy-six feet, and during this time, 12 days (5 in April and 7 in May), were lost, that is to say, there was no blasting done from want of timber, and from want of fresh air, in consequence of the brattice not having been built near enough to the bottom of the shaft. In blasting in the East Shaft 2 miners, 3 laborers, and 1 chargeman are employed on each shift. There are three shifts of eight hours each per day.

In the first 300 feet drilled in the West Shaft the rock was hard ; in the East Shaft it was principally soft rock and slate. The plan of boring the holes to a depth of 300 feet at once, filling them with sand, and then using portions of them, as wanted for blasting, was first suggested by Mr. Shelley, formerly superintendent of the William Penn Colliery, in Schuylkill County. Mr. Bullock, formerly superintendent of the Pennsylvania Diamond Drill Company, took up the idea and suggested it to Mr. Pleasants. After carefully considering the question and testing it, Mr. Pleasants recommended Mr.

Go wen to sink the two deep shafts with the diamond drill in this manner, and upon his advice the company decided to try it. After this endorsement of Mr. Pleasants, and the decision of the company, Messrs. Shelley and Bullock patented their process of " drilling deep holes, filling them with sand, and firing them in sections." The patent now belongs to the Pennsylvania Diamond Drill Company,

As soon as he had decided to use this process, Mr. Pleasants became satisfied that the form of engine then employed with the diamond drill was too large and unwieldy for use in the confined space at the bottom of a shaft, where several of them would be in operation at one time; he therefore determined to use the Root rotary engine to drive the drill, and employed the superintendent of the Pennsylvania Diamond Drill Company, Mr. Bullock, to carry out his idea of a small compact drilling machine to be attached to such an engine. The plan, when completed, was submitted to two of the best machinists in Schuylkill County, who suggested some slight modifications. The plan finally adopted has been given in what precedes. Nine of these machines have been constructed by Messrs. Allison and Bannan, of Schuylkill County, for this work. It is, of course, impossible to determine what will be the exact cost of sinking by this method until the work has proceeded much further. The estimate of the cost of the two collieries has not been made public, being, I believe, a confidential communication to the company. As neither the depth of the shaft nor the exact nature of the strata to be passed through were known, it could only be approximate. Mr. Pleasants, however, informed me that he did not consider that the cost per foot of sinking by this method would necessarily be less than by the old one. The great advantage, he says, will be in the saving of time, which, he thinks, will be fully fifty per cent.; this is, of course, a consideration of immense importance in an operation involving the outlay of so much money. Another advantage is that most of the men employed need not be skilled miners. Mr. Pleasants considers that the method will be employed with peculiar advantage in sinking shafts of moderate depth (from 200 to 300 feet). In such eases, after a shaft has been sunk through the earth, clay, or wash, to the rock, the machines can be put to work on the surface and the holes bored down to the depth which it is intended to reach by the shaft. The shaft can then be sunk without any hand drilling. The great advantage of this method, where the strata to be penetrated contain large quantities of water, is self-evident.

SUPPLEMENT.

Since the foregoing paper was read, and before its publication, I again visited the shafts and obtained, on April 25th, 1873, the following additional data.

The East Shaft has been finished to a depth of 530 feet, and the holes for 200 feet more have been drilled. The West Shaft has been finished to a depth of 400 feet, and they are beginning to bore the next set of holes. During the last six months the East Shaft has been sunk on an average over 60 feet per month. In one month 80 lineal feet of the shaft was blasted and timbered.

The permanent guides have been put in place in the East Shaft as far as it has been sunk. The two shafts have been connected on the surface by a railroad. Six machines arc used in the East Shaft for boring. In place of the screw feed described in the foregoing paper, a new hydraulic feed has been tried with success. The revolving sleeve is placed between two cylinders, in which two pistons, connected with the lower end of this sleeve, move; by admitting water under a greater or less head, by means of a stopcock, the drill can be moved forward as fast or as slow as may be wished, with any required pressure. The shaft has passed the level of the cross-cut, and the water in the shaft has been cut off by forming water-tight gutters around the shaft upon one set of timbers, and from them the water is conducted to the slope. There is not water enough met with below this level to keep the timbers wet. If the slope was not there, and the water had to be pumped from the bottom of the shaft, it would require five lifts of pumps, a Cornish engine, rods, pumps, etc., to raise the water from the bottom of the shaft when the work was completed.

A double-acting Allison & Bannan steam-pump, with fourteen-inch plungers, has been put into the slope, replacing the Cameron pump.

A double-acting Waring compressor has been erected, by which from four to five of the drilling machines and the steam-pumps in the shaft can be driven. Some of the drilling machines are actuated by steam, *in* order to prevent the temperature in the shaft from being too much lowered.

At the Ellangowan Colliery, near Mahanoy City, belonging also to the Philadelphia and Reading Coal and Iron Company, a shaft is now being sunk which will not exceed 300 feet in depth. The holes for the blasting have all been bored from the top to the bottom in one operation.

The East Shaft, which was originally on the south side of the basin, has passed the synclinal and is now cutting through the south-dipping strata, the dip being about 30°. This was predicted by Mr. Pleasants, as may be seen by his section, Fig. 1, which was made at least a year before the shafts reached the synclinal.

PITTSBURGH MEETING.

OCTOBER, 1872.

THE POSITION OF THE AMERICAN PIG-IRON MANUFACTURE.

BY EDMUND C. PECHIN.

THE iron trade of America seems on the point of a new departure. After years of struggling against heavy odds, patient endurance in periods of depression and loss, fears and hopes alternating as failure or success seemed to be the penalty or reward; wanting in sufficient capital, embarrassed by reason of imperfect knowledge and lack of skilled labor, confronted by a powerful foe—every doubt has at last vanished, physical and mechanical difficulties have been largely overcome, capital has become more abundant and remunerative, the excellence of our product has been everywhere established, and the peculiarities of American character—pluck, energy, and perseverance—have at last placed the trade upon a foundation so broad and stable that upon it we begin to erect the structure of a world-wide business.

Concerning the future of the iron trade in the United States there can be but little doubt.

The growing scarcity and constantly increasing cost of raw material in Great Britain, their loss of labor by emigration, the social disturbances among the working-classes, assuming a more threatening attitude on each new outbreak; the rapidly decreasing value of money, in consequence of the enormous production of gold and silver, combine to forbid any return to former prices, and indicate that a point has been reached beyond which any marked increase of production is improbable.

The same causes are operating to a greater or lesser extent upon the Continent.

In the meanwhile the growing wants of humanity are rapidly outstripping these sources of supply. In addition to the steadily increasing foreign and home demand, we find, the world over, the most intense activity everywhere displayed in enterprises requiring prodigious quantities of iron. Railways of colossal magnitude are building or projected in Russia, Australia, the East Indies, North and South America, and now the hoary and laggard East unbars its venerable portals and invites, with open arms, the fresher and nobler civilization of the West to renew its life by giving to it what the other, out of its own fertile brain, has created.

In the United States, irrespective of the 60,000 miles of railroad to be maintained, and the 5000 miles annually building, the uses of iron arc almost infinite. Day by day the application of iron and steel in new directions, and in novel forms, is increasing.

It is authoritatively stated that at the present rate of annual consumption, in eight years the forests of Maine will have disappeared. In the Northwest the ravages of fire and the axe of the woodman are rapidly diminishing that source of supply. This growing scarcity of timber is *compelling* the use of iron in buildings; bridges of wonderful size and strength; huge ocean steamships; barges and boats for lake and river traffic; churches; cars, and thousands of minor articles of every shape and size. Thus, looking over the whole field of operations, the present is most favorable, the future most promising. Thus far what has been said applies equally to all branches of the iron and steel business. What follows is applicable more particularly to the manufacture of pig-iron.

That the stocks of raw irons are inconsiderable the world over, seems to be admitted. No better evidence is needed than the present scarcity and high price. The chances are against any material increase abroad; so that the only matter likely to disturb the home market is excessive domestic competition.

From the very nature of the business, it can only be increased with moderate rapidity. Under the most favorable circumstances it takes a long time to build a modern furnace; the capital required is very great, allowing only men of large means to engage in such an enterprise. The localities naturally adapted to the business are comparatively few. A still greater obstacle is the time and money needed to open mines and deliver material. Whether the furnaces in existence to-day can obtain full supplies of ore for the ensuing year is by no means a settled question, and, from all the data obtainable to day, the probabilities are against it.

The outlook, therefore, is favorable.

But all this may change; excessive prices may check consumption, and a falling off of demand may cause lower prices, and possibly loss; unexpected crises may come, just as they have come before, causeless panics may again unsettle trade. It is, therefore, a duty that each man owes to himself to ward off disaster by present watchfulness.

There is, however, a higher standpoint to take, a nobler aim to strive for, than merely present gain or a temporary success. The future is to be controlled.

The American iron-master should plan, construct, and manage, *as* if the barest profit that rewards capital and labor were his; as if he were assailed on all sides by the fiercest competition at home; as if he had to seek the market of the world for his living, and find himself opposed to the product of all nations and countries.

To build up a business that will be permanently successful, that will grow with our nation's growth and strengthen with her strength, we must put ourselves in a position to make as good an article, and sell it as cheaply as any other people can or will, and anything short of this is practically failure.

To accomplish this, we must summon to our aid three assistants,—science, mechanical appliances, and contented labor. Those three are so closely connected, that take one away and the others are paralyzed.

The time has come when scientific research is to assume its true position—the day of "sheer force and blind stupidity," whose only protection was a high tariff, has gone by forever. The prodigal waste of the rich gifts of nature; the vast sums of money thrown away; the hard labor, in the aggregate too large to be even approximately estimated, which has been uselessly expended; the mishaps, drawbacks, and failures which have followed every step of our business, show most conclusively that the physicist, the geologist and mineralogist, the chemist, the engineer and mechanic, are as essential to success as the furnace itself, or the labor that works it. They teach us how to apply the laws of air and heat and power most advantageously, where and how to look for our raw supplies, what they are worth to us when found, how to admix them to produce the most economical and profitable results, how to extract them from the earth, and transport them at least expense, how to take them from crudeness and unproductiveness to the thousand forms of use and beauty.

There is no merely practical man, no matter how varied may have been his experiences, or how long his practice, that will not be benefited by the results of scientific investigation. That there is a growing sense of the importance of having thoroughly prepared scientific men in every department of business is evinced by the institutions that are springing up in different quarters, provided with able teachers, most complete apparatus and models, and, significantly enough, splendidly endowed by men, who while achieving success and acquiring wealth without the advantages of a scientific education themselves, are giving to others those advantages which they could not themselves enjoy.

While our country has lacked these opportunities, scores of young men have availed themselves of the facilities afforded by the admirable schools abroad, and have come home accompanied by thoroughly educated foreigners, attracted by the growing prosperity of our country, to offer their services, while America is preparing her own sons for her future needs. It should be alike the duty and pleasure of the trade to recognize their abilities and liberally sustain them in their high and honorable calling.

Before coming to our second assistant it may be observed that the location of a blast furnace must be governed by circumstances. Convenience of supplies and accessibility to market usually determine this point.

Ores bear transportation for a greater or lesser distance, according to purity and richness, without loss, as does pig metal. Fuel suffers materially by handling, carriage, and storage. The loss by abrasion and breakage is much larger than is generally supposed, while recent investigations have demonstrated that all fuels suffer a loss of carbon by exposure; especially with bituminous and semibituminous coals, is the loss heavy—an exposure of only two weeks causing a loss of carbon to the extent of from ten to twenty-five per cent. The carriage of limestone should be avoided as much as possible, thereby saving expense on slag. The true rule is to pay freight on the manufactured article, and not on the raw material.

The supplies and the knowledge of how to save them being obtained, the next consideration is the furnace and its appliances.

The contrast between the furnace of to-day and the type of only ten years ago is astonishing. Light and graceful structures of iron have taken the place of huge and expensive masses of masonry ; compact, durable, direct-acting engines have superseded acres of machinery ; a simple arrangement of pipes and flues replaces the complicated system of olden times; ingenuity has been successfully taxed in devising methods for heating the blast to high temperatures, thereby economizing fuel, increasing the yield and improving the product; careful scientific and experimental investigation has so modified the interior lines of the furnace that the gases act with a uniformity and effectiveness in the reduction of the materials utterly unknown a few years since; closed tops control the hitherto waste gases to the useful purpose of generating steam and heating the blast; simple and ingenious devices raise the stack to any height, determine accurately the materials supplied, calcine the ores and limestone and break them in suitable size, properly prepare the fuel, and day or night, without rest or cessation, perform the work of an army of men.

The manufacture of iron may be robbed of very many of the uncertainties which have characterized it in the past. With duplicate engines, of greater power than ordinarily required, a steadier blast can be obtained, and in event of an accident to one, the other can be temporarily taxed to take its place. A reserve of boilers and hot-blast stoves permits cleaning and repairing without the furnace standing idle, and every iron-master knows too well what a stoppage of twenty-four hours costs him; height utilizes the gases in the reduction of the ores and economizes the fuel; the larger the bosh, the larger the yield and the cheaper the product; the wider the throat and bigger the flues, the more readily the gases pass off.

Of course these general features must be modified to suit particular ores and different kinds of fuel.

To do all this, money must flow like water; in the usual sense of the word, there can be no such thing as economy in the construction of the blast furnace. Whatever is proved to be the best adapted for the particular purpose to which it is to be applied, must be adopted, regardless of cost. In our case "to be penny wise is *not* to be pound sure," and a furnace is one of the exceptions which prove this rule. Whatever can be done by machinery, let machinery do, for *it* at least is insensible to Fourth of July, Washington's birthday, political meetings, pay-clays, and whisky.

The most unreasonable, unreliable, crankiest, and most troublesome machine is the human machine; and this brings us to our final assistant, labor.

In treating this, we at once get upon most delicate ground.

The labor question is one of the great unsolved problems of the day. How to manage it—to determine its proper relations to capital—to render it efficient, satisfied, and productive, are questions which wise and good minds everywhere are anxiously seeking to answer.

That capital and labor should not be antagonistic is a truism, but a truism very difficult to apply to everyday life.

It is quite impossible on an occasion like the present, to discuss at any length the various bearings of a question so full of interest, and so potent in its consequences. All that will be attempted, will be to present most briefly the views of the writer, formed as the result of observation, considerable personal experience, and a good deal of reflection. They are advanced with diffidence, as they may be widely at variance with the opinions of those better calculated to form wiser conclusions.

At the outset, then, let a sympathy and confidence be established between the master and his men. There is something more to be done than exact the full hours of service and pay the wages therefor; there is a kindly feeling to be created, a sense of mutual interest to be aroused, a sentiment of fellowship to be developed. To make a thoroughly good workman, we must make him intelligent; to make him contented, he must be able to comfortably support his family, and lay by something for a rainy day ; to make him sober and moral, while bring decided, we must appeal to those better feelings, often covered up and dulled, but rarely entirely absent. In pursuing such a course, many discouragements will be encountered; the motives may be misconstrued; ingratitude may oftentimes be the only return, but in time the effect will be produced.

It must be remembered that a very large number of workingmen arc imperfectly or not at all educated. Many of those coming to us from the Old World have been led to believe that their masters are their natural enemies, to whom they are to give as little, and from whom to take as much, as circumstances will permit; their impulsiveness and credulity often make them the willing tools of some of their own class, who, with a smattering of knowledge, are generally wiseacres, impracticable and dangerous—never wise, and rarely useful; their just demands are often needlessly refused, their unjust ones not met with sufficient firmness. Workingmen, *as* a rule, are more prejudiced than unreasonable; more suspicious than malicious; much more easily led than driven. Convince them that an appeal to the master will be met with consideration and fairness, and they will make the appeal before they strike; let their employer gain their confidence by impartiality and kindness, and if he can give a good reason for refusing their demands, they will suffer much before coming to an open rupture.

Their life at best is an unenviable one; their toil is incessant, their homes in many cases miserable, their improvidence prevents accumulation; deprived of work, by sickness or otherwise, their house-holds suffer; if they die, their families are thrown upon the charities of the cold world.

Let us masters be philanthropists as well as money-makers. By becoming benefactors to those under us, we will make them better and happier, more attentive and more profitable, and in addition to the larger return from their better labor we will reap the most satisfactory reward of an approving conscience.

Another important point is to make labor intelligent. Most excellent practical results are reached by workmen without their having the least idea of how or why they arc so. In the blast furnace, where so much depends upon the accuracy and attention of the hands, if they could understand, even in a general way, *why* they should do thus and so, they would save themselves much labor and oftentimes injury, their employers loss, and take away from the business many of its drawbacks. The simplest knowledge of the effect of heat, of blast, and of the nature of materials, is usually wanting, and the "rule of thumb" being the only guide, the result is whatever good or bad luck may happen to bring.

For the present generation the only method of mental improvement would be by night-schools, with a series of lectures. Discarding technical terms, and using only the simplest language, with such diagrams as could readily be drawn upon a blackboard, a vast deal of most useful information could be imparted, and by allowing, and, indeed, inciting questions, many points misty and unsettled, could be made plain and firmly fixed in the mind.

For the future, a class of reliable furnace-men may be made by taking bright, industriously disposed boys as apprentices, and just as in other trades, good workmen may be built up.

By supplying a comfortable, well-lighted, and regulated reading-room, where men may gather after their work, find the papers and journals of the day, and especially the industrial and mechanical publications, and enjoy the opportunity of talking together, or amusing themselves in an innocent manner, not only may many hours be snatched from grosser pursuits, and the disgusting associations of the grog-shop and gambling saloon counteracted, but a wholesome influence may be exerted in rendering the manners less rude and boisterous, the mind more susceptible to reason, and the desire for improvement more intense.

By all means, if possible, workmen should be attached by local interests. The class of men most difficult to control are single men; they have no local attachments; one place is as good as another; a desire to see the world, as they call it, makes them restless, and upon the slightest provocation they leave. On the contrary, a man with a family dependent upon him dislikes change, he cannot afford to lose time, and a natural desire is present to save something for those he may leave behind him. The strongest hold that can be had on a laboring man is to make him the owner of his own home in the vicinity of his work. Besides securing steady men, the employer is thus largely relieved from the necessity of providing houses, and more profitably employs his capital in his business. The formation and proper conduct of mutual building and loan associations, where circumstances will permit, should therefore be encouraged.

Sickness or disability is the greatest misfortune that can come to a laboring man. His income is cut off, medical attendance is expensive, family expenses run on, and when he once more goes to work he is burdened with debt and harassed with care; if honest, he struggles along under a heavy weight; if not, he steals away as the easiest way of paying a debt, often taking his first step in dishonesty, which he is apt to repeat for a less potential cause, and each time with greater ease, until he becomes a scamp himself and by his example makes scamps of others. The establishment of an hospital and pension fund in which the master takes a liberal share and interest makes a workman contented, because he can look forward without dread to sickness and old age. The benefit being lost if he voluntarily leaves, or for good cause is discharged, is a strong incentive to duty.

The co-operative plan, whereby the workman is entitled to a certain share in the profits of the business, is of recent adoption. In many instances it is working well. It is, however, so dependent upon the peculiarities of a business that to lay down any rule of action is impossible. Where workmen alone have attempted it the result has oftentimes been a failure, owing to lack of proper commercial education, diversity of opinions, and want of vigor and unity. Where the master has retained the general direction, and simply divided a proper proportion of profit, success has usually followed, strikes are avoided, good men are attracted by such a partnership, and self-interest prompts them to work well themselves, and to watch that their fellow-workmen do their duty.

The calling of an iron-master is more than interesting. We wage a Titanic warfare with nature, compelling her to relinquish from her tenacious grasp those varied treasures which, through countless ages, she has hidden away within her deep recesses. We summon to our aid all that science can afford, mechanical ingenuity devise, money purchase, and energy and ability achieve, and when this is done, we must fain confess how little we have accomplished, and how little we know compared with the vast possibilities that lie before us. Our occupation is fascinating because so uncertain. It demands the most careful attention, the nicest accuracy, the most incessant watchfulness, the boldest expedients, the strongest nerve.

We may not make the best iron that is produced, but it is our own fault if we do not make the *best* product that our materials will admit of, at the smallest possible cost, and at the largest possible profit.

A patriotic Virginian once declared, that "Eternal vigilance is the price of liberty." In these more utilitarian days we may truthfully and feelingly exclaim, "Eternal vigilance is the price of pig-iron."

DISCUSSION.

During the reading of his paper, Mr. Pechin remarked that he had sent to New York for comparative analysis, samples of Connellsville coke which had been exposed to the weather for two years and others freshly manufactured, and to his surprise the analyses, carefully made by Mr. Schuyler Van Rensselaer, showed there was no loss of carbon whatever by exposure in the Connellsville coke. This being the fact, it proves conclusively that coke is one of the most valuable materials for the iron-master, because it can be stored indefinitely, while even the best anthracite will lose a percentage of its carbon; and bituminous coal loses from 10 to 25 per cent and upwards in weight by exposure.

MR. JAMES PARK, JR., said: This is the first time I ever heard the subject broached in this practical way, and I trust all the members of our Institute will look into it. Let us test our coals, and see how fast they do lose carbon. I believe that when carbon is crystallized, as it were, in coke, it is fixed and permanent, but it is a great thing to know that as a fact.

MR. WILLIAM FIRMSTONE: I have tried coke after two years' exposure, and it gave as much heat in the blast furnace as that freshly made. We thought the old coke made better iron, probably on account of the elimination of sulphur, but otherwise there was no perceptible difference.

PROF. COX: Some coke that had been made five years was sent to Buffalo for analysis, and the report was that it was just as good as new coke.

PROF. JOHN W. LANGLEY: The question, whether a given fuel will suffer waste by exposure to the air, appears to me to be dependent on the combustibility (or igniting temperature) of the substance. Experiments first performed by Herr Grundmann, at Tarnowitz, in Germany, have proved conclusively that an exposure of bituminous coal in heaps to the action of the weather, for a period varying from two weeks to a year, results in a large percentage of loss.

This loss is in the nature of a slow or incomplete combustion; it is greater and more rapid in large heaps than in small, and is also favored by the greater or less state of subdivision of the coal, large fragments losing proportionately less than small ones.

The total diminution of weight of coal so exposed ranges from twenty-five to forty per cent. in eight months, and the chief portion of this action takes place within the first three weeks after mining. The chemical nature of this waste has been investigated by Varrentrapp, of Brunswick, Germany, and by others, and the method of proof was as follows :

A quantity of pulverized coal was placed in a tight vessel, through which a current of air could be drawn. The vessel and air were brought to a temperature of 280° Fahr., and the air, after passing through the apparatus, was caused to bubble through certain chemical solutions which have the property of retaining and rendering visible carbonic acid. The substance used was a solution of baryta. Under these circumstances the carbon of the coal was ultimately removed by the chemical solution from the air as carbonic acid, showing conclusively that a true combustion had taken place.

The combustion is so complete, that in three months nothing but ash is said to remain. This, however, occurs at 280° Fahr.; at lower temperatures the process goes on much more slowly.

I have found, in experimenting on our Pittsburgh coals, that they suffer loss even when kept in porcelain dishes in the laboratory of the University, but that, if the surrounding air is *perfectly* dry, no appreciable loss takes place at ordinary temperatures; on the other hand, the air in its ordinary state contains moisture enough to cause the slow wasting of the fuel, and if the coal is kept wet the change is quite sensible. Still, I have in no case, operating on the small scale, found our native coal to suffer as much as the foreign experiments would indicate. This is probably due to a difference in the character of the fuel.

In the remarks which have just been made, analyses have been quoted to show that coke loses no carbon by exposure; and the question has been asked, why there should be a difference between it and coal. There is good reason for supposing that the carbon in coke is physically different from that in the raw fuel. It is well known that any carbonaceous body requires a temperature for its ignition higher in proportion to the degree of heat to which the fuel has been previously exposed; thus, coke and anthracite both require a higher initial temperature, and to be used in larger volumes for successful ignition and combustion.

I may draw an illustration from the domain of abstract science, and instance a point which I first observed three years ago, but which, very probably, is not original with myself.

A feeble current of electricity, as from a thermoelectric battery, will not be conducted by a fragment of anthracite; but if the lump is first heated red-hot and then cooled, the current will flow through it readily.

Taking the well-known increasing series of the. igniting-points from bituminous coal, charcoal, anthracite coke, gas-carbon, plumbago to the diamond, and the somewhat parallel order of their conducting power for electricity, 1 think we should be justified in assuming that the carbon of each of these is not physically or chemically exactly identical with that of its neighbor, and that *à priori* we might expect coal to enter into slow combustion, but should not look for any such result in coke.

THREE-HIGH ROLLS.

BY ALEXANDER L. HOLLEY, C. E.

(WITH FIGURES ON PLATE I.)

A CHARACTERISTIC, and, to Americans, an amusing discussion of the three-high rail-mill, arose out of the reading of Mr. Lauth's paper on three-high plate-mills, at the Glasgow meeting of the Iron and Steel Institute.

From the report of the meeting in the English papers, it appears that Mr. Menelaus, the celebrated rail-maker of Dowlais, could not wait for the discussion of Lauth's *plate-mill*, but launched at once into the British objections to the three-high *rail*-mill, which is quite another matter.

The American mill, which is very different in principle and arrangement from the mill used abroad, appears never to have been understood by foreigners, although many of them have observed its working, during the last fifteen years, in our various iron and steel works. American iron-masters certainly do not complain of this oversight, much as they may wonder at it.

Mr. Menelaus, Mr. Snelus, and Mr. Williams prefer the two-high mill for the following alleged reasons :

1st. It requires a smaller stock of rolls, as compared with the three-high mill.

2d. The section of American rails is not uniform on the two sides, due to the fact that the top and middle rolls in a three-high mill are movable, while the bottom roll is fixed.

In order to test the value of these objections, it will be necessary to observe the difference between the English and the American mill—a subject which I had the honor of presenting to this Institute at a former meeting. Fig. 5, Plate I, shows the American three-high rolls. The top and bottom rolls are deeply grooved, and the middle roll is nearly plain, *i. e.*, the middle roll answers as a cover or lid to the grooves of the other rolls. The piece enters groove No. 1 between the bottom and middle rolls; it is then returned through No. 2, between the top and middle rolls, and so on above and below the middle roll, to the end. There must of course be a slight space between the groove and its cover, that is to say, between the collars of the upper and lower rolls and the collars of the middle roll, and into this space a fin of metal is squeezed out at each pass. If this space always occurred at the top of the groove, or always at the bottom of the groove, the fin would be increased at each pass, and would ultimately spoil the rail. It is necessary to reverse the position of this fin at each pass, and this is just what the American three-high mill does. The grooves open alternately upwards and downwards. In groove No. 2, the top of the flange conies against the solid body of the roll, and no fin forms. But the bottom of the flange occurs at the opening between the top and middle roll, and here a fin forms. On the next pass, No. 3, the fin that was formed on the bottom of the flange is smoothed out by coming in contact with the solid body of the lower roll, and a fin forms at the top, which fin is, in turn, smoothed out by No. 4 groove, and so on to the end. At the same time it will be observed that the rail is *not turned over;* the flange is always at the right. This feature is essential in rolling, not only rails, but beams and all finished bars that require closed grooves.

Now in the English three-high mill, Fig. 6, the bottom and *middle* rolls are grooved, instead of the bottom and top rolls. The grooves all open upwards, instead of alternately upwards and downwards. Hence, to smooth out the fin left at the top of the flange by pass No. 2, the rail must be turned over before it enters pass No. 3, in order to bring the fin in contact with the solid body of the bottom roll. The rail *must be turned over after each pass,* with hooks and tongs and hard work, while in the American mill it is simply caught on the hooks and entered just as it comes out.

It will also be observed that the English mill requires much more length of roll for a given number of passes. The rolls shown are of the same length, but the American mill has seven passes while the English has but five. This is due to the fact that in the latter mill the plain roll—in this case the top roll—forms a cover to the grooves of one of the grooved rolls only, *i. e.,* of the middle roll. Enough space has to be taken out of the middle roll to form the covers for the grooves in the bottom roll. In the American mill, however, the middle roll forms the cover for the grooves in both the grooved rolls.

The question now arises, Why is the English form of mill used? With collared rolls and deep box grooves it is necessary to employ the guide, *a,* Fig. 7, which is a sort of chisel, lying in the groove like a turning tool, to peel the piece out of the groove. Otherwise the side friction of the collars against the piece would wind it around the roll. When the three-high mill was first introduced abroad, it seems to have been supposed that the guide must lie in the groove by gravity—that it could only be applied to the top of a roll. Hence the bottom and middle rolls, Fig. 8, must be grooved, for on the top of these rolls the piece passes. The Messrs. Fritz, of Pennsylvania, however, did not take this for granted. They saw the immense advantages of the grooved top roll instead of the grooved middle roll, and they at once devised the very simple expedient of a hanging guide, *c,* Fig. 7, to peel the piece out of the *bottom* of the groove in the upper roll. But a guide in the bottom of a groove will fall out —then it must be held in ; and what more simple and durable device for this purpose can be imagined than the counter-weight, affording a uniform pressure on the roll, and capacity to yield to its inequalities. We have read that for the want of a horse-nail an army was lost; for the want of an almost equally small and obscure piece of iron—a hanging guide—our English friends have lost, and ever persist in not finding, the signal advantages of the grooved top roll—

the advantage of not turning the piece over at each pass, and the advantage of shorter rolls for a given number of passes.

We can now understand why Mr. Menelaus, having, as he states, an acre of two-high rolls of different patterns, objected to the three-high mill, on the ground that it would give him an acre and a half. The three-high mill he really criticizes, has but five passes in a given length; the mill he meant to criticize has seven, in the same length, and this fact alone places the American three-high mill nearly on a par with the two-high mill in respect of number of spare rolls required.

But this is not all; taking beams and miscellaneous bars, as well as rails, the length of roll to be changed, in order to go on another pattern, is actually less in the three-high than in the two-high mill. This arises from the fact that in the three-high the same groove is in most cases used twice over.

In Fig. 5, if a groove were cut at *a*, directly under No. 2, and a groove at *b*, directly over No. 3, and so on, these passes all being of the same width and contour, but with regularly decreasing depths, the figure would represent a three-high mill for beams and many other shapes—and, indeed, rails are sometimes, and may always, be rolled in this way. Now in this mill, supposing the length of roll occupied by a groove and its collars to be 9 inches ; two passes would require 9 inches length of bottom roll, 9 inches of middle roll, and 9 inches of top roll = 27 inches total length of roll. In a two-high mill, however, two passes would require 18 inches length of bottom roll and 18 inches length of top roll = 36 inches total length of roll. The amount of three-high rolls to be changed, then, to produce a new pattern of beam or bar, is but 75 per cent. of the amount to be changed in the two-high mill, so that for general work Mr. Menelaus's acre of rolls would be reduced to three-quarters of an acre instead of increased to an acre and a half, by using the three-high mill.

In a common form of American three-high rail rolls, 2 roughing grooves are worked over and over, making 4 passes, and 3 are worked once = 7 passes in 5 grooves. One finishing groove is worked over and over, and 4 are worked once = 5 passes in 5 grooves. If a groove and its collars occupy 8 inches length of roll, the total length of three roughing and three finishing rolls will be 240 inches. In a two-high mill having the same number and size of passes, the total length of all the rolls will be 208 inches, or about 87 per cent. of the length required in the three-high mill. To offset this slight increase in the amount of rolls used, the three-high mill presents very great advantages over the old form of two-high mill with rolls moving continuously in one direction. 1st. It turns out twice as much product in a given time, since in the two-high mill the piece returns over the top roll without getting any reduction. 2d. It keeps the piece the same side up, while the two-high mill requires it to be turned over at each pass. The two-high mill is perfectly represented, in this respect, by removing the top roll of Fig. 5. All the grooves open upward, and in order to prevent the fin from growing on the top of the flange, the rail must be turned over so as to come against the solid body of the bottom roll. 3d. The piece in the two-high mill has to be dragged over the top roll, while in the three-high mill it is forced back by the rolls.

As compared with the reversing two-high mill, the American three-high has the advantage of keeping the piece the same side up all the time, thus increasing the product and decreasing the strain on the men. The reversing mill, with either the clutch or the reversing engine, is a much more costly machine to construct and maintain than the three-high mill connected directly to the engine. It works somewhat more slowly than the three-high, and the impression among experts is that it is less economical of steam.

As we have observed, the three-high mill requires less changing of rolls for miscellaneous purposes. In beam-making—a large and increasing branch of the manufacture—its advantages are most conspicuous. Orders for beams are always smaller than for rails—often less than a turn's work—so that the rolls must be often changed. American mill-men can hardly understand how beams can be produced with profit, when these heaviest of rolled masses have to be turned over at each pass, and when a quarter more than the necessary weight of rolls has to be shifted for each order.

We now come to the second objection to the three-high mill. As stated by Mr. Williams, it is, that accuracy in the section of a rail is "utterly impossible" in the three-high mill, and that this is due to the fact that the bottom roll is fixed, while the other two are movable. Mr. Snelus attributes the inaccuracy, not to the three-high mill, but to the fact that the middle roll is not fixed; and he states that in a three-high mill, with fixed middle roll and movable top and bottom rolls, he has seen just as accurate rails produced as in the English two-high mill.

This objection, as we shall observe, is entirely without foundation. The inaccuracies of section mentioned must have, and may easily have arisen from other causes, one of them being that American rail-makers do not dress off their rolls as often as English makers do. Again, the middle roll is sometimes improperly set endwise, and is allowed to have end play. And it certainly requires more care to adjust the distances between the rolls in the ordinary three-high mill, than in a three-high mill with a fixed middle roll, or in a two-high mill; but it is no less possible or practicable to adjust the rolls.

In respect of shape of groove, the two-high and three-high mills are precisely alike. Rolling a rail in a three-high mill is just the same as rolling it in two two-high mills. The shape and relation of the grooves in the bottom roll and the roll above it, in the two-high mill and in the three-high mill are identical. The shape and relation of the grooves in the top and middle rolls of a three-high mill are identical with the shape and relation of the grooves in a two-high mill. Remove the top roll from Fig. 5, and you have left, a two-high mill, differing in no respect, as far as the shape and relations of the *finishing groove* are concerned, from a two-high mill. The finishing groove shapes the rail. Now to say that taking away the top roll, which does not touch the rail on the finishing pass, will alter its shape, is at least amusing.

As to the statement that the inaccuracy occurs because the middle roll is movable and the bottom roll fixed—take the finishing groove, in Fig. 5. The top roll has nothing to do with the rail on this pass, so we will remove it. We now, for the purposes of the finishing groove, have a two-high mill, in which the top roll is movable and the bottom roll is fixed, and this, we are told, is *wrong*. But it singularly happens that this is precisely the state of things with any and every two-high mill—the top roll being movable and the bottom roll fixed. And this, we are told, is *right*.

If any further statement is necessary to dispose of this objection, it is the fact that although the rolls in a three-high mill, as in a two-high, are capable of being moved, they are not moved while the rail is going through them ; they are all fixed rolls, as much so as if their bolsters were cast in the housings. The fact that for the purpose of setting the roll, the middle roll *can* be screwed towards the bottom roll, or the bottom roll *can* be screwed towards the middle roll, has no more to do with the final shape of the rail, than the fact that the engine that drives the train is vertical instead of horizontal.

Finally, if the fixedness of the middle roll did have anything to do with the shape of the rail, it could be as well secured in the three-high mill as in the two-high. This Mr. Snelus admits, so that his objection is not to the three-high principle. Among our own rolling-mill men, independent bolsters for all the rolls are getting into favor. Mr. George. Fritz's thirty-inch blooming-mill at the Cambria Works, has a fixed middle roll. So has the steel train built by Mr. William A. Sweet, of Syracuse, and now running in his works. The splendid train constructing at Bethlehem by Mr. John Fritz, is similarly arranged. In all these trains the top and bottom rolls are movable by screws. In the thirty-inch blooming-mills erected by the author, and now running at Troy and at North Chicago, the middle roll is movable by screws, and the top and bottom rolls are fixed. In all these mills, the rolls are set while the mill is running, and the same passes are used over and over. Another advantage of the independent bolster over the old three-high mill is that each roll journal has only the friction of its own roll to resist, while in the usual form of mill, the top roll rests on the journal of the middle roll, and the weight of all three rolls is borne by the journal boxes of the bottom roll.

THE TERTIARY COAL-BEDS OF CANYON CITY, COLORADO.

BY R. NEILS CLARK, M.E.

(WITH MAP OS PLATE I.)

THE coal-beds of Canyon City are situated six miles below the town, upon the Arkansas River.

At this point the Rocky Mountains have thrown out from their main ridge two spurs. The one to the north, containing Pike's Peak and Cheyenne Mountain, is known as part of the "Rim Range;" the one to the west and south is known as the "Greenhorn Range."

Against these syenitic mountains, the later rocks are piled and uplifted; at right angles to the direction of this main uplift is the axis of a lesser plication.

On the north, west, and south, the pitch is steep, gradually flattening as it approaches the centre of the basin and rising again to the east at a pitch of about 5°, thus forming a perfect basin, the centre of which is only three miles east of the base of the Greenhorn Range.

Over the centre of this basin and against the Greenhorn Range are situated the highest geological rocks of this region,—the coal-bearing sandstones.

The bed is ten miles long at its greatest extent north and south, and five miles across at its greatest extent east and west; it contains in all about thirty-four square miles of coal-bearing rocks.

A section through these rocks would give—from the bottom upwards :

First—the sand-rock, known for a hundred miles north of here as the " hog-back,"—probably Jurassic.

On top of this a limestone,—cretaceous.

Then the black shales.

Then the clay-bed—perhaps two hundred feet in thickness.

Then the sand-rock—perhaps one hundred and fifty feet thick—immediately underlying the coal,—Eocene.

To the north and cast these seams are very thick, but they thin out to the west and south, the limestone and all intermediate strata disappearing, until at the south the bottom sand-rock lies upon the Greenhorn Range. The pitch at this point is not more than 15°, while but three miles to the north and west it is 60° to 80°, and stands apart from the range. Still further to the northwest, the other strata begin to appear; the clay-bed, however, I have found, on the western edge.

The coal-yielding rocks are about 600 feet in thickness; they are sand-rocks, with some black, yellow, and red shales.

There are very few of our characteristic bituminous shales so common in the carboniferous measure. The shales and slates contain but few fossils; the sand-rocks are full of the leaves of the oak, the cinnarnomum, and the calamopsis. These rocks contain at least nine seams, varying from 6 feet to 8 inches in thickness. They are thickest at the south end of the basin, gradually thinning out to the north as the intermediate rocks thicken; thus two seams at the south, close to the range, are respectively 6 and 7 feet thick, and but 50 feet apart; at the north, on the river, they are but 2 and 4 feet thick and at least 150 feet apart.

The lowest of all of these seams is known as the "Canyon City Goal." Its section gives—from the bottom up—1st. Sand-rock. 2d. Shale. 3d. Coal 8". 4th. Shale and clay 24". 5th. Coal 51". 6th. Brown shale 8". 7th. Coal 13".

Twelve feet above is another thin seam of coal, and above this is a thin stratum of argillaceous iron ore, yielding in assay 54 per cent, of metal; samples of which I had the pleasure of forwarding to Professor Raymond some months ago.

This coal is block-like in structure, not so distinct as in the Indiana coal-fields, but the cleavage is distinct enough to make excellent working for the miners. The underlying clay is too tough to afford undermining.

It yields, by analysis made from samples taken from within ten yards of the surface, as follows:

By Professor E. T. Cox.

Brown coal—color jet black, contains no seams of calcite—specific gravity 1. 279; 1 cubic foot weighs 79. 63 pounds.

Coke,	61.30	Ash, ochre yellow,	4.50
		Fixed carbon,	56.80
Volatile matter,	38.70	Water,	4.50
		Gas,	34.20

Coke—slightly swollen, unchanged, semi-lustrous.

By Dr. Thomas M. Drown.

Volatile matter,	40.65
Fixed carbon,	53.69
Ash,	5.66
	100.00
Sulphur,	0.50

[These analyses are taken from a letter of Mr. Robert H, Lamborn to Mr. George D. Hall, published in the *Engineering and Mining Journal,* of August 20, 1872.]

Concerning its quality as a working coal I am happy to be able to place some figures before your notice.

The Denver and Rio Grande Railway have, up to this summer, always been forced to use the coal from near Erie. Some months ago I forwarded them a wagon-load of this coal for trial. I give an extract from the report of Colonel Greenwood, General Manager Denver and Rio Grande Railway, on the subject:

"This report shows an average of 154 miles run with a ton of coal, and, great as the distance is, there were 102 miles of it up a heavy grade averaging nearly forty feet per mile, and having two planes of nearly eight miles each, when the grade was seventy-five feet per mile. "

The engine was a four-driver passenger engine, - the train consisted of one eight-wheel baggage car, and two of the standard passenger coaches, capable of seating sixty-four passengers.

In the stove it burns very rapidly, with but very little smoke and no smut.

I forwarded specimens of this seam and the four-foot overlying one, known as the "River seam" to the Denver Gas-works.

Mr. Fay, the superintendent, has been kind enough to send me the result of their experiments. I copy verbatim:

"Result of Tests (for Gas alone) of Coal from the Arkansas River, and other districts, August 12, 1872:

Locality.	Weight in ounces.	Time in Retort.	Coke.	Residue in Retort.	Cubic feet crude gas.	Cubic feet wash'd gas.	
River seam	32	25	None.	18 oz. S. P.	18	8.6	Fair illuminating power.
Canyon coal	32	25	"	18 oz. S. P.	17	7.6	Poor " "
Trinidad	32	25	"	17 oz. L. P.	19	9.2	Good " "
Rock Spring, Wyoming T.,	32	26	"	18 oz. L. P.	15.6	7.2	Very good " "

" The letters S. P. (small pieces) denote that the residue is of no further use.

" L. P. (large pieces) that the greater portion of the residue will burn in our furnaces.

" Carbonic acid and carbonic oxide in considerable force, in each kind of coal. Sulfur present in each, but in very small quantity, the least in River seam; have no means of determining the proportions of either of the above obnoxious gases.

" Each kind of coal was tested three times.

" Respectfully, WILLIAM J. FAY,

"Superintendent Denver Gas-works. "

Openings are now being made of the eastern outcrop, in preparation for the shipment of one hundred and fifty tons per diem, during the winter months.

Experiments are soon to be commenced for testing the coal in the blast furnace, as large deposits of iron-ore are found in the neighborhood. The demand for iron hereabouts is already good and rapidly increasing, and it is hoped that the blast furnace and rolling-mill will be lucrative investments. The amount of rails to be rolled is enormous; the nearest mills are at St. Louis.

As it may be of interest I add an analysis of the iron ore:

"GRAPE CREEK IRON ORE, " FREMONT COUNTY.

Silica,	2.75	Oxide of manganese,	trace.
Mag. ox. of iron,	67.76	Magnesia,	3.20
Titanic acid,	18.98	Sulphuric acid,	trace.
Alumina,	9.70	Phosphoric acid,	trace (faint).

The deposit is very large and only twenty miles distant; large deposits of ironstones abound; limestone is in great plenty.

DISCUSSION.

Specimens of the coal and argillaceous iron-ore were exhibited to the Institute.

MR. PECHIN inquired where the argillaceous ore was found, and upon the President's reply that it was shown at present only in a lean and slender outcrop near the slope of the coal-mine, Mr. Pechin continued, that this need not discourage exploration of it, as the carbonate ore of the Pennsylvania coal-measures appears at the outcrop as a mere stain of rust and gradually increases to beds of 30 inches thickness as it penetrated.

PROFESSOR Cox: I have myself seen on the borders of New Mexico at least 250 feet in thickness of magnetic iron ore. I regard the resources of that country in iron-ore as unlimited, and it is to be regretted that we cannot reach them and make them available now. But they will be reached before long.

THE PRESIDENT remarked that the iron industry of the world has usually been developed first by the use of charcoal; but this means is not available in many of our Western districts, by reason sometimes of the scarcity of timber, sometimes of the high price of labor. The charcoal-burner of the West is not a person reduced by misfortune or condemned by ignorance and lowly birth to follow that business for a meagre living. He wants to make his $4.50 per day at least. Charcoal costs in Colorado about 20 cents, in Eureka, Nevada, 30 cents, and in Utah 29 to 33 cents in most localities, though the price for charcoal (dust and all) at Salt Lake City is 25 cents per bushel. In Cerro Gordo, California, the price is 29 cents. We may fairly assume the general price in the West, dependent upon that of labor, as about 20 cents per bushel, at or near the heaps. I saw in the. neighborhood of Salt Lake last summer several car-loads of Connellsville coke, costing, when delivered, about $33 per ton; and at this price it was much more economical than charcoal as a smelting fuel. The charcoal used in Utah is either brought by rail from the Sierra Nevada, or burned in the canyons of the Wasatch and Oguirrh Ranges. The latter variety being made of light woods, is inferior in quality. It has been reported to me that deposits of genuine anthracite exist in New Mexico ; but their extent is not determined. The principal mine in the Placer Mountains, near Real de Delores, has an anthracite bed of 5 feet, with roof and floor of shale. The coal contains 87.5 per cent, of fixed carbon. A detailed description of these anthracite beds, so far as they are known, is contained in my *Report on Mines and Mining* for 1870, Part I, Chapter LIX.

PROFESSOR Cox: I believe I bad the pleasure of being the first to visit the anthracite mines of New Mexico. In my report on the subject I described the coal as hard and brilliant. But it contains a large amount of water, the volatile matter being nearly all water, though in appearance the coal is like the best Pennsylvania anthracite. When we have thoroughly studied these Rocky Mountain coals, we may change some of our notions concerning their classification. I analyzed this anthracite, and, so far as I now remember (it was many years ago), there was not more than 12 per cent, of volatile matter in it.

PHOSPHORUS IN THE ASHES OF ANTHRACITE COALS.

BY J. BLODGET BRETON.

To the question, "Do the Pennsylvania anthracites contain phosphorus?" asked at the last meeting of the Institute during the discussion on the metallurgical value of Western lignites, I can now give a definite answer.

Through the kindness of a gentleman connected with the Philadelphia and Reading Railroad, and another connected with one of the principal ironworks on the Lehigh, there was sent to the Ironmasters' Laboratory a number of samples of the coals now largely shipped from the Schuylkill and Lehigh regions. Seventeen of these I examined for their contents of ash and phosphorus, and obtained results as follows :

	Ash.	Phosphorus.
No. 1,	4.10	.0063
" 2,	7.97	.0209
" 3,	5.53	.0049
" 4,	6.55	.0056
" 5,	5.39	.0761
" 6,	14.15	.0593
" 7,	10 43	.0049
" 8,	5.29	.0354
" 9,	3.01	.0042
" 10,	3.08	.0012
" 11,	2.75	.0014
" 12,	2.82	.0111
" 13,	3.69	trace
" 14,	2.85	trace
" 15,	7.22	.0014
" 16,	3.49	.0167
" 17,	4.63	trace

If it be conceded that about two parts, by weight, of raw coal are consumed in the production of one part of pure iron, and that all of the phosphorus existing in the raw material will, after smelting, be found in the pig-metal produced, then, in estimating the value of the coals examined, double the quantities of phosphorus found should be taken. It will thus appear that nine, or more, than one-half, would not give to the pig as much as one-hundredth of one per cent, of phosphorus (average .0078), that three would give something more than one-hundredth of one per cent, (average .0154), and that the remaining five would give, respectively, .0418, .1522, .1196, .0708, and .0334. In considering these quantities, they must, of course, be taken in addition to the quantities that the pig would receive from the ore and limestone. The results of the analyses, therefore, show that where the object of the iron-master is to make anthracite pig-metal adapted for good Bessemer steel, he should first look carefully to the quality of his fuel.

I examined also two semibituminous coals, and found in one, ash, 5.03, and phosphorus, .0085, and in the other, ash, 4.94, and phosphorus a trace. My purpose was to go further, and examine some of the leading Pennsylvania bituminous coals, but I met difficulty in procuring proper samples. The method of examination was as follows: A portion of each sample was reduced to fine powder, and a given weight carefully burned in a large platinum crucible over a Bunsen burner. The resulting ash was fused with pure carbonate of soda, and afterwards dissolved completely in hydrochloric acid, and the solution then evaporated to perfect dryness. The dried mass was treated with dilute nitric acid and boiling water, and the solution filtered. The phosphorus was separated first with molybdate of ammonia, and determined finally as pyrophosphate of magnesia,

I made no attempt to ascertain whether any of the phosphorus existing in the raw coal was lost in the incineration.

DISCUSSION.

In the discussion following the reading of the paper, Mr. BEITTON said that he did not make the analyses to find other constituents, but simply to answer a question raised at the last meeting, and the result seems to support the views then advanced as to the phosphorus in the ash. He made the analyses in order to lead chemists more fully into an examination of the subject.

Several members thought there was danger of losing phosphorus by volatilization during the ignition of the coal.

MR. BRITTON : I have been endeavoring for a long time to ascertain from different samples of Bessemer steel ho\v much phosphorus it will bear for rails. I have found considerable over 12 hundredths —up to 20 hundredths—in steel called a very good article; and as much as 50 hundredths in steel rails of quality unknown to me.. The gentleman at the Johnstown Iron-works who has charge of the laboratory, said he could not say positively how much phosphorus the Bessemer steel would bear, and yet be good for rails. We were told from England, first, that it could not bear more than 1 hundredth per cent., and afterwards that it must not have more than 5 hundredths; it could not bear it. He thinks it could bear from 12 to 15 hundredths of phosphorus, and EOT be good. I asked him then with reference to sulphur. They are making at those works Bessemer steel from pig-iron produced near Lebanon ; and I believe in almost every instance they find in that metal copper. He told me that where there is over 25 hundredths of copper, it is injurious; that where there is some 7, or 8, or 0 hundredths of sulphur, it is not injurious ; but that sulphur and copper together are bad. It is really important to know more of these relations, because, if we are going to believe blindly that we cannot make Bessemer steel with ores of certain constituents, we shall have to reject large quantities of ores that could otherwise be used.

THE LONGWALL SYSTEM OF MINING.

BY J. W. HARDEN, M.E.

APART from the merits of the respective systems of mining under conditions alike, there is much in the nature of the coal and the measures with which it is associated, to make that system which is successfully practiced in one locality ill adapted to that of another; the structure of the coal itself, the roof, the floor, the depth and character of the overlying strata, each exercising more or less controlling influence. Again, in the highly bituminous districts, and with such as have caking coals, where the size of the coal as it comes off the face does not affect its value, as the very smallest of it may be utilized, and in the hard, the open and free-burning coals, in some of which the round only (large coal) is merchantable, we have opposite and fixed conditions; hence it follows that a system of mining which would not affect the commercial value of one, might be such as greatly to reduce that of the other.

Seven or eight years ago, after some of the more serious explosions in England, men talked and wrote about the long-wall system of mining as being the one calculated, by its greater easiness of ventilation, to have prevented some of those catastrophes,—in which there was some reason. For the constantly recurring fatalities by falls of the coal and the roof, the extent of which, in the anthracite region of this State, as well as in other places, is not by any means realized, it was recommended as a remedy. The system was not new, it was confined to a district; for while in the north of England the pillar-and-stall method had been that invariably followed, in the midland counties, excepting in the "thick coal" of South Staffordshire, long-wall was universally adopted. The colliery in which the writer spent his earlier days was opened with the beginning of the eighteenth century; old miners of the neighborhood had never heard their fathers talk of any but the long-wall method, and in mining the clay ironstones at a later day, over ground exhausted of coal, evidence was abundant that all the coal had been taken out, and that nothing had been left but the slack in the gob. Here it was that Boulton and Watt, in 1778, erected their first pumping-engine, a sixty-inch cylinder, with eight-feet stroke, with a load of over 26,000 Ibs., doing a duty of near 20,000,000. Mamatt, in his *Collection of Geological Facts and Practical Observations,* etc., etc., 1834, claims for the Moira Colliery, Leicestershire, where the same system of mining was practiced, a much more remote beginning. He says: "In Meashan, where the (coal) bed was not more than forty or fifty feet from the surface, indications of ancient workings were found in stone hammer heads and large wedges of flint, with hazel withs round thorn."

On the long-wall system of mining, within the last year or two, excellent articles have been written, in the London mining journals, exhibiting its advantages and recommending its practice, and these articles have been reproduced in our own mining periodicals; but pillar and stall being settled down to, we have seen no instance of an effort being made to benefit by the recommendation. To rouse inquiry in those about to operate in the coals of newly explored bituminous districts, then, is one of the objects of this paper; and in describing operations actually carried out in the writer's own practice, he will first give a brief description of the measures and a section of the seam operated in, as tending to aid in the inquiry.

The coal-measures of Warwickshire, England, lie in a partial synclinal, some eighteen miles long, bounded east and west by faults on its northern half, and on its southern the extension west is not known. Its known area, some little over thirty square miles, an insignificant patch by the side of American vastness, has some good collieries on it, and there is room for more, and we shall have been greatly mistaken if future generations do not aid their supplies from under the New Red Sandstone.

The measures consist of alternating beds of sandstone, shale, indurated clays, ironstone, and beds of coal, with a bed of limestone in the upper part of the series; the whole formation, from the base of the Permian to the top of the Great Conglomerate, being about 3000 feet, the lowest known productive scam of coal being some little over 1000 feet below the base of the Permian.

The workable seams of coal are five in number, and in that part of the coal-field in the several shafts sunk by the writer, varying in depth from 450 to 900 feet, four of the seams come close together, cropping to the east with a rise of 1 in 3 1½ under the base of the horizontal beds of the Lower Keuper Sandstone, which is here conglomerate, called by the miners the "gravel wall, " and extending westward under the New Red Sandstone.

Beginning; under a 20 feet bed of sandstone holding calamites and lepidodendra we have immediately over the coal:

		Ft.	In.
	Blue Binds (indurated clay) with a 3 inch Ironstone band, .	24	0
	Black Bat (hard sand mud), .	7	0
	Dark Gray and Blue Binds, .	21	6
	Light-colored coarse Sandstone, .	4	0
	White Binds,	1	6
	Black Binds mixed with Coal,	4	0
	Blue Binds with two thin beds of Brown Sandstone, .	27	7
	Blue Binds with two bands of Sandstone, 3 inches and 4 inches,	13	10
	Soft Black Binds, .	3	0
The Workable Coals.	The Two-yard Coal,	6	0
	Black Marl (a fire clay),	0	7
	The Bare Coal,	2	0
	Hard Black Slate, .	0	4
	The Ryder Coal, .	6	0
	The Ell Coal with slate parting 3½ to 9 inches,	5	7
	Gray Fire Clay, .	1	0
	The Slate Coal, with 3 inch slate parting,	6	10
	Gray Fire Clay, .	2	0

	Ft.	in.
Black Marl,	1	0
The Lady Coal,	3	0
Blue Binds with Ironstone bands and balls,	32	7
Seven-feet Coal, not worked,	4	6
Fire Clay,	11	6

It will be seen, then, that the measures to be dealt with in the roof arc made up principally of clays of varied colors and consistencies for more than 100 feet, holding thin bands of ironstone with a three-feet bed of soft black clay lying directly on the coal. Such measures in their separated and disjointed condition, while not contributing to an increase of the weight on the bank face and props as the mining extends, as compared with the less yielding character of the stronger measures, arc yet more costly to keep up, and render necessary more than ordinary caution along the face.

The coals also, though close together, are not so close and free from separating matter as to allow them to be worked in one seam, if that were preferable; they have therefore to be mined in their separate beds, and in the order in which they lie. To take out the lower seams first would be to break the uppermost to pieces in the settling of the measures; the top seam (Two Yard) is therefore always mined first, and by the same rule, time being allowed for the measures to settle, the next seam is taken; but here the Bare coal which is next is not worth mining, and the Ell coal and Ryder, while distinct in their parting and characteristics, yet have no separating strata. The Ell coal then is next mined with the Ryder coal for a roof, followed up immediately by the latter, before it, or the Bare coal, which it has for a roof, has had time to come down, both being: brought out by the same gang road. Next below comes a six feet ten inches seam, the slate coal, having a foot of fire clay over it, and a parting of slate at two feet from the top. The lower four feet seven inches is mined, leaving the upper portion of the seam for a roof; this, as the props arc moved forward, falls behind them, and is then loaded out, and the known workable seams are here exhausted. The seven-feet seam, fifty feet lower, being only four feet six inches thick, has not been thought worth working.

In the days of long-wall proper, two shafts would be located to the rise of the seam and abreast of each other, at a distance far enough apart to give the half of a pit's face of work to each, or from four hundred to five hundred yards; these shafts would then he connected by a drift forming the return air course, ventilated in the driving by a "blow george" (hand-fan). From the bottom of the shaft, a hill (slope) and side head, the latter connected with the drift between the shafts, would be put down parallel to each other with a twenty-feet pillar between; these would be thurled (cross-cut) at every forty or sixty feet, or at such a distance as the air could be induced to pass the last thurl made. On the boundary of the property being reached, opening heads would be driven at right angles on each side the slope, ventilated by bratticing, until on the one side a junction of the two pits was completed, and on the other as great a width of coal had been opened as was intended to be worked. These openings, then, would present a face of work extending the whole width of the two pits, when, by a succession of holings to the rise, yard after yard, the whole of the coal would be mined out to the shaft, the roof being allowed to come down on to the packings of the gob behind the miners, ten or twelve feet next the face being kept up by rows of prop timber set diagonally one to the other, and moved forward a row at a time as the mining progressed. It was not of consequence whether the working of the two pits progressed evenly or not, nor would it be imperative that both should be mining the same seam of coal, so long as the air courses were kept inseverable.

Usually a pit's working would be set to two or more contractors, who were called "butties," one of whom would lead the men each in their several departments of work, detailed into holers, getters, and loaders. The holers, the men who undermined the coal, would commence their work at midnight, each man's stint or length to be holed being measured off for him. A stint would vary in length according to the distance he had to hole under, the hardness of the coal, and like conditions. In some seams the slines, smooth planes of cleavage parallel with the face, are much closer together than in others, hence the holing cannot be put so far under; some seams part much more readily at the roof than others, producing a like contingency. The holer generally knows when he cuts a sline, and holes no further; his work has become unsafe notwithstanding the sprags set under the coal he is holing. In a seam where two feet six inches was holed under, eight yards, containing sixty feet superficial, was the stint; in another where a yard under was holed, five yards, containing forty-five feet superficial, was the stint. A good holer would undermine these amounts in five hours, not making his holing greater than six, or at most nine inches high up the face. Sometimes three or four inches of soft mushy coal occurs at the bottom of a seam, or the floor might be somewhat easier to cut than the coal; the latter not often so; in either case this would be called " the pricking, " and, taken advantage of by the contractor at work by the ton, would be holed in, thereby reducing by so much the waste in the coal.

As the length of face, then, in a given case, so was the number of holers; these had generally finished their work by the time the getters and loaders came on, with whom the daily work of the mine commenced. Beginning at the far end of his work the getter knocks out or loosens the sprags that had protected the holers, retreating as he operates, when, in a scam with a free parting roof, much of the coal will "weight itself down, " easily so, where a sline is cut past in the holing; where it docs not do so, and in cases where gunpowder is not used, he wedges it down and breaks up the coal. With the getter, the loader commences to load the coal out of the face; this he docs, laying the rails of a portable tramway as he goes along until the whole of the coal is cleared out, when the last row of props supporting the roof next the gob is removed and set so much nearer the face by the slice taken off it, and the seam is again ready for another holing. Thus, then, the whole of the coal would be taken out right across the pit's area, and the gob and water, if any, left behind; the short return air course built in the gob, by which the far side of the pit was ventilated, would be abandoned, there being first another built of timber and the fallings of the roof nearer to the face, and so on until all was mined out to the shaft, when, if there was yet another seam below, the shaft would be sunk to it and the process repeated.

Fowler, in his *Papers on Mining*, speaking of the difference in detail as being greater than that of any other system, says: "The principle of long-wall is the same in every case, to work the coal out in long faces, and to bring the coals through roads packed through the goaf." But this is not so in respect to the gob roads. In the work just described, the coals were brought along the face to the hill on a "dan"—small car—there reloaded and hauled to the shaft by the engine, the hill becoming shorter as the face advanced. An opinion, obtained in the lack of thoroughness in doing the work, and held until very lately amongst operators, that owing to the liability of a spontaneous ignition of the gob their coal could not be mined through gob roads, had made mining below bottom, excepting as to the ironstone, the almost universal practice in Warwickshire, until the exigences of particular cases, such as the mining of small areas out of existing shafts, that were not worth sinking anew for, and the getting of odd acres out of corners heretofore left and lost, and increased demand, rendered necessary varied and more extended schemes of operation. Larger areas mined below bottom, divided into panels by solid ribs of coal, rendered gob roads necessary there, so that while the working face is in reality "retreating" from the dip boundary towards the shaft, there is also in the method long-wall "advancing." With shaft capacity, plenty of room at bottom, and adequate engine-power, mining may be going on both above and below bottom at the same time, that is, from the dip boundary to the shaft, and from the shaft to the rise boundary, or in a level seam "advancing" and "retreating" in the same pit.

In mining coal above bottom in a dipping seam, or long-wall "advancing" in a level one, assuming a shaft to have been sunk on the solid coal, set away on each side of it a pair of parallel drifts, twenty or thirty feet apart, the distance being regulated by the thickness of the scam and depth and character of the measure over it, thurling only as often as necessary to carry air. These will be driven carefully as to their intended course; the grade necessary for economical haulage will also, with a hard floor, be that for drainage, and will incline the water to the shaft. On reaching a distance that will give the necessary width of shaft pillar, put out on the rise side the road from which the gob road is to be a continuation, and from it set away another parallel in the shape of a chamber, leaving a good pillar between it and the gang road; this chamber will be the opening head of the long-wall face.

Assuming the three parallels to be driven together and on both sides of the shaft at the same time, at sixty yards further crosscut again for the next gob roads, and we have a bank face of that length on each side the shaft ready for working, while the parallel drifts and chamber are continued onward. On these banks being mined far enough to the rise, so that a continuation of their face through would leave a sufficiency of shaft pillar, set away an opening chamber from each side, and on thurling, there is another bank face the length of the rise side of the pillar, the three being in line and continuous. Sixty yards as the width between the gob roads, the coals being led to them half way from either side, is not assigned unconditionally. Where the roof is tolerably reliable, there will be no difficulty, in a four or five feet seam, with ordinary care, in keeping the face in constant working order with a greater distance than sixty yards, but where it is not so, and in thicker seams, the roads had better be put nearer together. According, then, to the thickness of seam and length of face will be the number of tons each road commands, which, multiplied by the number of roads, I need not say, will live the working capacity of the pit.

With the opening head made, the holing and turning out of the coal, strip by strip, across each bank, is commenced, and with it the building of the chocks and pack-walls, which are to form the gob roads and support the roof as it settles on to them. For some distance from the solid rib there will be but little fall from the roof with which to build up for the setting out and support of these roads; then timber, the length and size of cord-wood, is used, built up parallel pieces crosswise on parallel pieces, and filled in with gob to make them solid. A square pillar is formed, battering from four feet at the base to some little less at its contact with the roof. Such pillars, well built on either side of the road, a few feet apart, become fastened and solid when the weight comes on them, and make good supports until falls of the roof provide material for the building of stone-packs between them. It is well sometimes to build stone-packs, fifteen or twenty feet apart, immediately at the back of the props, along the bank face. The falling and loose material should also be thrown together in a ridge behind them, the object being to support the broader spaces of the roof, and so relieve the face and props of some of the weight, which increases on both as the work extends, as well as to prevent sudden and violent falls by receiving and letting down the roof gradually. These packs must be. moved forward as the face advances, or, in the case of new ones being built of fresh material, they should be thrown down, or they will prevent the free falling of the roof, one of the conditions most to be desired.

The building of these roads, and good packing of the gob between, is of the utmost importance; success depends upon it, more particularly where there are two or three seams to be mined which lie close together, as exhibited in the section given. As the working of the face retreats from the gangway and the roof lowers, it will so compress the packing that greater height in the roads will be from time to time necessary; this will be obtained either by taking up the floor, or ripping down the roof; the latter is preferable where the associating conditions do not militate against it.

The daily extension of these roads increases the cost of their aintenance and that of conveying the coal to the gang road. On the limit of economy being reached, these items of expenditure may be reduced by making a gang road across the gob roads at a point near the face and leading to one main "jig-brow, " or incline to the gang road in the solid coal, in a dipping seam; or into a main horse road in a level one. This will also liberate rails and ties, and improve the ventilation by making the course of the air-current shorter.

Building the packs and setting the props is done by men whose duty it is to keep the gob roads built up to the face, and do similar work, and to follow the getters after the face is cleared of the coal. In setting the props where the roof is tender, a " lid" (flat piece of wood) will be put between the props and the roof; and where both roof and floor are hard, they will round off the ends to prevent the burring and splitting of the prop, which often takes place when the weight comes on it. It is not well to have more packs or props than is necessary along the face. These men, however, soon become good judges of the action of the roof.

Under most conditions, it is best to set off a deviating road at a right angle to that from which it deviates, either when drifting in the solid or building a gob road, as the weight brought on is more uniformly sustained. But where there are planes of cleavage forming a marked feature of the roof, it is better to let the gob roads cross them obliquely; or in a coal of cubical structure the face might be worked at a right angle with it, assuming the lay of the seam not to prevent it. Occasionally, under similar circumstances, " buttocking" the seam will be resorted to, that is, it will be mined in a series of banks with the faces one in advance of the other. This form of work makes more cutting, therefore more slack, and it is not so easily managed in the gob.

Of the ventilation of long-wall work it is not necessary to enter into detail. The manner of doing this is simple, and can hardly fail to suggest itself; generally speaking, the main road will be the intake, when, if the works are not extensive, the air will be passed on to the face, in at one end and on to the other, where, by a " carving" or half gob road, that is, gob on one side and solid coal on the other, lengthening as the face recedes, the current is guided to the main return, thence to the up cost. In mines extending to divisions in the working, doors, stopping, and regulators are necessary to divide and divert the current, avoiding doors in the working roads where possible.

In the books the advantages and disadvantages of long-wall work are variously represented. One writer in his objections says, that " unless the pack-walls are exceedingly strong and well built, the weight will crush them down and cause great expense in keeping the roadways. " Another, in the same strain, says: " This method of working is not favorable for a tender seam having a heavy roof, as the weight on the bank crushes the coal, " Another says he believes " that, where the seam exceeds *two feet nine indies* in thickness (the italics arc his own) long-wall is dearer than stoop-and-room; but if the scam is only two feet, it is decidedly more applicable and economical than pillar work. "

Some years ago, Warington Smyth, in one of his lectures, said of the system: " Nor is it necessary that the roof should be good, although the expense will be very different according to its fragility; " and he repeats the same in a handy little book lately published. But is not such the ease with any system of mining? It is not necessary that a Cunard steamer should have fair weather to cross the Atlantic; but the certainty of its doing so, and the profits too, would be very much reduced by weather invariably foul. The roof over the coal to which the section given applies is not a good one; beginning with three feet of soft black binds, fissile in structure, with forty-five feet of blue binds above it, ordinary timbering was not enough. Monday morning would frequently find portions of the face covered by these binds coming down between it and the props, during the Sunday's interval, and sometimes carrying the props with it. " Saddlebacks, " also, truncated oval-shaped pieces four or five feet long, with a smooth surface, would not unfrequently fall, and sometimes maim or kill a man. Vigilance and rapidity of mining were the secrets of its management.

But there are other conditions of badness besides that of " fragil- ity, " and there are writers who recommend the system without qualification. One gentleman, after quoting from Mr. Smith's lecture the passage alluded to, goes on to say, "In France and Belgium the system is in very general use both in small and large seams with all kinds of roof, but more particularly where the roof is bad, " and recommends its adoption in the anthracite of the Wyoming Valley. He would provide the necessary gob for catching the roof by sending it down from the surface. Now, while there are no conditions to which the pillar-and-stall system cannot be applied, there are some to which long-wall would not be suitable, and I take it, that the discordance of levels, the heavy and unyielding nature of the roof, together with the liability of sudden and heavy falls, are conditions fatal to success in the Wyoming Valley; and however desirable it might be to get those hideous heaps of wilful waste out of sight, it would not answer to send them down the pit to gob with. We have proved this in mining ironstone above bottom and coal below, when running the surplus binds down hill to be packed with the coal gob. It will not pay.

It is not uncommon to speak of long-wall as rendering more infrequent the accidents by falls of the roof, but such is not unqualifiedly the case. As, for instance, where in pillar-and-stall the workings are divided into panels separated by strong ribs of coal, and an early "robbing" of the pillars takes place, the coal, having sustained no damage by standing, is as easily got and with as great freedom from accident by falls. It is, moreover, absolutely necessary to the success of long-wall work that the supply of prop timber and cordwood for chocks should be *ad libitum*, and that delay should never take place in the setting of it, whereas pillar-and-stall, in the nature of the work, is not so looked upon. Scores of accidents have taken place and are taking place daily, which a proper setting of timber at the right time would have prevented. In the mining of a thick scam by whatever method, there will be less accident by falls, if advantage is taken of the partings and it is mined in thin seams, two or more as the case may be, rather than mining it in one whole, and in such case long-wall offers the greater facilities.

Owing to some peculiarity in the nature of the coal there arc scams which are liable to spontaneous combustion; this in long-wall work is the cause of much trouble. Though not common, we know of it in one of the seams of three of the Midland Counties of England. Whether these seams are associated with any particular period affecting them in common, does not appear, but from the local position of each we should think not. The peculiarity is attributed to the presence of iron pyrites contained in each of the seams or their roof, yet there are other seams containing pyrites that do not ignite. In the case of the Two Yard seam given in the section, however, decomposition of the pyrites in the black binds of the roof helping to make up the gob is clearly the cause; absorbing the moisture given off in the pit, the gob gradually becoming consolidated, at a low temperature, 65° or 70°, decomposition commences, sulphuretted hydrogen gas, called by the miners " fire stink, " is evolved, and ignition of the coal-slack follows. The process is accelerated by a sluggish ventilation and consequent increase of temperature; if after stagnation the ventilation is increased, the ignition of the gob will be correspondingly quickened.

Here, then, in long-wall advancing is an element of serious difficulty; once started, the trouble is only overcome by turning out the heated place and filling it up with sand or burnt stuff. Sanding off the gob immediately the "stink" is recognized, while it will not stay decomposition, will yet suffice to keep down actual ignition for a while, but leave only the smallest chink by which air can penetrate and that spot will soon be at a red heat.

In speaking of this condition of things at the Moira Colliery, Mammatt, in 1834, and again Fowler, in 1861, tell us, that to prevent the spontaneous ignition of the gob, a wall of well-tempered clay, lengthened as the work advanced, was built up on each side the gob roads behind the packs and next to the gob, the object being to prevent the air circulating through the gob. And the purpose would seem to have been answered, as the plan is still followed.

In working the Two Yard coal the writer pursued an opposite course, and with much success. Mining the seam in panels, and aiming to prevent decomposition in the pyrites by keeping the gob dry, it was freely ventilated. This had the effect of reducing the temperature and lessened the local humidity, and, aided by rapidity of mining, enabled a panel to be worked out before any very serious interruption, took place. Post-and-stall work had been made trial of, but without any mitigation of the trouble. Driving out the roads in the solid and mining back to the shaft, " retreating, " as of old, where there is nothing to prevent it, is unquestionably the best method of working a seam, the gob of which is liable to spontaneous ignition.

Driving out to the extremity of the property before commencing to work the coal, is often opposed by the pecuniary circumstances of the operator, who, if he cannot turn out coal for the market immediately he cuts it, has not the means to go further. Even those who have the means, object that the return for capital employed is not rapid enough; but for one of moderate expectations there is no reason why this method should not be pursued. If the extent of the property places the boundary several hundred yards away, a panel of work may be set but on either side the slope, after getting far enough away from the shaft, leaving a broad pillar between the slope and the panel, and mining for the market may be going on while the slope is at the same time being extended. Where the area to be mined is not great, the objection bears no comparison to the ad- vantage.

In a dipping seam, with just enough water to be troublesome, but not enough to necessitate a pumping shaft, by driving a slope to the dip boundary, and mining back to the rise, the water is left in a pound behind, when, if from any cause it occasionally rises faster than the mining retreats, a water car may be run into the pound, by the slope, and the water drawn off. Water may be avoided by the same means, as in a case where the dip would have necessitated a shaft 1670 feet deep, and the tapping and cost of putting back known and heavy feeders; whereas by sinking a shaft 900 feet deep at the rise, 2700 feet off, those feeders were avoided, and 770 feet of sinking saved. It has its advantages also in the fact of there being no gob roads to maintain.

The more prominent advantages of long-wall working arc the ability to get out all the coal, and to get it out of a larger size; the reduction of the yardage, and in consequence the largest amount of coal for the smallest amount of holing and side cutting, and the more ready and efficient manner by which the workings are ventilated.

With a dipping seam it is not only more advantageous to work to the rise, but absolutely necessary. One of the important features of the system is the continued gliding pressure of the roof on the face, which helps to bring down the coal after it is holed. Labor will also be saved by having a length of face in work, sufficient to let the coal stand two or three hours after holing before breaking up for turning out, as much of the coal will be brought down by that pressure. At the same time it is essential to success that the ground be got over as quickly as possible, particularly where the roof is jointed and tender, or the floor soft. Rapidity of mining will keep down the cost of production, while a halting pace, on the contrary, will be productive of contingencies which need not here be enumerated, and increase, it.

A hard or a long-grained coal is best got by long-wall, while that of a soft prismatic structure is best got by pillar-and-stall. The constant weight on the face of such a coal would crush it, and the best roof for either is a tough, broad, interlaminated stratum, that will bend rather than break, and having reached the gob, will continue to yield as the mining advances.

In pillar-and-stall work, where the stalls are driven out narrow, and the pillars left of such a size that they are of strength sufficient to support the superincumbent weight without crushing, care being taken also to keep up the roof of the stalls, we have in the extra breadth of pillar a variety of longwork, by which the whole of the coal may be gotten, and in the best possible condition.

In a seam with a thick and unyielding rock immediately over it, liable to sudden and heavy falls, long-wall would be impracticable, except at the cost of all the advantages attributed to it. Neither would it be in place where the surface has to be sustained for the protection of buildings of value. Where the buildings are only secondary, and detached, and there is a good depth of intervening strata, it is better to mine right under them and let them settle with the surface. Canal and railroad companies, under similar circumstances, find it less costly to raise their roads and banks as the surface settles, than to purchase an area of coal on each side that will keep their properties intact.

Of the relative merits of wood and iron props much has not been urged. Greenwell, who gives half a dozen lines to the subject in his second edition (1870) of *Mine Engineering*, says; "If, instead of chocks, metal props are used, they may either be set upon the thill, in which ease, if any heaving takes plaec, they require to be drawn by the aid of a powerful lever, or they may be set upon a chock placed upon small rubbish, and drawn as above escribed. These metal props weigh about half a hundred weight to the four feet length, and will support, without breaking, CO tons each, if properly formed."

Smyth (18C9) says, "Cast-iron has been occasionally used for the purpose." The props used by the writer, like those ordinarily used, were invariably of oak or larch, varying in diameter from 4 to 7 inches, occasionally more. It is not the weight of the whole superincumbent strata that has to be carried, but that part of it next the coal which, by its own weight, detaches itself in the general movement from the more enduring strata above it, and on the character of this, the roof stratum, and the length of time they have to stand, will depend the strength and number of the props needed ; if it is of a jointed and fragile description, a greater number of lighter props will be necessary, than where of a broad and laminated character, when, while less in number they will need to be stronger, and whether of wood or iron, the same number of props in either case will be needed, and the same removals forward, as the mining advances.

But a timber prop will wear out, and often break, and in either ease-must be renewed, when an iron one under like circumstances will not. The question of comparative value then will appear to lie in the greater first cost and longer enduring character of the one, as against the lesser cost and less enduring character of the other, with which is associated the cost of labor in renewals, and the haulage of the material to the places of operation, a not unimportant item in a colliery where gang roads and bank faces are measured by miles. While there is little need of argument at any time in favor of labor-saving inventions, still less is there for any on the side of the coal-cutting machine. The most irksome and laborious part of coal getting, and that needing most skill in the miner, is the holing—undermining. This the coal-cutting machine will sooner or later entirely supersede. The demand for coal and the scarcity of skilled miners will urge its adoption, and the long-wall method of mining being that to which it can be most easily and profitably applied, there is matter for reflection to those about to open new fields of operation, or extending old ones, as to whether they had not better adopt long-wall working at once and be prepared for the—most assuredly—coming change.

A COMPARISON BETWEEN CERTAIN ENGLISH AND CERTAIN AMERICAN BLAST FURNACES,

AS TO THEIR CAPACITY, BY MEASUREMENT AND THEIR CAPACITY BY WEIGHT.

BY FRANK FIBMSTONE, GLENDON IRON-WORKS.

IN *Chemical Phenomena of Iron Smelting,* Mr. Bell gives the weight of materials required to fill furnaces of various sizes at the Clarence Works; as this differs very much from the weight required for furnaces at Glendon, where anthracite and magnetic and brown iron-ores are used, a comparison is interesting.

Taking furnaces at Glendon of 4800 and 11, 900 cubic feet capacity and comparing them with the Clarence furnaces of 6000 cubic feet and 11, 500 cubic feet, we find that the 4800 cubic feet at Glendon and the 6000 cubic feet at Clarence required respectively—

Glendon, 4800 *cubic feet.*		*Clarence, 6000 cubic feet*	
Coal,.	93.2 tons	Coke, ...	55.7 tons
Ore (½ brown), ...	57.2 "	Irontone,(cale'd) .	28.8 "
Limestone, ...	28.8 "	Burnt lime, . . .	10.85"
Cinder,.	26 "		
Total.	195.2 "	Total.	94.85

Comparing the 11, 900 Glendon with the 11, 500 Clarence, we have—

Glendon, 11,900 cubic feet.		*Clarence, 11,500 cubic feet.*	
Coal,	213.2 tons	Cake	119 tons
Ore (½ brown),	165.2 "	Ironstone (calc'd),	99.3 "
Limestone,	82 "	Limestone,	35.9 "
Clinder,	42.4 "		
	502.5 "		254.2

The weight of material per cubic foot is:

	Cubic ft.	Tons.	Lbs.
Glendon, for	4, 800	=.041	= 91.84
" "	11,900	=.042	= 94.28
Clarence, "	6,000	=.016	= 35.84
" "	11,500	=.022	= 49.28

The weight of a cubic foot of material at Glendon, therefore, is about double that of a cubic foot at the Clarence Works, and for equal volumes the Glendon furnaces hold twice as much material by weight as the Clarence.

The pressure of the column of materials in the furnace on the lower layers, will be, for equal heights, in proportion to its weight per cubic foot.

The 11, 900 cubic feet furnace at Glendon therefore, which is 72 feet high, is in that respect under the same conditions as a Cleveland furnace 144 feet high, and furnaces 50 feet high are the same as the highest coke furnaces that have ever been built.

Looking at the much greater weight of stock under treatment in the Glendon furnaces, it might be supposed that the limit to a profit- able increase in size would be sooner reached in them than in the English furnaces, for the difference in the specific heat of the two classes of material must be too small to appreciably affect the great difference in heat-absorbing powers due to the difference in weight per cubic foot.

On this point we cannot yet speak positively. The large furnace at Glendon works with a consumption of coal less, by from 3 to 4 cwt. per ton of iron, than that of the old furnaces of about 5000 cubic feet capacity and 50 feet high, the temperature of blast being about the same at all of them; while at Stanhope, N. J., of the two furnaces of the Musconetcong Iron Company, which use only magnetic ore, one 80 feet high, and containing 16, 400 cubic feet, uses several hundredweight less coal per ton of iron than the other, which is 55 feet high and contains 9200 cubic feet.

The above numbers of course apply only to furnaces as filled and ready to start; could we know the weights when actually at work under full burden, the difference would probably be greater. They seem to show, however, that anthracite furnaces may be worked successfully when the pressure of the column of materials is as great as it would be in a Cleveland furnace 144 feet high, and that a givenincrease of height and capacity in the one case has resulted in nearly the same saving of fuel as in the other, notwithstanding the much greater weight of stock contained in the anthracite furnaces.

After the reading of the paper, some desultory discussion ensued with regard to the economical limit of height in blast furnaces, and the danger of crushing the fuel by excessive burden. Reference was made to the charcoal furnace of Messrs. Witherbee & Co., in Essex County, N. Y., which runs successfully with a height of 65 feet. This furnace recently began a campaign on charcoal, and finished it on anthracite—the charcoal supply having failed. The charcoal iron continued to be produced without apparent disturbance of the furnace, down to the very moment when the anthracite iron began to come. Hence the charcoal charges must have carried without injury the entire column of the anthracite charges. The quantity of fuel (charcoal) consumed by this furnace per ton of iron produced, is about 19 cwt.

A NEW OCCURRENCE OF THE TELLURIDE OF GOLD AND SILVER.

BY A. EILERS, M. E.

THE telluride of gold and silver, the "Tellurgold-silver" of Hausmann, and "Petzite" of other mineralogists, has been found in so few localities, that a late discovery of the mineral in a new locality, may not be uninteresting.

So far this mineral has been found in Europe only in a few mines in Transylvania, and in. Hungary; and in the United States in the Stanislaus Mine, in Calavcras County, California, in the Golden Rule Mine, Tuolumne County, California, and in a mine in Montana, the precise locality of which I have forgotten. The new locality referred to is at the Red Cloud Mine, Gold Hill istrict, Boulder County, Colorado.

The district is an old one, and was at one time, as long as the decomposed surface ores lasted, quite prosperous; but when the sulphurets of iron and copper were found in the veins, the stamp-mill process was inadequate to the extraction of the gold, and the camp received a check from which it has not recovered to this day.

The country rock is the same as is found at Central and Georgetown, *i. c.*, a granitic rock, which is sometimes a true granite, often a syenitic granite, and occasionally gneiss. In all cases the country rock is more or less altered in the immediate vicinity of the veins. The latter have all a northeast and southwest strike, but the dip varies from northwest to vertical, and in some veins it is to the south- east.

In the mines formerly opened the minerals occurring in the quartz gangue are iron and copper pyrites, small quantities of galena and blende and native gold, but no tellurides have ever been found in any of them to my knowledge. In the Red Cloud, which was discovered in the early part of this summer, tellurium minerals are, on the contrary, of frequent occurrence; in fact they may be said to constitute half of the minerals found in the quartz.

When pieces of the "float" from this vein (for the outcrop was hidden by some ten or twelve feet of soil) were first brought to the Denver branch mint for assay, the enormous figures per ton obtained for the contents of gold and silver almost staggered the assaycrs. Subsequently five tons of surface rock were brought down to Mr. Schirmer's sampling-works, and it was here that I first saw the ore. In breaking open some of the pieces I found an undecomposcd mineral, which I took for sylvanite (AgAu) Te_3. As the shaft went down deeper, more and more undecomposed ore was found, and samples of the steel-gray, soft mineral, which was so rich in gold, were sent by Mr. Sehirmer to Dr. F. A. Genth of Philadelphia for analysis. This gentleman pronounced the mineral petzite, the formula for which is given by Petz, from analyses made of European samples, as AuTe + 41/2AgTe, and by Genth, from analyses of American specimens, AuTe + 3AgTe, the composition of the mineral from the Golden Rule mine being, according to the latter authority, Te 34.16, Ag 40.87, Au 24.97; and of another specimen, Te 32.68, Ag 41.86, Au 25.60. No analysis of the mineral from the Red Cloud mine has yet been published, but I understand from Mr. Sehirmer that Dr. Genth is engaged in making one. Some hasty blowpipe experiments, which I found time to make at Denver, proved the presence of tellurium and a large quantity of gold and silver.

To the presence of this rich telluride rather than to the occasional occurrence of native gold in the ore of the Red Cloud is due its high value. The gangue is not pure quartz, but a mixture of quartz, and half-decomposed feldspar on one side of the vein (which stands very nearly vertical), and of dark quartz on the other. In the former gangue the telluride occurs principally, while in the latter iron pyrites, sometimes mixed with small quantities of galena and copper pyrites, predominates. All these minerals are, however, very much distributed through the gangue, so that, in case the ore were to be beneficiated by smelting, it ought to be first concentrated. But as this would undoubtedly cause large losses on account of the peculiar way in which petzite breaks up in stamping (namely, into thin flakes, the finest of which are carried off by water, the same as certain silver minerals and native gold), a dressing process will probably have to be avoided. It is reported that extremely solid iron pyrites, carrying some $ 20 to the ton in gold, is found a few miles off in a neigh- boring district. If this is so, the most complete and probably also the cheapest way of extracting the gold and silver from the Red Cloud ore will be smelting this ore with roasted iron pyrites to a matte, in order to remove the quartz, and then concentrating the matte after roasting it to the degree required.

The shaft was, at the time of my visit to the mine, 50 feet deep, and a few feet had been drifted on the vein on both sides of the shaft. The vein was in the shaft 6 feet wide, but the mineral contracted in the drift towards the northeast to less than 2 feet in a distance of not more than 12 feet, the remainder of the vein being filled with a greenish-blue argillaceous material. Work is energetically prosecuted to open up the mine. So far one lot of 5 tons of surface ore had been shipped, assaying $ 200 per ton in gold and silver. A second lot of first-class undecomposed ore, 6 tons, yielded $ 400 per ton, and a third lot of 5 tons of first-class ore was ready for shipment, its value being not yet determined. Besides, there were on the dumps some 70 tons of second-class ore, the value of which was not known. But as there was much of the telluride visible in it, it will probably not fall below $ 75 per ton.

Finally, to point out the enormous influence which the occurrence of this telluride must exert towards raising the average value of the ore from the whole vein, I will append here the assays from ten samples, as transmitted to me from the Denver branch mint:

" The following is an abstract of some assays of Red Cloud ore as requested in your note of this morning, viz.:

" 1. Blossom or Float Ore :

Gold,	$1,416 51	per ton.
Silver,	320 37	"
Total,	$1,736 88	

" 2. Surface Ore:

Gold,	$19,652 62	per ton.
Silver,	2,282 40	"
Total,	$21,835 02	

"3. At depth of 10 feet:

Gold (some Petzite),	$16,638 31	per ton.
Silver,	9,304 00	"
Total	$25,942 31	

" 4. At depth of 14 feet:

Gold	$538 37	per ton.
Silver	202 17	"
Total	$740 54	

"5. At depth of 19 feet:

Gold (Sulphuret of Iron),	$5,360 14	per ton.
Silver,	4,258 22	"
Total,	$9,618 36	

"6. At depth of 25 feet:

Gold (containing Petzite),	$5,663 68	per ton.
Silver	2,851 16	"
Total	$8,517 84	

"7. At depth of 30 feet:

Gold (containing Petzite),	$4,220 19	per ton.
Silver,	3,040 37	"
Total,	$7,260 56	

"8. At depth of 35 feet:

Gold (containing Petzite),	$5,360 14	per ton.
Silver,	4,258 22	
Total,	$9,618 36	

" 9. At depth of 42 feet:

Gold (containing Petzite),	$3,840 15	per ton
Silver,	2,510 30	"
Total	6,350 18	

" 10. At depth of 50 feet:

Gold (containing Petzite),	$7,240 25	per ton.
Silver,	3,425 61	"
Total	$10,665 86	

"Yours truly,
J. F. SCHIRMER"

As shipments continue to be made regularly of first-class ore, we shall soon know how high its average value really is. Meanwhile it is significant that 16 tons of first-class ore have so for been obtained to only 70 tons of second-class, or 1 ton to 4| tons; while the usual proportion in the Central City gold-ores in the richest mines is 1 ton of first-class rock to 10 of second-class.

The discoverers of the mine are two poor miners, who have for years "stuck to" the almost deserted camp of Gold Hill, and who seem to be now in a fair way of being rewarded for their patience and endurance.

REMARKS ON THE PRECIPITATION OF GOLD IN A REVERBERATOY HEARTH.

BY R. W. RAYMOND, PH.D.

I WISH to call the attention of the Institute to a curious subject, brought to my notice last summer by Mr. Begger, the accomplished metallurgist of the smelting-works of the Boston and Colorado Company at Black Hawk, near Central City, Colorado. At these works, the richest auriferous sulphurets of Colorado (particularly copper pyrites) are smelted in reverberatories, together with roasted tailings (iron pyrites), and the gold and silver are concentrated into a new, artificial sulphide, or copper matte, containing 81500 and upwards of the precious metals per ton, and this is shipped to Swansea. I will say in passing, that this shipment of an unrefined product, like the similar shipments from Utah and Nevada to San Francisco, Chicago, St. Louis, Newark, New York, and Europe, of crude argentiferous lead or " base bullion," is not a sign of incomplete metallurgy here, but has a sound business reason. The separation of the precious metals in the West would be more expensive, to begin with ; and then it would necessitate the movement of these metals by express, at high rates and risk, to commercial centres or coining mints, while the base metals having no home market, must be shipped and sold at little or no profit. At present, the gold and silver, safely packed, as it were, in the base metals, are transported with safety as ordinary freight; and the base metals probably more than pay cost of ship- ment and separation.

To return to the Black Hawk reverberatories. On a recent occasion, the hearth of one of them was broken up for repairs, when it was found that throughout the mass of pounded quartz of which it was made and to a depth of fourteen inches and more, below the surface, gold had deposited itself in the bright metallic form which we find in nature, and, in many places, quite isolated from any other metallic combination ; like free gold in natural quartz. Near the surface, of course, we find also particles of the matte; and a little deeper there are bright green spots, doubtless consisting of an arseniate of copper; but the isolation of the gold is complete, and difficult to explain. Mr. Begger and other metallurgists have been able to suggest only the bold hypothesis of a downward sublimation of the gold. A great difficulty arises from the absence, so far as we can judge, of such a temperature as would effect this. But perhaps we may venture to fall back on our ignorance of what nature may accomplish with a smaller force acting through a longer time.

DISCUSSION.

MR. A. EILERS: I noticed in several instances that this gold was associated with arseniate of copper. This is perhaps significant, when we recall that in nature gold occurs so often with arsenides and arseniates.

PROF. Cox: It is possible that this reduction of the metal took place from heated vapors by the presence of copper, or it may have been formed by a galvanic process. It seerns likely that the copper had some agency in reducing the gold.

THE PRESIDENT: An appeal to galvanism is only a change of words. Galvanic action does not take place without a corresponding chemical decomposition.

PROP. LANGLEY remarked that substances are frequently volatilized at lower temperatures than their proper points of volatilization, through the presence of more volatile bodies. Thus the vaporof lead might carry gold with it, and the gold might be precipitated while the lead remained in vapor form, and so escaped.

THE PRESIDENT : That is very nearly the hypothesis to which we are crowded by the circumstances of the case, though I must confess that lead is not usually a principal ingredient of the ores treated in the Black Hawk furnaces. Prof. Hill has, however, I believe, smelted lead-bearing ores in his reverberatories, and it is also true that some galena occurs in the sulphurets of Gilpin County. If the members could inspect all the samples of the hearth which I saw, I think they would give up the hypothesis of a simple fusion. Still, we must remember the strange phenomenon of filtration, observed in so many operations of chemistry—on the border-land, as it were, between physical and chemical reactions. The decolorization and purification of liquids, the phenomena of dialysis, and even the asserted protection against miasma afforded by so coarse a filter as a mosquito-netting, are instances, though not, perhaps, in strict analogy, which may lead us to suspect that through the interstices of a hearth of pounded quartz a segregation of one metal might take place, even out of a fluid matte.

COKING UNDER PRESSURE.

BY JOHN A. CHURCH, M.E.

AT the last meeting of the Institute, a discussion arose upon the question, " Is there pressure in coke ovens?" and many of the members seemed to think that the superiority of the Belgian furnace might be due to the fact that it is a completely closed chamber, in which the gases given off by the coal are, or may be, at more than the atmospheric pressure. It seems to me that this position is untenable, and that an examination of one of these ovens in operation will show, not only that there is no excess of pressure in the coke chamber, but that the contrary is true, and a partial vacuum exists.

The Belgian or François oven consists of a rectangular chamber closed at the ends by sliding doors, and furnished with flues in the side walls and floor. The new charge is introduced at a time when the furnace is so hot as to cause immediate and copious discharge of the volatile constituents of the coal. The gases pass downwards through the side flues giving out their heat to the walls and thus to the coal. Underneath the floor air is introduced and the gases burn, producing intense heat. Heat is also reflected from the arched roof upon the coal which is therefore heated from all sides. The especial advantage which this construction was designed to secure is that no air is admitted to the coke-chamber. All the heat is produced by the combustion of the uncokeable gases, and the yield ought to be a *maximum*. It is so in fact, allowing for the imperfections inseparable from furnace construction and management. Sometimes the yield is in excess of the percentage indicated by assay, showing that the operations in the large way are more thorough than in assays performed upon comparatively minute quantities.

The sliding doors of course form no perfect joints, and to prevent the access of air the crevice around the door is closed by a clay luting. Except when the clay is of unusual excellence the luting cracks and sometimes scales off in places. It is evident that if there is excess of pressure in th furnace the gas will issue from these crevices, however minute, and will burn when it meets the air. With a pressure in the coke-chamber we ought to see the oven doors fringed with small flames.

On the other hand, if there is a partial vacuum in the chamber the air will enter, the gases will burn, and there will be flames within the furnace. The coke will also burn, and will leave proof of its combustion in the form of ashes.

Which of these conditions does observation point to as the one really existing? Evidently the latter. No flames appear around the door; but when the coke is drawn out, the ends of the mass are found to be covered with ashes—proof conclusive of the entrance of air, and the existence of a lower pressure within the furnace than without. I have seen ovens luted with a short clay that cracked easily, and required frequent renewal during the operation. In these there was an amount of ash which indicated a serious loss of coke, and whoever has the management of coke-ovens will find that the selection of a proper clay for luting is well worth his attention.

These circumstances seem to me to sufficiently disprove the sup-position of those who look to pressure of gas as a cause of the excellence of the coke from the Belgian oven. It is possible, however, that pressure docs exist for a short time after the furnace has re-covered from the temperature lost upon the first admission of the moist and cold charge, and while the coal is still rich in hydro- carbons. It is possible that, for a short time, the evolution of gas. is greater than the capacity of the flues to carry off; but this cannot last very long, nor be very marked, and it is doubtful if it has any effect whatever upon the formation of the coke, I am the more inclined to this opinion, for the reason that progress in the construction of coke-ovens has not taken the direction of increasing or maintaining this pressure, if it exists. It does not appear that any attention has been paid to it. Dating from the time when the great step of cluding the air from the coking chamber was taken, improvement has followed two lines. They are:

1. To increase the height of the bed of coal.

2. To increase the temperature at which it is coked.

Recent changes illustrate the character of this improvement in a striking manner. Instead of broad and low chambers, narrow and high ones have been built. Formerly, the coal lay in a thin horizontal layer; now it is a thin vertical layer. The thickness of the interior walls, which transmit the heat to the coal, has been lessened nearly 60 per cent, in one instance. The time of coking has been reduced to 24 and 36 hours. Twenty-four hours is a length of time which seems to meet with general favor, both from the convenience of anagement, and also from its effect upon the result.

The gradual improvement of coking processes has enabled us to increase the thickness of the coal in the oven from 18 inches to four feet, or a little less.

A greater pressure, due to height of the mass, and therefore a denser coke, has been the result of the change in form ; while a higher heat is obtained from the use of thinner walls, and from making the charge while the furnace is still at the high temperature produced by the combustion of rich gases. Both causes permit the use of a poorer coal, whether its poverty results from the presence of ash, or from lack of volatile constituents.

The Belgian oven produces a coke that seems to be about as near perfection as we can expect to obtain. It is large in fracture, finely gray in color, firm and ringing. It contains a minimum of volatile matter, and, strange to say, the very thoroughness of the coking process in this furnace has caused its rejection in at least one instance. Mr. I. Lowthian Bell mentions that his firm returned to the old form of oven—probably the Beehive—after trying the Belgian. The reason was, that the latter furnace made too hard a coke, and more fuel was necessary in the blast furnace. Mr. Bell's view of the case seems to be that the hard coke resisted solution by the carbonic acid formed .lower down in the furnace. This produced a lack of carbonic oxide, which is necessary for the deoxidation of the ore. Thus the train of operations upon which iron-making depends was interrupted. But these effects are, of course, dependent upon the furnace and charge employed. It is very possible that the change from a oft to a very hard coke will hrow the usual run of a furnace into disorder, but this is nothing against the positive value of hard coke, which certainly cannot be more difficult to handle than anthracite coal.

The building of a hundred new ovens in a Westphalian establishment, side by side with hose which have been in use for years, enables us to observe the changes that experience dictates. We find that for the same charge of coal the length of the furnace remains unchanged, while the width has been reduced 45 per cent., the thickness of the interior walls 54 per cent., and the time of treatment from 25 to 33 per cent. The only dimension that has been increased is height, 30 per cent, having been added to the height of the chamber, and 88 per cent, to that of the coal. The dimensions of the two sets of furnaces are :

	Old Ovens.	New Ovens.
Length,	22 ft.	22 ft.
Width,	2 ft. 7 in.	1 ft. 4¾ in.
Height,	5 ft.	6 ft. 6 in.
Charges,	4 tons.	4 tons.
Time,	36 to 48 hours.	24 to 36 hours.
Surface of floor,	57 sq. ft.	36 sq. ft.
Thickness of inner walls,	29 in.	13½ in.
Yield,	65 to 72 per cent.	

The object of these changes was not to increase the yield; that was already satisfactory. But it was desired to use a drier coal, or a mixture which would not produce a good coke in the old furnaces.

Having glanced at the changes which have met with approval, it is worth while to mention those which did not prove to be entirely advantageous. We find that in the early days of the Belgian oven it was sometimes made as much as two metres, or nearly seven feet high, and also that very large ovens were built, to take a charge of as much as seven or nine tons. Neither of these forms has met with entire approval. A bed of coal 40 to 50 inches in thickness has been found to give sufficient solidity to the coke, and the use of thinner walls with a moderate height of chamber permits a sufficiently large product from a given area of ground. Thus 100 ovens of the dimensions given above will cover, old style, about 11,000 square feet, and new style about 5500 square feet, or just one-half. The average time of coking was in the old ovens, 42 hours; the charge four tons ; and the product from 11,000 square feet in twenty-four hours was therefore the coke from about 230 tons of coal. By the new method of construction, the charge being the same and the time thirty hours on an average, the product from 11,000 square feet will be the coke from 620 tons of coal, or nearly three times as much. Inasmuch as the very large furnaces take an exceptionally long time to do their work, it is plain that the smaller ones fully equal them in the amount of their product.

REMARKS ON THE WICKERSHAM PROCESS OF REFINING PIG-IRON.

BY EDMUND C. PECHIN.

I REGRHET that I am unable to present this subject in definite form and detail. All I shall attempt at this meeting is to lay before you some curious facts, the bearings and explanations of which must be reserved for future consideration. I hope before the next meeting to have carried experiments far enough to furnish a more important contribution to the science of iron metallurgy.

The Wickersham process consists in the introduction into the molten metal, as it runs from the furnace, of air from the hot blast. Mr. Samuel Wickersham is the originator of the plan, as applied in practice, although Mr. Martien had the idea a long time ago, and, I believe, went to England about it. But at that time Mr. Bessemer was coming before the public with his invention, which engrossed the attention of iron-masters, and Mr. Martien accomplished nothing.

The principal difficulty in our experiments at Dunbar was to get a practicable runner or trough, through which the molten metal should pass, and in which it should be exposed to the action of the blast. The runner we used was ten feet long, and perforated on the sides to permit the entrance of the air-currents. When we used a cast-iron and fire-clay runner, the heat was so great that before we were more than half done with a run, the lower part of the runner was melted, and we had a magnificent Fourth of July display of fireworks until the blast was shut off. We had to abandon fire clay. The runner with which we have had the best success is made of wrought-iron tubes, 2 1/2 inches in diameter, attached to a wronght-iron frame, and lined with a mixture of crushed conglomerate (quartz) and a little fire clay to give it cohesion. The wrought-iron shell curves inward over the upper edges, so as to catch and throw back into the current the flying sparks and particles of metal thrown out by ebullition. With this we have been able to run 12 to 14 tons at a heat with great ease. Mr. Wickersham has since prepared this material (pounded quartz) into a shaped brick or tile, with the necessary perforations for the passage of the air, which promises to answer every requirement for steady working.

As regards the improvement in the quality of the iron, there seems to be no question. A large number of practical tests were made in the several mills of Pittsburgh, and in every case the result was favorable.

Sheet-iron of standard excellence was produced from the Wicker- sham, that could not be made from the ordinary pig. The same result was obtained in hoop-iron. The uniform testimony was that the iron worked more readily, and in puddling, 30 per cent, less "fix" was required. This physical change is the more singular and interesting, from the fact that various analyses of the treated and untreated irons gave negative results. In one series the elements remained the same ; in. another, the merest trifle of phosphorus, silicon, sulphur, and carbon had passed off. The only explanation that remains, is that the improvement is caused by the physical rearrangement of the particles of the iron. The pig untreated gave the dull leadened sound of prime gray iron. The same iron passed through the runner, had the clear, bell-like ring of white iron or steel, yet remaining perfectly gray, with the sharp, pricking feeling upon a fracture, of charcoal iron.

We are now preparing a 20-feet run, and hope by the next meeting of the Institute to give more complete data. If by this simple and inexpensive process we can decidedly improve the quality of pig-iron, it is well worth the careful consideration of iron-masters.

DISCUSSION.

MR. JAMES PARK, JR. : I believe they were using something like that in England the last time I was over. I regard this matter of air thrown through iron, or iron through air, as one of very great importance, though I know very little about it. I believe you are aware of the experiment of throwing iron through air, tried some years ago at a furnace on the Alleghany River. They had occasion to tap some metal, and, wishing to save the metal, they conveyed it down the hill in an old stand-pipe, and they found at the bottom that excellent wrought-iron had been made. That encouraged them to take out a patent for the process, and they erected a derrick seventy or eighty feet in height, and from the centre of it suspended some old boilers; but the whole trouble then was the hoisting of the iron up to the top to throw it in; it chilled the iron before it got up.

MR. JACOB REESE : I fear this Wickersham process, when care- fully carried out, will be found to waste the iron more than it will benefit the remainder; and if that is so, then the process will be like a return to the old puddling, before boiling was introduced.

ME. HOLLEY : Of course this process should not be carried too far. I think the loss could be determined. In the first experiment, according to Mr. Pechin, sparks were thrown all over the casting-house. There was evidently a loss there.

ME. PECHIN : With regard to that question of loss in the runner, I would say that when we first started there seemed to be consider- able loss. The bubbling of the iron rose eight or ten inches high, when there was really not more than two inches of iron passing over the runner. After it was over, we could gather up this iron which had splashed out. We have it so arranged now that whatever is thrown out, drops back into the stream. I am not claiming that we have completely demonstrated great merit in this Wickersham process. All that I can say is that it seems to open a very interesting question for discussion.

MR. HOLLEY : It occurs to me that the loss can be absolutely ascertained by taking tests at different stages of the process. In that way you will know exactly what you cannot learn after you are done. I would like to ask what was the pressure of the blast.

MR. PEOHIN: About four pounds. It is a very short time that the metal is in the runner; but I suppose it is as much as ten seconds, because, as the metal enters the runner it is checked for an instant, when the boiling commences. We made it almost level. We do not specially heat the trough, except that before trying the experiment, we put on the blast for a few minutes. We first dry it and then turn on the blast and let it run there until the furnace is tapped.

MR. HOLLEY : We do not find any elimination of phosphorus in the Bessemer process at any stage. As to sulphur, it is not a very serious drawback.

MR. PECHIN : Mr. President, I would like to ask one question: Do you suppose there would be a probability of mottled iron turning into gray ?

ME. F. FIRMSTONE: I understand Mr. Bell to say that it is largely a matter of temperature that determines the quality of the iron, whether it is white or gray. I understand him to mean that when the iron is in the furnace, and when it comes to the point of melting, it depends then upon the temperature as to what kind of iron it will be. It does not depend upon the amount of carbon present, it depends upon the temperature alone. I think that there is something in that. Suppose we are making white iron, we have a certain amount of carbon in the furnace. We can, by increasing the heat of the blast, say to 600 or 1000 degrees, in a very short time make that furnace make gray number one iron, instead of white iron. Therefore I think there is some reason to suppose that the result depends upon the temperature at which the iron melts.

MR. BURTIS : My experience is that the first bed that runs out, that is, the one that runs the furthest, would be the mottled iron, or white iron, and the other beds would be gray iron.

MR. RIDER : I believe the temperature has a great deal to do with it; the beds are further away, and therefore cooler.

ME. PECHIN : I have seen the upper beds thoroughly gray iron, while the lower beds were white iron. I have seen mottled, white, and gray iron all in the same place.

ME. JONES : I had a case where one or two beds would be mottled iron, with one white below them, and one white above them. I do not think you can rely upon white iron at the lower end of your casting-house.

MR. W. FIRMSTONE : I have been convinced for a number of years back that the production of white iron and mottled iron, so much of which has been cast this summer, when people did not want to make it, is due to the variation of the humidity of the atmosphere, between summer and winter. I feel quite certain that that was the case at our works this summer. We did not want to make white iron at all, and we had a burden on that should have made gray iron. A slight change in the burden would turn it into white iron. We did not make the change, but the weather was constantly changing. Whenever there was a cold and very humid atmosphere, the metal would turn into white iron. That was the case over and over again. I could tell when I got up in the morning with great certainty. If it was a very humid atmosphere, and if the furnaces had been making gray or mottled iron, I would find them making white. Then all at once the weather changed, and all the furnaces changed to gray iron; and then, after running about a-week, there was another change of weather, and we found that there was another change in the kind of iron. Then, again, we had one furnace which was sometimes blown by water-wheels. It so happened that this summer it was convenient to blow that furnace by the water-wheels. That furnace continued to make white iron with the same burden that the other furnaces were making gray iron of. I am perfectly convinced that the reason of that was because the atmosphere in the place where the cylinders were, was rendered much more humid by the spray from the water-wheels. You could see the fog in the air. I do not think there is any doubt about it. If we take into consideration the great variations in the amount of water in the air, we have enough to account for the furnace changing from gray iron to white iron. It is a clear increase of one-fifth of the burden. I do not doubt that the reason so much white iron has been made this summer is because there has been so much moisture in the atmosphere.

BOSTON MEETING,

FEBRUARY, 1873.

THE GEOGNOSTICAL HISTORY OF THE METALS.

BY T. STERRY HUNT, LL.D., F.R.S.

THE geognostical relations of the metals and their ores present many problems of great interest, alike for the geologist, the chemist, and the mining engineer. The association with certain rock-formations of characteristic mineral species may help to guide the geologist in the identification of geological horizons, and throw light on the chemical activities which have been especially manifested in certain periods; while it is clear that such relations, if established, must be of great utility to the miner, and especially to the explorer of new regions. In inquiries of this kind, however, it is only by careful observations over wide areas, and by the collocation of a great number of facts, that anything like a safe basis for induction can be attained. The effects of hasty and imperfect generalizations in this field have already in many instances been felt to the prejudice of scientific progress. I come before you to-night, therefore, not to lay down any laws or general principles, but to call your attention to certain facts, many of them doubtless known to you, which have forced themselves on my attention, with regard to the associations of various metallic ores and other useful minerals with different series of stratified rocks, and to ask you to aid the progress of this branch of geognostical inquiry. Your observations in the various regions to which you may be called by your professional duties will enable you to determine how far these associations are mere coincidences, and how far they are chemical and geological constants. The associations here to be noticed concern only those mineral species which occur, either distributed through the strata in such a manner as to show that they are contemporaneous deposits, or occupy rifts or gash-veins in these strata, and may be supposed to have been filled from them. The question of the mineral contents of those great lodes which penetrate to unknown depths, and traverse successively rock-formations of different ages, is but indirectly related to our present inquiry.

I begin by the consideration of the crystalline stratified rocks of Eastern North America, which I believe to be entirely distinct from and anterior to the uncrystalline paleozoic strata of which they have very generally been regarded, in part at least, as only altered portions.

Among these crystalline rocks we may, I think, distinguish at least four great types which are lithologically and, at the same time, geographically distinct. These four series are as follows:

I. The Laurentian, including the ancient gneissic series of the Laurentides, the Adirondacks, the. Highlands of the Hudson, and the southern prolongation of the latter.

II. The Norian or Labradorian series (the Upper Laurentian of Logan), distinguished by the predominance of norites or labradorite and hypersthene rocks, which are, however, associated with more or less of gneiss, limestone, and quartzite, like those of the Laurentian. The rocks of this second series are extensively developed in Labrador, and occur, spreading over various areas, among the Laurentides, from thence to Lake Huron. They are well known in Essex County, New York, and have lately been recognized alike in the Black Hills in Wyoming, in the White Mountains in New Hampshire, and further eastward in New Brunswick. They are newer than the Laurentian series, upon which they rest unconformably, but their age in relation to the two series about to be noticed is not so clear.

III. The Huronian series, which is lithologically distinguished by the predominance of dioritic, epidotic, doleritic, talcose, and micaceous schists. This is widely spread along both the north and south shores of Lake Superior, along the north shore of Lake Huron, and constitutes the Green Mountain range of Eastern Canada and New England, stretching thence northeastward into Newfoundland, and sonthwestward along the Appalachians. Rocks apparently belonging to this series fringe portions of the eastern coast of New England, and are seen with a wider development in the coastal range of Southern New Brunswick.

IV. The Montalban or great gneiss and mica-schist series of the White Mountains, which may be traced northeastward across the State of Maine to the St. John River and beyond, and southwestward to

Manhattan Island, and thence along with the Huronian in its continuation in the Appalachians. Rocks apparently of this type are also found in proximity to the Huronian at various localities in the vicinity of Lake Superior; and the broad surface marked as Laurentian in the geological map of Canada contains, in various positions, as, for instance, between Lake Ontario and the Ottawa River, areas of rocks presenting the characters of the Green Mountain and of the White Mountain series. It is long since Owen called attention to the close resemblance between the crystalline schists of Wisconsin and those of New England.* The distribution of the crystalline rocks of the Norian, Huronian, and Montalban series suggests the view that they are the remaining fragments of great formations once widely spread over an ancient floor of granitic gneiss; but that the four series mentioned include the whole of the crystalline stratified rocks of Eastern North America is by no means certain. How many more formations may have been laid down over this region and subsequently swept away, leaving only isolated fragments, we may never know; but it is probable that a careful study of the geology of New England and the adjacent British provinces may establish the existence of many more than the four series above enumerated. When it is considered that we find within the limits of Southern New Brunswick alone small areas of paleozoic sediments, which are shown by their organic remains to belong to no less than five periods, namely, Menevian, Lower Helderberg, Chemung, Lower Carboniferous, and Carboniferous, all perfectly well distinguished, and each reposing on the older crystalline rocks, we are prepared for a history not less varied and complete for the rocks belonging to Eozoic time.

But to return to the subject which we have proposed for consideration at this time, let us briefly notice some of the more prominent facts connected with the metalliferous deposits which appear to be proper to these several series of crystalline rocks. The Laurentian is remarkable, as is well known, for its great deposits of crystalline iron ore, in part specular, but chiefly magnetic, sometimes associated with iron pyrites and copper pyrites, and not unfrequently offering a considerable admixture of crystalline apatite, and more rarely of graphite. These iron ores appear, as a general rule, to be not far removed from the great formations of limestones and pyroxenic rocks

* See for a farther discussion of this subject the author's address before the American Association at Indianapolis in 1871.

which are intercalated, as subordinate parts, in this ancient gneissic series. The ores occur in the form of beds or interstratified masses, evidently of contemporaneous deposition, the layers of sedimentation being in some cases marked by the occurrence of a greater or less amount of disseminated apatite, orthoclase, pyroxene, quartz, or calcite. There are not, however, wanting examples of transverse veins in this series holding crystalline magnetite, in some cases in such quantity as to be available for exploitation. So far as my observation goes, the ores of this series, though frequently more or less titaniferous, are seldom, if ever, highly so, in which respect they offer a marked contrast to those of the series next to be described. A noticeable fact in the history of these Laurentian rocks is the occurrence in New Jersey of the red zinc-ore, with its associated franklinite and zincic and manganesian silicates. These minerals seem, from the descriptions given, to belong to veins. We may recall the fact, in this connection, of the abundance of graphite and of apatite, not only in the iron-ore beds, but in the limestones and pyroxenic rocks of the series, both in the beds and accumulated in veins, which seem, however, to be of limited extent, and are probably rather gash-veins than true lodes. They are of great antiquity, as shown by the fact that they do not traverse the Potsdam sandstone, which rests upon their outcrops, and sometimes includes fragments of these ancient veinstones. The other metallic ores known in these ancient rocks are small amounts of copper pyrites, pyrrhotine, and iron pyrites, sometimes associated with nickel and cobalt.*

The Norian or labradorite and hypersthene rocks are noticeable chiefly for their titaniferous iron-ores, which, so far as I have examined them, are either pure titanate of iron, menacannite, or at least contain so much titanium as to render them unfit for treatment by the ordinary methods in the blast furnace. While I am not as yet aware of a single deposit of pure magnetite in the Norian rocks, I can mention numerous examples of highly titaniferous ore occurring in them. Rawdon, near Montreal, and Chateau Richer, near Quebec, present areas of norites holding thin layers or small masses of pure menacannite; Bay St. Paul offers a third Norian area on the north side of the St. Lawrence, where huge beds of titanate of iron,

* For a detailed notice of the mineralogy of these Laurentian rocks see the author's essay in the Report of the Geological Survey of Canada for 1863-66, reprinted in the Appendix to the Report of the Regents of the University of New York for 1869.

often mixed with rutile, are found. Farther down, at the Bay of Seven Islands, and in the vicinity of Lake St. John, occur large deposits of more or less highly titanic ores, also in norites; and other less important examples might be mentioned in the same region. I may add that the titaniferous ores of Westport, in Essex County, New York, appear to belong to the norites of this region, and that those near St. John, New Brunswick, contain small masses of a similar ore, which I have also detected in the norites of the Isle of Skye, the original hypersthene rocks of MacCulloch; while to the westward, in the Black Hills of Wyoming, highly titaniferous granular ores are associated with a beautiful granitoid norite, of which I am indebted for specimens to Prof. R. W. Richards. These titaniferous ores are not, so far as my observation goes, accompanied by apatite, and are comparatively free from phosphates in any form.

The Huronian rocks, and what I regard as their equivalents in the Green Mountains, and elsewhere in North America, are a highly metalliferous series. To these belong the great deposits of hematite and magnetite of Lake Superior, and similar, though less important, beds in the Green Mountains and their prolongation, which, though less extensive than those of the northwest, are sometimes very pure. Associated with them in the Appalachians are, however, beds of more or less titanic ore, and in parts of the province of Quebec great beds of rich ores, holding from twenty-five to thirty per cent. of titanic acid, are associated with chloride schists, dolomites, and serpentines. The generally schistose structure of these titanic ores, as well as of the hematites of this series, is a noticeable characteristic when contrasted with the uniform absence of such a structure in the ores of the Laurentian and Norian series. There are, however, not wanting examples in the Green Mountain range of granular ores which are magnetic, and at the same time more or less titaniferous. These, at least in one example, are separable when crushed into a non-magnetic highly titanic portion and a pure magnetite. A similar result may be obtained with the granular titanic ores of the Norian series, when, as is often the case, these, instead of being non-magnetic ores, holding the maximum of from forty-five to fifty per cent. of titanic acid, contain a less proportion of this element, and are found to be mechanical mixtures of highly titaniferous non-magnetic grains, with a magnetic portion which, although sometimes retaining a little titanic acid, is at other times got nearly pure by a process of magnetic separation. The disintegration of ores of this kind appears to have given rise to the abundant iron sands of the Lower St. Lawrence, which are mixtures of nearly pure magnetite with a highly titaniferous non-magnetic portion.

The chromic iron-ores seem to be characteristic of this Huronian series, and the occasional presence of micas and various other silicates colored bright green by chromic oxide, marks these rocks, in their distribution from Lake Superior to New Brunswick and Newfoundland, though this element is more rarely concentrated in the form of chromic iron-ore. The chemical process which has given rise to the deposits of this ore is not yet understood; but it is worthy of note, that while it is sometimes a compound of the oxides of chrome, iron, and magnesia, it includes in other varieties a large proportion of alumina. This presence of unsilicatcd alumina suggests a relation both with spinel and with corundum; and in this connection it should be noticed that the emery deposit of Chester, in Massachusetts, occurs associated with rocks apparently belonging to the present series, and with mineralogical associations which, as Dr. C. T. Jackson has shown, resemble very closely those of the emery of Asia Minor, studied by Dr. J. Lawrence Smith.

The presence of nickel with the serpentinic and other magnesian rocks of this Huronian series is almost as general as that of chrome, while both of these metals appear to be absent from the serpentines and similar rocks of the Laurentian series. It is worthy of notice in this connection that the olivine of some meteoric stones contains nickel, and the frequent presence both of nickel and chrome in these uranolites is curiously suggestive in relation to extra-terrestrial geology. Daubrée, by the fusion with reducing agents of serpentines containing nickel and iron-oxides, has, as is well known, obtained an alloy of iron and nickel together with the magnesian silicate chladnite or enstatite, an association common to meteoric masses.

It is scarcely necessary to call attention to the well-known fact that the Huronian rocks abound in copper, which generally occurs as a sulphuretted ore, and forms intercalated contemporaneous beds of cupriferous iron pyrites, or is disseminated in magnesian limestones, chloritic, talcose, or micaceous rocks, or finally fills fissures and veins which traverse the strata. It is occasionally associated with both gold and silver.

The White Mountain series in the Appalachians seems to be comparatively poor in ores of iron, though these are not wanting, but abound in copper, and have, moreover, yielded the only traces of tin-ore as yet known to us in Eastern North America. It is with the gneisses and mica-schists of this series that cassiterite has been found in Massachusetts, New Hampshire, and Maine, in concretionary aggregates with tourmaline, beryl, micas, feldspars, fluor-spar, etc., recalling the associations of the tin-ores of Europe. At Winslow, in Maine, the veins traverse a micaceous limestone, which,! conceive, belongs to this series. Bismuth and its ores are, moreover, met with in several localities in rocks of the White Mountain series, which in some localities arc cut by well-defined lodes, carrying copper ores with molybdenite and pyrrhotine, which suggest analogies with those great lodes which, in Colorado, are so rich in gold and silver, and traverse gneissic and granitoid rocks of Eozoic age. Examples of these are seen in the great deposits of sulphuretted copper-ores which occur in the Blue Ridge in Tennessee, North Carolina, and South-western Virginia.

The gold of the Appalachians is certainly in part in rocks of the Huronian series, and occurs in veins with quartz, chalybite, copper-sulphides, and specular iron in the talcose schists, and also in the true steatites of the series. The gold-bearing quartz veins of a still higher horizon in New Hampshire and Quebec have been referred by Logan to the Upper or true Silurian period, but, I think, without good reason; since the containing argillites are not to be confounded with the Lower Helderberg limestones which sometimes rest upon them. I am disposed, in the present state of our knowledge, to look upon them as of the same age as the similar gold-bearing slates of Nova Scotia, which are considered by Hartt and Matthew to be not far from the age of the Menevian of New Brunswick, thus belonging near the base of the Cambrian; a horizon below anything represented in the New York paleozoic system. Mr. Sehwyn has well compared these auriferous strata of Nova Scotia with the Lower and Middle Cambrian rocks of Wales, which are also gold-bearing; but there, as here, the gold is found alike in these paleozoic strata and in the underlying crystalline schists. The auriferous quartz of Quebec evidently fills fissures, and is of subsequent deposition, while that of Nova Scotia is often intercalated in such a manner that I have expressed the opinion that it belongs in part to contemporaneous beds, although Mr. Selwyn regards them as of subsequent origin. In face of the evidence urged in favor of his view, I am disposed to admit that some of the intercalated beds may be of subsequent introduction; but I still think that many of them, at least, are like those described by Emmons in North Carolina, contemporaneous beds of auriferous quartz.*

We are here led to mention the once famous theory of Murchison that the gold deposits of the world occur only in rocks of Lower and Middle Cambrian (or what he called Lower Silurian) age, a notion now well known to be untenable, even when coupled with his view that the introduction of the gold took place in the Tertiary period. The conglomerates at the base of the Carboniferous in Nova Scotia are in some places a cemented auriferous gravel of later paleozoic age, holding spangles of gold derived from the erosion of the far older Cambrian schists, which were, at that early time, already impregnated with the precious metal. It is well known, moreover, that the gold-bearing veins of Vöröspatak in Transylvania intersect Eoccne sandstones, while on our western coast we have auriferous lodes of Jurassic age; and it even appears, from the observations of Laur, that the silicious matters now deposited from the thermal waters of Nevada contain gold, and thus that the deposition of auriferous quartz which, in Nova Scotia, was anterior to the coal period, and probably belonged to the earliest Cambrian, is still going on.

This conclusion is the less surprising since Sonstadt has lately informed us that the sea-water of the present day, in addition to the silver which it has long been known to contain, holds, dissolved, an appreciable quantity of gold, equal to a grain to a ton, and that in the iodine of the sea we have an agent capable of dissolving this metal, even at ordinary temperatures. The views maintained by Lieber, Genth, and Selwyn, as to the solution and redeposition of gold in modern alluvial deposits, seem to be well grounded, and we are led to the conclusion that the circulation of this metal in nature is as easily effected as that of iron. The transfer of certain other elements, such as titanium, chrome, and tin, or at least their accumulation in concentrated forms, appears, on the contrary, to require conditions which are no longer operative, at least at the surface of the earth. We have here a problem suggested which is of great interest, alike to the chemist and the geologist; but I reserve its consideration for another occasion.

The gold and silver which are met with in the Huronian rocks in the Appalachian region of Canada appear, like the associated

* See my Report on the Gold Region of Nova Scotia. Geological Survey of Canada. 1868.

copper-ores, to be contemporaneous with the strata; and such, from the information received, is, I am inclined to believe, the case with the rich deposits of these precious metals, accompanied with tellurium, recently found in the Huronian of Lake Shebandowan, to the north of Lake Superior. A few words about the silver deposits of a more recent period in that vicinity, which have lately attracted so much attention, may not be out of place. We may here remark that the late researches of Messrs. Brooks and Pumpelly seem to establish that the great copper-bearing series of Keweenaw occupies a place between the Huronian schists and the nearly horizontal red and white sandstone of the region, which is itself below the Trenton limestone. In all this they have confirmed the previous conclusions of Houghton, Whitney, Hall, and Logan. The silver deposits of Thunder Bay and its vicinity, including Silver Islet, are in veins traversing a series of dark-colored argillites and sandstones, which are as yet known only in this region, and are overlaid in slight discordance by red and white sandstones, apparently the same with those of the Keweenaw district and the St. Mary's River. This older series of Thunder Bay and its vicinity, which may be named the Animikic group, from the Indian name of the bay, is the lower division of the upper copper-bearing series of Logan.*

The great Keweenaw group, with its cupriferous amygdaloids, is here absent, though met with a few miles to the eastward, and the almost horizontal dark-colored sediments of the Animikie group rest directly upon the edges of the crystalline Huronian schists, and are cut by great dykes of diorite. These in their turn are intersected by the metalliferous lodes which traverse, without apparent change, both the stratified and the eruptive rocks, and carry silver in the one and the other. The great deposit of this metal in the vein on Silver Islet is found between walls of diorite; but the same vein, in its prolongation, is barren alike in the sandstones of the Animikie group and in a second diorite dyke, while at the same time other and similar veins in the region are rich in silver at points removed from diorite, leading us to suspect that there does not exist, as has been supposed, any connection between the eruptive rock and the presence of silver in the lodes. It is asserted, though I was not at the time of my late visit able to verify the fact by my own observation, that one of these lodes has been traced

* I am indebted for important observations on tha geology of this region to Mr. Peter MeKollar, of Fort William, Lake Superior, and shall soon publish them in connection with my own.

beyond the limits of the sandstones, and found to cut the underlying Huronian schists, still preserving its metalliferous character.

The consideration of these facts leads us to inquire into the grounds of the generally received notion that metallic deposits are often connected with plutonic action. Many facts are adduced in support of this view; and it may not be amiss to ask what is their real significance, and how far they justify the conclusion. In a great number of instances, as in the lead and zinc deposits of the Mississippi valley and of many other regions of uncrystalline rocks, it will be admitted that there is no apparent connection between the accumulation of these metallic ores and plutonic action, except so far as this may be implied by the probable intervention of thermal waters. The case is different when we come to regions of crystalline rocks, where, however, we find that the presence of masses whose plutonic character is more than doubtful, arc adduced in support of the theory. So long as diorites like those frequently interstratified in the Huronian series were regarded as rocks of igneous origin, so long as serpentine and even steatites, certain quartzites and crystalline limestones were supposed to he eruptive, nothing was more easy than to find in the vicinity of most deposits something which would do duty as an igneous rock and thus help to support the hypothesis. Yet those of us who learned geology twenty-five years ago are aware that such views of the nature of many crystalline rocks were then almost universal, and that they still hold a place in the systems of many of our eminent teachers. Even when the hydrous character of serpentine gave rise to doubts as to its plutonic origin, it was maintained, in accordance with the views of a well-known school, that this rock had probably resulted from a complete chemical transformation of eruptive granites, or related rocks, by a process of what was variously designated pseudo-morphism or metamorphism. When, however, we recognize, as I think we inevitably must, the indigenous character of most of these magnesian silicated rocks, we shall find that by far the greater number of examples adduced in favor of the relation of plutonic rocks with metalliferous deposits will have disappeared. Many of those which still remain connected with the name of granite will, I believe, share the same fate, when we carefully distinguish, as we must, between true eruptive granites on the one hand and the great masses of indigenous granitic gneiss which occur interstratified with crystalline schists, and have been so often confounded with exotic granites; or between these latter and the granitic veinstones, which are evidently of hydrothermal and concretionary origin, and abound in the ancient crystalline strata, and even in the eruptive granites themselves.

That the metallic impregnations of more recent depositions are, in many cases, connected with the proximity of older crystalline rocks, whether eruptive or indigenous, is however undoubted. Thus the deposits of copper ore in the newer strata which, in the province of Quebec, lie along the northwest base of the Green Mountains, are not improbably due to the results of oxidation of the cupriferous beds which abound in the crystalline schists of these mountains, from which the dissolved metal accumulated in basins at their foot, by a process similar to that suggested by Murchison with regard to the cupriferous Permian strata at the base of the similar crystalline rocks of the Ural Mountains. To a like process we mav perhaps ascribe the rich deposits of native copper in the Keweenaw amygdaloids and conglomerates which rest upon the ancient Huronian schists. That the same metalliferous character which belongs to the stratified indigenous diorites of the latter is also to be found in certain eruptive diorites is not to be questioned; and these, like stratified rocks, may not only furnish metallic ores to fissures traversing them, but by the results of their partial decay or by the oxidation of the metallic ores which they may contain, give rise to metallic solutions, which like those from the crystalline schists, may impregnate adjacent and more recent sediments. If the view which I hold, in common with many other geologists, that most, if not all, of our known eruptive rocks are but displaced and altered sediments, be true, then it may be fairly affirmed, not that eruptive rocks are the agents which impregnate sedimentary deposits with metals, but, on the contrary, that in such deposits is to be sought the origin of metalliferous eruptive rocks, and that all our metallic ores are thus to be traced to aqueous solutions. The appearance of thermal waters charged with metallic matters may, perhaps, in some cases, be connected with the extravasation of plutonic rocks, thus affording a certain justification of the notion of a relation between the latter and ore-deposits.*

I have thus, in the spirit of an inquirer, brought before yon many questions which demand for their discussion far more time than we can command this evening. I have not sought to generalize with regard to the distribution of metals in our crystalline rocks, but rather to invite your attention to some of the facts which have come under

* See a lecture by the author on "The Origin of Metalliferous Deposits" in the Appendix to this volume.

my notice. Your wider observation may serve to confirm or perhaps to modify the conclusions to which they now seem to point. To you, therefore, I trust to continue the inquiries here suggested, feeling sure that it is only by bringing together facts in their natural relations that we may hope to extend the bounds of geognostical science, and arrive at wider and more philosophical views of the origin and the distribution of metalliferous deposits.

NOTE.—Shortly after the publication of this address I received an abstract of a paper on that region by Prof. Robert Bell, read before the Montreal Natural History Society, February 24th. He there confirms the statement made in my address, that the gold of Lake Shebandowan occurs in the Huronian, which is also seen to be cut by the, silver-bearing lodes just mentioned. Prof. Bel], in this paper, proposes to designate both what I have called the Animikie and the overlying red and white sandstones and marls by the name of the Nipigon group, for the reason that this upper division is best displayed about Lake Nipigon. This latter is by Logan supposed to be overlaid by the copper-bearing amygda-loids (with conglomerates and sandstones) of the north shore (apparently identical with those of Kewcenaw); and the whole together, including the Animikie group, constitute his Upper Copper-bearing group. These copper-bearing strata are by Logan supposed to bo overlaid by the red and white sandstones of St. Mary's, which are apparently the same with those sandstones which, according to Brooks and Pumpelly, overlie unconformably the similar cupriferous rocks of Portage Lake, and are, in their turn, overlaid by the Trenton limestone.

Thus the red and white sandstones and marls, which at Thunder Cupe overlie the Animikie group, are by Logan placed in the midst of the copper-bearing series, and far below the paleozoic sandstones of the south shore. Macfarlane, on the other hand, looks upon the two series of sandstones as identical, and at the same time ascribes to them a mesozoic age, which is inadmissible far the latter series. It is not the time nor the place to enter into a discussion of the vexed question thus presented, but I may here suggest in a few words as a probable solution, that the horizontal sandstones of Thunder Bay, whether identical with those of the south shore or not, and whether paleozoic or mesozoic, are really newer than the adjacent cupriferous amygdaloids, and are not to be confounded with the sandstone strata which, on both sides of the lake, are found interstrati-fied with these as integral parts of the more ancient Keweenaw or copper-bearing series. Since, therefore, a difference of opinion exists as to the stratigraphical equivalence and the age of these horizontal sandstones of the north shore, it is well to distinguish them by a local name, and that of the Nipigon group, proposed by Prof. Bell, is very appropriate. It should, however, in my opinion, be confined to the upper division, consisting of red and white sandstones and marls, and not include the gray sandstones and argillites, to which I have given the name of the Animikie group, and which, so far as yet known, are not met with beneath the red sandstones of the south and east shores of Lake Superior.— T. S. H.

DISCUSSION.

THE PRESIDENT : Dr. Hunt's address has brought up a number of important subjects, too important, as he remarked in reading it, to be fairly overhauled in a single evening. It is always at a disadvantage that we listen to a paper for the first time, without the leisure to examine carefully its statements of detail from which its conclusions are drawn. Some of Dr. Hunt's suggestions (if I may use a milder term than conclusions) are extremely interesting. Some of them are novel; some of them I cannot accept. I refer particularly, under the last head, to the suggested denial of the influence of igneous rocks on the formation of mineral deposits. But I do not mean to discuss these points to-night. It is, as I understand, with the desire that observers who have had their experiences in different fields from those described in that paper, should throw what light upon the subject they can, that these views were brought forward. I trust that many members, both those who are present and those who are absent to-night, will be led by Dr. Hunt's address to collect evidence bearing upon this point, that they will keep the subject in mind until the next meeting, and make it the text of fresh conclusions drawn from other data. We have never had more profitable contributions in this Institute than those which sprung up, some of them at the earliest meeting, and have been passed back and forward, like shuttlecocks, from one to another, so that what was brought up at one meeting has been criticized and discussed at future meetings with wider information. I could give several illustrations which have led, not by the original paper or debate, but by the study and investigation of the members " between times," so to speak, and the discussions at succeeding meetings, to valuable results. I hope, therefore, that the very important and profound questions raised in this address will be carefully examined and illustrated by as much of our individual experience as can be brought to bear upon it. I want to ask Dr. Hunt, in regard to another statement in his paper, whether I understood him to say, that in his experience phosphates, and particularly apatite, were wanting in the Norian rocks in New York, and in the deposits attached to these rocks ?

DR. HUNT: That is certainly what I said. So far as my observations go, I have never found in these granular ores of the tita-niferous class any phosphate of lime. I have made several analyses of these titaniferous ores, and have found them to contain a very small proportion of phosphorus. But I merely state the facts so far as I observed them, in order to awaken inquiry and get further contributions to our knowledge of this matter. Apatite certainly occurs with the iron-ores of the older Laurentian gneiss, intermixed with the ore in considerably large quantities, and freely disseminated through some of the limestone and pyroxenic rocks which are the immediate accompaniments of the ores, as it were, and it is commonly found in those rocks, and not, so far as my observation and experience goes, in those of the Norian series,

THE PRESIDENT : At our Troy meeting we took an excursion to the deposit of iron-ore at Mount Moriah, in Essex County, unfortunately without the company of Dr. Hunt, We all knew he had examined that ore quite carefully, and some member of the Institute, as I understood at the time, spoke of the rocks around Mount Moriah inclosing the great beds that arc being worked there, near Port Henry, as the Norian rocks of Hunt. That is probably a mistake, which my question was intended to bring out.

DR. HUNT : In a report which I made two years ago, which was never published, and which I went over with Prof.Silliman this mom-ing, I made it a point that the ores around Port Henry arc in the old Laurentian rocks; but when you get further to the northeast you come to the Norian region, and get an entirely different character of ore. I could not mention any more remarkable instance of the union of phosphates with the ore than what is presented in the Port Henry ore-bed, where in some layers the phosphate of lime predominates; but in Elizabeth town and Westport, the Kingdom ore-bed and some others, you lose the phosphates. I do not mean to generalize too much, because there are large beds of iron-ore in the older Laurentian rocks in which there are but traces of phosphates, and there are small amounts of phosphates in the titaniferous rocks. A small amount of titanium is found in some iron-ores of the Laurentian series. There are, perhaps, no sharp lines to be drawn; but the distinction in regard to the distribution of these different classes of ores is one which probably has a money value in regard to working them.

THE PRESIDENT: I would like to ask Dr. Hunt whether he thinks this difference, as to the presence or absence of apatite, has any bearing upon the question of the organic or other origin of the deposits; whether the phosphorus in the apatite is referred by him to organic sources, coexistent with the original deposition of the beds ?

DR. HUNT : I could scarcely affirm anything of that kind; for I do not see any necessary connection between the presence of phosphates and organic matter. To a certain extent there is a connection between the accumulation of phosphates and life, as we see in our beds of guano; but that these phosphates were first disseminated in the rocks, and existed there before animal or vegetable life, is evident.

Sir Roderick Murchison and Danberry have reasoned as if they supposed the presence of phosphates depended on animal life; but neither animals nor vegetables have power to create phosphates; they only assimilate and bring together the mineral elements in the soil. Hence I do not consider that there is any necessary connection between the presence of phosphates and organic life. I would recall the fact that in granitic veins alongside with ores of tin, we find large crystals of phosphates. Such an association carries us back to the whole question of the distribution of this element, and the nature of the processes by which different mineral species are gathered together.

PROF. SILLIMAN : I do not propose to prolong this discussion; but I desire to say that I will take occasion to-morrow to make a communication in regard to the occurrence of magnetites in Northern NewYork, as bearing particularly upon this question of the presence and absence of phosphates and titanic acid. I have had some opportunity during the last season to study the region near the St. Lawrence River. I desire to second the President's remarks, which, I have no doubt, meet the full concurrence of all gentlemen present, concerning the delight with which we have listened to the address of Dr. Hunt. The general scope of his remarks as regards the distribution of metals by solution, and the precipitation of those metals in sedimentary rocks by processes which are analogous to those which are taking place to-day, is one so particularly suggestive, and so rich in practical value, that it is sure not to slumber for want of observation. You, sir, and other gentlemen here, who have witnessed the singular deposition or mode of occurrence of the argentiferous and other ores in the limestone of the regions in the centre of the continent, will bear testimony to the complete revolution which we are compelled to make in our early ideas on this very important subject, and the acceptance of results which are as yet but imperfectly understood. You will bear in mind, probably, the extraordinary method of occurrence of the silver ores of the Oquirrh range on the west bank of the Jordan River, opposite the Wahsatch, in Utah, which present the most wonderful, singular, and beautiful appearance. You have everywhere, distributed through the cracks of the limestone (which may be likened to the cracks in the varnish of an old picture), ferruginous ores of silver, lead, and antimony. There is evidence, constantly, in the abundance of aqueous action, of the erosion of large cavities in the interior of the limestone. There are these deposits of epigene minerals, having no manner of connection with the rocks in which they occur; for limestones are destitute of lead, antimony, and silver ; and the question occurs, what has been the source of the solutions which have found here their precipitation ? I mention it only as serving to lend force to the remarks of Dr. Hunt upon the very important subject which forms the theme of his address.

THE MIDLOTHIAN COLLIERY, VIRGINIA.

BY OSWALD J. HEINRICH, M.E., SUPERINTENDING ENGINEER.

IN this paper I shall attempt a description of the successful extraction of coal from this property after it had been on fire for probably fifty years, or more, and after attempts, made at various times, which had still left considerable coal behind.

The Richmond coal-field has a well-founded bad reputation, arising from the circumstance that many of its collieries have had to be abandoned, from time to time, if not entirely, on account of fires, caused by spontaneous combustion, to which the character of the coal in this field renders them peculiarly liable.

While I fully assent to the opinion that this trouble lies in the nature of the coal, which is highly bituminous, and the seams of which are, moreover, divided by slaty bands, through which, as also in the coal, iron pyrites is more or less disseminated, often in microscopically small particles, I must, nevertheless, declare that many lamentable disasters, causing great loss of life and property, could have been avoided if a suitable system of mining had been pursued in all the collieries. If this could not have been done from the beginning of mining in this section of country (the history of which can be traced back to over one hundred years), at least experience enough existed upon this subject thirty and forty years ago to dictate the avoidance of the dangers to a considerable extent. It is therefore necessary here to refer first, in a few remarks, to the character of the coal deposits, particularly in this immediate neighborhood, the Midlothian being one of the oldest and most extensive mines, and some of its coal being much subjected to spontaneous combustion. I must also refer to the history of former managements to explain more clearly the results which were arrived at.

The Midlothian coal-mine property, situated upon the eastern outcrop of the basin, about four miles south from James River, exhibits probably the largest development of coal in this basin. The seam here, except where pinched out to small leaders in troubled ground, is seldom less than thirty feet thick, and often attains thicknesses of sixty and seventy feet from floor to roof. Although it is frequently considered to be but one seam, it is in reality divided into at least three, which can be recognized by the separating slates and bands, as well as by the character of the coal.

Beginning above the top seam (to show the character of roof), the following is a section fairly representing the deposit when in its undisturbed state, in that section of the property called Bailey's Hill, upon which the pits on fire were located:

Hard dark-gray sandstone,		3 feet	7 inches.
Hard bluish-gray sandstone,		4 "	
Bluish-gray clay slate,		2 "	3 "
Black slate,		2 "	
Gray argillaceous sandstone (jointed),		6 "	2 "
Gray slate and indurated shale (very jointed),		4 "	10 "
Top seam of coal,	5 feet to	6 "	4 "
Top seam of slate, often interstratified with inferior bony coal,	5 " to	6 "	4 "
Clean good coal,	3 " to	4 "	
Dark slate,	1 inch to		2 "
Rich coal, highly bituminous,	9 feet 10 " to	12 "	
Sulphur band,	1 " to		7 "
Coal,		2 "	7 "
Dark slate,			1½ "
Good clean coal (bottom coal of main seam),		5 "	7 "
Light-gray slate (gipsiferous),			9 "
Coal,		1 foot	6 "
Gray slate band,			2 "
Coal,		6 feet	
Slate (gray),		1 foot	6 "
Coal,	5 inches	1 "	
Gray slate,	4 "		
Hard gray sandstone (floor),	3 "		

From this it will appear that the coal-bearing strata attain a thickness of 45 to 50 feet, with a roof of 13 to 15 feet of a very inferior character as regards its strength to stand when the coal has been removed. The sandstones above are very strong, and stand even in large openings for a long time.

The pitch of the coal varies from 25° to even 75° (in the saddles), and even real faults dislocating the coal almost vertically are met with at disturbed points. Under these circumstances, it will appear at once that the regular square pillar system, largely used in districts like many English coal-fields, with moderate and generally very regular dip and seams of medium thickness, cannot be adopted here, if the object is to gain the largest amount of coal., This was the system by which nearly all the pits in the coal-field were formerly laid out, although even the Staffordshire system of stalls and openings has been used, and we may say, with even worse results, as could readily be expected. Very frequently no system at all was followed.

By the first-named method, after the pits were laid out in pillars, and work commenced homewards, the pillars could not bear the weight and were crushed from above, or at steep pitches and in troubled ground, where they were like wedges, lying with the thin edge upwards, and the larger face to the dip, they actually slipped off upon the inclined floor. A great deal of the coal was lost, and dangerous, unventilated ground, subject to accumulations of gas and the most dangerous rubbish to stimulate spontaneous combustion, was left behind. Ultimately, the heat accumulating from a constant grinding process upon the weak pillars, and not sufficient air being admitted to retard, by cooling, this process of slow combustion (it being considered most dangerous to admit sufficient air), the pits took fire, and, after vain and costly attempts, were abandoned.

No better results were attained from the Staffordshire system. Openings 300 to 400 square yards in base, and 15 to 20 yards high, were frequently effected, entirely beyond the means of support by timber-work; often even more coal tumbled than the small capacity of the shafts permitted to be hoisted before the top broke down upon the remaining coal. It was impossible to clear the chambers of this dangerous rubbish, and it had to be left behind. Large breaks were formed in the top rock, often clear up to the surface, giving sufficient vent to increase the spontaneous combustion and preventing a regular system of ventilation on the one side to cool off the heating chambers, or an air-tight damming, on the other hand, to smother combustion.

These and a series of other errors, too numerous to be all recounted here, but all due to ignorance, want of system, and false economy, have concentrated all the worst elements imaginable to prevent the continuous prosperity of these mines. Otherwise, under good management and improved systems of mining, the superiority of the coal, the large yield per acre, and the close proximity to home and foreign markets, ought to have placed them amongst the most prosperous and remunerative mines in the United States. The statement, so often made with regard to the irregularity of the seams, loses its force, if not its accuracy, under impartial investigation. Although the existence of such irregularities may be freely admitted, it could have been made comparatively harmless by proper records, surveys, maps, and timely explorations. It is not the irregularities, but our ignorance of them, that has worked trouble. Yet these important precautions have scarcely been observed at all.

Although a number of the mines in this section of country have paid handsomely at times, hardly any of them will do it now, in consequence of the above-mentioned causes. Even the Midlothian pits, where a great deal of money has been made, were, in 1869, in the condition to be sold at public auction, after the outlay, during the previous two years, of $180,000, without any show of improvement. On the contrary, the property had been allowed to go to wreck and ruin.

It was under these conditions that I was placed in charge of this property, after the sale, with a lawsuit about some claims pending over it, which prevented complete possession. Houses, fences, machinery, roads, shafts, were all out of repair; no available pit of any consequence was in condition to raise coal; and, amongst other drawbacks, we were compelled to keep constantly going a 500 horsepower pumping engine to keep the water from drowning out the last vestige of available ground.

I shall now proceed to give a more detailed account of the opening and working of that portion of the Midlothian property called Bailey's Hill, occupying a position at the eastern outcrop on the northeast portion of the property.

The tract of land included within the old pits, and where, therefore, coal could be supposed to be left behind, extended from the northeast to the southwest about 660 yards, and from the outcrop 176 yards west to the deepest shaft available on account of water. It contained in all about eighteen acres, of which fully one-third, near the outcrop, was a perfect honeycomb of old pits and slopes, and only partially accessible by temporary open workings. One acre of good ground from the adjoining property was added by lease, the coal being thrown by a saddle beyond the dip of the main shaft on its level course. Therefore, in all, about eighteen acres of ground were accessible from the main shaft, and formed the main workings.

Before the property was given under my charge it had already been proposed to run down a slope in the southeastern portion of this ground, to gain a body of coal said to have been left behind, and which had partially been explored by a shaft, 170 feet deep. Although the use of slopes for main working shafts in this broken and fiery ground was objectionable, it was still decided to make the experiment. After passing a very broken piece of ground, filled with loose coal and connected with a portion of ground already heating, the slope nevertheless was successfully driven to the bottom of the works, 280 feet on the incline, and a connection made for air, the slope forming naturally the up-cast. By that time it was already discovered that the loose piece of ground about 160 feet from the surface was on fire; and, after some unsuccessful attempts to remove the cause, the slope was, with difficulty, closed on the top. The smoke set so strongly up the slope that it was all we could do to save the men, our only retreat being by that route. Perceiving the impossibility of fighting the fire effectually and with safety to the men, so long as the slope remained the up-east, we connected a fan with the hoisting engine at the mouth of the slope, and built also a cupola at the down-east shaft, in order to reverse the natural air-course. After giving the fire some time to subside a little, I determined to make at least the effort to close the slope just above the part on fire, and to save the ground won above, if we should not be able to gain the lower part. After partially removing the dam at the mouth of the slope we followed downward the strong artificial current of air, effected as just described, and succeeded by strenuous efforts in putting in a strong clay dam just above the fire. Effecting now a communication with another old shaft, north of the slope, for a return air-course, we prepared to make the effort to save the rest of the slope, by making it as far as possible air-tight through the broken and burning ground, and maintaining it long enough to raise the coal below. For various reasons, but particularly on account of the great expense, the ground not justifying the use of such materials as iron or brick, I concluded to pack the timber-work outside and between with moist clay, of the consistency of putty, keeping it in position by nailing planks in front of the timber sets. This operation was performed by opening the dam partially near the top, and substituting a temporary stopping of plank while the clay dam was constructed lower down, and in this manner was lowered eight feet, and always renewed firmly and as speedily as possible to shut off the lower works. Then the side-casing of clay was carried eight feet further down. In this attempt we succeeded completely in passing the point of fire, casing it, and once more gaining even access to the bottom of the slope. But during this time we had discovered that, after a certain lapse of time, the smoke (of burning wood) would always puff up with a great rush, requiring the strictest attention to get the men out in time. This originated from the smoke filling some old and probably extensive works, and, when the maximum of expansive force was reached, forcing itself out at the lower part of the casing, which could not always be made immediately airtight. Getting below the fire, we found that during the seven months it had taken to do all this work, including the time the slope had to be kept closed, much of the timbering had been burned out and the ground required some time to be retimbered. We had now closed tolerably firmly both sides and top of the slope; but the smoke burst through the floor, where we had never before experienced any breaks or leakage. This last accident was of so dangerous a nature (we being hardly able to get the men out) that it was—for economical reasons also—concluded to go no further down, but to close the ground below and recover expenses at least from the coal left above.

This was successfully done, about 96,000 bushels of coal being raised, the casing below, answering now as a long and substantial dam, being all filled up.

During this time, sufficient information at various points had been obtained to warrant the effort to open out a regular pit upon the ground to raise coal upon a larger scale. For this purpose, a shaft, called Rise Shaft, about 300 feet deep to water-level, lying nearly in the centre of the ground at its lowest available depth, had been selected, it being found by examination to be in good condition, but requiring to he retimbered and refitted at the surface. Having also satisfied myself that the clay-casing system, to make the sides airtight as much as possible, would answer when applied in time, I started to clean the shaft and retimber it, providing for a good centre brattice, and putting up a twenty-five horse-power engine for hoisting purposes. Moreover, all breaks and openings in the ground at the surface were closed as far as it possibly could be done, to help in killing out the fire. The ground above having formerly been worked from more than a dozen shafts of various depths, from 100 to 400 feet, I made it a point if possible to prove that two shafts would have been sufficient to operate the whole ground. For this purpose another old shaft, 350 feet deep, about 200 feet southeast and to the rise of the former main shaft, was selected for the upcast, to enable us to keep up always a strong supply of air.

From all reliable information that could be collected, no maps of any description being available, it was very certain that the best part of the coal accessible from those shafts was left at the extremities of the property, about 100 to 150 yards southwest, and from 70 to 100 yards northeast of the main shaft. All the ground to the rise of the main shaft was considered tolerably well torn to pieces and destroyed nearly to the bottom of the upcast shaft, having been always the main seat of fire. This surmise I found afterwards fully confirmed.

Entering from the main shaft by a cross-cut east, we intersected the top seam at about fifteen yards. Having no communication yet with the air-shaft, bratticed air had to be used in the shafts and levels. -Just where the cross-cut entered the top scam, the ground was found already heating, and had to be closed on the cast. Levels, north and south, were started at once in the top scam to have two sides well protected against fire (the roof and water-level at top and bottom forming natural protection). The main object now, it being springtime, was to make a communication with the air-shaft before early summer; since the southwestern winds almost invariably prevent ventilation in our pits, when bratticed air is used without the aid of a fan. The ground immediately between the main shaft and the desired upcast being known to be on fire and broken ground, it was impossible to make a direct communication; but after driving fifty yards through heavy rock-tumbles, where every foot had to be forepaled,* and powder was required to blast the large rocks encountered, a communication was ultimately effected, and the fiery ground south of the main shaft was successfully and securely flanked by casing through all the broken ground. This, being done *in time*, answered the purpose for nearly two years—long enough to remove the coal from both sections laid out south of the shafts at the respective shaft bottoms. The temperature at the south level during the time it required to make the connection, had increased from 78° to 95° Fahr., and it was certainly a difficult undertaking to make men stand up to perform such work for weeks together. But afterwards we never suffered for want of air, and in colder days had to close the doors, some of the levels being too cold for the men. The levels cooled off splendidly; and the ground behind heated but very slowly, although it was of such extent and in such bad condition that we never succeeded in stopping the spontaneous combustion entirely.

The plan, determined upon from the beginning, to work this ground, was to surround the fiery ground and make safe communication with the upcast by as few levels as possible; thence, if solid, or

* That is, the work was protected by driving the timbers ahead, or keeping the working face closely timbered, and preventing sudden movements of rock masses.

at least remunerative ground was encountered, always to open out and exploit the ground by two gangways upon the same level, one at the roof, the other at the floor, and only for the sake of air to crosscut between them, at distances of about 33 yards. Pillars were thus left with a base 100 feet long, by 30 to 60 feet wide, and, in the beginning, 40 feet high perpendicular to the floors above. The base of the pillars, therefore, was upon a level instead of being on the pitch of the coal, as formerly. In consequence of the old works we had sometimes to deviate from this plan. Two levels either near the roof or near the floor, but from 30 to 60 feet apart upon the dip, had to be used. The object, then, was by working homewards to work out the pillars, according to the nature of ground, by crosscuts or by benches in the course of the coal, taking the dividing slates for a guide, and to fill up and sustain the ground so exhausted as much as possible, and, when necessary, to clam it up against the fires originating from connections with the old works. Of course, for this purpose a great deal of waste stuff had to be procured at the surface and sent below.

The pit was then laid out in four sections, two north and two south of the shafts, each two being about sixteen yards apart vertically, and independent of each other, being only connected in the beginning at two points by winzes for the return air course, and to discharge the coal from the upper sections to the main shaft level. Precaution was taken to secure points sufficiently solid, in case of necessity, to permit damming off the sections, and so securing the shafts. The connection through the south level has already been described.

The attempt to make the connection, in a similar manner, north of the main shaft, where most of the coal was anticipated, was less successful. A large old work or chamber, filled with fine loose coal, was encountered, and took fire in front of us while we were driving. I abandoned the work, after some severe but fruitless attempts to penetrate the chamber, using even double casing, with a layer of clay between. It was then determined to run a rock tunnel in the course of the coal, but in the roof rock, from the main shaft, until I could intersect the coal at a safer point, of which we had some information. This was by estimate found to be the cheapest plan, and this we succeeded in, by driving seventy-seven yards along the roof; but although fifty feet from the coal, we still encountered the broken part of the roof opposite the big chamber mentioned above. This was now, however, easily closed by a rock-dam. But we had the gratification to reach a body of coal of a very solid character, being eighty-five feet thick from roof to floor, and the connection with the up-cast was here effected in good ground by driving a winze up twenty-three yards to the main top level. Here we were compelled to use a small hand-fan, to supply the men with air.

Having now succeeded in flanking all the fiery ground, and completely surrounding it, we were in the condition to exploit the rest of the ground in the manner described above. As it was, of course, necessary to defend the field, much work in course of time had to be done to clam off and protect the main levels. For this purpose, also, a line of water-pipes was provided down the up-east shaft, connected with a cistern above, and conducted through the main top levels. To these hose could be attached, and, in the first beginnings of fires, they were of the greatest advantage. Sometimes considerable quantities of old rubbish on fire were actually excavated by the hydranlic process! In one instance, the main air-course being threatened, and the timber being already on fire, a brick arch twenty-five yards long had to be run underneath the wooden casing on fire. Here the hose was freely used to put out the fire, to enable the bricklayers to go on; and the work was completed, and answered its purpose until the south sections had been all successfully robbed, and a new air-shaft, a little north of the former, had been cleaned out, to be used for the north sections. Here much of the coal had yet to be won, and the old air-course was too much in danger to be trusted for the length of time required to work homewards.

In loose coal, we succeeded in making dams out of old iron pipes and railroad iron, covered with old boiler plate nearest the coal, and then cutting out the timber and packing the whole with clay, we could stay the fire for a considerable time. I also experienced in such broken ground that arched work was not as good as passages made with straight walls, the top covered with railroad iron and old boiler-plates, with a heavy coating of rock on the top of that. These have answered until the heat was too great for men to pass underneath.

In this manner, we succeeded in working out thoroughly the two south sections, and closing them off securely near the main shaft, and also exploiting the largest portion, or the two north sections. But here we encountered in the top section a piece of most dangerous ground, connected with the bottom level through a big chamber. It took fire from bottom to top; and we never succeeded in getting all the coal out, but were ultimately compelled to close it up entirely, at places left in the top seam for dams, in such an event. Those dams, twenty feet thick, of clay and masonry, are now, after eight months, still as hot as a bake-oven.

During the time those four sections were working, we had discovered a saddle at the northwest corner of the north section, where the coal, although inferior, and not very thick, took an eastern clip, and therefore indicated a reversed dip beyond the saddle. Having satisfied myself that we could pass the saddle on the south end, a rock tunnel forty-four yards long was driven to protect this new developed section from the old fires. But the new section proving good coal a little below the shaft bottom, we were compelled to keep the water at its lowest point, and in consequence of this, the fires from the former section found a passage to the west end of this rock tunnel underneath. Having only bratticed air in that tunnel we could not fight the fire successfully. The smoke from the return, mixing with the fresh air, made the back workings as bad and dangerous as the places near the seat of fire. We had seventy men *horn de combat* in the course of fifteen hours, through exhaustion and black damp and smoke; and we had to withdraw the force to save them from being suffocated. Being at the same time threatened right over the top in the old section, not then entirely cut off, nothing was left us but to close all the works up and let the water rise for awhile. The existence of coal at the level of our present shaft, in the new section, could not have been well anticipated, being only at that elevation in consequence of the saddle-shaped upheaval. It nevertheless offered a fine prospect; and it was therefore determined to carry out my former plan, for economical reasons not yet executed, namely, to drive another rock tunnel, 55 yards long, to shorten the line of transportation over 500 feet, getting a direct air-course with an independent return and a safe retreat for the men in case of fire breaking out again on our return. This was also successfully carried through, and the old air-course was superseded by driving a winze up through the rock in the roof to the air-shaft. It was impossible to keep the old air-course open on account of fire, and we failed to obtain the air through the top seam coal by reason of breaking into the large old work partially known to us before.

This undertaking was the most trying work performed. Although 23 feet, of rock was between the men and the old work below on fire, the heat of the floor increased to such an extent that shortly before the junction was effected it actually burnt the feet through the soles. From 5 to 10 minutes only could the men stop at the working face, at a temperature of 100° Fahr.; and ultimately 8 men in the eight-hour shift were employed to break through. The black damp at that time prevented our working down from the upper level also to meet the men. But, to the credit of the men be it said, they stood up like soldiers until the job was completed.

Having now fully secured the pit again, the new section was exploited until the coal thinned out so as not to pay for working, and, successfully working homewards, we have, after being three years and four months in this pit, still a few months' work to expect.

To sum up the extent of this forced enterprise, I will only say that 2,037,961 bushels (29 bushels = 1 ton) have been raised so far from the whole tract, of which 1,448,862 bushels were obtained from the rise shaft workings alone. While the expenditures have been very large, amounting often to $1500 to $2000 per month for fire service alone, almost the year round, besides heavy general expenses of an extensive enterprise so peculiarly situated, with a large amount of water to be kept at bay, I can only say that after all the costs for opening the pits and repairing the property (houses, roads, and such machinery as was needed) have been paid, a profit as interest upon the capital invested in the late purchase will be left, over and above all remaining expenses.

I mention this simply to show what may be accomplished in this coal-field by taking up *new* ground, free from the curse of former bad management.

There is no shadow of doubt that, under skilful management and by introducing late improvements in mining, even the deep mines in this coal-field would pay handsomely, the advantage of freight to market giving them constantly an advantage in the competition with other coals.

I cannot refrain at the close of this description from mentioning the fact that most of our labor here is colored labor, although we have a few good white miners amongst us. The men have faced great danger and undergone much hardship bravely.

In the whole of this enterprise I have been most ably assisted by underground bosses, of which three are still with me,—William Dickinson, George Jewitt, and Thomas Cornue, also my assistant Mr. Thomas Jewitt, all English miners, who have faithfully executed the very trying tasks which I was compelled to ask of, and to share with them, in carrying out this work. Their experience in general and their knowledge of portions of the ground in particular, was often of the greatest service. I will add that in spite of all the dangerous work performed we have not to lament the loss of a single life nor even the material crippling of any man.

DISCUSSION:

PROF. ALFRED ROCKWELL: If much of the coal-bed had so steep a dip as 75°, I do not see how the long-wall system could be applied to it. The long-wall method, as I remember to have seen it abroad, can be used on beds 20 to 30 feet thick, when they are nearly horizontal, so as to take out the whole thickness at the first working, leaving a few large pillars—what is called side-work. According to modifications recently adopted in South Staffordshire, the bed is worked in two or three "leads," taking off the upper part of it as a separate bed, allowing the roof to fall, and letting it rest for two or three years, and then working the lower half of it, the broken-down roof resting upon the top of the lower part, forming a sufficiently good roof, provided a foot or two of coal or slate be left below it. The benefit of that modification was sufficiently evident. In the best mines which I saw, this method was shown to me by Mr. Hadley, who was the Government Inspector of the District of Devonshire. He spoke of this as an entirely safe and economical way. The report by the Government Inspector of the loss of life by the old method was terrible. Out of one thousand miners, in the course of a year, some fifty or one hundred would lose their lives. They certainly were frightful places to go into—those chambers where the falling of the roof was constantly occurring.

THE PRESIDENT: My impression, from the paper, is that Mr. Heinrich simply employed a wise modification of pillar-work; that is, instead of taking out as much as they used to take out, he has made his pillars larger. This is common sense; if you leave large pillars, they will hold until you can rob them. In regard to the Staffordshire system, I do not understand him as saying it had been employed in this particular mine. In his general remarks on the Richmond basin, he says the two methods have been tried. We shall, perhaps, get from him a supplementary communication on these points. The present paper was prepared at my suggestion, in reference to the question of fighting fire, and not in reference to the method of extracting coal. No doubt, he will have no objection to explaining the method more in detail to our satisfaction. We must all agree that a great deal of pluck and ingenuity has been shown in the attack of such a problem, and the way in which it has been so successfully solved. It is a good thing for us to know that we need not leave a mine because it is on fire.

MR. H. M. HOWE: In the Bessemer Works, at Troy, I have measured a temperature, with men at work five minutes at a time, of 255°, and men were at work for 15 or 20 seconds at a temperature of 327°.

MR. FIRMSTONE: If you have a thick overcoat on, and your hands and face are protected, you can go into places of that kind. I have gone under arches that were very hot, and remained three or four seconds—going in and crouching down with an overcoat on and good thick clothes, when the iron would be red hot over my head. Of course no man could work there. I went in to see if men could work there, and was satisfied that they could not.

THE PRESIDENT: My experience corroborates what has been said about the possibility of enduring very severe radiating temperature, where the skin was protected and the face averted from the radiating surface.

The temperature in the Crown Point mine (at its 1300 level, 1900 feet below the highest point of the Comstock lode) has been as high as 128° Fahrenheit. That was due to thermal water in the rock. I know the water that dropped from the roof gave me a scalding sensation through my woollen shirt. This was in a blind drift, run for an air connection; the great heat was not the ordinary temperature of the mine. The heat rapidly declined after the air connection was established, and some degree of ventilation was obtained, although very imperfectly. The men who were obliged to carry forward that drift were supplied with air by a tin pipe, through which it was forced by a fan. The result was, that at the working face of the drift the air was not so bad as elsewhere. It was very hot, because there was a good deal of radiated heat; but if you put your face within six or eight inches of the pipe, you could get cool air, while a few feet off the air was banked up, and when you got half way into it yon met a volume of heated air coming out like a flood, driven out by the fresh air. It was almost intolerable, not so much to the skin as to the lungs. The moisture of perspiration protected the skin, but the lungs, so to speak, could not perspire.

The men worked in that temperature a very few minutes at a time. They were naked, or nearly so, and ran into the drift, and worked at the end of it until overpowered. Old hands did not really faint away, but new hands frequently did. They took men that had been in the mine a good while, and promoted them by degrees to the hottest place. They perspired enormously, and I presume the perspiration weakened them as much *as* work. They would rush out of this drift into the main drift outside, where there was more air, and there, after sometimes washing themselves, and especially wiping off the perspiration, they remained a short time—not long enough to be chilled—before returning to work.

I think the lower stopes generally had a temperature near 90°. The trouble to me in the stopes was not the heat, but the foulness of the air, from animal exhalation and candle-smoke. I did not detect anything like sulphurous acid, or products of mineral decomposition.

The sensation produced was nausea. I have no doubt that the ventilation could be much improved in such mines, even without tunnels, though these would be very effective. The air-courses are often unnecessarily small and *irregular*. We may have a large passage for air a part of the way in; but if we stop the air by making it go through a small hole, we neutralize the advantage.

PROF. ROCKWELL: I remember one mine in Cornwall, where the greatest temperature was about 120°. The level, while I was there, was about 105° to 106°. The men worked, almost naked, for only about fifteen minutes. They could only work that length of time, and would then come back to the foot of the shaft, where the temperature was 90°, and cool off. There was an abundance of water, which appeared to cool the rocks some. The heat seemed to be due to decomposition going on in the rocks, and the water flowing along the level would almost scald the feet.

THE PRESIDENT: The expression used by Professor Rockwell about "cooling off" at 90°, suggests the important principle that our sensations of heat are relative. We have no such apparatus for the determination of heat as we have for the determination of color, or the pitch of sounds. It is only the changes of temperature that produce any impression, and therefore it is quite possible for us, as Professor Rockwell has said, after being in a hotter place, to go and cool off at 90°.

The first sensation of extreme heat and cold are the same. The secondary sensation must come very quickly.

THE MIDLOTHIAN COLLIERY, VIRGINIA.

SUPPLEMENTARY PAPER.

BY OSWALD J. HEINRICII, SUPERINTENDING ENGINEER.

(WITH FIGURES ON PLATE V.)

THE origin of spontaneous combustion in collieries is, of course, chiefly due to bad system in laying out the pits, unclean workings, insufficient ventilation, and neglect in damming off works after they are exhausted of the main coal. This is particularly indispensable in the Richmond field, because it is difficult and dangerous here, on account of the inferior roof, to remove the last vestiges of coal; and we are compelled also to retain all the slates and bands, as far as possible, in the pit, to help fill up, although such material is liable to fire. This, however, can be prevented to a great extent, as mentioned below.

I am satisfied that the only system of working this thick coal is by cross-cutting (*Querbau, ouvrage à travers)* or working in benches, as practiced in France (Creusot, Rive de Gier, St. Etienne), in Silesia (Königsgrube), which I have used as far as it is practicable in an old pit, almost torn to pieces by former workings. Modifications may, of course, be needed, even in the same pit, on account of irregularities in the seam. I am also satisfied for economical reasons (on account of the heavy cost for timbering) that pits here ought to be worked upwards, even if it requires a longer period of time to win the coal, and a greater outlay of capital to commence with. The various saddle-shaped "troubles" making natural minor basins in the main basin aid in the execution of this plan. A pit worked once ought to be worked out clean, given up, and dammed off forever.

If sections of proper height are assumed, according to the required amount of production for a certain period of time, they ought to be worked out and filled in as much as possible, dammed off, and ultimately allowed to fill up with water, in order to protect the upper works in future from fire in the gob below. This I consider indispensable, because we may not be able profitably to fill in all the ground. To do so we have to use the waste of the mine, although it is liable to fire in time. In using this stuff, it ought to be surrounded by walls of rock not liable to take fire, laid firmly in clay, the gob being in the middle, and firmly covered and packed with clay on top. In this way it will answer for a considerable time—until the section is cut off, or the water allowed to rise; the latter means will also help materially to support the lower works.

We experience here also, as elsewhere, the greater danger of spontaneous combustion near the troubled ground. In such instances the casing used by me may be of advantage, even in new pits. In new ground it is easily carried out without much extra work.

A strong ventilation to every corner of the pit would also be indispensable, to keep the temperature as low as possible, if it were not so for other reasons. All upward workings not lying in communication, or ventilated by brattice, must be avoided, being the most dangerous for fire, particularly near troubled ground.

The first indication of spontaneous combustion is the sweating of the coal or the ground near to it. This should be closely watched. Left awhile, the peculiar odor of the light carbureted oils, perceived in the distillation of coal for oil, is perceptible. Then follows the generation of carbureted hydrogen gas. It will fire, but generally not explode, on account of its being mixed with carbonic acid gas, generating at the same time. We have continued to work in such an atmosphere, by taking the necessary care to watch the gas and keep up a fresh ventilation. Ultimately carbonic acid predominates, so far as to prevent further working. If remedies are not supplied in time the ground will soon be found a mass of fire. All our attention is required to watch those indications constantly. The increasing temperature perceptible by the hand, or still better, the thermometer, the flame of the lamp and the smell, will give sufficient and timely warning.

The timber used near spontaneous combustion, if practicable, should be of oak ; pine timber being more dangerous on account of its resin. All kinds should be barked before using.

If the plan of working the coal upwards from the lowest shaft bottom is followed, all new sections must be connected with the shaft by cross-cutting the measures. This work progressively going on will at such times furnish valuable materials for purposes mentioned before. The cost of driving the cross-cuts has almost been saved out of the material obtained.

In old pits it will often be as profitable to drive a "rock lead" in roof or floor, if the rock is a slate or soft sandstone, as to use cased levels, if all sides have to be cased. In such cases I have found the rock-cutting nearly as cheap as the casing, particularly since it requires no further attention or repairs. Circumstances must be the guide; a little calculation will soon show the difference.

Where casing is unavoidable, the following descriptions of drawings on Plate V will serve as a guide. (The same letters apply to all the diagrams.)

Fig. 4, Plate V. Used in " rock-tumbles," liable to heat on account of loose coal or gob below the rocks, (*a*) is a two-inch plank, (*b*) a packing of clay, 18 inches to 2 feet thick, well packed and loaded on top with loose rock. The clay must generally be somewhat sandy, to prevent cracking; it should not be too wet; the consistency of putty is best. The greatest attention is to be paid to this tedious but most important part of the work. If badly executed, it is worthless. By putting the planks behind the timber, a closer job is effected. In less important instances, however, where no immediate danger of fire was anticipated, packing behind and round the timber, and spiking planks in front of the same, has been used. But it will generally give way in time, and can only be used occasionally.

Fig. 5 has to be used in running ground, of loose, fine coal. It is necessary here to use double timbering, on account of the "forepoling;" small sets of 6-inch timber inside are sufficient. This casing will answer when the loose coal is not already too strongly heating; otherwise, use the following.

Fig. 6 is employed in loose coal, almost on fire, (*d*) are old iron pipes; (d^l) old railroad iron bent, as shown in Fig. 7, wedged in with iron keys; (*c*) old boiler-plate, or anything else at hand not liable to burn. Inside casing as before. The lightness of the material enables us to do this work more easily than with timber, and more securely, the pipes being used to prevent the timber near the coal from catching fire. We constructed dams in this manner, filling all inside with clay, which kept the fire off permanently in very loose and dangerous ground, where other dams could not be used on account of the running of the coal.

Figs. 8 and 9 show the method used to run below burning timber and coal; it is also used in dams which we are compelled to leave open for a time (to remove coal left behind), but which we may have to close up at a moment's notice. It being a tedious and laborious work to cut in for a dam sufficiently into sides and top, no time would be allowed in such cases to do the work properly. For precaution, therefore, where it was anticipated that the ground must at some time be suddenly abandoned, this construction was used with very satisfactory results. The small doorway is easily closed, even if the fire is close at hand.

Fig. 9 is used where side pressure exists. It answers better than rock-arching in old works, and particularly when the ground is already on fire. It is then impossible to make a lasting job of an arch. The frames are bolted together. Great care must of course be taken to place dams in as solid ground as can be made available, and in all instances to cut in for the dams far enough at the sides, and particularly at the top, to prevent the fire from flanking the dams before it is smothered. 'This, in loose ground, is very troublesome, and requires often regular drifting in the sides and working overhead. Casing in front of such dams will help materially.

We have used the same system of casing in shafts with equal advantage, packing clay behind the curbing.

In damming off sections simultaneously which communicate with each other, an iron pipe must be inserted in each dam, to allow circulation of air to the last. These pipes are then closed simultaneously at a given time or signal.

Figs. 10 and 11 illustrate the robbing of the pillars when working homewards. Fig. 10, "cross-cutting," was used in partially old ground, cross-cutting to the gob, and also in the thickest part of the seam. Levels midway between the main section levels were used to aid. The top behind was supported by filling in and by "cogs," or cob-work (we have fortunately plenty of timber for our use).

Fig. 11 was used in more solid ground, and where the seams were thinner. The top seam worked independently, keeping top-seam-slate as temporary support. Strong rows of props in connection with cogs protected the lower ground of the workings. It was necessary here to work downwards, to keep open the lines of transportation.

Care must be taken not to open out too much ground at once, on account of the difficulty and cost of supporting the ground.

The arrows marked 1st, 2d, and 3d in the ground plan indicate the changes of air-course we were compelled to make from time to time on account of fire.

The Roman figures in the ground plan of the pits indicate the series of main dams used to out off the exhausted ground. Similar figures denote places cut off simultaneously. The main dams themselves and a great number of minor dams are left out, in order not to crowd the drawing.

Good judgment will be required in all instances. Use should be made, in executing such work, of material of as little value as possible, it being in almost all instances lost forever.

All my remarks being based on actual experience, I can warrant the practicability of the details here described. A close account of expenditures must be kept constantly, since the question of the abandonment or prosecution of work in each section of dangerous or already burning ground, must be decided from the financial as well as the engineering standpoint.

REMARKS ON THE MAGNETITES OF CLIFTON, IN ST, LAWRENCE COUNTY, NEW YORK.

BY PROF. B. SILLIMAN.

THESE ores occur in the Laurentian rocks in the town of Clifton, St. Lawrence County, New York.

The Clifton Mining Company have opened these magnetites upon their estate of 23,000 acres, on the waters of the Grasse River, an affluent of the St. Lawrence, which flows for about nine miles across the estate, exposing a section of the formation, and affording ample water-power at numerous points. In approaching this district from De Kalb Junction, upon the Watertown and Ogdensburg Railway, the observer passes from the zone of the specular ores, which abound to a great extent in Jefferson County, across a belt of non-metalliferous limestones, continuing for some miles intermingled with metamorphic rocks, and gradually giving place to heavy beds of granitic and porphyritic gneiss, the weathered surfaces of which present a gray and rough appearance, from the washing out of the feldspar; leaving the quartz very prominent, and completely disguising the real character of the rock, which, when freshly broken, has a lively reddish appearance from the predominance of flesh-colored and red feldspar. Beds of fine-grained quartzite appear also intercalated in the granitic gneiss. These are the dominating rocks of the magnetite region, but the magnetite is always found, so far as the speaker's observation extended, associated with beds of calcite, carrying hornblende, black and green, biotite, and brown garnet interspersed with yellow and magnetic pyrites. The strike of these rocks is about northeast, and their dip about 40° to 45° southeast.

[Prof. Silliman exhibited an approximate section of the Dodge ore hill, in which the most important exploitation has been made for ores upon this property, showing the relative position of these beds of magnetite, and two of limestone (calcite) of dip conformable to the formation, and parallel to each other.] This hill is from 100 to 120 feet above the adjoining valley at the steel-works, and near its summit the magnetite crops out under the glacial drift, and carries yet the glacial scratches on its smoothed and rounded surface. This bed has been laid bare by what is known as the Dodge Opening, or "Big Pit," upon a vein of magnetite which averages about twenty feet in thickness, for a distance of 400 to 500 feet, to the level of about thirty feet, and is provided with a tramway for a locomotive. This is the terminus of a line of about twenty miles of railway, *built wholly of wood,* for carrying these ores to market. A few months' use served to reduce the wooden rails to splinters, and render quite useless an expenditure of several hundred thousand dollars. The Dodge vein is contained between walls of granitic gneiss, but is sprinkled in places with white calcite, mica, garnet, etc. Above it is a bed of pink and white calcite from 12 to 15 feet in thickness. This is opened by a tunnel at the northeast end of the hill and affords a flux which appears to be free from any objectionable minerals, and far better than the flux actually used in the charcoal furnace. There is a bed of blue quartzose gneiss above the line and in contact with it. The Dodge vein, which is also called the Arendal vein, is likewise opened beyond the open cut to the southwest, by a whim shaft, sunk for the width of the ore (20 feet at right angles to the walls), to a depth of about 30 feet from the surface. From this exploration I obtained a carefully prepared mining sample, which was analyzed at the laboratory of the School of Mines in New York, with the following result:

Magnetic Oxide of Iron,	79.29	equivalent to	Metallic Iron,	57.42
Oxide of Manganese,	0.35	"	Metallic Manganese,	0.23
Alumina,	3.45			
Lime,	4.46			
Magnesia,	3.09			
Sulphur,	0.35			
Phosphoric Acid,	0.32	"	Phosphorus,	0.14
Silicic Acid,	8.82			
Water,	0.51			
	100.14			

A charcoal furnace situated at Great Falls, on the Grasse River, about two and a half miles from the Dodge opening, was run for some time exclusively upon the ores obtained from this vein. The flux used was a very impure limestone, a coarsely crystalline and granular calcite, carrying a considerable quantity of green pargasite (magnesia-lime-iron amphibole), disseminated in grains through the flux. This will account probably for the considerable amount of silicon found in the subjoined analyses of the pig, produced from this ore and flux, as well as for the sluggish slags formed in the furnace. These analyses of pig are interesting, as they represent, more nearly than any ore sample can do, the character of the ore, and especially the relatively small amount of sulphur and phosphorus, which is concentrated in the pig metal, by the process of smelting. The analyses are as follows:

	No. 1, Open Grain, Gray Pig.	No. 2, Close Grain, Gray Pig.
Carbon,	3.94	3.30
Silicon,	2.21	4.48
Manganese,	0.11	0.12
Sulphur,	0.04	0.11
Phosphorus,	0.22	0.15
Iron and undetermined,	93.48	91.84
	100.00	100.00

The ores, before smelting, were roasted in open heaps, with wood and charcoal dust. While the analysis of the ore sample above given, and of the pig metal, both show the content of phosphorus in excess of the demands of the Bessemer process, it is quite possible to select crystalline magnetites from these beds which are of remarkable purity, and nearly free from sulphur and phosphorus. This is shown by the following analysis of a hand specimen, from the most southerly portion of the property examined:

No. 7. MAGNETITE (above lower tunnel).

Magnetic Oxide of Iron,	80.91	equivalent to	Metallic Iron,	58.59
Oxide of Manganese,	0.42	"	Metallic Manganese,	0.29
Sulphur,	0.08			
Phosphoric Acid,	0.03	"	Phosphorus,	0.01
Silicic Acid,	8.77			

Above the Dodge or Arendal vein is another well-characterized ore body, about eight feet in thickness, exposed by an open cut along its course for 200 to 300 feet, and by a slope sunk nearly 90 feet upon it. This is called the St. Lawrence vein, and from it a large quantity of ore has been sent to market. It is more sulphurous than the Arendal vein, so that masses of it which have lain long exposed to the air are deeply rusted from the oxidization of the pyrites it contains. Lumps of some pounds weight of yellow pyrites may occasionally be found in it, but for the most part a little selection will avoid any injurious quantity of sulphur, or more than can be got rid of in the metallurgical treatment without serious injury to the pig. The "Dannemora vein" is another well-marked deposit beneath the Dodge or Arendal vein, upon which, as yet, but little work has been done.

Other magnetite deposits exist upon this property, which have as yet had no exploration. They are in the unexplored depths of the grand primeval forests which still cover this isolated region, with such a supply of hard-wood timber as exists nowhere else in the State of New York. [The speaker mentioned, in this connection, two such localities—the Tooley Lake bed and the Sheridan vein—distant respectively about seven and two and a half miles from the Dodge opening.] The ore comes to the surface in a very wet, moss-covered region. The only indication of its presence was the occurrence of boulders carrying black hornblende, brown garnet, black mica, and pyrites, mingled in masses of calcite. These boulders the prospectors have learned to recognize as sure indications that magnetite is not far distant, and to these indicia they trust more than to the dip compass. A surface sample of the Tooley Lake bed gave the following analysis:

TOOLEY LAKE (new discovery).

Magnetic Oxide of Iron,	75.01	equivalent to	Metallic Iron, . .	54.32
Oxide of Manganese, .	0.42	"	Metallic Manganese, .	0.29
Sulphur, . . .	0.08			
Phosphoric Acid, . .	0.03	"	Phosphorus, . .	0.01
Silicic Acid, . . .	13.34			

The Sheridan vein has been opened many years since by some unknown prospectors, and a pit sunk in it which may correspond to the removal of 15 or 20 tons of ore. The ruins of the cabin occupied by the unknown adventurers, now fallen into decay, may still be seen, and a small quantity of the ore remains stacked up for removal. The pit was full of water, but the fissure appeared to be about five feet wide. The magnetite breaks in distinct rhombic masses, and is quite free from pyrites. Biotite and lime-iron garnet are the mineral associates. The analysis is as follows:

SHERIDAN VEIN (new discovery).

Magnetic Oxide of Iron,	79.83	equivalent to	Metallic Iron, . .	57.81
Oxide of Manganese, .	0.72	"	Metallic Manganese, .	0.50
Sulphur, . . .	0.41			
Phosphoric Acid, . .	trace			
Silicic Acid, . . .	8.55			

Prof. Silliman remarked, in view of these analyses and of the general mineralogy of the district, upon the total absence of *titanic acid* in these ores, and also the absence of *apatite*, in the limestones, which are otherwise quite similar in appearance to those limestones of Northern New York, which elsewhere abound in phosphate of lime.

These circumstances have an important bearing upon the commercial value of the ores of this estate.

Prof. Silliman confirmed the statements of Major Brooks respecting the use of the magnetic dip compass, which is often a complete puzzle to the most experienced observer. For example, near the Sheridan vein its indications were so feeble that this important deposit could never have been discovered by it, and the same is true of the bed near Tooley Lake. In both these cases the mineralogical, and not the magnetic, phenomena were the only safe guide. On the other hand, we were able, by the aid of the dip compass, to run a line over the Dodge hill beyond the point of exploration, and to stake out the course of the ore in a direction different to that which was previously believed to be its course. In careful and experienced hands, it is no doubt a useful and important companion, but by no means a very safe guide in many cases.

The projected Adirondack Railroad from Saratoga to the St. Lawrence River passes through the Clifton estate, and will open a market in both directions for its ores.

DISCUSSION.

MR. FRANK FIRMSTONE: In respect to the analysis of pig-iron, I observe that what you call "close-grain pig" contains twice as much silicon as open-grain pig. Did you have any means of ascertaining the nature of the face or surface of the pig? Was the surface of the pig smooth or honeycombed?

PROF. SILLIMAN : I can recollect that they were both rusty, and had been exposed so long—four or five years—to the action of the air, that I did not set much importance upon their external appearance. I supposed the excess of silicon was due to the flux employed, —a highly silicious limestone. There was a large stack of it lying by. They had dug over and used the best portion of it, and I concluded the silicon came in that way.

MR. FIRMSTONE: It is to be observed that, according to the writers, the proportion of silicon decreases as the iron passes from very gray towards white; but there is apparently an exception to that rule in what is known as "silver-gray iron," and in commerce as "carbonized iron." It is never made intentionally, because its properties render it almost useless. Sometimes, in blowing in the furnace, it works lighter than we expect, and we make twenty to thirty tons of that iron, which remains to ornament the stock-yard for years. The grain is very fine. I have seen cases in which the color was pure white. It is to be distinguished from true mottled iron by the surface of the pig, which is smooth, and free from honeycombs and fibres. That is not the case in gray forge and mottled iron. It resembles No. 1 iron, in the fact that the pigs are always very clean. The sand never sticks to the outside, and they have a perfectly smooth surface. It is exceedingly easy to break a pig. They will break as easily as white iron. And I am inclined to think the specimen you called close-grain gray-pig is something of that kind.

PROF. SILLIMAN: Have you any analyses of that iron?

MR. FIRMSTONE: Only analyses made under other names; but it is known to experienced furnace-men. I have known people to buy it for white iron, though its properties are the reverse of white iron. A great many mistakes in books on metallurgy are undoubtedly founded on the same blunder of confounding the two kinds of iron. It contains generally more carbon, and notably a large percentage of silicon, two or three times as much as the good gray iron made from the same ore; and its properties are supposed to be due to the silicon. It is very weak and tender; will break, as I have said, like a pig of white iron; but it is not resonant like white iron. The grain is close. The commercial name of carbonized iron rests on the supposition that the carbon is all chemically combined in the pig. On that point I have no knowledge, and am not aware of any analysis that will touch the matter. There is so much confusion on that point that it is dangerous to say anything about it. This silver-gray iron is made in both anthracite and charcoal furnaces. It is impossible to make wrought iron out of it on account of the amount of silicon it contains, DR. T. STERRY HUNT: As regards the iron ores of the ancient crystalline rocks of Northern New York, referred to by Prof. Silliman, my views have already been denned in the opening address, and in the discussion which followed it with regard to the iron ores of the Laurentian, Norian, and Huronian series. One point noticed in the address, and again brought forward by Prof. Silliman, is, however, worthy of further remark, if only for its economic value, viz., the fact that the iron ores in the old gneissic Laurentian series are constantly found in the vicinity of the crystalline limestones, which, with pyroxenic and hornblendic rocks, are intercalated in this series. This association, according to Prof. Silliman, is now so well known as to be recognized by the explorers in the ore-districts of Northern New York. Dr. Hunt remarked that this important fact had been pointed out by him several years since, and referred to his essay on *The Mineralogy of the Laurentian Limestones,* in the report of the Geological Survey of Canada for 1863-66; since republished in the Appendix to the Regent's Report of the University of New York for 1869. It was there pointed out that the true Laurentian series (the Lower Laurentian of Logan), as seen in the valley of the Ottawa, includes in an apparently conformable series of at least 20,000 feet of strata, three limestone formations, each from 1000 to 1500 feet in thickness. Associated with these, it was said, are found "strata made up of foreign minerals to the entire exclusion of carbonate of lime, by an admixture of which they, however, gradually pass into the adjacent limestones. These strata generally consist of pyroxene, sometimes nearly pure, and at other times mingled with mica, or with quartz and orthoclase, often associated with hornblende, epidote, magnetite, sphene, and graphite. . . . They occasionally assume a great thickness, and are then often interstratified with beds of granitoid orthoclase-gneiss, into which the quartz and feldspathic pyroxenites pass by a gradual disappearance of the pyroxene. These peculiar strata, which contain at the same time the minerals of the associated gneiss and of the limestones, may thus be looked upon as beds of transition between the two rocks. . . . Besides the minerals already mentioned as predominating in these strata, other species characteristic of the limestones, such as serpentine and magnetite, sometimes make up by themselves great beds in these intermediate or transition strata, which from their mineralogical relations may all be looked upon as related to the accompanying limestones. . . . These limestone-groups, as we may designate the limestones with their attendant rocks, appear to be the parts of the system to which the economic minerals belong. The ores of iron, copper, nickel, and cobalt, the apatite, mica, and plumbago, as well as the serpentines and the marbles of the great Laurentian series, belong, so far as is yet known, to the limestone-groups."

In subsequent parts of the same essay, the principal facts then known with regard to the occurrence and association of the chief minerals of these limestone-groups were set forth, including a description of the iron-ore beds, and of the pyrites, graphite, and apatite; together with examples of the frequent and intimate association of these various species, both in beds and in fissure-veins. Under the head of *magnetite* will there be found a description of large veins of an admixture of orthoclase with crystalline magnetite, in which the latter mineral sometimes predominates. These are, however, to be carefully distinguished from the far more common beds of magnetic iron-ore which, unlike these veins, are doubtless of contemporaneous formation.

ON THE PROBABLE EXISTENCE OF MICROSCOPIC DIAMONDS, WITH ZIRCONS AND TOPAZ, IN THE SANDS OF HYDRAULIC WASHINGS IN CALIFORNIA.

BY PROF. B. SILLIMAN.

THE occurrence of diamonds of some size in the gold-fields of California is by no means uncommon, and was noticed by me in a communication to the California Academy of Science in 1867, when specimens of this gem, from at least five different localities, were exhibited. I then suggested that a more attentive examination of the heavy sands left in the sluices of hydraulic washings would in all probability detect diamonds, mingled with other rare species not commonly believed to have occurred in these sands.

Mr. George A. Treadwell, of San Francisco, has lately sent me a small package of these sands, collected by him from the sluices of the " Spring Valley Gravel Mining Claim," Cherokee, Butte County, California. A microscopic examination shows these sands to abound in beautiful colorless zircons (hyacinths), of the form well known in the hyacinths of Expailly (France), associated with crystals of topaz, quartz in fragments, rounded grains of chromic and titanic iron, and a few small, almost globular, masses of very high refracting power, which appeared to be diamonds. To determine this chemically, a portion of the sands was treated with acid for the removal of any carbonates which might be present. There was no effervescence from this treatment. The same sample was then digested in strong sulphuric acid of a high temperature, to destroy any particles of organic matter which might be present, washed out in pure water without contact with organic matter, dried and ignited in a vessel of platinum out of contact with air. This sample of the sands thus freed from anything that could afford carbonic acid but the diamond, was then ignited in a platinum boat in a tube of hard glass, and in a current of pure dry oxygen gas, which, for precaution, was passed over soda lime, and then, after passing the ignited assay, was delivered through a solution of baryta-water. The transparency of this delicate test was soon disturbed, and by continuing the experiment for about an hour, a notable quantity of baryta carbonate was obtained. This experiment seems to prove that diamond powder was present in small quantity.

It will be remembered that Prof. Wöhler, some years since, found diamonds by a similar method in the platinum sands from Oregon, associated with the rare species *Laurite,*—sulphide of osmium and ruthenium. His paper will be found in the American Supplement to the *Chemical News* for November, 1869, p. 317.

The black grains, which contribute fully one-half the bulk of the Butte County sands, are about equally chromic iron, which the magnet removes, and titanic iron, which is unaffected by the magnet. The chromic iron was so proved by the blowpipe, and no magnetite could be detected. No metallic grains of any of the platinum or iridosmium metals, or gold, could be found.

Under polarized light, these crystalline sands form a splendid microscopic object.

When I am provided with a larger quantity of these sands, I propose to determine the amount of diamond dust quantitatively.

In his letter to me, accompanying the sample sent, Mr. Treadwell says: "I have examined much of the sand under the microscope, and think there are a few fragments of broken diamonds. These sands were taken from the tailings after passing through a long flume paved with stone. You know what sharp and hard pounding the gravel gets, mixed with boulders, in a hydraulic flume. No doubt, some diamonds are ground, or rather broken, by hard knocks, to powder."

A more attentive observation, by a mineralogical eye, of the sands accumulating in the sluices of hydraulic washings will, no doubt, be rewarded by the discovery of many rare species, which have thus far escaped notice for want of scientific skill. To show how much may be learned from an attentive study of such sands, Dr. John Torrey has informed me that in a sample of sands from gold washings in Nicaragua, he has found not less than twenty distinct mineral species, many of them of rare occurrence. No doubt, a careful examination of the sands of Oregon, where Dr. Trask found the platinum minerals, would reveal many unsuspected species.

REMARKS ON AN OCCURRENCE OF TIN-ORE AT WIN SLOW, MAINE.

BY T. STERRY HUNT, LL.D., F.R.S.

I HAVE already referred to this interesting locality in the opening address, but at the request of some of the members of the Institute, brought before them specimens of the ore and the accompanying rock. The ore, which is cassiterite, is also met with elsewhere in Maine, at Paris and Hebron, but it there occurs associated with orthoclase, quartz, tourmaline, and beryl, in concretionary granite veins, which cut the micaceous gneisses of the White Mountain series. At Winslow the veins traverse an impure gray micaceous limestone, which is found in many parts of this region, and is subordinate to the same gneissic series. The veins, which are seldom more than an inch or two in thickness, are abundant through a considerable breadth of the rock, and are interlaminated with it, occupying places between the sedimentary layers, which are distinctly marked by different shades of color. Occasionally, however, they cut across the stratification for a little distance, showing that the disrupting action was not always confined to tearing the layers apart. The vein-stone consists of purple fluor-spar, and silvery white mica with quartz. In this gangue the cassiterite, nearly black in color, is disseminated in small crystalline masses, sometimes one-half an inch in diameter, and is associated with a little mispickel. I have only seen the veins as exposed at a single point, but was informed that similar veins holding the ore are met with at a distance of several thousand feet.

The locality is a promising one, and it is to be hoped that efforts will be made to develop it.

DISCUSSION.

THE PRESIDENT: This is not the first time that tin has been reported from New England. Dr. Jackson, I believe, described a vein of it, many years ago, in New Hampshire, in the town of Jackson; and I think attempts were made to work the vein. Dana's *Mineralogy* reports also scanty occurrences of it at Paris and Hebron, in Maine, and at Chesterfield and Goshen, in Massachusetts. But none of these deposits have proved commercially valuable.

PROF. SILLIMAN : There is a very small one at Haddam.

THE PRESIDENT : Taking a view of the whole country, we have an occurrence of tin in Missouri, which seems to consist in a curious replacement of titanic by stannic acid in sphene, or some similar mineral. This ore sometimes shows by analysis a small trace of tin ; but I think the amount is not such as to lead us to regard it as anymore than a mineralogical curiosity. It must be confessed that this minute discovery of it, bearing the same relation to a valuable ore as Prof. Silliman's experiment does to commercial diamonds, does not confirm the Missouri "specimens," particularly those of *pulverized* and dressed tin ore, once shown to me in New York, and which I matched at once with specimens of tin washed in Cornish works. I never was able to obtain any genuine visibly tin-bearing Missouri specimens in mass. The pulverized specimen now in my cabinet probably came from Cornwall.

It is well known to the members that tin ore varies greatly in its physical appearance. It runs through a wide range of color, from almost white to almost black. We have considerable variety of structure, from earthy to massive and variously crystalline. And it is often easy to recognize the origin of specimens of tin when they are presented, particularly with associated minerals. The specimens shown by Dr. Hunt strongly resemble in some respects those of Zinnwald. The country rock is different, but the association with fluor-spar and mica is similar.

We have had very encouraging discoveries of stream-tin in Idaho, but no mines have as yet come of them. There have been small pebbles of tin-ore found in Prickly Pear Creek in Montana. There is a remarkable deposit of tin-ore in San Bernardino County, in Southern California. Some of that ore is very rich, and associated with melaphyr, and not with the character of rocks in which we have been accustomed to expect it. Then we have a curious occurrence from Durango, in Mexico. Mr. Ashburner, of San Francisco, who examined the locality, presented me with some specimens, and gave me a description, from which it appears that the tin-ore occurs in an unmistakable trachytic dike. To what extent it could be made commercially valuable it is difficult to say, for the reason that explorations of the deposits were superseded by the fact that the transportation involved from this point was so precarious and costly *as* to preclude the idea of working at present with profit. It is not very easy to say whether tin mines could be worked in this country, with profit, on a large scale. Very pure ores might be worked, if the production did not affect the market. But the great difficulty in regard to the economical production of tin in this country lies in the unknown limit to which the price of tin might be reduced, if competition required it, by the East Indian producers. I do not know how low they could reduce their price; it is said that they have always kept it at such a figure as would allow the bare existence of the Cornish mines, and leave the Saxon mines scarcely more than a local market. The Malayan deposits are described as being alluvial in origin, though they are mined partially under ground. They are worked with Chinese labor, and with such advantage and so little expense of machinery, that it has been supposed that the owners could drop their price one-half if there were any object to be gained by it. If this is so, they are in the position of rulers of the market of the world, in respect to tin, with a power we are not able to gauge. This certainly was the state of affairs some years ago; but there are some indications that the balance is changing, or has changed. The recent Australian discoveries are very rich and abundant, and will not suffer from long transportation inland. The question is certainly one that requires for its solution a careful study of the financial and commercial as well as the mineralogical conditions.

REMARKS ON A MINING TRANSIT AND PLUMMET-LAMP.

BY R. W. RAYMOND, PH.D.

HAVING had recently the opportunity of examining a transit and a plummet-lamp, manufactured by Messrs. Heller & Brightly, of Philadelphia, and intended for the use of mining engineers in underground surveying, I thought a description of them would be interesting to such of our members as have work of that kind to do, and accordingly I requested the makers to prepare and send to me a detailed account. There is nothing specially novel, I may remark, in the construction of the transit; its claims to favor must rest upon its compactness and lightness, together with the general excellence of its workmanship. The principal peculiarity is the ribbing and flanging of the parts requiring strength, so as to dispose the minimum amount of material where it will secure the greatest rigidity. This transit is said to be the lightest of American make. I believe Caselli has sent some from London which are still lighter; but they are perhaps not so completely furnished for field-work. I confess I do not see how the weight can well be reduced any further, unless an instrument could be made of aluminium—a plan which Mr. Rothwell once suggested; but which may not, perhaps, be entirely practicable, and, at any rate, has not been tried.

The following is the manufacturers' description of this transit, which they have designed and introduced within the last year:

It is a small, portable angle instrument, similar in principle to the ordinary "engineer's transit," and a fac-simile in every respect (excepting size and weight) of their "complete engineer's transit." It has long compound centres; the horizontal limb is read by two double opposite verniers, placed outside the compass-box, the vernier openings in the plate being made very wide, so as to allow the easy reading of the graduations. There is a three-inch magnetic needle, and its ring is divided to half degrees. The telescope is 7¼ inches long, with object glass fifteen-sixteenths inch in aperture, and shows objects erect and not inverted. A sensitive level, 4½ inches long, is attached to the telescope, for reading angles of elevation and depression, etc. The tripod is furnished with an adjustable head for precise plumbing of the instrument over a centre; and the wooden legs of the tripod are made in such a manner as to form one leg when folded together. The plates, vertical circles, etc., are provided with clamps and tangent-screw movements; and the clamps on the axis of the telescope are arranged with sighting slits and indexes, so as to answer also for right-angle sights. The numbering of the compass ring and horizontal limb, instead of being in quadrants from 0° to 90° each way, as usual, is a continuous one, or from 0° to 360°; but every quadrant of the horizontal limb is also marked with its magnetic bearing, *i. e.*, from 0° N. to 90° E., every ten degrees is marked N. E.; from 90° E. to 180° S., every ten degrees is marked

S. E., etc. The advantage of this arrangement is, that if, at starting, the vernier of the horizontal limb be set to read the same bearing as the needle, the needle can be screwed up, *and both the angles and magnetic bearings read from the horizontal limb, without using the needle for the remainder of the survey,* thus precluding any error from local attraction, reading from the wrong end of the needle, or loss of time in waiting for the needle to settle. The telescope, though short, is a very powerful one, magnifying and having the clearness of an ordinary 17-inch level telescope. A reflector for illuminating the crosswires in dark places is used, as is also an extension tripod leg for lowering or raising the instrument. All the working parts of the needle-lifter, clamp and tangent-screw movement are concealed between the plates, making the instrument more compact. A prism and tube for attaching to the eye-piece of the telescope, for sighting vertically in shafts, is also furnished. The weight of the instrument, exclusive of the tripod, is about 5½ pounds; the weight of the tripod is 3½ pounds; the height of the instrument from the tripod legs is 7 inches ; the extreme diameter of plates, 5 inches; the diameter of the horizontal plate at the point where verniers and graduations meet, 4½ inches. The instrument and tripod head are packed in a box 7½ inches square, arranged with straps to allow its being carried over the shoulder in the same manner as an army officer's field glass, while the folded tripod legs answer as a cane. Though these instruments have been specially designed for mining use, yet from their lightness and compactness they are also meeting with favor for geological surveys, and for preliminary railroad reconnoissances; when used for these purposes, an extra pair of hairs for stadia purposes *(i. e.,* measuring distances without chaining) besides the ordinary cross-hairs, is added.

The same manufacturers make a very convenient plummet-lamp, for underground work. It consists of a brass lamp, suspended by two chains, and terminating below in a conical plummet. The so-called compensating ring is an equatorial ring, surrounding and supporting the lamp, which swings freely within it, upon an axis. The two chains are attached to this ring at the extremities of a diameter perpendicular to the axis. By means of this arrangement, the point of suspension, centre of lamp flame, and steel point of plummet always lie in a true vertical line, no matter how much the brass supporting chains may alter in length from the heating of the lamp, kinking or wearing of the links. A shield at the top prevents the flame from burning the string. These lamps are generally used in pairs for back and forward sights.

I understand that Mr. McNair of Hazleton, and Mr. Coxe of Drifton, both members of this Institute, have used this instrument with satisfactory results.

REMARKS ON THE USE OF THE PLUMMET-LAMP IN UNDERGROUND SURVEYING.

BY ECKLEY B. COXE.

IN the anthracite coal regions of Pennsylvania the custom has been to sight either at an open light (generally a mine-lamp), or at the string of a plumb-bob. If the station was intended to be a permanent one, a spud, as it is called, that is, a nail resembling a horseshoe nail with a hole in the head, is driven into the timbers over the station, or, if there be no timber, a hole is drilled in the coal or rock roof, into which a wooden plug is driven, which serves to hold the spud.

The first operation in making a survey is to lay out the stations, that is, to mark the place where the holes are to be drilled for the plugs or the points on the timbers where the spuds are to be driven in. This should be done before any instrumental work is begun, as much labor can generally be spared, and the use of very short sights can often be avoided, by carefully laying out the stations beforehand. When the stations were laid out, a plumb-bob was hung from the innermost spud, which I will call No. 1, the instrument was put in position at No. 2, by plumbing down and putting a centre-pin under the spud, and then setting up over the centre-pin, and another plumb-bob was suspended from No. 3. If great accuracy was not required, a mine-lamp was set up under the plumb-bobs, at No. 1 and No. 3, and the engineer sighted at them. If great accuracy was required, a lamp or some white surface was held by an assistant behind the strings of the plumb-bobs. To work with any speed by the latter method *(i. e.*, the accurate one), it was necessary for the engineer to have three assistants on whom he could rely even when the chaining was done afterwards; viz.: one to hold the light behind the string at No. 1, one at No. 3, and an assistant at the instrument to hold the light while levelling, reading the instrument, etc. When using lamps on the ground, it is necessary to examine them from time to time, to see that they have not sunk in the mud or turned on one side, etc.; besides, the flame of a mine-lamp is a very large object to sight at, and sometimes it is impossible to see it on the ground (when it can be well seen two or three feet above it), in consequence of some intervening obstacles. Being so situated that it was necessary for me to do a certain amount of accurate work, where I could not rely upon having more than one competent assistant, I had the plumb-bob lamps constructed, and I work with them with a single assistant in the following manner:

When the stations have been laid out, I go to station No. 2 with the transit, and by means of the plumb-bob belonging to the instrument, I place the centre-pin (a small block of lead with a steel pin in it) precisely under the spud No. 2; I then remove the plumb-bob and set up my instrument. While I am doing this, my assistant takes the two lamps, suspends one from spud No. 1, and the other from spud No. 3, and then comes back to hold the light for me while I make the final adjustments and take the readings. My instrument is graduated to 360°, and has two verniers 180° apart. I set the vernier at zero, and sight backwards to lamp No. 1. The flame is very small, and has a blue central cone, which I bisect. I then read the compass-needle, invert the telescope, deflect and sight at No. 3, and read both verniers and the needle. I then turn the telescope back, sight upon No. 1, and turn the vernier plate round nearly 180° until I sight No. 3, and again read both verniers. I obtain thus four readings of the deflection from the vernier, and a compass reading as a check, and as the lights are steady and small, the readings can be made very accurately and quickly. If the four readings agree (with their difference of 180°), I am sure there is no mistake, and go on. I then take up my transit, go to No. 3, run down the lamp to near the ground, put my centre-pin under it, remove the lamp and begin to set up.

In the meantime, the assistant brings the lamp from No. 1 to No. 2, and then takes the lamp from No. 3 to No. 4, and comes back to No. 3, to assist me at the reading of the instrument. The work goes on in this way until all the angles are measured. I then go back and chain the distance from one station to another, and take notes of the workings, etc. In this way, two persons can make a very accurate survey as quickly as three can by the old method. Of course, if one has assistants enough, the chaining can go on with the instrumental work.

CONTRIBUTIONS TO THE RECORDS OF LEAD-SMELTING IN BLAST FURNACES.

BY A. EILERS, M. E.

COMPOSITION OF CHARGES AND CONSUMPTION OF FUEL AT VARIOUS WORKS.

A MARKED peculiarity of most of the smelting-works of the Far West is the looseness with which accounts of the operations are kept. Indeed, probably over half of the works do not keep any detailed accounts at all, the yearly gross statement of profit or loss being considered sufficient for all purposes. The reasons for this must apparently be sought in the as yet unsettled state of *all* business relations, and in the deplorable fact that only in isolated cases educated metallurgists are in charge of the smelting-works. Continual and regular assays of the ores, by-products, and slags, are almost unknown, so that it is impracticable to ascertain, even approximately, the losses in the smelting processes.

Of cases where regular accounts are kept of the quantities of ore smelted, of the composition of charges, and of the fuel consumed, I know only two or three. Under these circumstances it is extremely difficult to collect figures which cover the operations for a considerable length of time, and which are so valuable for the metallurgist, who wishes to get an insight into the economy of smelting operations, as shown by practice. Figures obtained by personal observation, which can of course cover only the brief space of the visit of the travelling metallurgist, must, therefore, be made to replace the more valuable data.

The writer has had occasion, during the last and the preceding summer, to visit the larger number of the Western lead-smelting works, and offers, in the following pages, such data relating to the economy of lead-smelting in the blast furnace at various works, as he has been able to obtain. The only object in doing so is to place these figures on record, so that they may be from time to time supplemented with other data, which are now wanting.

I. EUREKA CONSOLIDATED COMPANY'S SMELTING-WORKS.

These works smelt the ores from the mines of the same company on Ruby Hill, Eureka, Nevada. The supply is almost unlimited, but the ores are comparatively poor. They are ferruginous carbonates, with occasional lumps and masses of galena, containing, in the summer of 1872, on an average about 12 per cent. of lead, and $25 to $30 per ton in gold and silver, the values of the two precious metals being about equal. Arseniate of iron enters largely into the composition of the ore, so that a "speiss," principally an arsenide of iron, is formed in smelting the raw ores. Since last noticed, several important changes have taken place in these works.

There are at present five large blast furnaces for the ore-smelting, of which Nos. 1, 2, 3, and 4 were in blast during my visit in the summer of 1872; No. 5 being in the course of construction.

No. 1 is a rectangular furnace. The dimensions of the hearth, at the level of the slag-spout, are 6½ by 3 feet; at the tuyeres, which are 12 inches above the slag-spout, 5 by 3 feet. One foot above the tuyeres a short bosh commences, sloping back at an angle of 45 degrees, until the section of the furnace is 5 feet 9 inches by 4 feet 6 inches. From here to the top the walls are perpendicular. The total height from the tuyeres to the charge-door is 10 feet.

There are eight water-tuyeres of 3½ inches nozzle, two of which lie horizontally in the back and parallel to each other; and three in each side, also parallel to each other. But the opposite tuyeres, instead of blowing directly towards each other, are all pointed forward, so that lines through the axes of the front pair, for instance, meet about 6 inches back of the middle of the breast. The blast is supplied by a No. 8 Sturtevant blower, which makes 2100 revolutions per minute. Pressure of wind, 1 inch mercury.

Nos. 3 and 4 are octagonal furnaces, with the same area of hearth as No. 1; but they have only seven tuyeres each. Otherwise they have the same bosh, height, and vertical walls. They smelt the same charge as No. 1, and do equally good service.

Charge for Nos. 1, 3, *and* 4.

Charcoal, . .	6 measures	@ 1.2 bushels	= 7.2 bushels @ 15 lbs.	= 108 lbs.	
Ore, . . .	40 shovels	@ 15 lbs.	= 600 lbs.		(100)
Slag, . . .	2 "	@ 15 lbs.	= 30 lbs.—630 lbs.		(5)

Smelted in 24 hours: Ore, ... 50 tons.
Slag, ... 2.5 to 5 tons—52.5 to 55 tons.

Coal consumed, ... 1200 (1197) bushels = 9 tons.
Coal consumed per ton of charge, . 22 8 bushels = 342 lbs. = 17.1 per cent.
" " " " ore, . . 24 " = 360 lbs. = 18 per cent.

Cost of labor in 24 hours per furnace smelting 50 tons.

3 smelters, @ $4.50, ...	$13 50	
6 helpers, @ 4.00, ...	24 00	
6 chargers, @ 4.00, ...	24 00	
		$61 50

To this must be added:

¼ of wages of engineers,*	$1 50	
¼ " " " two foremen, ...	3 00	
¼ " " " blacksmith, ...	1 50	
¼ " salary of metallurgist, ...	8 33	
For roustabouts, etc., ...	12 00	
		24 33
Total, ...		$85 83
Cost of labor per ton of ore, ...	$1 71	

The cost of repairing furnaces, wear and tear of machinery and tools, oil, and materials generally, as well as the waste of coal in handling, must be added to the costs given above. They are not in my possession at present, but to judge from the total cost of smelting given in the annual report of the Eureka Consolidated Company for 1871, these items must foot up heavily.

Furnace No. 2 is smaller than the others, and is charged differently. The size of the hearth at the level of the slag-spout is 5 by 3 feet; at the level of the tuyeres, 3½ by 3 feet. Above the bosh, which effects the transition to the larger section in the same manner as described in the larger furnaces, the size is 4 feet 6 inches by 4 feet 3 inches, and the whole height above the tuyeres is 10 feet. There are four tuyeres of 3½ inches nozzle. Pressure of wind, 1 inch mercury.

Charge for No. 2.

Charcoal, . .	2 measures	@ 1.2 bushels	= 2.4 bushels at 15 lbs. = 36 lbs.	
Ore, . . .	11 shovels	@ 15 lbs.	= 165 lbs.	(100)
Slag, . . .	1 shovel	@ 15 lbs.	= 15 lbs.—180 lbs.	(9.09)

Smelted in 24 hours: Ore, ... 30 tons.
Slag, ... 1.5 to 3 tons—31.5 to 33 tons.

Coal consumed, ... 870 bushels = 6.525 tons.
" " per ton of charge, . 26.6 bushels = 399 lbs. = 19.95 per cent.
" " " ore, . 29.09 bushels = 436 lbs. = 21.81 per cent.

* Assuming that four furnaces are running at a time.

Cost of labor in 24 hours per furnace smelting 30 tons of ore.

3 smelters, @ $4.50,	$13 50	
3 helpers, @ 4.00,	12 00	
3 chargers, @ 4.00,	12 00	
		$37 50

To which must be added:

¼ of wages of engineers,	$4 50	
½ " " " two foremen,	3 00	
½ " " " blacksmith,	1 50	
⅓ " " " metallurgist,	3 33	
For roustabouts, etc.,	8 00	
		$20 33
Total,		$57 83
Cost of labor per ton of ore,	$1 93	

The remarks as to the other costs, made in speaking of the larger furnaces, are equally applicable here.

II. THE RICHMOND CONSOLIDATED COMPANY, EUREKA.

This company smelts the same class of ores as the foregoing, but they are richer in lead and silver. They come from the Richmond and Tip-Top mines, on the western end of Ruby Hill. The furnace running in the mouth of August, 1872, was an exact copy of furnace No. 1 of the Eureka Consolidated Company, with the single exception of the depth of the furnace above the boshes, which was 6 feet 6 inches.

Charge.

Charcoal, ... 18 scoops = 5.5 bushels at 15 lbs. = 82.5 lbs.
Ore, ... 25 shovels at 18 lbs. = 450 lbs. (100)
Slag, ... 2 shovels at 15 lbs. = 30 lbs.—480 lbs. (6.66)
Smelted in 24 hours, 180 (?) charges = 40.5 tons of ore, or 43.2 tons of charge.
Coal consumed, ... 990 bushels = 7.425 tons.
" " per ton of charge, . 22.9 bushels = 243.5 lbs. = 17.17 per cent.
" " per ton of ore, . 24.4 bushels = 366 lbs. = 18.3 per cent.

The cost of labor at these works is not in my possession. I can only say that the same number of workmen are employed immediately around the furnace as at No. 1 furnace of the Eureka Consolidated Company, but the cost of supervision, blast, and roustabouts is different; and, as only one furnace is run, probably considerably higher per ton of ore than at the works mentioned. At the Richmond Works the top of the furnace is intentionally kept blazing, eight billets of wood being thrown in on top after every charge. The effect claimed is the melting of the dust, and its adhesion in that state to the walls of the stack, from which the crusts are from time to time loosened, and allowed to fall into the furnace. It is evident that only a very small portion of the dust can be arrested in this way, and more than probable that there is more dust created when this device is employed than there would be without it, to say nothing of the lead and silver which must be volatilized.

III. THE MILLER MINING AND SMELTING COMPANY'S SULTANA WORKS.

The works are located near the head of American Fork Canyon, Utah. The ores smelted come from the Miller mine near by, and consist of very ferruginous oxidized ores of lead, containing much galena and very little quartz, too little in fact to permit the formation of a fluid slag in smelting the ore alone. This fact, however, was not understood by those running the works in the summer of 1872. The ore contained, according to many assays, 40 to 42 ounces of silver, and 0.4 to 0.6 ounces of gold per ton, and 56 per cent. of lead.

There are three circular furnaces of the. Piltz pattern, nine feet high above the tuyeres. The section of the hearth of No. 1 is 28 by 36 inches. It has six water-tuyeres with two and a half inch nozzles. The size of Nos. 2 and 3 in the hearth is 24 by 32 inches. They have four tuyeres each of the same size as *No. 1*. They lie about six inches above the slag-spout, and are inclined inward, so that they must blow directly on the metal-bath, thus occasioning volatilization of lead. All the furnaces are provided with the automatic tap.

Charge.

Charcoal, ...	6 scoops = 1.8 bushels @ 16 lbs. = 28.8 lbs.
Ore, ...	5 shovels @ 20 lbs. = 100 lbs.
Slag, ...	About ¾ shovels @ 16 lbs. = 12 lbs.—112 lbs.
Smelted in 24 hours, .	240 charges = 12 tons of ore, or 13.44 tons of charge.
Coal consumed, ...	432 bushels = 3.45 tons.
" " per ton of charge,	32.1 bushels = 513.6 lbs. = 25.68 per cent.
" " per ton of ore, .	36 bushels = 576 lbs. = 28.8 per cent.

The product, per furnace, at these works in 24 hours was 4 to 4.5 tons of lead, containing 85 to 121 (rarely) ounces of silver and 1.2

to 1.45 ounces of gold. This shows an enormous loss of lead, and of the precious metals. There are two causes for this, both evident at once to the observer. The first is the flaming top of the furnaces, out of which a roaring bundle of fire issues continually, tearing along great quantities of fine ore and coal, which are deposited in a thick layer on the roof of the smelting building, and in the vicinity. The second is the fact that the slag produced is far too basic, thus enveloping metallic lead and matte, and preventing separation. There is no matte saved so far as I know.

IV. SATURN WORKS, SANDY STATION, ELEVEN MILES SOUTH OF SALT LAKE CITY.

The ores smelted are principally ferruginous carbonates with some galena from the Cottonwood canyons, quartzose carbonates from Bingham canyon, and occasionally ores from Tintic (?). There are three small circular furnaces of the Piltz pattern, with four tuyeres, two in the back and one in each side. One Sturtevant blower, driven by steam, supplies the blast, which is kept at a pressure of about one inch quicksilver. Two furnaces were running at the time of my visit (August 23, 1872). Slag free and apparently a singulo-silicate.

Charge.

Charcoal,	4 scoops = 1.2 bushels @ 16 lbs.	= 19.2 lbs.	
Ore,	3 large shovels @ 20 lbs.	= 60 lbs.	(100)
Rawlins iron-ore,	1 shovel,	15 lbs.	(25)
Limestone,	½ "	6 lbs.	(10)
Slag,	1 "	15 lbs. — 96 lbs.	(25)

Smelted in 24 hours: 345 charges = 10.35 tons of ore, or 16.56 tons of charge.

Coal consumed, ... 414 bushels = 3.32 tons.

" " per ton of charge, . . 25 bushels = 400 lbs. = 20 per cent.

" " per ton of ore, . . 40 bushels = 640 lbs. = 32 per cent.

V. BRISTOL & DAGGET'S WORKS, BINGHAM CANYON, UTAH.

The ores smelted are very silicious carbonates containing little iron, and some galena, principally from the Winnemuck mine, on the hillside behind the works. There are two circular Piltz furnaces, 14 feet high above the tuyeres. Their diameter at the level of the tuyeres is 3.5 feet. There are six of the latter with 2.5-inch nozzles, lying 10 inches above the slag-spout. The blast is supplied by two large Root blowers, and a pressure of 1.5 inches mercury is maintained.

A report for the three months from April 1st to June 30th, 1872, furnishes the following items:

Average assay of ore smelted: Lead 37.7 per cent.
Silver, 56.18 ounces per ton.

Smelted:	Ore,	1,268.	tons.
	Iron oxide,	407.888	"
	Limestone,	518 140	"
	Own slags,	208.352	"

Coal consumed: 74,830 bushels = 598.64 tons.

This gives an average charge as follows:

Ore,	100	
Iron oxide,	32.16	
Limestone,	40.86	
Own slags,	16.43	
		189.45

Charcoal, ... 47.2

Coal consumed per ton of charge, 31.14 bushels = 498.24 lbs. = 24.9 per cent.
" " per ton of ore, . 59 bushels = 944 lbs. = 47.2 per cent.

The product from the above materials was:

Lead,	439 951 tons.
Silver,	67,478.2 ounces.

Which would show an apparent loss of

Lead,	7.9 per cent.
Silver,	5.3 per cent.

This loss, it will be observed, is not a very large one for Western circumstances. From the writer's own observations he is indeed led to believe, that Bristol & Dagget's works are more intelligently managed, and lose less in lead and silver, than any other works in the West, with the single exception of, perhaps, one or two smelting-works at Eureka, Nevada. The average length of campaigns at these works is from 20 to 22 days and 14 tons of ore are smelted in 24 hours. Iron ore from Rawlins costs $ 25 per ton; limestone, $ 7 coal, 33 cents per bushel, and the ore (mining, including all prospecting and construction), $ 6 per ton. The cost of labor is not in my possession.

VI. BELSHAW & JUDSON'S SMELTING WORKS, CERRO GORDO, INYO COUNTY, CALIFORNIA.

The works smelt the ore from the Union mine, consisting of gray carbonate, ferruginous earthy carbonates, and galena. Small quantities of very silicious true silver ores are added to the charge for the purpose of concentrating their silver in the lead. The furnace is a low round shaft-furnace with three cast-iron tuyeres of two and a half inches diameter, Iving about 12 inches above the slag-spout. The diameter of the furnace is uniformly 30 inches from the tuyeres to the charge-hole, the latter being seven and a half feet above the former. The lower part of the furnace up to within five feet above the tuyeres is constructed of masonry. On top of this rests an iron cylinder two and one half feet high, its upper rim reaching to the bottom of the charge-hole. Above are again three feet of masonry, from which the flue leads into a so-called "down-throw" and a low chimney. The furnace is not charged up to the charge-door, but only to the lower edge of the iron cylinder, it being claimed, that, if the furnace is filled to the top, the smelting is much slower, and considerably more coal is used per ton of ore. This can only be explained by great weakness of the blast, the increased weight of a higher column of charge preventing the penetration of the blast to the middle of the furnace. With a proper blast the heightening of the smelting column should cause a saving of fuel and an increased production. The blast is supplied by a small Root blower No. 2), which is driven by a teu-horse-power engine. The blower makes 325 revolutions per minute, which is many times more than it is in- tended to make by the builders. The consequence is that frequent repairs become necessary. Formerly the ores were first roasted and slagged in a Mexican "galemador," and then smelted in the shaft- furnace, but the slag falling at that time contained still from 15 to 20 per cent, of lead with one to 4 ounces of silver per ton. It was found that in smelting the ores immediately in the blast-furnace, the slags contained only from 8 to 10 per cent, of lead, and less silver than formerly. So the latter less expensive process was altogether introduced, as the choice of the least evil of the two. It is the pride of these works, that they smelt comparatively more ore with less fuel in twenty-four hours, than any other works in the country. But from the great loss of lead it is evident why this is the case, to wit, because so large a portion of the lead in the ore is not reduced at all, and, consequently, consumes no carbon for that purpose, but is converted into a silicate of lead which requires little heat for fusion. The charcoal is a very excellent article, and made altogether of piñ fion and mahogany.

Charcoal, ...	1.75 bushel s @ 18 lbs.	= 31.5 lbs.	
Ore, fine carbonate, . .	12 shovels @1 16 lbs .	= 192 lbs.	(100)
Ore, galena,	1 "	= 20 lbs.	(10.4)
Ore, quartzose silver ore, .	1 "	= 15 lbs.	(7.8)
	—	227 lbs.	
Slag,............................	2 shovels @ 15 lbs.	30 lb	(1.5.6)
		257 lbs.	

Smelted in 24 hours, .200 charges = 22.7 tons of ore, or 25.7 tons of charge.
Coal consumed, . . 350 bushels = 3.15 tons.
" " per ton of charge, .13.6 bushels = 244.8 lbs. = 12.2 per cent.
" " per ton of ore, . . 15.4 bushels = 277.2 lbs. = 13.8 per cent.

The consumption of fuel is remarkably small, and it is only possible for the reasons above stated. It is to be regretted, that exact data could not be btained at the works, to elucidate the economical bearing of the Cerro Gordo process fully and incontrovertibly. As it is, there is barely a sufficiency of data on hand, to show that fuel is economized by means of an almost unprecedented loss of lead. It is also claimed by the manager of the works, that it is cheaper to lose the lead, than to procure iron oxides for the purpose of mixing with the charge. But whoever has seen the enormous masses of hydrated oxide of iron in the Cerro Gordo mines, will hardly be able to ealize this.

The whole management of the works is rather calculated to create the suspicion, that the proper composition of the charge is not understood. It is certain, that either by an addition of iron oxide to the present charge, or by omitting the addition of the quartzose silver ores altogether, far better results might be obtained than at present. The exact proportion of the smelting mixture ought, of course, to be regulated upon determination by analysis.

The following are a few additional data, which help to give some idea about the work done at this smelter. Two hundred charges are generally made in 24 hours; when the furnace is in the best smelting order, the number of charges in 24 hours rises sometimes as high as 240. From 100 to 148 bars of bullion are made in 24 hours, a bar weighing 85 lbs. Different lots of bullion contained respectively 130, 125, 147, 145, 134 ounces of silver per ton. The lead bars, after deducting the silver, contain 98 per cent, of lead, the principal impurity being copper, which comes originally from the quartzose silver ores. It enters into the lead, because the lead-copper matte, which forms in the proportion of 100 lbs. to one ton ofbullion, is always given back raw into the smelting process. Thefine ore contains about 25 ounces of silver per ton, the galena from50 to 80; the silver ore, third class, 50 ounces, second class, 65 to100 ounces, first class, 250 to 300 ounces; the abundance of thesethree classes being in the order given. The silver ores roper are bought from other parties, §20 per ton being paid for third class. The Union mine, furnishing the lead ore, belongs to the works. The average contents of lead in the charge is not precisely ascertained at the works, but from calculation it must be about 34 per cent., if 22.7 tons of ore furnish 5.25 tons of bullion, and the slag contains 15 per cent, of lead.

All that has been said of the last works applies also to Beau dry's furnace in the same district.

VII. THE OWEN'S LAKE SILVER MINING AND SMELTINGCOMPANY'S WORKS.

At Swansea, ten miles west of Cerro Gordo, on the eastern shore of Owen's Lake. This company has two furnaces, which are in their general features like those ; st described. They are eight feet high above the tuyeres, of which there are three, with three-inch nozzles in each. They lie only a few inches above the slag-spout, and are inclined downward. This accounts for the formation of the extremely small quantity of matte produced, though there is more Sulphur in the charge smelted here than in that of Belshaw's works. Hereafter these works will smelt the lead ores of Santa Maria and Cerro Gordo, together with such small quantities of quartzose silver ores as can be bought to advantage, and the charges for the furnaces can, therefore, be kept more uniform than formerly, when small lots of different custom ores were smelted, as they could be picked up. Daily records have heretofore not been kept at the works, but the following is given as about an average charge:*

Charcoal, . . . GO to 80, average 70 bushels @ 18 lbs.	= 1260 lbs.		
Ore; 3 tons of carbonates,		6,000 lbs.	(100)
1 ton of galena,		2,000 lbs.	(33.3)
0.5 ton of quartzose silver ore, . . .		1,000 lbs.	(16.6)
		9,000 lbs.	
Slag: 0.675 tons		1,350 lbs.	(22.5)
Total		10,350 lbs.	

Coal consumed per ton of charge,13.52 bushels= 243.36 lbs. = 12.16 per cent.
" " per ton of ore, . 15.55 bushels = 280 lbs. = 14.11 per cent.

* These items were obtained in September, 1872. Since then the charges ave been changed.

Fuller returns from these works are promised hereafter.

For the purpose of comparison, I give here the blast-furnace charges and a short description of the furnaces of European works, which beneficiate lead-ores by the same or similar processes, as practiced at the American works above enumerated.

VIII. WORKS AT LA PISE, DÉPAETEMENT DU GARD, FRANCE.

Circular furnace of about 30 inches diameter at the tuyeres and above. The tuyeres, of which there are three of not quite two-inch diameter, lie in pillars of masonry between water-cooled cast-iron plates, 0.82 feet above the slag-spout. Only two of the tuyeres are generally used in smelting. The total height of the furnace above the tuyeres is 9 feet 6 inches. Campaigns last from 2 to 3 months. Pressure of blast 1.18 inches mercury.

The ores treated come from Pulliè res, near Anduze, and from Sardinia. The former are reported to contain, after roasting, 40 per cent, of lead, 0.11 per cent, silver, and 20 per cent, silica. In 24 hours 8.8 to 11 tons of ore are smelted with 25 per cent, of coke =2.2 to 2.75 tons.

Charge:

Roasted ore, ...	10	tons.
Limestone, ...	2.5	"
Iron ore, ...	0.3 to 0.4	"
Iron, ...	0.2 to 0.3	"
	13.2 tons.	

Metallurgists generally rate the effect which can be produced with one ton of coke equal to that of 200 bushels of inferior charcoal, weighing 12 lbs. per bushel, or 2000 lbs. of coke = 2400 lbs. char- coal. According to the above, 25 per cent, of coke is used in smelt- ing the ore in the La Pise shaft furnace. The charge, in which there are ten tons of ore, requires, therefore, 2.5 tons of coke. Express- ing this in charcoal, weighing 15 lbs. to the bushel, which is the fair average weight of Western charcoal, we have 400 bushels of charcoal consumed to smelt ten tons of ore. Therefore:

Coal consumed per ton of charge:	30.3 bushels @	15 lbs. =	454.5 lbs. =	22.7 per ct.
" " per ton of ore:	40 bushels @	15 lbs. =	600 lbs. =	30 per ct.

IX. SMELTING-WORKS AT CLASTHAL (I), LAUTENTHAL (II), AND ALTENAU (III).

The smelting is done in Raschette furnaces, 3 metres (9.8 feet) long, and 0.94 metres (3.08 feet) wide at the tuyeres, and 6.277 metres (20.59 feet) high, with ten tuyeres of 0.049 metres (0.16 feet = 1.92 inches) diameter. In twenty-four hours 7500 kilo. = 16,500 Ibs. of ore, or 20,000 kilo. = 44,000 Ibs. of charge, are smelted with 2500 kilo. = 5500 Ibs. coke; the latter, according to the data above given, equal in effect to 440 bushels of charcoal.*

From the above it appears that, expressing the values for fuel as charcoal, there are consumed :

Per ton of charge: 20 bushels @ 15 Ibs. = 300 Ibs. = 15 per cent.
Per ton of ore : 53.33 bushels @ 15 Ibs. = 799.95 Ibs. = 39.99 per cent.

The charges at the three works named are as follows:

	I.	II.	III.
Ore,	100	100	100
Roasted matte,	51	56	50
Copper slags from the Lower Hartz,	60	115	87.3
Slags from the same smelting,	93	75	55.3
Dressed furnace scrapings,	3	...	....
Slag from the smelting of scrapings in the copper process,	...	...	26.6
Scraps rich in lead,	...	...	4
Total,	307	346	321.2

Early in 1872, when the "Kast" furnace had been introduced and in operation for some time, Mr, A. Wolters, M.E., Assayer at the U. S. Assay Office, Boise City, returning from Clausthal, brought the following notes : The charges for both the Kast and Bascbette furnaces were, with due regard for the differing gangue of the ores and the varying contents of lead and silver, mixed so in quantities . of 1000 cwt. (dry), that the average contents were:

Lead, ... 58 to 60 per cent.
Silver, ... 0.1 per cent.

and the proportion of the different gangues was made so as to furnish an easily fusible slag.

Such a quantity of 1000 cwt. was divided into 20 "charges" of

* Further and late information in regard to the furnaces and smeltingoperations at the Upper Hartz, can be found in Metallurgie des Bleies, by Dr. 0. Rammelsberg, pages 248-270.

50 cwt. each. To this "charge" are then added the following substances in the proportions given :

Ore	100
Roasted matte from former smelting, ...	50
Copper slag from Lower Hartz, ...	80
Slag from matte-smelting, ...	40
Impure slag from same process, ...	32
	302

The last two items vary somewhat, according to the acidity of the gangue. To the charge for the Raschette furnace there are often added twenty additional parts of slag from the same smelting.

The quantity smelted in a Kast furnace in twenty-four hours, according to an average of a month's working, is 63 cwt. of ore, or 190.26 cwt. of charge, equal to about 9.5 tons; 100 cwt. of ore requires 51 cwt. of coke in smelting. One pound of coke carries, therefore, according to the foregoing, approximately six pounds of charge, or, 16.66 per cent, of coke are used. Assuming again the effect of one ton of coke, equal to that of 160 bushels of charcoal of 15 lbs. each, we have :

Charcoal consumed per ton of charge, 27.7 bushels @ 15 lbs.= 415.5168 . = 2 0.77

Charcoal consumed per ton of ore, 81.6 bushels © 15 lbs.= 1224 lbs.= 61.2 p.c.

X. SMELTING-WOKKS OF FREIBERG, SAXONY.

All the ores occurring in the Freiberg mines are now subjected to the same metallurgical treatment, with the exception only of the ores containing more than 30 per cent. of zinc, and those containing a large amount of arsenic. These two classes are specially treated.

The ores smelted at "Muldener Hütte," during 1869 (16,589,500 kilo. = 36,573,211 lbs. = 18,286.60 tons), contained on an average 17.6 per cent. of lead, and 0.6 per cent, copper. The smelting, both at the " Muldener" and at the "Halsbrückner" works, is done in round shaft furnaces (with 8 tuyeres each) of 1.726 M.= 5.66 feet diameter, and a height of 3.84 M. = 12.59 feet above the tuyeres.

Charges.

	Muldener Hütte.	Halsbrückoer Hütte.
Roasted ore, . .	.100	100
Raw matte, . .	. 1 0	3.03
Kiln-roasted pyrites,, .	15	—
Slag	80—100, Avg. 90	50
Entzinkungsrückstande,		3.338
Fluor-spar,		0.35
Calcspar,		1.583
Heavy spar,		0.145

In twenty-four hours, at the former works (25,000 to) 30,000 kilo, ore = (55,000 to) 70,000 kilo. charge are smelted; at the latter, 35,000 kilo. ore = 50,000 kilo. charge. (11 to) 12 per cent. of coke (referring to the charge) are used.

This shows for:

Muldener Hütte.

Charge 70,000 kilo. = 154,322 pounds English.

Coke consumed, 12 per cent. = 18,518 pounds, which is equal in effect to 1,481.44 bushels of charcoal of 15 pounds each.

Charcoal consumed, per ton of charge: 19.2 bushels =288 lbs. = 14.4 per cent.

In the 70,000 kilo. charge are 30,000 kilo. ore =66,138 pounds English.

Therefore:

Charcoal consumed per ton of ore : 44.8 bushels = 672 lbs. = 33.6 per cent.

Hahbrüchier Hütte.

Charge, 50,000 kilo. = 110,230 pounds English.

Coke consumed, 12 per cent. = 13,227.6 pounds, equal in effect to 1,058.2 bushels charcoal of 15 pounds each.

Charcoal consumed per ton of charge: 19.2 bushels = 288 lbs. = 14.4 per cent. 50,000 kilo. charge contain 35,000 kilo. = 77,161 lbs. English ore. Therefore:

Charcoal consumed per ton of ore : 27.4 bushels = 411 lbs. = 20.5 per cent.

The following table will give the amounts per ton, and percentage of fuel used at the American and European works, brought forward in the foregoing article :

CONSUMPTION OF CHARCOAL IN LEAD BLAST-FURNACES.

Names of Smelting Works.	Bushels of Charcoal per ton of		Pounds of Charcoal per ton of		Percentage of Charcoal per ton of	
	Charge.	Ore.	Charge.	Ore.	Charge.	Ore.
AMERICAN WORKS.						
1. Eureka Consolidated Co.:						
a. Furnaces Nos. 1, 3, and 4,	22.8	24	342	360	17.1	18
b. Furnace No. 2, ...	26.6	29	399	436	19.9	21.8
2. Richmond Consolidated Co., .	22.9	24.4	343.5	366	17.17	18.3
3. Miller Mining and Smelting Co.,	32.1	36	513.6	576	25.68	28.8
4. Saturn Works, ...	25	40	400	640	20	32
5. Bristol & Dagget's Works, . .	31.14	59	498	944	24.9	47.2
6. Belshaw & Judson's Works, . .	13.6	15.4	244.8	277	12.2	13.8
7. Owen's Lake S. M. and S. Co., .	13.5	15.5	243	280	12.16	14
EUROPEAN WORKS.						
8. La Pise, ...	30.3	40	454.5	600	22.7	30
9. Clausthal, Lautenthal, and Altenau:						
a. Raschette Furnace, . . .	20	53.3	300	799.9	15	39.99
b. Kast Furnace, ...	27.7	81.6	415	1224	20.7	61.2
10. Freiberg:						
a. Muldener Hütte, ...	19.2	44.8	288	672	14.4	33.6
b. Halsbrückner Hütte, . .	19.2	27.4	288	411	14.4	20.5

According to a supplement in *Rammelsberg's Metallurgy of Lead*, the Raschette furnace at Clausthal consumes for 100 lbs. of ore 48 lbs. of coke, and the Kast furnace, 41.6 to 42.4 lbs. Accepting for he Kast the first or the two figures given, we would have, calculated for charcoal:

Names of Furnaces.	Bushels of Charcoal per ton of		Pounds of Charcoal per ton of		Percentage of Charcoal per ton of	
	Charge.	Ore.	Charge.	Ore.	Charge.	Ore.
Raschette Furnace, ...	25	76.8	375	1152	18.7	57.6
Kast Furnace, ...	22	66.5	330	997.5	16.5	49.8

It is evident that these figures cannot be reconciled with those given before. Yet both are on equally good authority, and all those in regard to the Raschette furnace are even taken from the same author. I am inclined to think that the main error is in Dr. Rammelsberg's statement, page 258 of. his *Metallurgie des Bleies:* "In 24 hours there are smelted 7500 kilo. ore with 2500 kilo. coke." This would be a consumption of coke of only 33.3 per cent., while all other authors, who have written on the Clausthal works, have always given for the Raschette furnace a consumption of 43 to 50 lbs. of coke to 100 lbs. of ore.

From the foregoing tables it appears that, setting the two Cerro Gordo cases aside (sufficient reason for which is given in the text), American works use more fuel in smelting their blast-furnace *charges* than European works, although their ores are " kindlier;" but that, in referring the quantities of coal used to the ore in the charge, American works appear to be conducted more economically in this respect. Whether *true* economy is practiced must, for the present, remain an open question, which can only be answered after American works have begun to control their whole process by means of chemical analysis. European works generally add large quantities of slag, and other indifferent materials, from previous smeltings, to their charges, in order to protect the metal, and the slags finally thrown over the dump contain usually only from 0.5 to 1 per cent. of lead, and silver in hardly appreciable amounts. American lead-slags hardly ever contain less than 5 per cent., and in some exceptional cases up to 20 per cent. of lead, while the contents in silver correspond with those of lead. There are cases in which this loss cannot, with economy, be avoided at the present time, but there are more of those in which metallurgical skill could, without increase of cost, compose charges, the result of which would be slags as clean as the European ones. There is, however,one consolation for this present unnecessary loss: while the robbing of mines leaves them generally in such a shape that a subsequent generation cannot repair the losses occasioned by the first method of working, the robbing of ores leaves residues from which, in the future, science can profitably extract the useful constituents.

BECENT IMPR0VEMENTS IN DIAMOND DRILLS AND IN THE MACHINERY FOB THEIR USE.

BY PROF. WILLIAM P. BLAKE.

THE use of diamonds upon a large scale in drilling rocks, and the substitution to a certain degree of rotary diamond drills for the ordinary steel percussion drills, marks a new era in the art of mining.

Since the invention by Leschot of the diamond drill, it has steadily advanced in its utility and range of application, and in the appreciation of miners and engineers. It must be claimed as One of the many gifts of science to the arts; and it is, in particular, one of the fruits of the scientific education given at the Ecole Centrale, at Paris.

Members are all, doubtless, more or less familiar with the construction of the drill and of the machinery by which it is applied in boring. It is, therefore, my present purpose only to direct your attention to some recent marked improvements, made by the American Diamond Drill Company, by which the economy and efficiency of the machines have been increased.

Form of Bit.—The annular or ring form of the drill-head or bit was, I believe, the earliest; and it is still in use, without essential modification, wherever it is desired to obtain a sample "core" or specimen of the rock traversed. But for mere drilling, regardless of the preservation of a test-core, a solid-head bit is preferred, except for very large holes.

Until recently, these solid-head bits were made with a pointed cutting face shaped like an obtuse cone. This form was assumed to be the best, being most in accordance with the experience obtained with percussion drills. It is found, however, that the exact reverse of this pointed conical form is the best. The bits are now made concave ; and the diamonds are studded over the concave surface.

The hollow chamber in the centre of this bit is connected with the cutting face of the bit by three or more tubular channels drilled through to the face. These convey the water, forced down through the tubular rods. This water streams through the bit, and rapidly removes the abraded rock from among the diamonds, keeping the surface of the rock clean.

This form of drill is a partial return to the annular form. It bores faster, and cuts a straighter hole than the pointed bits.

Setting the Diamonds.—In setting the diamonds in the solid steel heads it has been the practice, until recently, to first drill sockets deep enough to receive the stones, and then to punch up the surrounding metal, so as to cover the projecting edges and hold them. Now holes are drilled and the stones arc, in some cases at least, forced through the steel from the inside of the bit by hydraulic pressure. The holes are first drilled smaller than the stones; and stones much larger than the diameter of such holes have been thus forced forward to the face of the bit. This method insures the most perfect bedding and contact of the gem, and gives a firmer setting. This is an interesting fact in physics as well as practically important; for it is a good illustration of the mobility of the particles of what appears to us to be solid and unyielding matter. It gives, also, a hint which may be of some value to jewellers, since cut stones could equally well be forced into solid gold or silver settings.

New Forms of Prospecting Machines.—Among the mechanical changes in the prospecting machines, probably the most important is the modification which facilitates hoisting and lowering the drill. Up to a recent date there was no provision made for raising the drill-rods from the hole without moving the machine. Now the machine may be bolted to its place, and remain until the bore is completed. The drill-stock is upon the end of a hinged arm, which, when not required, can be swung back out of the way, while the rods are being drawn or inserted.

A hoisting-drum has been added to facilitate handling the drill-rods. This being fixed to the machines, and the drill-stock being out of the way, the rods can be hoisted and lowered quickly and easily. Powerful pumps have been added, of double the former capacity, with four-inch cylinders. They supply a body of water under pressure sufficient to wash the drill-holes out clean.

Other Machines.—The tunnelling and blasting machines are now made with hydraulic feeding apparatus instead of the mechanical movement. The latter is, however, retained for the prospecting drills, where the holes are vertical or nearly so, and the weight of the rods enters as an element. With the hydraulic feed, the pressure is constant and uniform, while the speed of the drill varies with the hardness of the rock.

Im proved Underground Drill.—The American Diamond Drill Company is now making an improved light machine for underground or tunnel work. It is built of steel and gun metal, weighs only about four hundred pounds, and can be bandied by two men. For convenience it may be mounted on wheels. There are two driving cylinders working upon one crank-shaft. Either steam or compressed air may be used.

. *Wear of Diamonds.*—Experience teaches that there is a great difference in the effective hardness or cutting power of different stones. In general the African diamonds are avoided, they cleave too readily and split up. The Brazilian stones are the best. The-compact black carbon or bort is preferred to the vitreous stones; it lasts longer and is tougher. Mr. Tompkins, President of the American Diamond Drill Company, informs me that he has ascertained, by careful weighing, that after boring 200 feet, there was hardly any appreciable loss by weight in twelve pieces of carbon set in one bit. When the stones were set their aggregate weight was twenty-four carats ; when returned, twenty-three and three-quarter carats; but this loss of a quarter of a carat in weight is attributed wholly to the breaking of one of the stones in cutting it out of the bit.

The Use of the Diamond Drills.—With regard to the present extended use of these drills, and their valuable services in mining and prospecting, it is not my purpose now to speak particularly. Some of the more important localities are enumerated in a recent valuable article in the *Engineering and Mining Journal* of Feb. 4th.

I must, however, refer to one or two notable examples which illustrate the value and economy of this method of boring. Foremost is the great work undertaken in Pennsylvania by General Pleasants, one of our members, and ably described at our meeting in New York in May last, by Mr. Coxe. A recent summing up of the work in a tabular form shows that in the shaft, 14 by 21 feet, twenty-five holes were drilled, averaging 254 feet in depth. In 58 working days the average number of feet drilled daily was 109 ½. Average number of machines at work two and eight-tenths. Average cost of wear and tear of bits, etc., 13 ¼ cents per foot. The rock is the " blue-stone conglomerate." A concave bit is used, and the holes are one and three-quarters of an inch in diameter.

On the 1st of February the east shaft was 530 feet deep, and the west shaft 261 feet, work having been delayed in the latter by an explosion in the engine-house. The best blasting thus far has been 80 feet per month of shaft sunk, and the best drilling 79 feet of hole drilled in a twelve hours shift. The cost of wear and tear of diamonds and damage to bits was about 15 cents per foot.

These are some of the many improvements which are now making in this valuable invention. I am sure that gentlemen who are engaged in prospecting, or examining mineral regions for unknown deposits of ore, would find this machine of very great service. Even in mines that are already in active work it is very desirable to know, in advance of the working, what the ground is, and what amount of ore may be counted upon, in order that the work for its extraction may be properly projected and carried forward.

DISCUSSION.

THE PRESIDENT : Allusion has been made by Professor Blake, to the use of the diamond drill in prospecting. It was tried at the South Aurora mine, one of the mines lying upon Treasure Hill, in the White Pine mining district, so celebrated a couple of years ago, but now suffering a rather disastrous collapse. The characteristic deposits of Treasure Hill are, so far as explorations have ever shown, irregular masses and impregnations in limestone of Devonian age; and when exhausted were entirely without indications of the direction in which further ore was to be sought. The chambers have sometimes been of vast extent, and great richness; as, for instance, the celebrated Blue Bell chamber, in the Eberhart mine, where I have seen at one time more than a million dollars' worth of solid silver chloride, and into which I could put a pick for half the length of the blade. Yet these richest chambers were exhausted ; and the phenomenon was encountered, so universal in silver mining, that they had ten tons of poor for one ton of rich ore. After the available ore had been worked out, the question occurred in some of the mines, how far explorations should be conducted ; and it was with the idea of exploring the hill still further, to find, if possible, the direction of the deposit, that the diamond drill was pretty thoroughly tried in the South Aurora, and, to some extent, in other mines. The result has shown, what I ventured to expect beforehand, that, for deposits of this very irregular character, a drill is a poor prospecting apparatus; and the diamond drill, which is a convenient contrivance for boring a small hole to a very long distance, in any given straight line, shares this objection. Where deposits are very irregular, the hole that is made, with the sample taken from it, proves too little. The discovery of ore in that way might not be sufficient to justify the expenditure of a large amount of money to develop in that direction. And, what *is* still more disheartening, the failure to discover ore does not prove enough to justify the abandonment of the property. At the South Aurora mine, small holes were bored to a considerable distance in a dozen different directions. There were many drawbacks connected with the inexperience of the workmen and the hauling of the machinery, so that the work was not cheap, and yet the results were negative, but not conclusive. They cannot be quite sure, even to this day, but that a different method of exploration, permitting larger sections and cross-cuts, might have got indications which would have led them to a more favorable result. As an actual result, I hear the mine has been abandoned, and they probably did well to abandon it. But, at the same time, the evidence obtained by the expenditure of money in diamond drilling, was not conclusive, not even conclusively discouraging. The same amount of money would have drifted a good way in that limestone, and the drift would have opened a so much larger sectional area, and given them a chance to study so much more carefully and conclusively the character of the side-walls, that if there were no results to lead to new indications of ore, there would at least be a better ground for calm and final despair.

In its new form—the solid bit—the diamond drill has the same disadvantage that the old-fashioned percussion forms had. It grinds everything fine, and it is all washed out together, being removed, in this case, by a continual stream of water rushing down through the drill-rods; and, in the old-fashioned drill, by the sand-pump, used at intervals, the tools being removed. This gives little opportunity of studying with minuteness the character of the sides of the holes, and the mineralogical indications at any given time. A core must ' be taken for that, and even a core gives a small and possibly misleading section. I do not think drills can quite supersede exploring drifts. On the other hand, it must be said for this drill, that it is the only one permitting the boring of long holes in any desired straight line; and that for prospecting to determine the succession of strata, the order and character of regular veins or beds, and the nature of the rock for the excavation of which contracts are to be let, it is invaluable. Applied to ascertaining the position of coal-seams, it may save great expenditure.

THE MINING AND METALLURGICAL LABORATORIES OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

BY PROF. ROBERT II. RICHARDS.

OF the several professions—the chemist, the civil engineer, the mining engineer, the mechanical engineer—the courses of instruction, as arranged at the scientific schools, differ considerably as to the amount of practical information which the student is able to gain. The analytical chemist has facility for a very thorough review of the processes which he will be called upon to perform. The student in civil engineering by his field practice learns the use of his tools and the art of taking field-notes. The mechanical engineering student is in the vicinity of machine-shops, which he can visit, and at which he can work. The student in mining engineering has no such advantages. The mines are at a distance, and the railroad fare to get to them is oftentimes an insuperable difficulty.

The aim of these laboratories is essentially to give to the student in mining and metallurgy a chance to study on a small scale the practical parts of his profession. We cannot, in a small laboratory, build a mine to timber, to work, and to survey; we cannot make artificial quicksands and other impediments to mining. In short, we cannot study exploration ; but we can study the mechanical preparation and the subsequent smelting of ores. Before presenting the plan of these laboratories it may be interesting to indicate the progress of the idea from its beginning.

During the summer of 1870 President Runkle visited the mines of Colorado, and while there, conceived the idea of making an expedition with the mining students to some of the Western mining regions. He talked over the scheme with many railroad and mining men, and everywhere received encouragement. In the summer of 1871 the Institute party visited the mines of Colorado, and spent six weeks in taking notes of them. President Runkle here conceived the idea of building up a mining and metallurgical laboratory ; and by the aid of Booth & Co. of San Francisco, a stamp-mill was obtained, with the Washoe silver-working apparatus. During the year

1872 the metallurgical laboratory was brought to its present state of advancement by Prof. Ordway.

The two laboratories are intended to give students an opportunity to work, on a small scale, with all the mining and smelting apparatus which can be used to advantage in a laboratory. And this apparatus has been chosen with the view to illustrate, as far as possible, the principles of all machines used in mining.

The mining laboratory now contains a fifteen horse-power engine; a blake crusher; a stamp-mill; a Washoe pan, settler and concentrator ; a Rittinger automatic shaking table ; a little hand-jigger ; a rotary pulverizer ; and a fan-blower. The metallurgical laboratory contains a blast furnace; a roasting and a smelting reverberatory furnace; a cupelling furnace; assay furnaces and a forge. The laboratory is equipped for easy blast-furnace experiments, such as the smelting of copper and lead ores, for roasting operations on gold, silver, lead, copper, and antimony ores, and for the " Freiberg process " for silver.

A student receives an ore for examination, and in the presence of his instructor selects specimens containing all its characteristic minerals, which he determines, and then selects the method of treatment. Specimens are saved ; the ore is crushed and sampled ; assays are made, to determine its value. The ore undergoes the treatment which was chosen. Actual results are compared with the assay value of the ore, and, wherever practicable, the amount of fuel, power, labor and water consumed, is noted.

But few experiments have as yet been tried, since the laboratories are scarcely yet completed. A gold ore from Acworth, Georgia, yielded the following results when treated by battery amalgamation:

Ore taken, ...	176 lbs.
Gold on plate, ...	3.07 grains.
Gold panned from battery, ...	13.4 grains.
Kate of gold in the ore, ...	$7.76 per ton.
" " " tailings,.	1.57 "
Percentage saved, ...	83 per cent.

Apparatus for iron working is not yet represented in the laboratories, partly for lack of space, and partly because we have not yet decided what furnaces could be most usefully employed in a laboratory. A pair of crushing rolls is now in course of manufacture.

The mining schools of Prussia are owned and controlled by the government, as is the case also with most of the mines and metallurgical establishments. In consequence, students have great facilities afforded them for acquiring practical information. In this country no such bond of union exists between the mines and the schools. The schools must here depend on the generosity and sympathy of the public, and, to obtain such help, they must in some way reciprocate it.

It is fully expected, that, by making students do systematic and careful work, results will be obtained which will be of such value to the donors of the ores that they will feel more than repaid for sending them. If this expectation fails, the alternative always remains that ores can be bought and shipped by the school.

The mutual interchange of ideas between the instructors of the Institute and the miners, which will grow out of such work, is regarded as no mean part of the value of this laboratory to the school and to the public.

With regard to working ores for outside interest only, results being returned promptly, and a fec received in compensation for work done, I can only say that we have not force enough this school-year to make any promises whatever. I expect to be able to do prompt work in future years.

With reference to the students' work, the suggestion has been made that we should hold a tournament, as it were, for a month, keeping all mining students engaged at work in their regular shifts; that we should use all the apparatus during the month; have our regular break-downs, stoppages, and patchings up, and settle up accounts at the end of the mouth, making such assays and analyses as are needed.

DISCUSSION.

PROF. BLAKE : I have listened with great pleasure to the reading of this paper. I saw a part of the machinery described when it was set up in the Institute of Technology, and it gave me great pleasure, because I recognized in it a step in the right direction for the instruction of young men and scientific students who desire to apply directly the information they obtain in the laboratory, and to ascertain where they need the most light, and become familiar with those points in practical work which they require. Experience has shown this to be the case upon the Western coast, where, after a long and expensive trial of the laboratories of the chemist, the mill-men, the men who were accustomed to do things by main strength, became satisfied that they needed some help from outside, and finding they could not get it always satisfactorily from the assayers and chemists, who did not know what they wanted, and did not care as long as they got their fee for the assays and analyses, they went to work and put up in San Francisco assay laboratories upon a large scale. It grew first out of a demand, a commercial demand, to ascertain the value, in silver or in copper, of ores shipped to San Francisco. Miners from down the coast, sent large quantities of ore from Lower California and Mexico, to San Francisco, to be assayed. The parties to whom these ores were sent wanted to know what they were worth; the parties to whom they proposed to sell them would not take the ores upon the ordinary assay of a fragment selected out of the mouth of the sack, but only after the ores were crushed and sampled in a proper manner to make the assays. The miners found out how this was done and they went to work and put up establishments of their own, where loads of ore weighing five hundred pounds, or even a ton could be crushed up into small fragments, shovelled together over and over, and then when they got a fair admixture, they could send the sample to an assayer. After this experience, it was very natural that they should desire to know how such ores could be worked; and that led them to try the ores in the various pans and machines for grinding that have been manufactured. Inasmuch as the samples of ore were not large in quantity, they commenced making small trial pans—little working models sometimes would answer the purpose—into which they could put 10, 20, or 50 pounds of ore and work a batch of it. The results were very satisfactory. They gave great satisfaction not only to the miners who had ores to sell, but to the mill-men and to the manufacturers of machinery, because the parties who were engaged in manufacturing machinery for the miners in the interior could, right in their own establishments, see the many difficulties which the mill-men had to en- counter. They became aware of all the conditions connected with the erection and running of their mills and were enabled to provide for them. It has led to a succession of improvements, to the rejection of a great many worthless and useless machines, designed by parties who were not familiar at all with the working of ores, but who had patents on peculiar shaped or formed machines for crush- ing or grinding, and desired to sell those machines in the markets. Most of these worthless machines have been eliminated from the practice on the Pacific coast; and now I think I may say without danger that we make a better stamp-mill in the United States than is made in any part of the world, and we make better machinery for grinding and amalgamation, in pans, at any rate, than has ever been made before. It is very gratifying to any one who has seen the progress of improvement on the Western coast, and knows how much has been done there by the experimental works of the mill- men and the miners, to see here in Boston an establishment complete in all its parts and capable of not only educating persons who are so fortunate as to receive instruction here, but also to do a great deal of good, probably, in making us aware of the value of the ores of this region, or any ores that come to this market, and of introducing a better knowledge of mining engineering to the manufacturers of this coast.

THE PRESIDENT : Besides the function of instruction of students which requires that such apparatus should be of the received form, there is an important function which I think these practical laboratories will some day fulfil; and that is the carrying out of such experiments as will further improve the processes now in vogue. It is one thing to instruct our young men so that they can go West and handle the machinery now in use there. It is another thing, and an equally important one, to have machinery at our disposal somewhere where it can be run in a truly experimental manner, where truly scientific experiments can be made—by which I mean experiments so shielded from possible complexities and mistakes that the results shall be traceable to the proper causes. I may instance an investigation upon which I entered some years ago, in relation to the efficiency of stamps, calculated with regard to their speed, weight, and drop. Those three elements must have some definite relation to the efficiency of the stamp in the quantity it will crush. It does make some difference whether we drop a heavy stamp a certain distance, or a light stamp, weighing half as much, twice as far. I have been for some time a partisan of lighter stamps and more rapid blows than have been the fashion in many parts of the country, and in investigating that question and developing results, although I was able to eliminate from the problem such disturbing elements as depended upon the generation and transmission of power, I was not able to eliminate or perfectly estimate the influence of the facility and area of discharge, which has a decided effect on the quantity crushed, nor, on the other hand, the character of the rock; since, in comparing different stamp-mills in different localities, you have always to bear in mind that you are comparing them by different standards. Some quartz may crush and does crush easier than others. We must throw out abnormal results on either hand. I have known seventy-two tons to be run in twenty-four hours through a ten-stamp mill. The average would be something like twelve and a half to fifteen, and anything that varies far from that average in either direction might be fairly attributed to some abnormal quality in the rock. To make complete experiments of this kind you want to have all the conditions maintained except one. If you wish to test discharge, you want to use the same battery and the same quartz and vary nothing but the discharge; if yon wish to test the speed and the weight of the stamp, yon must vary nothing but the speed or the weight. That is impossible when you come to collect the results of experiments in ordinary practice. You cannot ask the mill-man to vary the weight or speed of his stamps', or to keep taking different kinds of rock, and stop his running at short intervals, and clean up with spasmodic frequency, just to suit your desires. Hence it is almost impossible to get absolute results. I trust the creation of such laboratories as have been described to us in the paper just read will open the door to something like careful work of this character. A specimen of what I mean is furnished by the experimental investigation of the Washoe amalgamation, which was made under the charge of Prof. Brush, Mr. Hague, and Mr. Dagget, on the ores of the Comstock lode, at the laboratory of the Sheffield Scientific School, at New Haven. The results are published in the third volume of Clarence King's report. Another specimen of what I mean I have been fortunate enough to secure myself, through the assistance of Mr. G. F. Deetken, of Grass Valley, California, who has made a very thorough analysis at every stage of the California stamp-mill process.

I think it is a question worthy the consideration of the faculty of this school, whether some of the peculiar amalgamating machinery employed in California might not be with advantage substituted for the simple amalgamation in battery and on copper plates, which is recognized in practice now to be a wasteful method.

PROF. ROCKWELL : There is one point I want to call attention to in regard to the method of instruction,—the practical course at Freiberg and some other schools abroad. As a prominent feature there, the student goes into the mines in the immediate vicinity and does actual work. That practical course is aimed to be given to him to a certain extent here; though, of course, not in regard to working under ground. But there is one feature here that does not exist there. There he can only learn one process, one method of dressing, one kind of ore, and one method of smelting. Here it is possible to give him all the methods which he wishes to learn, not only in gold and silver, but all our processes for every kind of ore, the smelting processes of different kinds applied to the same ore, and also different ores treated by various processes.

ON THE WASTING OF COAL AT THE MINES.

BY J. W. HARDEN, M.E.

AT our meeting in October last we saw in operation at Pittsburgh, the comparatively modern process of the utilization of small coal by washing, *by* an arrangement similar to that of Berard or Morrison. The small coal washed was that of an old pile, the refuse of the mining of the Pittsburgh bed, and which had long lain uncared for. Value was thereby restored to it when it was converted into a very good coke.

This circumstance led to comments on the mountains of broken coal lying wasted, and in its present condition worse than useless, in the neighborhood of the mines of the Wyoming Valley, though they are not confined to that district. Some things were said condemning the course which produced it, some were left unsaid. Of a system that destroys one-half the coal-bed in producing the other half there can, however, be but one opinion. Schemes have been suggested for the utilization of present accumulations which, if successfully applied, would in so far be beneficial. More than ordinary attention is now being given to the same subject in England; a Mr. Barker has invented a means by which he amalgamates the "dust," too fine to burn in ordinary grates, with a composition he calls " diamond cement," producing blocks of coal said to resist water, both hot and cold, and which a smart blow will only break to pieces, not cause to crumble. But any scheme less than the one which will prevent the wasting of coal, which still goes on, though that involves the abandonment of the breaker, will only be one of expediency; and the latter can only be done by the aid of the consumer. But the wasting of coal is not alone with the breaker; much is made in the mine. The cause is not far to seek ; the remedy is with capitalist and owner. Owners and consumers then are alike interested, and they have it in their power, in the one case, to mitigate, in the other, almost entirely to remove the cause of the evil. Of consumers there is one in every householder of the city, and of capitalists, interested in one form or other, there are many, hence my reason for choosing the subject of this paper at this, our Boston meeting.

In discussing this matter, we will take the waste made at the breaker first. Every consumer knows that when ordering coal he can obtain it of any size he likes, out of a list with which he is acquainted, made up of lump, steamer, large egg, small egg, stove, chestnut, and pea, each representing a particular size, and he also knows that to provide them the coal has had to be broken purposely and prepared, but I doubt whether he is aware of the quantity wasted in this preparation, and for which waste, as well as the cost of making it, he has to pay in the price he pays for the coal he uses. This he will see the equity of, but, unacquainted with the process of preparation, wonders why it costs so much. For his information we will describe it.

The coal turned out of the mine, whether by shaft, slope, or tunnel, is hoisted some 60 to 100 feet above the surface, to the top of a building known as the "breaker," where it is dumped, the small passing through a screen of longitudinal bars, the large into a hopper guiding it through and between a pair of cast-iron rollers armed with strong conical and birdbill-like teeth. These revolve and break up the coal to larger and smaller pieces, which fall, as broken, into cylindrical screens. These have a circumference of under or over 15 feet, formed of various sized meshes, fitted on a revolving shaft. The various sizes are separated and collected into the varieties named, during which process and while passing to the shoots into pockets provided for them, boys are employed to pick out the slate once adhering to the coal and broken up with it.

Now the consumer will have noticed that this coal, of whatever size, is rounded at the edges; the angles made in breaking are worn off; this is owing to the distance the pieces have had to travel in being whirled round and round and on and on in the screens, at a speed of 200 feet a minute and more, until they come to that screen the mesh of which is large enough to let them through. The edges are ground off by the abrasion and blows against the overlapping of the wire screens and the ribbed intersections of the cast-iron ones. The smaller particles of coal not being heavy enough to resist the current of air created, fall through the screen, being floated into the atmosphere in the shape of a thick dust.

Now, as a breaker, there is no fault to find with this machine; it is an ingenious and labor-saving arrangement, and represents fully the name it bears. It is a breaker to all intents and purposes.

But the cost of all this. To the wealthy of the present day, while the coal is within easy reach, it does not signify much, but to the laborer, the poor man with a large family to care for, and in a winter like this, too, it is of vital importance. There is first the cost of the building and machinery, and the steam engine to drive it, which, for a first-class breaker, will not be less than $100,000, and upon which, of course, there is interest and the redemption of capital to provide. Say a breaker lasts twenty years, as it will with dry coal, and if kept in proper repair; but if the coal is washed or comes out of the mine wet, it will last only about half that time: this will require a sum per year which, divided by the number of tons prepared, together with the cost of engine power and manual labor, will be nothing less than 50 cents per ton, with an addition varying as the above conditions. To the lessor there is the loss of royalty on the coal wasted in the process, the quantity depending on the quality, the hardness or softness of the coal, and the condition of the machinery; soft coal will necessarily make more small than hard, and rollers with worn and blunted points will crush, and, in a manner, grind the coal. More small will be made, too, when passing it through two pairs of rollers, as is often done, breaking it from larger to smaller sizes.

Under ordinary circumstances, with a car holding 75 cubic feet, the miner will be paid for a ton and a half of prepared coal, or four-fifths of that sent out of the mine. In tolerably hard coal, and with some watching, it probably will hold out to that, but this difference does not represent the total waste. We have from time to time seen large quantities of pea coal dumped in the "dirt" bank at times when such was not in demand. Disregard to a hole in the screens also sends good coal to the same heap. It is needless for me to say that such cannot take place in well-managed collieries, but that it does take place is nevertheless true. The average waste at the breaker, then, will be more than a fifth of that sent out of the mine, and will represent the value of so much merchantable coal.

The foregoing does not, however, represent the cost; men and boys are frequently maimed, and sometimes killed, in the breaker, to say nothing of the injury to health by the constant inhalation of coal-dust,—by no means unimportant evil, which some boys probably outgrow on being put to other and more healthy occupation, but which others do not.

To the consumer who asks whether these evils cannot be mitigated, we have said, that they can be almost, if not entirely, done away with, but that he must do it, or at least help to do it himself. Operators would be glad to be spared the extra capital and labor which the production of these "fancy brands" of the coal market entails, but having aided in the spreading and cultivation of this fastidiousness, he has now to meet it. It is a mistake to have the coal broken at any other place than that at which it is consumed, or at most not further off than the mart from whence the consumer receives it, and where, in the multiplicity of the wants of a great city, some use would be for all of it, of whatever size. Nothing, however, would so conduce to economy as breaking the coal on the premises of the consumer.

But the consumer says again he is driven to ask for such coal as he has the means of burning; that the best effect from his stove can only be obtained by the use of a given size of coal. I judge this is true; but then stoves in rooms and iron furnaces in cellars are not the best economizers of heat—the material is wrong. They are moreover great destroyers of health, licking up every particle of the moisture in the air we breathe, changing the normal condition of the lungs and skin, and laying the foundation of lingering disease, which, in weakly constitutions, results in death, the cause being ascribed to a something which is only the effect, and no more is thought about it.

To economize heat, then, and efficiently and agreeably to warm a room, that material is best for the fireplace, be it of what construction it may, that absorbs the largest amount as the temperature increases, and gives it out again by radiation. The principle is recognized in the linings of firebrick some inventors have given their stoves, and there is room for a much extended application of it, and at the same time for the invention of a stove that will not need so refined and fastidious a preparation of the fuel. That inventor will render the greatest service, who produces one in which the working man can obtain the heat value of the coal when broken by himself in his own cellar. The breakers at the mine will sooner or later be done away with.

Of the coal wasted in the mine, it has been said to be very considerable in proportion to the amount mined, a question, one gentleman says, " not very creditable to the mining engineering profession," but in which he is not quite just—the mining engineer being seldom consulted about the working of a mine. The inside boss is generally assumed to know the most about it; sometimes the operator has been a miner himself, and is therefore said to be a "practical man," The waste here alluded to is not intended to apply to pillars left in the judicious working of a mine; they are necessary for supporting the superincumbent strata; the mining could not he done without them. It has been suggested that stone pillars might be built to prevent the carvings in which are occasionally taking place, but it is not possible to construct pillars of stone that will answer the purpose of pillars of coal properly left, even if that could be done at a cost of the value of the coal, nor does the anthracite give choice of methods of working : pillars, therefore, must be left where the surface is to be kept up, or where there is coal to be mined beyond them, and where such is not the case, any attempt to mine out all the seam would be accompanied with disaster.

But coal is wasted in a variety of ways in the working, most frequently by the too great haste, after a shaft has been sunk, to get out coal for the market, insufficient pillars being left where the area of coal to be mined beyond would take a time extending over a period longer than the pillars could sustain the weight upon them. In a case where substantial pillars had been left by the operator who first opened and worked the mine, the lease being disposed of to another, wide openings were put through some of them and the remainder " robbed " to an extent which brought down the intervening roof, to the sacrifice of eleven acres of a seam above.

In an instance of a thick seam, where the shaft had been sunk through it, but not low enough, a sump being needed, the seam was commenced to be worked in its top bench, thus taking off the roof of the lower half; the area so stripped will never he gotten.

Another source of considerable waste arises from a disregard to regularity in the position and size of the pillars caused by the uncertain course on which the chambers are driven after being started. Having been worked up 50 or 100 feet, it is not uncommon to find the chambers out of parallel, and the otherwise 15 feet pillar half that thickness, or less. Shots fired in one chamber have blown through to the next, sometimes killing a man, and while the amount of coal left in the aggregate would have been enough, probably, to have kept up the overlying strata, a want of uniformity in the sustaining power of the pillars has permitted a movement finally resulting in a caving in of the surface and a loss of gangroads and the coal in work beyond.

Much waste is often made in the mining of a thick seam. In one of nineteen feet, with a two or three feet parting of slate in the middle, where under tolerably fair management both benches would have been gotten, we have seen sometimes the lower bench mined, sometimes the higher, and occasionally both, as chance or incapacity dictated, producing little more than half the coal the area mined over would demand. Want of system and the lack of ability to deal with the special condition of the seam were the real cause of the trouble.

Of the less fruitful sources of waste in the mine we will only say there are such; enough has been said by others before me, showing that inquiry is neither premature nor out of place; it is a question which does not only concern the owners of coal properties but every member of the community. To the capitalists, in the coining competition with bituminous coals, of which the whole seam of many feet may be mined out and the very smallest of it turned to account, there is matter for thought.

I have said the owner has in himself the power to remedy much of this. In a business which he can by the light of day overlook, no corner of it is left unscrutinized, no part of it unproductive of profit, but the cause is at once ferreted out. No expenditure of money is begrudged where he can see a prospect of return. But, when the same individual owns, or is interested in, coal property, the successful working of which is out of his ken, and calls for the exercise of man's best faculties, he leases it to another without supervision or cheek, contented while he receives the stipulated royalty, or until some hitch takes place, when he discovers that he is not so well versed in his own affairs as he ought to have been. The lease granted stipulated that the mine should not be worked " in any unusual or unskilful manner," and he had relied upon its protecting him ; he had the power to enter the mine, but had never availed himself of it, but he now finds that the income from property which he had reason to believe would provide for the lives of his children, will barely last his own, and that more intellect is necessary to the proper mining of coal than he had conceived. This is not a fanciful case.

Not to go into the details of a mine lease, it will be sufficient for our purpose here to notice the clause bearing more particularly on the care to be taken of the mine. Quoting from a lease before me, it is provided that the lessee for himself, etc., " will, at his own cost, work the mine in a judicious and workmanlike manner, for the term of_years from_to_, that he will leave sufficient pillars of coal for the support of the gangways and the protection of the mine generally, that he will not work the same in any unusual or unskilful manner, that he will mine — tons per year," etc.

Here, then, is all that is said about the mining, and enough if carried out in the spirit of the intent, but the letter ought to have been such that no two constructions could be put upon it. Easily defined by Webster, what is judicious, or unskilful, or a sufficient number of pillars, to the mind of one individual, as has been exemplified in more than one instance before the courts, is not so to another. A course pursued in the mine, and deprecated in evidence by one engineer as certain to result in loss, another has testified to as not being injudicious.

Complaint has been made, that lessees have worked out parts of the mine, and abandoned them before the lessor has had an opportunity of knowing for himself what had been done; in one instance it was found he had given absolute possession for a term of years, in the fact that the clause which should have empowered his entry had been omitted in the lease, and from causes explained only by facts afterwards ascertained, he was for months debarred entry.

In all of this, then, the owner has the power of remedy; it is not impracticable in any given case, without embarrassing the lessee, to frame a clause which, put into practice, would secure the interest of both, and in so doing strengthen their relationship. The method of mining should be named; it might be that usually followed in the neighborhood; a minimum size of the pillars protecting the shaft, or whatever the entrance to the mine might be, should be specified, as well as the area of the chambers to be worked and the size of their pillars; a competent person should be appointed by the owner, whose business it would be to see that these provisions are properly carried out, to make periodical surveys of the workings, and report on the condition of the same; in which he should be provided by the lessee with facilities for doing, and have the assistance of the overman and those he would appoint; and ho workings should be abandoned before notice had been given of the intention to do so.

It has been said that lessees have not the opportunity of making the best of the mine for themselves or the owner, owing to the short period over which their tenure frequently extends: this should be remedied; every facility consistent with the proper working of the mine should be given, nothing reasonable withheld, as on the lessee rests the greatest share of contingencies and risk.

APPENDIX.

*THE ORIGIN OF METALLIFEROUS DEPOSITS.**

BY T. STERREY HUNT, LL.D., F.R.S.

THERE are about sixty bodies which chemists call elements; the simplest forms of matter which they have been able to extract from the rocky crust of our earth, its waters, and its atmosphere. These substances are distributed in very unequal quantities, and in very different manners. As regards the frequency of these elements in nature, neglecting for the present those which constitute air and water, and confining ourselves to the solid matters of the earth's crust, there are a few which are exceedingly abundant, making up nine-tenths, if not ninety-five hundredths, of the rocks so far as known to us. The elements of which silica, alumina, lime, magnesia, potash, and soda arc oxides, are very common, and occur almost everywhere. There are others which are much rarer, being found in comparatively small quantities. Many of these rarer elements are, however, of great importance in the economy of nature. Such are the common metals and other substances used in the arts, which occur in nature in quantities relatively very minute, but which have been collected by various agencies, and thus made available for the wants of man. It is chiefly of the well-known metals, iron, copper, silver, and gold, that I propose to speak to-night; but there are two other elements not classed among the metals, which I shall notice for the reason that their history is extremely important, and will, moreover, enable us to comprehend more clearly some points in that of the metals themselves. I speak of phosphorus and iodine.

You all know the essential part which the former of these, com-

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bined as phosphate of lime, plays in the animal economy, in the formation of bones; and how plants require for their proper growth and development a certain amount of phosphorus. Ordinary soils contain only a few thousandths of this element, yet there are agencies at work in nature which gather this diffused phosphorus together in beds of mineral phosphates and in veins of crystalline apatite, which are now sought to enrich impoverished soils. Iodine, an element of great value in medicine and in the art of photography, is widely distributed, but still rarer than phosphorus, yet it abounds in certain mineral waters, and is, moreover, accumulated in marine plants. These extract it from the waters of the sea, where iodine exists in such minute quantities as almost to elude our chemical tests.

There are probably no perfect separations in nature. We cannot, without great precautions, get any chemical element in a state of absolute purity, and we have reason to believe that even the rarest elements are everywhere diffused in infinitesimal quantities. The spectroscope, which we have lately learned to apply to the investigation alike of the chemistry of our own earth and that of other worlds once supposed to be beyond the chemist's ken, not only demonstrates the very wide diffusion of various chemical elements here on earth, but shows us that very many of them exist in the sun. If we accept, as most of us are now inclined to do, the nebular hypothesis, and admit that our earth was once, like the sun of to-day, an intensely heated vaporous mass; that it is, in fact, a cooled and condensed portion of that once great nebula of which the sun is also a part, we might expect to find all the elements now discovered in the sun distributed throughout this consolidated globe. We may speculate about the condensation of some of these before others, and their consequent accumulation in the inner parts of the earth, but the fact that we have all the clements of the solar envelope (together with many more) in the exterior portions of our planet, shows that there was, at least, but a very partial concentration and separation of these elements during the period of cooling and condensation. The superficial crust of the earth, from which all the rocks and minerals which we know have been generated, must have contained, diffused through it, from the earliest time, all the elements which we now meet with in our study of the earth, whether still diffused, or accumulated, as we often find the rarer elements, in particular veins or beds.

The question now before us is, how have these elements thus been brought together, and why is it that they are not all still widely and universally diffused ? Why are the compounds of iron in beds by themselves, copper, silver, and gold gathered together in veins, and iodine concentrated in a few ores and certain mineral waters? That we may the better discern the direction in which we are to look for the solution of this problem, let us premise that all of these elements, in some of their combinations, are more or less soluble in water. There are, in fact, no such things in nature as absolutely insoluble bodies, but all, under certain conditions, are capable of being taken up by water, and again deposited from it. The alchemists sought in vain for a universal solvent, but we now know that water, aided in some cases by heat, pressure, and the presence of certain widely distributed substances, such as carbonic acid and alkaline carbonates and sulphides, will dissolve the most insoluble bodies; so that it may after all be looked upon as the long-sought-for alkahest or universal menstruum.

Let us now compare the waters of rivers, seas, and subterranean springs, thus impregnated with various chemical elements, with the blood which circulates through our own bodies. The analysis of the blood shows it to contain albuminoids which go to form muscle, fat for the adipose tissues, phosphate of lime for the bones, fluorides for the enamel of the teeth, sulphur which enters largely into the composition of the hair and nails, soda which accumulates in the bile, and potash, which abounds in the flesh-fluid. All of these are dissolved in the blood, and the great problem for the chemical physiologist is to determine how the living organism gathers them from this complex fluid, depositing them here and there, and giving to each part its proper material. This selection is generally ascribed to a certain vital force, peculiar to the living body. I shall not here discuss the vexed question of the nature of the force which determines the assimilation from the blood of these various matters for the needs of the animal organism, further than to say that modern investigations tend to show that it is only a subtler kind of chemistry, and that the study of the nature and relation of colloids and crystalloids, and of the phenomena of chemical diffusion, promises to subordinate all these obscure physiological processes to chemical and physical laws.

Let us now see how far the comparison which we have made between the earth and an animal organism will help us to understand the problem of the distribution of minerals in nature; how far water, the universal solvent, acting in accordance with known chemical and physical laws, will cause the separation of the mixed elements of the earth's crust, and their accumulation in veins and beds in the rocks. The subject is one of great importance to the geologist, who has to consider the genesis of the various rocks and ore-deposits, and the relations, which we are only beginning to understand, between certain metals and particular rocks, and between certain classes of ores and peculiar mineralogical and geological conditions. It is at the same time a vast one, and I can to-night only give you a few illustrations of the chemistry of the earth's crust, and of the laws of the terrestrial circulation, which I have compared to that of the blood distributing throughout the animal frame the elements necessary for its growth. The analogy is not altogether new, since a great French geologist, Elie de Beaumont, has already spoken of a terrestrial circulation in regard to certain elements in the earth's crust; though he has not, so far as I am aware, carried it out to the extent which I propose to-night in my attempt to explain some of the laws which have presided over the distribution of metals in the earth.

The chemist in his laboratory takes advantage of changes of temperature, and of the action of various solvents and precipitants, to separate, in the humid way, one element from another; but to these agencies, in the economy of nature, are added others which we have not yet succeeded in imitating, and which are exerted only in growing animals and plants. I repeat it, I do not wish to say that these latter processes are different in kind from those which we command in our laboratories, but rather that these organisms control a far finer and more delicate chemical and physical apparatus than we have yet invented. Plants have the power of selecting from the media in which they live the elements necessary for their support. The growing oak and the grass alike assimilate from the air and water the carbon, hydrogen, nitrogen, and oxygen which build up their tissues, and at the same time take from the soil a portion of phosphorus, which, though minute, is in both cases essential to the vegetable growth. The acorn of the oak and the grass alike become the food of animals, and the gathered phosphates pass into their bones, which are nearly pure phosphate of lime. In like manner the phosphates from organic waste and decay find their way to the sea, and through the agency of marine vegetation become at last the bony skeletons of fishes. These are, in turn, the prey of carnivorous birds, whose exuviæ form on tropical islands beds of phosphatic guano. A history not dissimilar will explain the origin of beds of coprolites and other deposits of mineral phosphates.

But again, these plants or these animals may perish in the sea and be buried in its ooze. The phosphates which they have gathered are not lost, but become fixed in an insoluble form in the clayey matter; and when in the revolutions of ages, these sea-muds, hardened to rock, become dry land, and crumble again to soil, the phosphates are there found ready for the wants of vegetation.

Most of what I have said of phosphates applies equally to the salts of potash, which are not less necessary to the growing plant. From the operation of these laws it results that neither of these elements is found in large quantities in the ocean. This great receptacle of the drainage from the land contains still smaller quantities of iodine ; in fact, the traces of this element present in sea-water can scarcely be detected by our most delicate tests. Yet marine plants have the power of separating this iodine, and accumulating it in their tissues, so that the ashes of these plants are not only rich in phosphates and in potash-salts, but contain so much iodine that our supplies of this precious element are almost wholly derived from this source, and that the gathering and burning of sea-weed for the extraction of iodine is in some regions an important industry. When this marine vegetation decays, the iodine which it contains, appears, like the potash and phosphates, to pass into combinations with metals, earths, or earthy phosphates, which retain it in an insoluble state, and in certain cases yield it to percolating saline solutions, which thus give rise to springs rich in iodine.

In all of these processes the action of organic life is direct and assimilative, but there are others in which its agency, although indirect, is not less important. I can hardly conceive of an accumulation of iron, copper, lead, silver, or gold, in the production of which animal or vegetable life has not either directly or indirectly been necessary, and I. shall begin to explain my meaning by the case of iron. This, you are aware, is one of the most widely diffused elements in nature; all soils, all plants contain it; and it is a necessary element in our blood. Clays and loams contain, however, at best, two or three hundredths of the metal, but so mixed with other matters that we could never make it available for the wants of this iron age of ours. How does it happen that we also find it gathered together in great beds of ore, which furnish an abundant supply of the metal ? The chemist knows that the iron, as diffused in the rocks, exists chiefly in combination with oxygen, with which it forms two principal compounds: the first, or protoxide, which is readily soluble in water impregnated with carbonic acid or other feeble acids, and the second, or peroxide, which is insoluble in the same liquids. I do not here speak of the magnetic oxide, which may be looked upon as a compound of the other two, neutral and indifferent to most natural chemical agencies.

The combinations of the first oxide are either colorless or bluish or greenish in tint, while the peroxide is reddish-brown, and is the substance known as iron-rust. Ordinary brick-clays are bluish in color, and contain combined iron in the state of protoxide, but when burned in a kiln they become reddish, because this oxide absorbs from the air a further proportion of oxygen, and is converted into peroxide. But there are clays which are white when burned, and are much prized for this reason. Many of these were once ferruginous clays, which have lost their iron by a process everywhere going on around us. If we dig a ditch in a moist soil which is covered with turf or with decaying vegetation, we may observe that the stagnant water which collects at the bottom soon becomes coated with a shining, iridescent scum, which looks somewhat like oil, but is really a compound of peroxide of iron. The water as it oozes from the soil is colorless, but has an inky taste from dissolved protoxide of iron. When exposed to the air, however, this absorbs oxygen, and peroxide is formed, which is no longer soluble, but separates as a film on the surface of the water, and finally sinks to the bottom as a reddish ochre, or, under somewhat different conditions, becomes aggregated as a massive iron ore. A process identical in kind with this has been at work at the earth's surface ever since there were decaying organic matters, dissolving the iron from the porous rocks, clays, and sands, and gathering it together in beds of iron ore or iron ochre. It is not necessary that these rocks and soils should contain the iron in the state of protoxide, since these organic products (which are themselves dissolved in the water) are able to remove a portion of the oxygen from the insoluble peroxide, and convert it into the soluble protoxide of iron, being themselves in part oxidized and converted into carbonic acid in the process.

We find in rock formations of very different ages beds of sediments which have been deprived of iron by organic agencies, and near them will generally be found the accumulated iron. Go into any coal region, and you will see evidences that this process was at work when the coal-beds were forming. The soil in which the coal-plants grew has been deprived of its iron, and when burned turns white, as do most of the slaty beds from the coal-rocks. It is this ancient soil which constitutes the so-called fire-clays, prized for making fire- bricks, which, from the absence of both iron and alkalies, are very infusible. Interstratified with these we often find, in the form of ironstone, the separated metal; and thus from the same series of rocks may be obtained the fuel, the ore, and the fire-clay.

From what I have said it will be understood that great deposits of iron ore generally occur in the shape of beds; although waters holding the compounds of iron in solution have, in some cases, deposited them in fissures or openings in the rocks, thus forming true veins of ore, of which we shall speak further on. I wish now to insist upon the property which dead and decaying organic matters possess of reducing to protoxide, and rendering soluble, the insoluble peroxide of iron diffused through the rocks; and reciprocally the power which this peroxide has of oxidizing and consuming these same organic matters, which are thereby finally converted into carbonic acid and water. This last action, let me say in passing, is illustrated by the destructive action of rusting iron fastenings on moist wood, and the effect of iron-stains in impairing the strength of linen fibre.

We see in the coal formation that the vegetable matter necessary for the production of the iron-ore beds was not wanting; but the question has been asked me, where are the evidences of the organic material which was required to produce the vast beds of iron ore found in the ancient crystalline rocks? I answer, that the organic matter was, in most cases, entirely consumed in producing these great results; and that it was the large proportion of iron diffused in the soils and waters of those early times, which not. only rendered possible the accumulation of such great beds of ore, but oxidized and destroyed the organic matters which in later ages appear in coals, lignites, pyroschists, and bitumens. Some of the carbon of these early times is, however, still preserved in the form of graphite, and it would be possible to calculate how much carbonaceous material was consumed in the formation of the great iron-ore beds of the older rocks, and to determine of how much coal or lignite they are the quivalents.

In the course of ages, however, as a large proportion of the once iffused iron-oxide has become egregated in the form of beds of ore, and thus removed from the terrestrial circulation, the conditions have grown more favorable for the preservation of the carbonaceous products of vegetable life. The crystalline magnetic and specular oxides, which constitute a large proportion of the ores of this metal, are almost or altogether indifferent to the action of organic matter. When, however, these ores are reduced in our furnaces, and the resulting metal is exposed to the oxidizing action of a moist atmosphere, it is again converted into iron-rust, which is soluble in water holding organic matters, and may thus be made to enter once more into the terrestrial circulation.

There is another form in which iron is frequently concentrated in nature, that of sulphide, and most frequently as the bisulphide known as iron-pyrites. This substance is found both in the oldest and the newest rocks, and, like the oxide of iron, is even to-da\ forming in certain waters, and in beds of mud and silt, where it sometimes takes a beautifully crystalline shape. What are the conditions in which the sulphide of iron is formed and deposited, instead of the oxide or carbonate of iron? Its production depends like these, on decaying organic matters. The sulphates of lime and magnesia, which abound in sea-water, and in many other natural waters, when exposed to the action of decaying plants or animals, out of contact of air, are, like peroxide of iron, deoxidized, and are thereby converted into soluble sulphides; from which, if carbonic acid be present, sulphuretted hydrogen gas is set free. Such soluble sulphides, or sulphuretted hydrogen, are the reagents constantly employed in our laboratories to convert the soluble compounds of many of the common metals, such as iron, zinc, lead, copper, and silver, into sulphides, which are insoluble in water and in many acids, and are thus conveniently separated from a great many other bodies. Now, when in a water holding iron-oxide, sulphates are also present, the action of organic matter, deoxidizing the latter, furnishes the reagent necessary to convert the iron into a sulphide; which in some conditions, not well understood, contains two equivalents of sulphur for one of iron, and constitutes iron-pyrites. I may here say that I have found that the unstable protosulphide, which would naturally be first formed, may, under the influence of a persalt of iron, lose one-half of its combined iron ; and that from this reaction a stable bisulphide results. This subject of the origin of iron-pyrites is still under investigation.

The reducing action of organic matters upon soluble sulphates is well seen in the sulphuretted hydrogen which is evolved from the stagnant sea-water in the hold of a ship, and which coats silver exposed to it with a black film of sulphide of silver, and for the same reason discolors white-lead paint. The presence of sulphur in the exhalations from some other decaying matters is well known, and in all these cases a soluble compound of iron will act as a disinfectant, partly by fixing the sulphur as an insoluble sulphide. Silver coins brought from the ancient wreck of a treasure-ship in the Spanish Main were found to be deeply incrusted with sulphide of silver, formed in the ocean's depths by the process just explained, which is one that must go on wherever organic matters and sea-water are present, and atmospheric oxygen excluded.

The chemical history of iron is peculiar; since it requires reducing matters to bring it into solution, and since it may be precipitated alike by oxidation, and by farther reduction, provided sulphates are present. The metals copper, lead, and silver, on the contrary, form compounds more or less soluble in water, from which they are not precipitated by oxygen, but only by reducing agents, which may separate them in some cases in a metallic state, but more frequently as sulphides. The solubility of the salts and oxides of these metals in water is such that they are found in many mineral springs, in the waters that flow from certain mines, and in the ocean itself, the waters of which have been found to contain copper, silver, and lead. Why, then, do not these metals accumulate in the sea, as the salts of soda have done during long ages? The direct agency of organic life comes again into play, precisely as in the case of phosphorus, iodine, and potash. Marine plants, which absorb these from the sea-water, take up at the same time the metals just named, traces of all of which are found in the ashes of sen-weeds. Copper, moreover, is met with in notable quantities in the blood of many marine molluscous animals, to which it may be as necessary as iron is to our own bodies. Indeed, the blood of man, and of the higher animals, appears never to be without traces of copper as well as of iron.

In the open ocean the waters are constantly aerated, so that soluble sulphides are never formed, and the only way in which these dis- solved metals can be removed and converted into sulphides is by fixing them in organisms, cither vegetable or animal. These, by their decay in the mud of the bottom, or the lagoons of the shore, generate the sulphides which fix their contained metals in an insoluble form, and thus remove them from the terrestrial circulation.

It is not, however, in all cases necessary to invoke the direct action of organisms to separate from water the dissolved metals. It often happens that the waters containing these, instead of finding their way to the ocean, flow into lakes or inclosed basins, as in the case of the drainage-waters of an English copper-mine, which have impregnated the turf of a neighboring bog to such an extent that its ashes have been found a profitable source of copper. Under certain conditions, not vet well understood, this metal is precipitated by organic matters in the metallic state, but if sulphates are present a sulphide is formed. Thus, in certain mesozoic schists in Bohemia, sulphide of copper is found incrusting the remains of fishes, and in the sandstones of New

Jersey we find it penetrating the stems of ancient trees. I have in my possession a portion of a small trunk taken from the mud of a spring in Ontario, in which the yet undecayed wood of the centre is seen to be incrusted by hard metallic iron-pyrites. In like manner the old trees of the New Jersey sandstone became incrusted with copper-sulphide, which, as ecay went on, in great part replaced the woody tissue. Similar deposits of sulphides of copper and of ironoften took place in basins where the organic atter was present in such a condition or in such quantitv as to be entirely decomposed, and to leave no trace of its form, unlike the examples just mentioned. In this way have been formed fahl-bands, and beds of pyrites and other ores.

The fact that such deposits are associated with silver and with gold leads to the conclusion that these metals have obeyed the same laws as iron and copper. It is known that both persalts of iron and soluble sulphides have the power of rendering gold soluble, and its subsequent deposition in the metallic state is then easily understood.

I have endeavored by a few illustrations to show you by what processes some of the more common metals are dissolved and again separated from their solution in insoluble forms. It now remains to say somewhat of the geological relations of ore deposits, which are naturally divided into two classes; the first including those which occur in beds, and have been formed contemporaneously with the inclosing earthy sediments. Such are the beds of iron-ores which often hold imbedded shells and other organic remains, and the copper- bearing strata already mentioned, in which the metal must have been deposited during the decay of the animal or plant which it incrusts or replaces. But there are other ore deposits evidently of more recent formation than the rocky strata which inclose them, which have resulted from a process of infiltration, filling up fissures with the ore, or diffusing it irregularly through the rock. It is not always easy to distinguish between the two classes of deposits. Thus a fissure may in some cases be formed and filled between two sundered beds, from which may result a vein that may be mistaken for an interposed stratum. Again, a bed may be so porous that infiltrating waters may diffuse through it a metallic ore, or a metal, in such a manner as to leave it doubtful whether the process was contemporaneous with the disposition of the bed, or posterior to it. But I wish to speak of deposits which are evidently posterior, and occupy fissures in previously formed strata, constituting true veins. Whether produced by the great movements of the earth's crust, or by the local contraction of the rocks (and both of these causes have in different cases been in operation), such fissures sometimes extend to great lengths and depths ; their arrangement and dimensions depending very much on the texture of the rocks which have been subjected to fracture. When a bone in our bodies is broken, nature goes to work to repair the fractured part, and gradually brings to it bony matter, which fills up the little interval, and at length makes the severed parts one again. So when there are fractures in the earth's crust, the circulating waters deposit in the openings mineral matters, which unite the broken portions, and thus make whole again the shattered rocks. Vein-stones are thus formed, and are the work of nature's conservative surgery.

Water, as we have seen, is a universal solvent, and the matters which it may bring and deposit in the fissures of the earth are very various. There is scarcely a spar or an ore to be met with in the stratified rocks that is not also found in some of these vein-stones, which are often very heterogeneous in composition. In certain veins we find the elements of limestone or of granite, and these often include the gems, such as amethyst, topaz, garnet, hyacinth, emerald, and sapphire ; while others abound in native metals or in metallic oxides or sulphides. The nature of the materials thus deposited depends very much on conditions of temperature and of pressure, which affect the solvent power of the liquid, and still more upon the nature of the adjacent rocks and of the waters permeating them. The chemistry of mineral veins is very complicated. Many of these fissures penetrate to a depth of thousands of feet of the earth's crust, and along the channels thus opened the ascending heated subterranean waters may receive in their course various contributions from the overlying strata. From these additions, and from the diminished solubility resulting from a decrease of pressure, deposits of different minerals are formed upon the walls, and the slow changes in composition are often represented by successive layers of unlike substances. The power of these waters to dissolve and bring from the lower strata their contained metals and spars is probably due in great part to the alkaline carbonates and sulphides which these waters often hold in solution ; but the chemical history of the deposition of the ores of iron, lead, copper, silver, tin, and gold, which are found in these veins, demands a lengthened study, and would furnish not less beautiful examples of nature's chemistry than those I have already laid before you.

The process of filling veins has been going on from the earliest ages; we know of some which were formed before the Cambrian rocks were deposited, while others are still forming, as the observations of Phillips have shown us in Nevada, where hot springs rise to the surface and deposit silica, with metallic ores, which incrusts the walls of the fissures. These thermal waters show that the agencies which in past times gave rise to the rich mineral deposits of our Western regions, are still at work there.

Let us now consider the beneficent results of the process of vein-making. The precious metals, such as silver, are so sparsely distributed, that even the beds rich in the products of decaying sea-weed, which we have supposed to be deposited from the ocean, would contain too little silver to be profitably extracted. But in the course of ages these sediments, deeply buried, are lixiviated by permeating solutions, which dissolve the silver diffused through a vast mass of rock, and subsequently deposit it in some fissure, it may be in strata far above, as a rich silver ore. This is nature's process of concentration.

We learn from the history which we have just sketched the important conclusion, that amid all the changes of the face of the globe the economy of nature has remained the same. We are apt, in explaining the appearances of the earth's crust, to refer the formation of ore-beds and veins to some distant and remote period, when conditions very unlike the present prevailed, when great convulsions took place, and mysterious forces were at work. Yet the same chemical and physical laws are now, as then, in operation; in one part dissolving the iron from the sediments and forming ore-beds, in another separating the rarer metals from the ocean's waters; while in still other regions the consolidated and buried sediments are permeated by heated waters, to which they give up their metallic matters, to be subsequently deposited in veins. These forces are always in operation, rearranging the chaotic admixture of elements, which results from the constant change and decay around us. The laws that the first great cause imposed upon this material universe on the first day are still irresistibly at work fashioning its present order. One great design and purpose is seen to bind in necessary harmony the operations of the mineral with those of the vegetable and animal worlds, and to make all of these contribute to that terrestrial circulation which maintains the life of our mother earth.

While the phenomena of the material world have been looked upon as chemical and physical, it has been customary to speak of those of the organic world as vital. The tendency of modern investigation is, however, to regard the processes of animal and vegetable growth as themselves purely chemical and physical. That this is to a great extent true must be admitted, though I am not prepared to concede that we have in chemical and physical processes the whole secret of organic life. Still we are, in many respects, approximating the phenomena of the organic world to those of the mineral kingdom; and we at the same time learn that these so far interact and depend upon each other that we begin to see a certain truth underlying the notion of those old philosophers who extended to the mineral world the notion of a vital force; which led them to speak of the earth as a great living organism, and to look upon the various changes in its air, its waters, and its rocky depths, as processes belonging to the life of our planet.

[Since this lecture was delivered, I have seen the results of the researches of Sonstadt on the iodine in sea-water, which appear in the *Chemical News* for April 26, May 17, and May 24, 1871. According to him this element exists in sea-water, under ordinary conditions, as iodate of calcium, to the amount of about one part of the iodate in 250,000 parts of the water. This compound, by decaying organic matter (and by most other reducing agents), is changed to iodide, from which, apparently by the action of carbonic acid, iodine is set free, and may be separated by agitating the water with bisulphide of carbon. The iodine thus liberated from sea-water by the action of dead organic matters, however, slowly decomposes water in presence of carbonate of calcium, and is reconverted into iodate, the oxygen of the air probably intervening to complete the oxidation, since, according to Sonstadt, iodides are readily converted into iodates under these conditions. He finds that the insolubility of the iodides of silver and of copper is so great that by the use of salts of these metals iodine may be separated from sea-water without concentration, provided the iodate of calcium has first been reduced to iodide. By this property of iodine and its compounds to oxidize and be oxidized in turn, Sonstadt supposes them to perform the important function of consuming the products of organic decay, and so maintaining the salubrity of the ocean's waters. Their action would thus be very similar to that of the oxides of iron, as explained in the present lecture.

Still more recently the same chemist has announced that the seawater of the British coasts contains in solution besides silver an appreciable quantity of gold, estimated by him at about one grain to a ton of water. This is separated by the addition of chloride of barium, apparently as an aurate of baryta adhering to the precipitated sulphate, which yields by assay an alloy of about six parts of gold to four of copper. Other methods have been devised by him for separating these metals from their solution in sea-water. The agent which keeps the gold of the sea in a soluble and oxidized condition is, according to Sonstadt, the iodine liberated by the action already described.

The views maintained by Lieber, Wurtz, Genth, and Selwyn, as to the solution and redeposition of gold in modern alluvial deposits seem to be well grounded, and we are led to the conclusion that the circulation of this metal in nature is as easily effected as that of iron or of copper. The transfer of certain other elements, such as titanium, chrome, and tin, or at least their accumulation in concentrated forms, appears, on the contrary, to require conditions which are no longer operative at the surface of the earth.

It should here be noticed that Prof. Henry Wurtz, of New York, in a paper read before the American Association for the Advancement of Science in 1868, expressed the opinion that the ocean-waters contained gold, and urged experiments for its detection. According to his calculations the total amount of gold hitherto extracted from the earth, and estimated at two thousand million dollars, would give only one dollar for two hundred and eighty million tons of sea-water, while from the experiments of Sonstadt it would appear that the same quantity of gold is actually contained in twenty-five tons of water.]

RESEARCHES ON TEE CONSUMPTION OF HEAT IN THE BLAST-FURNACE PROCESS.

BY RICHARD AKERMAN.

(Translated by FREDERICK PRIME, JR., Professor of Metallurgy in Lafayette College, Easton, Pa.)

[THE attention now being paid both in this country and Europe to the greatest economy in the working of the blast furnace, and the eagerness with which all thoughtful men in the iron business look for any new information which will tend to throw light on this subject, is a quite sufficient excuse for presenting this paper to the American Institute of Mining Engineers.!

I. It must be borne in mind that when two bodies unite to form a chemical compound, heat is almost always evolved. In order to measure the quantity thus evolved, that amount of heat is used as a heat-unit, which is able to raise one pound of water one degree Centigrade. So that, when it is said the heat evolved by carbon, when burnt to carbonic acid, is 8080 heat-units, it is understood that by the combustion of one unit by weight (1 lb.) of carbon to carbonic acid, sufficient heat is produced to raise one pound of water 8080° C., or what is the same, to raise 8080 lbs. of water 1° C. In the combustion of one pound of carbon to carbonic acid, we find that 32÷ 12 = 2667 lbs. oxygen unite with the carbon. But we can also speak of the heating power of carbon, reduced to the unit by weight (1 lb.) of oxygen, by which we understand, not as in the preceding case, the amount of heat produced by the combustion of 1 lb. of carbon with 2.6667 lbs. oxygen to carbonic acid, but that amount of heat evolved when 12÷32 = 0.375 lbs. carbon combine with 1 lb. of oxygen to carbonic acid. The heat evolved by carbon when burnt to carbonic acid per weight-unit of oxygen, is therefore 0.375 x 8080 = 3030 heat-units. It is well known that, as a rule, one body unites with another to form several different chemical compounds, which fact is also true of carbon. This not only combines with oxygen to form carbonic acid (CO_2), in which one equivalent (12 parts by weight) of carbon unites with two equivalents (32 parts by weight) of oxy-gen, but it also forms carbonic oxide (CO), in which one equivalent (12 parts by weight) of carbon combines with one equivalent (16 parts by weight) of oxygen. The amount of heat evolved by carbon, per weight-unit, for these two stages of oxidation, is in the highest degree dissimilar, so that while 8080 heat-units (H. U.) are evolved by its combustion to carbonic acid, when burnt to carbonic oxide, it only develops 2473 H. U. But while, on the one hand, the heat of carbon by its combustion to carbonic oxide is solow, so much the greater is the heating power of the carbonic oxide by its combustion to carbonic acid, on which account the same amount of heat is always evolved, when a certain quantity of carbon is first burnt to carbonic oxide, and this then to carbonic acid, as when the same quantity of carbon is burnt directly to carbonic acid. By the combustion of 1 lb. of carbon to carbonic oxide 2473 H. U. are evolved, and thereby (12 + 16) ÷ 12 = 2.333 lbs. of carbonic oxide formed. And since the heating power of the carbonic oxide, by its combustion to carbonic acid is 2403 H. U. per weight-unit, we must obtain by the combustion of 2.333 lbs. carbonic oxide a heating power of 2.333 x 2.403 — 5.607 H. U., which together with the 2473 H. U. first produced make 8080 H. U., the same amount of heat which would be obtained by the direct combustion of 1 lb. of carbon to carbonic acid.

The heating powers of the various elements have been for the most part determined by direct experiment. On the other hand, it is an undisputed axiom that by the decomposition of a chemical compound of two bodies, as much heat is absorbed, or rendered latent, as was evolved when the compound was formed. If, therefore, (12+32) ÷ 12=3.666 lbs. carbonic acid are resolved into one pound of carbon and 2666 lbs. oxygen, the 8080 IT. U. must be absorbed, or in other words a cooling corresponding to 8080 H. U. must take place. From the axiom and the previously adduced fact, that the same amount of heat is evolved if a certain amount of carbon is burnt directly to carbonic acid, or first to carbonic oxide and then this to carbonic acid, it necessarily follows that if one pound of carbon is burnt to carbonic acid, and this by contact with glowing coal is reduced to carbonic oxide, by which 1 lb. of carbon is absorbed ($CO_2 + C — 2CO$), that the final difference between the amount of heat evolved and absorbed must be equal to the amount which would be obtained by burning two pounds of carbon directly to carbonic oxide.

II. It is of the greatest importance to distinguish accurately between the amount of heat, which is expressed by the number of heat- units, and the temperature (intensity of heat), or measurable heat, which a body possesses. If, for example, a vessel contains 10 lbs. of water of a certain temperature *(say* 15° C.), then the water possesses 150 H. U. above the freezing-point. If 2 lbs. of this water are poured out, the remainder in the vessel still retains the same temperature, but possesses only 120 H. U., since 30 H. U. have been removed with the water poured out. The temperature or measurable heat of a body depends not only on the amount of heat imparted to it, to which it stands in direct proportion, but is also dependent on the quantity or weight of the body in question, with which the desired temperature is in inverse proportion.

III. But even when like amounts of heat (an equal number of heat-units) are imparted to equally large weights of two different bodies, these do not have the same increase of temperature, the reason for which is, that different bodies have different specific heats. By specific heat is understood the number of heat-units which are necessary to raise one pound of any substance 1° C. in temperature. The specific heat of water is taken = 1. If we state that the specific heat of oxygen = 0.2182, it is understood that just 0.2182 H. U.

are necessary to raise one pound of oxygen 1° C. in temperature. From what has been stated it can readily be seen that in order to correctly determine the amount of heat of any body, not only its temperature, but also its weight and its specific heat must be known, and that the amount of heat, imparted to the body in question, is determined by the product of these three numbers.

IV. It is further to be remarked, that by melting heat is understood the number of heat-units necessary to convert the weight-unit of a solid body to the fluid state without any increase in temperature. And also by gaseous or gasifying-heat is meant the quantity of heat necessary to convert a liquid body to the gaseous state without causing any increase of temperature.

V. In order to more clearly understand the following calculation of the heat used in the blast-furnace process, it is necessary to know how the reduction of the iron-ores takes place and is used in this investigation.

The iron can be as readily reduced by carbonic oxide, which is thus oxidized to carbonic acid, as by contact with coal, which is burnt to carbonic oxide, and in order to correctly observe the blast-furnace process, it is an important question to know if the previously existing amount of heat is increased or diminished by these various kinds of reduction. If we assume that by the decomposition of a chemical compound as much heat is rendered latent as was evolved when it was formed, then it must be admitted that as much heat is rendered latent by the iron-ore as is evolved by the combustion of the iron with a like amount of oxygen. Consequently the above question is confined to ascertaining whether the iron, by its combustion with a determined amount of oxygen, evolves more or less heat than, on the one hand, by the combustion of carbonic oxide with the like amount of oxygen, or on the other, by the combustion of carbon to carbonic oxide with the same amount of oxygen.

In order to answer this question, it becomes therefore necessary to ascertain the amount of heat evolved by the bodies in question per weight-unit of oxygen. This heat of chemical combination is, for iron, according to Dulong, 4327, according to Woods, 4213, according to Andrews, 4134 H. U. In the following calculations it is assumed to be 4205 H. U.

If we examine how great the heating power of carbon is per weight- unit of oxygen used to turn it into carbonic oxide, it will be found as follows: From what has preceded, the heating effect of carbon by its combustion to carbonic oxide is 2473 H. U. per weight-unit of carbon, and since in this 1 equivalent (12 parts by weight) of carbon combines with 1 equivalent (16 parts by weight) of oxygen, the heat developed by the combustion to carbonic oxide is 2473 x 12 ÷ 16 = 1854.75, per weight-unit of oxygen used.

By a like examination with regard to the development of heat by the combustion of carbonic oxide to carbonic acid, it is found to be 4205.25 per weight-unit of oxygen. For, by the combustion, 1 equivalent (12 + 16 = 28 parts by weight) of carbonic oxide combines with 1 equivalent (16 parts by weight) of oxygen; and since the heating power per weight-unit of carbonic oxide has been assumed as 2403, we obtain 2403 x 28 ÷ 16 = 4205.25. The figures by which the relations of heat are determined, which take place in the reduction of iron-ores by carbonic oxide and carbon, are therefore the following:

The amount of heat evolved by carbon when it *is* burnt to carbonic oxide, amounts per weight-unit of oxygen to . . . 1855H.U

The amount of heat evolved by carbonic oxide, when burnt to carbonic acid, is per weight-unit of the oxygen, ... 4205 H. U.

The amount of heat evolved by iron per weight-unit of oxygen is, . 4205 H. U.

After the heat development of the carbonic oxide and the iron per weight-unit of oxygen have been found to be equal, it follows that in the reduction of iron-ores by carbonic oxide just as much heat is evolved by the production of carbonic acid as is rendered latent by the reduction of the ores, and consequently that the previously existing heat is neither increased nor diminished. On the other hand, a comparison of the heat development of carbon and iron per weight- unit of oxygen shows, that the reduction of the iron-ores by the oxidation of carbon to carbonic oxide does not take place without a considerable consumption or diminution of heat, since for every weight-unit of oxygen which is conveyed in this manner from the ores to the carbon 4205 —1855 = 2350 are rendered latent.

If it be not granted that the reduction of the iron-ores takes place by the action of carbon in the manner stated (or if it is claimed, in other words, that the oxygen of the ores cannot combine directly with carbon, but that the reduction can take place only by the combustion of the carbonic oxide to carbonic acid, and that this latter is again reduced to carbonic oxide by the absorption of carbon), the result with regard to the amount of heat required will not be at all changed. Since so long as the final products consist of iron and carbonic oxide, the same amount of heat—*i. e.*, 2350 H. U.—will be necessary to convey one weight-unit of oxygen from the iron-ores to the carbon. In order that the truth of this assertion may be evident, it is only necessary to remember that the heat development per weight-unit of oxygen is the same for iron and carbonic oxide; and that in consequence of this, with regard to the comportment of the heat, it must be immaterial whether, in the oxidation of carbon to carbonic oxide, one and the same amount of oxygen is obtained from the oxidized iron or from the carbonic oxide burnt without any change of heat.

VI, A few remarks are still necessary with regard to the manner in which the carbon is burnt by the blast of the blast furnace. Experiments made on this subject have shown that the coals next to the tuyeres are indeed burnt to carbonic acid, but this combustion is confined to a relatively very small space in front of each tuyere,* and that the carbonic acid thus formed oxidizes the surrounding coal to carbonic oxide, and is itself reduced to the same ($CO_2 + C = 2CO$). In consequence of the high heating power of the coal when it is burnt to carbonic acid, the temperature before each tuyere is a very high one, but outside of these different foci the temperature rapidly de-creases, owing to the reduction of the carbonic acid. The consequence is that the temperature in the different portions of the hearth of a blast furnace is a very unequal one. The action of the higher and lower degree of oxidation is confined to this inequality in the distribution of the temperature, since the difference between the amount of heat first produced by the formation of carbonic oxide, which is again partially used, is, as already shown, just equal to that quantity of heat which would be produced, if the coal in front of the tuyeres were burnt to carbonic oxide by the oxygen of the blast.

VII. In order that the following calculations with regard to heat might be adapted, so far as possible, to the conditions of the Swedish blast, furnaces, the author has attempted to conform the necessary assumptions to the conditions existing in the best Swedish practice.

Consequently, a furnace was chosen which is 42 feet high, blowing with two tuyeres having an internal diameter of 2 1/2 inches, and it was assumed that the charge of charcoal amounted to 360 lbs. The

charcoal consists of

82	per	cent,	carbon,
2	"	"	ash,
10	"	"	water,
6	"	"	other gases,

* This certainly docs not agree with Bell's ideas, nor with his experiments. He found the temperature at the tuyeres (see. pp. 90, 9J, vol. i, Journal Iron and Steel Institute) to be lower than above or below, and also that the gases consist essentially of carbonic oxide and nitrogen. Tunner does not agree with this view of Bell's, *but, facts*, which are such stubborn things, certainly seem to prove it, so far, at least, as our present knowledge extends, F. P.

which are expelled at high temperature. The gases consist, coo-rding to the researches of Rinmann and Fernquest, of

55.9	per cent,	carbonic acid,
22.8	"	carbonic oxide,
11.8	"	marsh gas,
1.0	"	hydrogen,
8.5	"	nitrogen.

It is also assumed that a burden of 8 cwt. is added to such a charge of coal, that the furnace makes 1600 cwt. of pig-iron weekly, that the burden contains 15 per cent, carbonate of lime, and that the ore consists of equal quantities of peroxide and magnetic oxide of iron, or Fe_5O_7. It is further assumed that there is obtained 45 per cent, of iron and 35 per cent, of slag from the entire charge, hence we can calculate the consumption of fuel on 100 Ibs. of pig-iron produced. The pig-iron is assumed to contain 4.2 per cent, carbon, and 0.25 percent, silicon.

It is also assumed (in accordance with the average temperature of Sweden) that the temperature of the atmosphere is 5° C., that the temperature of the hot blast is 200° C. higher, with a pressure of 1.7 inches of mercuiy, and that it contains an amount of water corresponding to the outer atmosphere and height of the barometer, consequently the composition of the blast is (by weight)—

Nitrogen,				76.40
Water 0.56 {	Hydrogen,		0.06	
	Oxygen,	0.50 }		23.54
Oxygen,		23.04		

The average temperature of the escaping gases is taken as being 450° C., which is not too high, as the materials charged are assumed to be dry, and the ascending gases, especially in the upper portions of the furnace, are considerably hotter than the descending solid contents which are being heated up. Besides which it must be borne in mind that in the majority of the Swedish blast furnaces the gases are for the greater part removed at some considerable distance below the tunnel-head, in order to be used for other purposes, and gen erally at the high temperature of 800° C.

VIII. Prior to passing to the direct calculation, it is necessary to give some requisite figures.

The heat evolved per weight-unit of the substance combining with the oxygen, is here assumed as follows:

For carbon by its combustion to carbonic acid, ...	8,080 H. U.
For carbon by its combustion to carbonic oxide, ...	2,473 "
For carbonic oxide by its combustion to carbonic acid, . .	2,403 "
For hydrogen by its combustion to water,.....................	29,638* "
For silicon by its combustion to silicic acid,...................	7,830 "

The heat evolved per weight-unit of caustic lime by its combination with carbonic acid is assumed to be, according to Schinz, 197.1 H. U.

The heat absorbed by the reduction of iron ores in the oxidation of carbon to carbonic oxide has been found to be 2350 H. U.-per weight-unit of oxygen, it is therefore per weight-unit of carbon 2350 X 16 / 12 = 3133.3 H. U.

The specific heat of oxygen at a constant pressure is	0,2182
" " nitrogen " "	0.2440
" " hydrogen " "	3.4046
" " steam " "	0.4750
" " carbonic oxide" "	0.2479
" " carbonic acid " "	0.2164
" " marsh gas " "	0.5929

The fusing heat of ice is 79 H. U., and the evaporating heat of water 536 H.U.

The combining weight of hydrogen is,..................................	H=1
" " carbon is,..	C=12
" " oxygen is,...	O =12
" " calcium is, ...	Ca=40
" " silicon is, ...	Si = 28
" " iron is, ...	Fe=56

One pound of the charcoal charged has been taken as the weight-unit, serving as the basis of all the following calculations; therefore, both the production and consumption of heat are always reduced to 1 Ib. of the harcoal consumed in the furnace.

Of the pure carbon contained in the charcoal 4.2 X 100 / 82 = 5.122 per cent, is combined with the pig-iron ; and if, in accordance with Rinrnann's researches, ** it be assumed that 12 per cent, of the carbon in the charcoal is used in reducing the iron ores, there re-

* The heating power of hydrogen is generally assumed to be 34,462 H. U.,but in such calculations as these the evaporating heat of the water formed (9 X 536 = 4824 H.U.) must be subtracted.

† See Jern-Kontoret's Annaler for 1865.

mains of each one pound of charcoal charged into the furnace only 0.82 — (17.122 X 82 / 100) — 0.6796 lb. of coal to be burnt by the blast.

In order to burn this amount of carbon to carbonic oxide, which is the final product of the carbon burnt by the blast, it is necessary to have 0.6796 X 16 / 12 = 0.90613 lb. of oxygen, which is contained in 0.90613 / 02354 == 3.84933 Ibs. of air; and in accordance with the previously adopted composition of the air this quantity contains 2.94089 Ibs. nitrogen and 0.00231 lb. hydrogen. Only 0.88688 lb. of the amount of oxygen occurs in a free state, however, as the remainder (0.01925 lb,) is combined with hydrogen to form 0.02156 lb. of water.

IX. By the combustion of the 0.6796 lb. carbon, in the pound of charcoal, to carbonic oxide, we produce 0.6796 X 2473 = 1680.6 H. U. While on the other hand, by the decomposition of the vaporized water, brought in by the blast, into oxygen and hydrogen, the heat is diminished by 0.00231 x 29638 = 68.5 H. U. So that in reality per lb. of charcoal burnt by the blast only 1680.6 — 68.5 = 1612.1 H. U. are produced.

X. There is introduced by the blast heated to 200° C. above the temperature of the atmosphere an amount of heat of (0.88688 X 0.2182 + 2.94089 x 0.2440 + 0.02156 x 0.4750) 200 = 184.2 H. U.* per lb. of coal charged.

Consequently, for each pound of charcoal used in the blast furnace, the total amount of heat produced is 1612.1 + 184.2 = 1796.3 H. U.

XI. According to the previous assumptions for each pound of char- coal charged there is produced 1 lb. of pig-iron and 0.7778 lb. of slag. If now it be assumed in accordance with Rinmaun's researches,** that the pig-iron flowing out of the blast furnace carries along with it 310 H.U., and the slag 440 H. U., there is then consumed in heating and fusing these two products an amount of heat of 310 + 0.7778 X 440 = 652.2 H. U. per pound of charcoal used.

XII. It has been assumed that the pig-iron produced contains 0.25 per cent, silicon, which must necessarily have been reduced from the silica in the charge, the latter parting with its oxygen to

* This calculation is in so far incorrect that no allowance has been made for the changed specific heat of the gases, produced by the altered pressure of the blast when pouring out of the blast-pipe.

† Transactions of the Royal Academy of Sciences at Stockholm, 1865, p. 327.

carbon to form carbonic oxide. Since 0.0025 Ib, silicon is reduced per pound of charcoal used, there have been consumed in doing this 0.0025 X 7830 = 19.6 H. U. But on the other hand for each equivalent of silicon reduced 3 equivalents or 0.0025 X 3 X 12 / 48 = 0.00187 Ib. carbon are oxidized to carbonic oxide; by which 0.00187 X 2473 = 4.6 H. U. are evolved. Therefore, in fact, in the reduction of the silicon by carbon only 19.6 — 4.6 = 15 H. U. are rendered latent per pound of coal charged.

XIII. With regard to the reduction of the iron ores it has already been shown that by that portion which oxidizes the carbonic oxide to carbonic acid, neither a development nor consumption of heat takes place. Therefore, only that portion which is reduced by the carbon need here be regarded. It has been already stated that 12 per cent, of the free carbon in the fuel, or 0,82 x 0.12 — 0.0984 Ib. per pound of charcoal charged, is necessary to reduce the ore. From this must be subtracted the amount necessary to reduce the silicon, separately calculated, and there then remains, as necessary for the reduction of the ores, 0.0984 — 0.00187 =0.9653. The amount of heat necessary to accomplish the reduction in question is 0.09653 X 3133.3 = 302.5 H. U.

XIV. There are 2.222 Ibs. of ore and flux charged into the furnace for every pound of fuel, and the former contain 15 X 2.222 / 100 — 0.3333 Ib. of carbonate of lime, which, when sufficiently heated evolve 0.3333 X 0.44 = 0.14666 carbonic acid, which is combined with 0.18667 Ib. of lime. The heat necessary to liberate this carbonic acid is 0.18667 x 197.1 — 36.8 H. U.

XV. Since it was assumed that the charcoal used contained 10 per cent, of water, there is necessary to volatilize this water 0.1 X (536 + 95)* = 63.1 H. U. per Ib. of coal charged.

XVI. The quantity of heat must also be determined which is lost owing to the gases passing out of the blast furnace being hotter than the outer air. For this purpose it is necessary to ascertain both the amount and nature of the gases occurring in the blast furnace, per pound of fuel charged. These gases consist :

1. Of the steam expelled from the fuel, amounting to 0.1 Ib. per pound of charcoal.
2. Of the remaining volatile constituents of the charcoal, which,

* This 95 is obtained by the author under the supposition that the temperature of the atmosphere is 5° C. and that 95 + 536 = 631 H. U. are rendered latent for every weight-unit of water converted to steam at 100° C.—F. P,

according to the previously assumed composition, consist per pound of fuel of:

0.559 x 0.06 = 0.03354 Ib. carbonic acid,
0.228 X 0.06 = 0.01368 " carbonic oxide,
0.118 x 0 06 = 0.00708 " marsh gas,
0.010 x 0.06 = 0 00060 " hydrogen,
0.085 x 0.06 = 0.00510 " nitrogen.

3. Of the carbonic acid expelled from the charge, which amounts to 0.14666 Ib. per pound of fuel charged.

4. Of the gases formed by the combustion of the carbon and by the reduction it produces (per pound of fuel charged). These gases consist, first of all, of those formed by the combustion with the blast.

0.90613 + 0.90613 x 12 / 16 = 1.58573 Ib. carbonic acid,
2.94089 " nitrogen,
0.00231 " hydrogen;
while in addition 0.09S40 " carbon is gasified

by the reduction of the ores ; by the reduction of the silica to silicon, oxygen, amounting to 0.0025 x 48 / 28 = 0.00428 Ib., is liberated; and finally the oxygen combined with the iron in the ores, which amounts per pound of fuel used to

0.9555 x 7 x l6 / 5 x 56_ 0.3832 Ib. oxygen.

The above-mentioned 0.0984 Ib. carbon combines with 0.1312 Ib. oxygen to form 0.2296 Ib. carbonic oxide, while the remainder of the oxygen (0.3822 + 0.00428 — 0.1312 = 0.25528 Ib.) has combined with 0.44674 Ib. carbonic oxide to form 0.70202 Ib. carbonic acid. Consequently the gases that have been formed by the combination of the carbon with the oxygen of the blast and by the reduction, amount per pound of fuel to

0.70202 Ib. carbonic acid,
1.58573 + 0.22 96 — 0.44674 = 1.36859 " carbonic oxide,
2.94089 " nitrogen,
0.00231 " hydrogen.

The escaping furnace gases are, therefore, per pound of fuel charged into the furnace:

0.01369 + 1.30859 = 1.38227 " carbonic oxide,
0.708 " Marsh gas,
0.0006 + 0.00231 = 0.00291 " hydrogen,
0.00510 + 2.84589 = 2.94599 " nitrogen,
0.1000 " steam.

Total, 5.32047 " fornace gases,

which contain 16.58 per cent, carbonic acid and 25.98 per cent, carbonic oxide. The heat* carried off by these gases, if it be assumed that they escape at an average temperature of 450° C. higher than that of the atmosphere and when using the previously stated specific heats, may be calculated as follows: 450 (0.88222 X 0.2164 + 1.38227 x 0.2479 + 0.00708 x 0.5929 + 0.00291 X 3.4046 + 2.94599 X 0.244) + 0.1 X 0.4750 X 350** = 586.55 H. U.

XVII. The heat lost by the use of water-tuyeres depends of course upon the amount of surface these expose to the interior of the furnace and must become as much greater as the tuyeres, having a certain thickness of metal, are broader, and become more exposed by the burning out of the hearth. Prof. Egertz‡ has determined, in respect to this loss of heat, that with a but slightly protruding water- tuyere, 2| inches in interior diameter, the heat carried off per minute amounted to 1.586 X 61.52 = 97.57 H. U., which corresponds in a tuyere having 2 1/12 inches interior diameter to 111 H. U. Since the blast furnace under discussion has two tuyeres and makes 1600 cwt. of pig-iron weekly, the amount of heat consumed is at least 2 X 111 X 7 X 24 X 60 / 16000= 14 H.U. per pound of pig-iron made or of coal charged.

XVIII. So far as the author is aware, no experiments have been made in Sweden to determine the heat carried off by the tymp and fore-hearth. If, however, we regard the comparatively large cooling surface and the loss of heat which must take place when cleaning out the fore-hearth, it is probably not too high an assumption if the amount of heat lost be taken as 11/2 times as great as that just men- tioned in the case of the tuyeres, *i. e.*, 1.5 X 14 = 21 H. U. per pound of fuel charged.§

XIX. Neither have any researches been made with regard to the cooling effect produced by the remaining surfaces of the blast fur-

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* There should properly be added to the heat carried off by the gases, the heat absorbed by these gases during their ascent in the shaft of the furnace due to the diminution of pressure; but as it is very difficult to ascertain this in the present case, and as its amount is inconsiderable, it has been omitted.

†The 350 in this portion of the equation is due to the fttct that it takes a temperature of 100° C. to convert water to steam.—F. P.

‡ See Jern-Kontoret's Annaler for 1852, p. 12.

§The quantity of heat lost depends of course in great part on the size of the fore-hearth, but it seems to me that Mr. Akerman'a assumption is much too small. Besides, instead of making this assumption, it would have been far better to have experimented in this direction, especially as no one had previously done so in Sweden.—F. P.

nace, which depends on the thickness of the walls and their power of conduction. Bell, however, has made experiments in this direction on a coke blast furnace, and has come to the conclusion that 55.4 per cent, of the heat which is necessary to fuse the pig-iron is conducted off merely by the walls of the furnace. It is evident that in English furnaces of the latest type, with their thin walls, the loss of heat must be considerably greater than in the Swedish ones. But on the other hand, if we take into consideration the much greater production of the English furnaces and the circumstance that in the case now under consideration it depends not on the loss of heat per unit of time, but per weight-unit of pig-iron produced, it would appear that the loss of heat in the English furnaces is comparable with that in the Swedish, As experiments are lacking on this point in Sweden, it may be assumed, with due regard to Bell's researches, that the cooling caused by the walls and bottom of a Swedish char- coal furnace, having exterior walls, inner and outer lining, is 30 per cent, of the heat necessary to fuse pig-iron, *i. e.*, 0.3 X 310 = 93 H,U. per pound of fuel charged.

In order to obtain a clearer resume of the different amounts of heat consumed and lost, they are here tabulated. There are consumed per weight-unit of charcoal charged—

To fuse the pig-iron, ...	310.0	H. U,
" " slag, ...	342.2	"
" reduce the silicon by carbon, ...	15.0	"
" " iron, "	302.5	"
" expel the carbonic acid from the charge, ...	36.8	"
" " moisture from the charcoal, ...	63.1	"
Heat carried off by the furnace gases, ...	586.6	"
" " " water cooling the tuyeres, . . .	14.0	"
" " " cooling of the tymp and fore-hearth, .	21.0	"
" " " side-walls and bottom, ...	93.0	"
Total quantity of heat used, . . .	1784.2	

The total quantity of heat per pound of fuel charged into the furnace, both by the combustion of the latter and that introduced from without, amounts, according to the previous calculations, to 1796.3 H. U.; therefore, only 12.1 H. U. remain unaccounted for,

XX, Before passing to a more minute examination of the various processes of the blast furnace which consume heat, we shall endeavor, in order to avoid all misunderstanding, to show more clearly, that in the conduction of the heat from the furnace by the hot furnace-gases, as previously stated, the great loss of heat from the imperfect combustion of these gases has been entirely neglected. Or, in other words, that a large portion of the escaping gases are still combustible, and must therefore be regarded as fuel. This great loss of heat includes, per weight-unit of fuel charged into the furnace, all that heat which could be produced if the amounts of car- bonic oxide, marsh gas, and hydrogen contained in the tunnel-head gases, corresponding to the above-mentioned weight-unit, were com- pletely burnt to carbonic acid and water. This loss of heat amounts to: 1.38227 X 2403 + 0.00708 x (8080 x 12 / 16 + 29638 x4 / 16 =0.00291 X 29638 = 3321.6 + 95.3 + 86.2 = 3503.1 H. U. On the other hand, the amount of heat which would be produced in the blast furnace, if the water carried in by the blast should leave the furnace in the same condition, and all the combustible ingredients of the charcoal, with the single exception of the chemically combined car-bon in the pig-iron, were burnt to carbonic acid and water, is 0,82 (1—0.05122) x8080 + 0.01368 x 2403 + 0.00291 X 29638 + 0.00708 (8080 X 12 / 16 + 29638 X 4 / 16) = 6286.2 + 32.9 + 86.2 + 95.4 =6500.7 H, U.* Hence the amount of heat lost in the blast furnace by the imperfect combustion of the fuel is 6500.7 : 3509.1=100: X.X=53.9 per cent, is the amount of heat lost, which could be gained by a perfect combustion.

Since a more perfect combustion can only be produced by the oxygen of the ores, it is very evident that the combustion will be more perfect the greater the burden of ore added to a given amount of coal. Hence it is clear that the iron-master should strive to improv£ the blast-furnace process so far as possible, both by diminishing the quantity of heat required in the blast furnace, as well as *by* the addition of *as* cheap an extraneous heat as possible. It is, how ever, under any circumstances, impossible to attain a perfect combustion of the fuel used, as among other conditions it is necessary that the carbonic oxide occurring in the blast-furnace gases should, even to the last trace, exert a reducing action on the ores; this it is impossible for it to accomplish in the case of the peculiarly refractory ores of Sweden (magnetite and specular iron ore). The reason

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* The difference between these figures and the heat produced in the blast furnace (compare X), increased by the heat carried off by the still combustible portion of tunnel-head gases, *i. e.*, 6500.6 —(1790.3 + 3509.1) = 1195.2 H. U., comes from that heat which has been produced during the reduction of the iron, silicon, and hydrogen, by the combustion of carbonic oxide to carbonic acid, and of carbon to carbonic oxide. Since this heat is again consumed in the reduction mentioned, it should not be credited to either side.

for this is, that precisely in the same manner as oxidized iron is reduced by carbonic oxide with the formation of carbonic acid, so also iron is oxidized by carbonic acid with the formation of carbonic oxide. Both of these reactions, due to the contact of a mixture of oxidized and metallic iron, on the one hand, with a mixture of carbonic oxide and carbonic acid on the other, depend on the temperature which prevails, as well as on the proportions in which the two gases exist in the mixture. Bell's experiments have shown that a mixture of oxidized and metallic iron remains unchanged at a dark red heat, if the mixture of the gases consists of 60 volumes carbonic acid to 40 volumes carbonic oxide; also, at a high red heat, if the gas-mixture contains 32 volumes carbonic acid to 68 volumes car-gas bonic oxide; and at a white heat, if there are 10 volumes carbonic acid to 90 volumes carbonic oxide. If, however, at the different temperatures, the carbonic oxide is present in greater proportions, this excess then exerts a reducing action on the oxidized iron or ore; while if the carbonic acid exceeds the amounts mentioned, it exerts an oxidizing influence on the metallic iron. The reduction, or oxidation, continues until the neutral proportions mentioned as existing between carbonic oxide and carbonic acid are attained. Hence it follows, that the higher the temperature so much the less must the proportion of carbonic acid be, in order that the gas-mixture may exert a reducing action; and further, that the heating of the ores must take place as slowly as possible, if a reduction should still be produced by gas-mixtures relatively rich in carbonic acid and poor in carbonic oxide. If, then, no reduction worth mentioning takes place at a temperature lower than a dark red heat, as seems to be the case in dense ores like magnetite, it is readily understood why—no matter how carefully the ores may have been heated, or how slowly they may descend the furnace-shaft—the blast-furnace gases can no longer exert a reducing action beyond the point where the amount of carbonic acid becomes about 11/2 times as great as the volume of carbonic oxide.

Although the efforts of the iron-master should always be directed towards oxidizing the fuel charged as perfectly as possible, or in other words to attain as great a burden of ore as possible to a fixed amount of fuel, still, for the reasons given, it is never possible to attain this so fully, especially with ores which are so refractory as specular iron and magnetite, as to entirely utilize the fuel. It is, therefore, of great importance to pay sufficient attention to a corresponding utilization of the considerable heating power which the imperfectly oxidized tunnel-head gases possess under all circumstances. If all this heat finds a suitable use outside of the blast furnace, which is impossible without a closed top, then the furnace acts as a great gas generator, where even the heat produced by gasifying the fuel is utilized, which but rarely takes place in ordinary gas generators. And a portion, at least, of the pig-iron produced appears, as it were, as a by-product, obtained without cost in the production of the gas.

In order to determine the possibilities by which the working of the furnace may be improved, through a diminished consumption of coal, or, where the quantity of this remains unchanged, through an increased burden of ore, it will be our endeavor to examine more minutely each of the causes of the consumption of heat, while the effect produced by the use of the hot-blast will also be considered.

XXI. The steam introduced into the furnace together with the blast is decomposed in contact with the glowing coals into hydrogen and oxygen, the latter of which at once unites with the coal to form carbonic oxide. This causes a great loss of heat, which can be understood by a comparison of the calorific equivalents of the bodies concerned (per weight-unit of oxygen). These are:

For hydrogen by its combustion to water, $29638 \times 2/16 = 3705$ H. U.
For carbon by its consumption to carbonic oxide, $2473 \times 12/16 = 1855$ H. U.

For each pound of oxygen, therefore, which passes in the formation of carbonic oxide from the hydrogen to the carbon there are $3705 - 1855 = 1850$ H. U. consumed; and for every pound of water introduced by the blast into the furnace there are $1850 \times 16/18 = 1644.4$ H. U. rendered latent, in addition to which the amount of carbon consumed for this purpose (0.6667 Ib. for each pound of water) is lost.

It would be supposed that when the hydrogen thus set free came in contact with unreduced iron ores, it would be oxidized to water at the expense of the oxygen of the ores, and thus the heat previously rendered latent by the decomposition of the water would again become active higher up in the shaft of the furnace. In such a case the water introduced by the blast into the furnace would, upon the whole, cause no loss of heat, but on the contrary would save a little, since a portion of the *gas* would be saved, which would otherwise have resulted from the production of the same action by carbon. But such an action does not seem to take place; since the gas anal- yses of Rinmann and Fernquist in Sweden, as well as those of others, have proved that the hydrogen once reduced in the blast furnace is not again oxidized; or at least if it does undergo oxidation that it is instantly reduced again by the coal. Consequently it follows that the hydrogen in the furnace must be regarded as a neutral gas with respect to its reducing action, and, like nitrogen, only robs the blast furnace of heat without performing any corresponding work. It must also be borne in mind, as already remarked, that the hydrogen on being liberated (by its reduction from water), taking into account the heating power of the carbon thus used, robs the furnace of 29,638 X 2 / 18 = 3293 H.U. per Ib. of steam blown in. From all of which it follows that the furnace should be supplied with air as ?ry as possible ; hence the winter months exert a more favorable influence in this respect on the working of furnaces than the summer months, during which there is more moisture in the air. It is remarkable, however, that the working of blast furnaces is not so sensitive to rainy weather as many persons suppose.

XXII. With regard to the quantity of heat necessary to fuse the pig-iron and cinder, sufficient experiments have not as yet been made to enable us to say with certainty how the charge should be composed so as to attain fusion with the least consumption of heat. Nevertheless it has been ascertained from the experiments made by Rinmann, and in France,* that a much greater amount of heat is necessary to fuse the ordinary blast-furnace cinder, than for an equal weight of pig-iron. If, in accordance with the previously stated calculations, it be assumed that the pig-iron flowing out of the blast furnace carries along with it 310 and the cinder 440 H. U. per Ib. of each, then the cinder must carry out of the furnace 440 / 310 = 1.42 times as much heat as an equal weight of pig-iron. Hence it follows that rich charges, or such as give but little cinder per ton of pig-iron produced, require in general less coal than charges poor in iron. If the amount of heat necessary for fusion were the only measure for the coal consumption in the blast-furnace process, it is self-evident that the quantity of ore that could be charged with a certain amount of coal would increase in proportion as the charge was richer. But it appears in practice, on the contrary, that on a given burden of coal less of the richer charge, by weight, can be added than of the poorer, the cause of which must be sought in the con-

* According to these experiments the cinders flowing from the blast furnace possess 550 and the pig-iron 330 H. U.; while in this memoir, in accordance with Einmann's researches, the figures are assumed as 440 H. U. for the cinder and 310 H. U. for the pig-iron. [See De Vathaire, Etudes sur les Hauts Fourneaux, F.P 72 and 76.—F. P.]

sumption of coal and heat combined with the reduction of the ores, which shall be fully discussed. In general, therefore, a smaller quantity of rich ores can be charged per ton of coal than of poor ones. Nevertheless, owing to the greater amount of cinder, as well as to its higher specific and fusing-heat, as a rule less coal is consumed per ton of pig-iron produced by rich ores than by poor ones. But there is no doubt that the charge should not be made poorer than the controlling conditions, and, above all, the wished-for character of the iron to be produced, demands.

XXIII. With regard to the reduction of the silicon and its combination with the pig-iron, there is first to be remarked that the silicicacid is so difficult to reduce, that the dissociation can only take place in the blast furnace at the expense of carbon, which is thus oxidized to carbonic oxide. The quantity of heat thus consumed per weight-unit of pig-metal produced is 14.3 X 4 = 57.2 H. U.* for each per cent, of silicon absorbed by the pig-iron, besides which the carbon thus directly consumed must be added; *i. e.*, 3 x 12 / 48= 3/4 of of the amount of silicon reduced. From which it is apparent that the more silicious the iron is desired to be, so much the more coal and heat must be consumed. It is scarcely necessary to mention that the greater the amount of silicon in the charge, so much the more of it is absorbed by the pig-iron.

XXIV. With regard to the reduction of the iron ores it is known that this is accomplished both by the burning of carbonic oxide to carbonic acid (which produces no change in the heat, as just as much heat is produced as is rendered latent), as well as by the combustion of the coal to carbonic oxide, by which latter sort of reduction there is a diminution of heat of 2350 H. U. (see V) per weight-unit of the oxygen withdrawn from the ores. Besides this there is also the noticeable loss of coal of 12 / 16 or 3/4 of a weight-unit for each weight-unit of oxygen thus removed from the ores. In order to save coal it is therefore of the greatest importance that the arrangements should be of such a character as to reduce as much ore as possible by car- bonic oxide. For this purpose it is necessary that the reduction should be effected so far as possible in the upper portion of the shaft, where the heat has not yet attained to such a degree that the carbonic acid formed by the reduction should be again reduced to carbonic oxide by contact with the surrounding coal, as otherwise precisely

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* In practice this consumption of heat is somewhat greater, since that mount of heat is here omitted which is necessary to decompose the silicate or to separate the silica from the cinder.

the same condition prevails as in the case where the reduction of the ores takes place by the direct oxidation of the coal to carbonic oxide. This aim, especially the most perfect reduction in the upper cooler portion of the shaft, is more fully attained the more readily the ores can be reduced and the more slowly they descend the shaft.

It would lead us beyond the limits of this memoir to go into a critical examination of the reducibility of the various iron ores. But this much may be here stated that, according to the analyses hitherto made of the tunnel-head gases of Swedish furnaces,* it seems that the reduction of the dense magnetites, specular irons, and red hematites smelted there, is not completed until they arrive in the immediate neighborhood of the tuyeres, and consequently a certain portion of the coal (7 to 16 per cent, of the amount of coal charged) is required as carbon for reduction. On the other hand, in the case of iron ores which, in consequence of their porosity, are more easily reduced, as, for example, the hydrated peroxides and carbonates of iron which form the chief ores of many countries, it seems, if the other conditions are properly arranged, that the reduction is com pleted without requiring a certain portion of the coal for this purpose. Thus Bell (in his previously cited work) has come to the conclusion that in a blast furnace 80 feet high, having about 12,000 feet cubical contents, worked with roasted Cleveland ironstone (earthy carbonate of the protoxide of iron), no special consumption of coal is necessary for the reduction of the iron ore.

The consumption of coal requisite for the reduction depends not only on the greater or less readiness of reducibility, but, as has been mentioned, on the longer or shorter period requisite for the descent of the ores through that portion of the furnace-shaft in which the temperature is sufficient for the reduction by carbonic oxide, but not high enough to again reduce the carbonic acid in contact with coal to carbonic oxide. The higher and more spacious the furnace-shaft is, the more extended must be the heated zone thus formed, and therefore the more completely can the ores be reduced before they pass into the hotter, lower portions of the shaft, where the reduction of the carbonic acid commences. The diminution of the coal required for reduction is therefore one of the causes why the consumption of coal is relatively less in large furnaces than in small ones. The further conclusion can also be drawn that the consumption of

* See Jern-Kontoret's Annaler for 1865 and Berg- und HÜ ttenmamänneshe Z eitung, 1865.

coal required for reduction will be so much the less, the more the descent of the ores is retarded by a diminution of blast. The fact must not, however, be overlooked that the consumption of coal does not only depend on that portion requisite for reduction, and that by too great a diminution of the blast the temperature of the upper portion of the hearth will soon sink to such a point that a proper fusion will no longer be possible. Hence it is clear that no saving of coal can be ac- complished by too great a decrease of the blast; but, on the contrary, that under properly regulated conditions, the least consumption of coal will be with a certain amount of blast (a certain rapidity in the descent of the charges), which last must vary under different circumstances. The separate zones in the shaft must be so regulated with respect to their position and extent, that every noticeable increase or diminution of the blast will be accompanied by an increased consumption of coal, in order to obtain a regular working of the furnace; while an increased amount of blast will prevent the preparation of the ores in the upper zones, and, on the other hand, a decreased quantity of the same will hinder a proper fusion in the lowest zone.

XXV. With regard to the heat necessary for the decomposition of the carbonate of lime, which according to Schinz * amounts, per weight-unit of this body, to $197{,}1 \times 56 / 100 = 110.4$ H. U., it is evident that this loss of heat in blast furnaces can be obviated by charging burnt lime. In order to obtain, however, any real advantage from this, it is necessary that the lime-flux should always be at hand in a freshly-burnt state, as otherwise more or less water and carbonic acid are absorbed by the burnt lime. Therefore it can never be known, without constant analyses, how much of such a par- tially-slacked lime should be weighed for each charge in order to have the wished-for amount of lime in the mixture. This same circumstance should also be regarded in the case of very ealcaieous iron ores. The more calcareous the ores are, so much the more necessary is it to bear in mind that after calcination they must not remain too long exposed to the air, and above all that they must be protected from moisture. In order to be able to preserve the necessary uniformity in the burden, ores of this kind which have been kept in stock for any length of time after their calcination, should be smelted in not too large quanties with other or recently calcinedores. The air appears to exert no action except in the case of such

* See Schinz, " Researches on the Action of the Blast Furnace," London, 1870, p. 53.—F. P.

a powerful calcination that the lime was able to combine with the silica present, or on dead-burnt lime.

In this connection it may be further remarked that the liberation of the carbonic acid from the limestone in the blast furnace can scarcely be concluded before the latter has reached such a zone of high temperature that a portion of the carbonic acid last expelled must be reduced to carbonic oxide in contact with coal. In addition to the direct loss of coal thus occasioned (twelve forty-fourths of the amount of carbonic acid reduced), the necessary consequence is a considerable diminution of heat amounting to 8080 — (2 x 2473) 12 / 44 — 854.7 H. U. per weight-unit of the carbonic acid reduced. At first sight it seems as if the loss of fuel thus caused could be avoided if the lime-flux were charged in a calcined condition; but Bell's experiments show that the calcined lime in contact with the furnace gases in the upper portion of the furnace absorbs carbonic acid from these, and as in raw limestone, this is only liberated at a higher temperature. The economy from the use of burnt lime must therefore be very small, if not infinitesimal, and must be confined to the heat necessary to expel the carbonic acid from its combination with lime. The fact that this last portion of heat is actually saved in the blast furnace, although the burnt lime again unites with carbonic acid in the upper portion of the shaft, becomes evident from the mere consideration that by this combination with the carbonic acid heat is evolved, which is rendered latent by the subsequent dissociation in the lower portions of the shaft. The question whether the lime should be charged in a calcined or raw state is confined to the consideration of how much more cheaply the lime can be burnt outside of the blast furnace than within it, which latter is but rarely the case.

In the previous calculations as to the consumption of heat in the blast furnace, the carbonic acid liberated from the limestone has been assumed to be only present in that condition, while it has here been shown that a portion of it must be reduced to carbonic oxide. It must, therefore, be here stated that the calculation was so made because it seemed simpler to consider the whole amount as carbonic acid, so long as it was impossible to tell with any degree of certainty how much of this carbonic acid was reduced to oxide. This simplification of the calculation was the more permissible as no real error thus crept into the heat-calculations. For as soon as the total amount of carbon necessary for all reductions effected in the blast furnace be assumed as given (in the present case about 12 per cent, of the free carbon present in the fuel), it is of course precisely the same in the consumption of heat whether it be assumed that a portion of the carbon is necessary to reduce the carbonic acid coming from the lime- stone, while only the remainder is used to reduce a portion of that carbonic acid which is formed by the reduction of the ores; or if, as has been done in the calculations, it be assumed that none of the carbonic acid from the limestone is reduced, and consequently so much a greater portion of the carbonic acid formed from the reduction of the ores be calculated as reduced to carbonic oxide. The amount of carbonic acid reduced remains the same in either case, and consequently the quantity of heat used in this reduction must remain the same.

XXVI. The progress of gasification of the water contained in the fuel, assuming that the coal is charged at a temperature of 5° C,, consumes 95 + 536 = 631 H. U. for each weight-unit of the water converted to steam at 100° C. In addition to this the hotter current of gas must impart to the steam formed sufficient heat to make the whole gas-mixture of a nearly uniform temperature. By this interchange there is no heat actually lost; but since the same amount of it has to be distributed over a greater quantity of gas, the temperature of the gas-mixture is lowered, and thus diminished in one way or another must act injuriously on the warming of the colder materials which come in contact with it; since through the decreased difference of temperature between the materials charged and the ascending gases the communication of heat is lessened. The final loss of heat, on the other hand, due to the gases escaping from the blast furnace, is less when wet coals than when dry ones are used, since these gases, in consequence of the heat withdrawn from them by the vaporization of the water, do not possess so large an amount of heat when the former as when the latter are made use of.

In the calculation stated, the amount of water in the coal was assumed as being only 10 per cent., and in consequence it was taken for granted that the coal was dry. A basket of such coal weighs 60 Ibs., and consists of:

49.2	Ibs.	carbon,
1.2	"	ash,
6.0	"	water,
3.6	"	other volatile bodies.
60.0	Ibs.	

In such a coal the amount of heat necessary to volatilize the water amounts per pound of coal or per 1/60th of the basket to 63,1 H. U, If it be examined how much heat is requisite to volatilize the water by coal, otherwise similar, but burdened with water to such a degree that the basket weighs 100 Ibs., which is consequently composed of:

49.2	Ibs.	carbon,
1.2	"	ash,
46.0	"	water,
3.6	"	other volatile bodies.
100.0	Ibs.	

and therefore contains 46 / 6 =7.6667 times more water than the dry coal, we find the following :

Just as much heat would be obtained in the blast furnace from 1.60 of this wet coal as from 1 Ib. of the dry, were it not that when the former is used more coal is required for reducing owing to the shortened period of reduction due to imperfect heating, and consequently less is left to be burnt by the blast. Since it is not, however, possible to state with any certainty, on the basis of experiments already made, how much more coal, in consequence of a certain percentage of water in the fuel, is necessary for the reduction, it must be provisionally granted that the same amount of heat is generated in the blast furnace per cubic unit of wet coal as of dry. In spite of this decidedly too favorable concession to the wet coal, the diminution of heat caused by the large amount of water remains in any case very great, for while in the case of coal assumed to be dry, 63.1 H.U. are necessary to gasify the water, the consumption of heat in this operation amounts in the case of wet coals to 7.6667 *X* 63.1 = 483.8 H.U.

This loss of heat is still further increased if the water in the coal is frozen to ice; since the amount of heat necessary to melt the ice has to be added, which is 79 H. U. per pound. In place of the 631 H. U. which have been assumed in what precedes, as necessary to gasify 1 Ib. of water, there are requisite in the case of ice at a temperature of 0° C. 79 + 636 = 715 H. U. If therefore the coal contains instead of water a corresponding weight of ice or snow, the loss of heat in the case of dry coal amounts to 71.5 H. U. and in the case of wet to 7.6667 x 71.5 = 548.2 H. U.

The loss of heat to the blast furnace caused by the amount of water in the coal is, on the whole, certainly less than the figures stated above, since the temperature of the escaping gases is diminished by the heat consumed in vaporization. But the figures given still show forcibly enough how absurd it is to expect as good results from a furnace working with wet coal, as one with dry; and it is also clear from this fact how important it is to keep the charcoal under cover, and that the outlay thus incurred must very soon be repaid.

XXVII. The quantity of heat conducted off by the tunnel-head gases* is very considerable, as the calculations above show, since in the assumptions stated, with every degree of heat by which the temperature of the escaping gases exceeds that of the air, 1,3 H. U. are removed from the blast furnace per weight-unit of coal charged.

The gases produced in the upper portion of the hearth, which in their ascent through the furnace-shaft are increased by the gases produced in the reduction and in part by those evolved from the fuel and the charge, part with a portion of their heat to the materials descending the shaft. This interchange of heat must be the more complete, the greater the amount of solid materials through which the ascending gases must pass, or the longer the period of contact between the gases and solid materials continues. In proportion as the gases can part with a greater quantity of heat to the descending materials, so much the less will be the loss of heat produced by the escaping tunnel-head gases, from which it follows that the larger the blast furnace, the more completely will the heat of the gases be utilized. While, on the other hand, a slower descent of materials also contributes, up to a certain limit, *by* prolonging the period of contact, to the same end, by causing the materials to absorb more heat from the gases.

The greater the difference in temperature between the materials to be fused and the gases heating them, the more quickly will the materials be heated, which accounts for the rapid decrease of temperature in the upper portion of the furnace-shaft. From this the reason is evident why the saving of heat produced by enlarging the furnace-shaft does not stand in a constant proportion to this enlargement, but is, on the contrary, for a certain increase of volume proportionably less, as the furnace-shaft was already larger before this addition. Thus experience has proved, in Sweden, that the saving in fuel, by raising a furnace forty feet high to fifty feet, was considerably less than in raising one from thirty to forty feet.

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* The term *tunnel-head gases*, instead of *waste gases*, is used here, as elsewhere; 8s the gases can in no respect be regarded in the present condition of iron metal lurgy as waste.—F. P.

This fact last mentioned becomes more evident from a consideration of the determination of temperatures made by Bell at four of the coke blast furnaces of the Clarence Iron-works, in the Cleveland district, which were of different heights, but otherwise worked under like conditions. The degrees of heat thus determined have, when taken each by itself, of course, no general application, least of all in the case of charcoal blast furnaces working under very different conditions. But if they are compared, they afford a striking proof of the fact just mentioned, on which account the graphic representation given by Bell is here repeated in Fig. 1.

In this figure the temperatures of the tunnel-head' gases determined by direct observation (845° F. = 452° C. for a capacity of shaft of 6012 cubic feet, 610° F. = 321° C. for 11,578 cubic feet, 595° F. =313° C. for 15,363 cubic feet, and 587° F. =308° C. for 25,497 cubic feet) are indicated by dots, and united by a curve, which shows the corresponding temperatures of furnaces working under similar conditions, the cubic contents of which lie between these amounts. It may be added that the furnace containing 6012 cubic feet was 48 feet high, and that containing 11,578 cubic feet was 80 feet high.

The economy of fuel obtained by enlarging the blast furnaces depends, however, not only on the lower temperature of the tunnel-head gases, but also (as has already been shown in the question concerning reduction) on the reduction promoted by increasing the volume of the furnace. On which account the economy of fuel in the furnaces examined by Bell did not increase in a proportion corresponding to the lower temperature of the tunnel-head gases and the saving in heat thus obtained, but in the proportions as graphically shown in Fig. 2.

While discussing the question of the heat lost by the escaping tunnel-head gases, a few words may here conveniently be said of the considerable loss of heat which is caused when the blast-furnace gases are taken off at some distance below the tunnel-head in order that they may be of further use. The greater this distance, so much the less heat can the gases part with before being taken off, and consequently so much the greater must be the loss of heat *to* the furnace. The temperature of the gases is 800° C. when taken off at the depth common in Sweden of one-third the distance from the furnace-top, and if the whole gas mixture on leaving the furnace possessed such a temperature, there would be withdrawn from the furnace an amount of heat of 1.3 x 800 = 1040 H.U. per weight-unit of the fuel charged.And if to this we join that loss which must be added to the reduction, caused by taking off the gases at such a depth, it is clear that the explanation of the fact that only within the last few years in Sweden the down cast have been placed higher (i. e., nearer to the

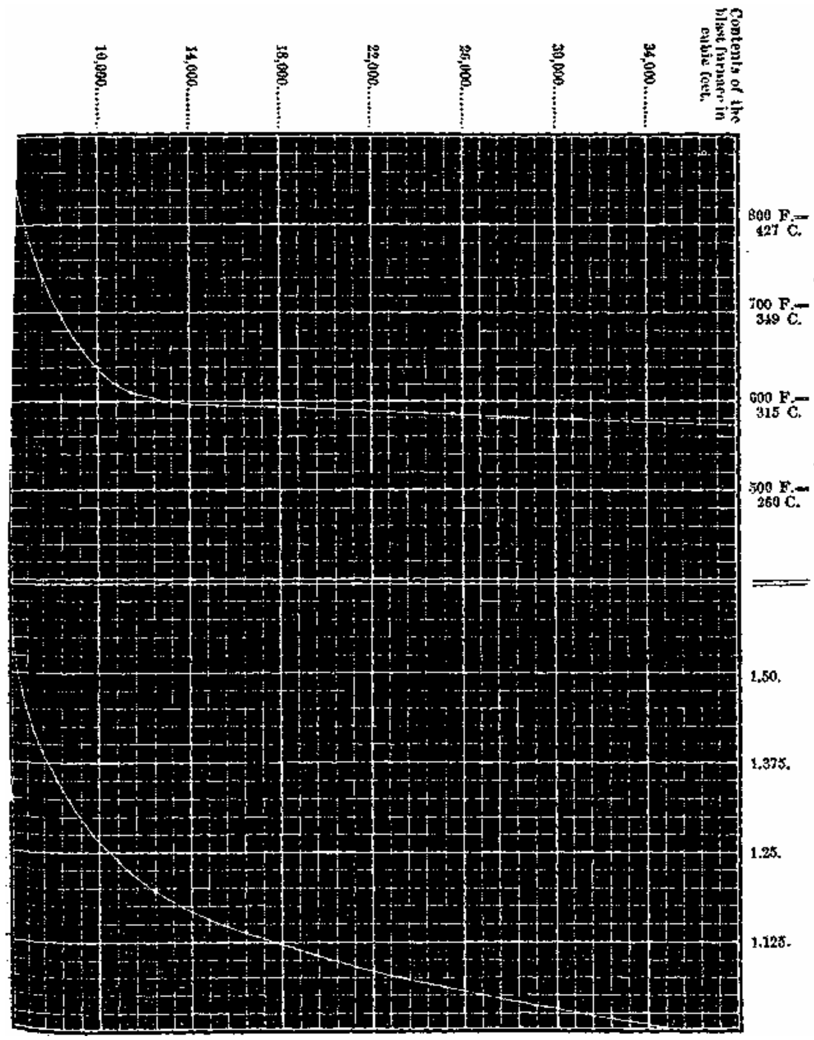

Fig. 1.—Temperature of tunnel-head gases.

Fig. 2.—Relative consumption of coke.

tunnel-head), is to be found in the relatively small quantities of gas winch were in this way withdrawn from the furnace in order to be used elsewhere.

Without a closed tunnel-head, however, the whole quantity of gas cannot pass through the entire column of materials charged, and still less can the gases to be used elsewhere be completely led off. On which account the author expresses the hope that in Sweden also the proposition to use closed tops will be assented to very soon.

It must finally be remarked that the size of the separate charges also exerts an influence on the amount of heat carried off by the tunnel-head gases, since the longer the period before a new charge is thrown into the furnace, so much the deeper has the last charge sunk in the furnace-shaft and so much the more incompletely is the heat of the gases utilized. The smaller the blast furnace the more easily must it be affected in this respect, since the increase of temperature downwards augments much more rapidly in small furnaces than in large ones. How much the loss of heat thus occasioned amounts to in some of the English furnaces is clearly seen from observations made by Bell on two coke-furnaces, of which the one had 15,000 and the other 25,000 cubic feet capacity. Immediately after charging, the temperature of the gases was nearly the same in both furnaces, viz., 204° to 233° C.; but after one and a half hours, the period customary at these furnaces between succeeding charging, he temperature of the gases assing off from the smaller furnace ad attained 520° to 560° C., while that of the larger one was only 455° to 485° C.

To prevent unnecessary loss of heat, the charger should, when the charcoal is so wet as not to catch fire at the tunnel-head, charge another basket of coal so soon as there is space enough for it.

XXVIII. The loss of heat occasioned by cooling the tuyeres with water does not seem to be especially worthy of notice, to judge from the experiments made and mentioned in what has preceded, at least so long as the number and size of the tuyeres are not greater than commonly met with in Sweden. This loss of heat must, however, necessarily increase in proportion as the tuyeres project more and more into the furnace from the burning away of the hearth. In any case it does not seem advisable to conduct so much water through the tuyeres, that on escaping it should be entirely cold, since a more considerable cooling of the tuyeres than is necessary to preserve them, always occasions an unnecessary, even though not consider-able, chilling of the hearth, and frequently, also, the formation of *a nose (i. e.,* slag prolongation of the tuyeres).

In blast furnaces of various countries, where the attempt has been made to use as many tuyeres as possible, the loss of heat occasioned by water-tuyeres must be considerable. Thus, for example, at the Thomas Iron-works, in Pennsylvania, it was found necessary for this reason to diminish the number of tuyeres from twenty-three, the number set previous to blowing in, to eleven.

XXIX. With regard to the loss of heat occasioned by the tymp and fore-hearth, it is evident that it must be less, the. smaller the exterior of the parts mentioned is and the less cooling produced by the wearing of the fore-hearth. The most radical move made in this direction is that of arranging the furnaces with a closed breast, as is customary in Styria, where there are no other openings than a tapping-hole at the bottom for the pig-iron, and a second tap a few inches below the level of the tuyeres for the cinder. In order to prevent the cinder-tap from being too readily attacked by the liquid cinder, and, consequently, being too much enlarged, it is constructed of iron, and, like the water-tuyeres, provided with an annular opening, through which water flows for the purpose of cooling. These so-called Lurmann's cinder-taps have recently been extensively introduced, especially in Germany,* and it is asserted, with respect to them, that they diminish the cooling of the hearth, as well as produce a shorter interruption in the working of the furnace when casting the iron ; so that considerable advantages are claimed for them,

XXX. The amount of heat lost through the exterior walls of the furnace depends, first of all, on the thickness** and power of conducting heat which they possess. Consequently, a blast furnace built of cinder-bricks, as sometimes occurs in Sweden, will lose more heat in this manner than one having equally thick walls built of sand or clay bricks, since the last-named have less power of conducting heat. The loss must also vary with the proportions existing between the surface of contact and cubical capacity of the furnace, so that the loss will be less in a broad and low furnace than in one of the same

* These cinder-taps were extensively introduced into the Lehigh Valley, but have been almost entirely again abandoned, there being, so far as the translator is aware, but a single one still in use there. The reasons given for throwing them aside vary. Some iron-masters say that the anthracite coal decrepitates so much as to choke up the cinder-tap, while others claim it is owing to the opposition of the furnace-keepers, who do not like being deprived of the coal they obtain under the plan of working with an open, breast and fore-hearth. There is no doubt of its success and economy when using some kinds of bituminous coals.—P. P.

** With regard to some experiments made with furnaces having very thin walls, the reader is referred to the Engineering and Mining Journal, vol. **xiv,** pp. 264 and 307, and Engineering, vol. xiv, pp. 208 and 281; also Berg- and Huttenmannische Zeitung, 1870, p. 436, with drawing of the furnace.—F. P.

capacity, which is narrower and higher, and possessing, therefore more surface. Besides which this loss of heat must, self-evidently, depend on the difference of temperature existing between the interior and exterior of the furnace, and is, therefore, somewhat greater in winter than in summer. But in the same season, and when making a uniform quality of iron, this difference in temperature, in the same furnace, can scarcely vary to such a degree that the amount of heat lost in this manner can be perceptibly changed. The loss of heat thus produced, must, therefore, in one and the same furnace, really depend on the time and the weight of the charcoal charged or pig- iron produced. Consequently, it will become relatively smaller as the number of charges or the production is increased within a given unit of time.

XXXI. It has already been shown that by increasing the number of charges, the warming of the materials to be smelted *is* diminished in the upper portions of the furnace, and if it also is borne in mind that the loss of heat by radiation from the walls of the furnace, is much diminished, per weight-unit of pig-iron produced, by increasing the number of charges, it then becomes very evident, that the changes in the number of charges, afford the most available means to effect an unequal distribution of heat in the interior of the blast furnace, since by increasing the number of charges the heat can be concentrated as much as possible in the lower portions of the furnace, while by decreasing the rapidity with which the furnace is charged, a more uniform distribution of the same through the furnace in an upward direction can be obtained.

XXXII. If it be assumed that the air contains as much water as it is possible for it to absorb at 5° C., the amount of heat conducted into the furnace, obtained by heating the blast, is per weight-unit of blast forced into the furnace: 0.2304 X 0.2182 + 0.7640 X 0.244 + 0.0056 X 0.475 = 0.239 H. U., for each degree Centigrade which the blast brought with it into the furnace. The amount of heat thus carried into the furnace, which with a temperature of blast of, for example, 205° C. (according to the preceding calculations with regard to heat), amounts per weight-unit of fuel charged to 184.2 H. U., or 12.5 per cent, of the total quantity of heat conducted to the furnace (1796.3 H. U.), does not, however, appear to correspond to the saving in coal attained in practice, which latter, by the use of heated blast, is generally much greater.

Most metallurgical writers, as Tunner, Percy, Wedding, etc., have attempted to explain this important phenomenon by the more active combustion which is produced by heating the blast. The total quantity of heat in the furnace cannot, however, be increased by such a lively combustion. Since even if it be assumed that the hot blast in the focus of combustion renders this last more perfect, and produces more carbonic acid than is the ease by the combustion with cold blast, still 116 actual saving of heat is attained, since it would then happen that the carbonic acid thus produced would not again be reduced by the white-hot coals to carbonic oxide. This reduction appears, however, always to occur, since the analyses of blast-furnance gases hitherto made, show, that in the case of hot as well as cold blast, the carbonic acid first formed in the focus of combustion, is immediately reduced to carbonic oxide on coming in contact with the white-hot coals with out the focus. Therefore, the production of heat will, on the whole, be no greater in the one case than in the other, or as if the whole of the oxygen contained in the blast had from the beginning been used for the production of carbonic oxide only. The influence of the more active combustion produced by the heated blast, must be con- fined, therefore, to a narrower limitation of the focus, within which the heat is more concentrated.

Within the focus the gases are well known to be oxidizing in their action, and the limitation of the actual space of combustion can therefore be, without doubt, of use, especially when employing a high pressure of blast. This limitation can be advantageous more especially in the case of coke, since the reduction by this dense fuel of the carbonic acid formed does not take place with the same ease or so rapidly, as in the case of charocal; although with an increased temperature, the reducing power of the coke must also increase. We must also look to this difference as the reason why the use of the hot- blast has been of greater advantage in coke blast furnaces than in charcoal ones. The limitation of the space of combustion in blast furnaces using charcoal, may also be of some advantage, and in any case, the hot blast has the advantage of keeping the mouth of the tuyere more readily clean. But if the saving of coal attained by the hot blast, together with the gain of heat, which, according to the ordinary calculation, is conducted to the furnace, were actually to be ascribed only to the action obtained by confining the space of combustion, as appears from a cursory examination, the action would in fact be unexpectedly great.

A closer examination shows, however, that the heat which is conducted to the blast furnace by heating the blast, acts, compared with the heat produced in the furnace by the combustion of the coal, very differently from what has hitherto been assumed, since it has hitherto been overlooked that, by the combustion of the coal, a portion of the heat thus produced (depending on the temperature of the tunnel-head gases) does not become available to the furnace, while on the other hand the heat conducted in by the hot blast is, with scarcely any deduction, utilized in the furnace. Not a cubic inch more of gas is produced in the blast furnace by the heat introduced into the furnace by the hot blast, than would be the case if ice-cold blast were used to consume the same quantity of coal. If, therefore, the excess of heat remaining in the furnace should be properly utilized, the tunnel gases withdrawn from the furnace do not need to carry off any more heat than would be the case with cold blast. The case is entirely different, if the heat carried into the furnace by the hot blast must be replaced by an increased charge of coal, or what is the same thing, by the combustion of more coal, since this can- not take place without increasing the quantity of gas, which increase is unavoidable from the augmented amount of coal burnt and quantity of air necessary to its combustion ; and in proportion as these increased products of combustion pass of from the furnace in a hotter condition, so must the portion of heat remaining in the furnace, produced from this augmentation of the coal, become less.

In order to illustrate better this comportment, we will examine how great this saving of fuel is, which is produced by the use of the hot blast in a furnace working under the conditions assumed in the heat calculations made in § VII, and the following paragraphs.

As the charcoal consists of 82 per cent. carbon, 2 per cent. ash, 10 per cent. water, and 6 per cent. gases, which volatilize at high temperatures (consisting of 55.9 per cent. carbonic acid, 22.8 per cent. carbonic oxide, 11.8 per cent. marsh gas, 1 per cent. hydrogen, and 8.5 per cent. nitrogen), there is necessary to burn the carbon present in one pound of the charcoal to carbonic oxide, 1.0933 lb. oxygen, which is contained in 4.6444 lbs. air. This amount of air contains, in addition to the oxygen, 3.5483 lbs. nitrogen, and in the assumed quantity of gasified water there is 0.0028 lb. hydrogen. The gas-mixture, formed by the combustion of one pound of char- coal with air to carbonic oxide, consists, therefore, of—

0.06×0.559	$= 0.0335$	lb. carbonic acid.
$0.06 \times 0.228 + 0.82 \times 28 \div 12$	$= 1.9270$	" " oxide.
0.06×0.118	$= 0.0071$	" marsh gas.
$0.06 \times 0.01 + 0.0028$ . .	$= 0.0034$	" hydrogen,
$0.06 \times 0.085 + 3.5483$ . .	$= 3.5534$	" nitrogen, and
	0.1000	" aqueous vapor.

The heat produced by this combustion amounts, per weight-unit of the charcoal, to: 0.82 x 2473 — 0.0028 x 29638 = 1944.87 H.U. To vaporize the water contained in the charcoal, 63.1 H.U. are necessary, and the heat conducted off by the tunnel-head gases amounts to: (0.0335 x 0.2164 +1.9270 x 0.2479 + 0.0071 x 0.5929 + 0.0034 x 3.4046 + 3.5534 x 0.244)450 + 0.1 x 0.475 x 350* = 1.368 X 450 + 16.6 = 632.2 H.U. The quantity of heat carried off from the furnace for each pound additional of the charcoal thus consumed amounts, therefore, to 63.1 + 632.2 = 695.3 H.U. And the heating power in question thus utilized in the furnace amounts to 1944.67 — 695.3 == 1249.57 H.U., or to 64.26 per cent. of the quantity of heat produced by the combustion of one pound extra of charcoal added.

It has already been shown, that the quantity of heat which is carried into a furnace working under the conditions assumed, with a temperature of blast of 205° C., amounts to 10.2 per cent. of all the heat which falls to the lot of the furnace. If we consider, in addition to the just mentioned relation, that only 64.26 per cent. of the heat produced by the combustion of the extra coal in the furnace is utilized, it becomes evident that the saving of fuel attained by the hot blast is not confined to this 10.2 per cent.; but, leaving out of consideration the advantages possibly attained by a more active combustion, that it amounts to 10.2÷ 0.6426 =15.87 per cent. of the amount of fuel required with cold blast.

XXXIII. From what has been stated, the reason at once becomes clear, why the saving of fuel, obtained through the hot blast, varies so much in furnaces of different dimensions, and working under otherwise different conditions. Since in proportion as the heating power of the fuel charged is more perfectly utilized within the furnace, the saving produced by heating the blast will decrease; and the reverse is also true.

The smaller the blast furnace is, and the greater distance below the top the furnace gases are withdrawn, so much the greater must be the saving in fuel which can be produced by heating the blast; and inversely, the larger the furnace, and the nearer the top the gases are taken off, so much the less must be the influence of the heated blast on the consumption of coal. Could such a point be attained, that the temperature of the gases passing away from the blast furnace was not higher than that of the exterior air, and that

* Compare the note at the close of § XVI.

the fuel used contained no volatile ingredients whose gasification consumed heat, then, indeed, heating the blast would be of not much greater advantage than that corresponding to the quantity of coal which, by its combustion, produces just as many heat-units as are carried into the furnace by the heated blast. But since such a perfect utilization of the heating power of the fuel charged cannot be attained, even in the largest furnaces, the heating of the blast must always cause a saving of fuel, even in those cases where the blast-furnace gases could very well be otherwise used.

It becomes also evident from what has preceded, that the larger the quantity of volatile ingredients in the fuel, especially the more moisture it contains, so much the greater must be the effect of the hot blast, since a considerable amount of heat is rendered latent and carried off by the gases in the gasification of these volatile ingredients, as appears proved by the preceding calculations.

Even the moisture of the air must affect the action of the heated blast in such a manner that the saving of fuel with a certain temperature of blast must be the greater the more water the air contains. The reason for this is soon discovered if it be remembered :

1st. That the moisture of the air, for the reasons mentioned in § XXI, always lowers the temperature of the furnace ; hence, in pro- portion as the air contained more water, it must be the more advantageous if, in consequence of the use of heated blast, less air has to be blown into the furnace per weight-unit of pig-iron made; and

2d. That the specific heat of steam is very considerable ; therefore the amount of heat of the blast corresponding to a certain temperature must be so much the greater the more moist the air is.

Finally, attention is particularly drawn to the following comportment. Since the action of the heated blast on the consumption of coal depends upon the quantity of air blown in per weight-unit of pig-iron, and this, in turn, is based on the amount of coal required for the same unit which has to be burnt by the blast, the saving in coal obtained through the hot blast—provided the same is calculated not in per cent. of the fuel requisite with cold blast, but by measure or weight—will become relatively less as the consumption of coal is smaller when working with cold blast. From this it also follow.-* that it cannot be demanded for each degree of heat by which the temperature of the blast is increased that the same saving of fuel in tons or pounds shall be attained, but rather that in proportion as the number of degrees increases the saving of fuel must be some- what diminished, since the gain in fuel amounts to about the same per cent. as the decreased amount of coal for each degree of the increased temperature of blast. The burden of ore that can be charged, by an unaltered charge of coal, relatively surpasses the temperature of the blast, in the same proportion as the consumption of fuel, calculated by volume, is less than the same temperature of the blast proportionally increased in degrees. This can be seen from the following example. Let it be assumed that with an increased temperature of blast of 100° C. the saving of fuel amounts to 10 per cent. of the quantity of coal previously required, and let the amount of fuel consumed per hundredweight of pig-iron and at 0° C. temperature of blast be designated by *a*, and the burden of ore charged to this quantity of coal by 6, it will be found—

At 0° C. temperature of blast.	The consumption of coal a.	The saving of coal.	The ore burden b.
" 100° C. "	$0.90a$	$0.10a$	$1.11b$
" 200° C. "	$0.9 \times 0.90a = 0.81a$	$0.19a$	$1.23b$
" 300° C. "	$0.9 \times 0.81a = 0.729a$	$0.271a$	$1.37b$
" 400° C. "	$0.9 \times 0.729a = 0.656a$	$0.344a$	$1.52b$
" 500° C. "	$0.9 \times 0.656a = 0.59a$	$0.41a$	$1.69b$
" 600° C. "	$0.9 \times 0.59a = 0.531a$	$0.469a$	$1.88b$

The saving in coal for every 100° C. which the temperature of the blast is increased amounts therefore—

For the first	100° C. to	$(0.10 - 0.)a = 0.10a$
" second	"	$(0.19 - 0.10)a = 0.09a$
" third	"	$(0.271 - 0.19)a = 0.081a$
" fourth	"	$(0.344 - 0.271)a = 0.073a$
" fifth	"	$(0.41 - 0.344)a = 0.066a$
" sixth	"	$(0.469 - 0.41)a = 0.059a$

While the burden of ore charged into the furnace with an unaltered charge of coal:

For the first	100° C. increases	$(1.11 - 1.00)b = 0.11b$
" second	" "	$(1.23 - 1.11)b = 0.12b$
" third	" "	$(1.37 - 1.23)b = 0.14b$
" fourth	" "	$(1.52 - 1.37)b = 0.15b$
" fifth	" "	$(1.69 - 1.52)b = 0.17b$
" sixth	" "	$(1.88 - 1.69)b = 0.19b$

XXXIV. It has already been shown that beat is carried into t furnace by heating the blast, without simultaneously increasing the quantity of gas. If now it be assumed that the endeavor should be quality of pig-iron as when using cold blast, the burden of ore will.

have to be raised as high as the desired quality of pig-iron and a good working of the furnace demand. So that in any case, with an unaltered charge of coal and the use of hot blast, the burden of ore will be greater than with cold blast; and consequently, when using the former, the quantity of gas passing off from the blast furnace will be less per weight-unit of ore charged than with the latter. But since the reduction of ores is chiefly effected by the gases, this reduction is rendered more difficult in proportion as the quantity of reducing gases becomes relatively less than the ores. The more imperfectly reduced the ores arrive at the upper portion of the hearth, the n ore heat must be present in the hearth to keep the furnace working well. For this reason it is scarcely permissible to increase the ore to an amount fully corresponding to the quantity of heat carried in by the blast.

In proportion as the furnace is worked with a higher temperature of blast, there must occur a somewhat greater excess of heat in the hearth of the furnace. In addition to which, account must be taken of the concentration of heat, previously mentioned, which is a consequence of the more rapid combustion produced by the use of heated blast. If, therefore, the temperature of the blast is raised, there must be, in spite of the permissible increased burden, a somewhat higher temperature near the tuyeres. But the higher the tempera ture is at this point the more must silicon and earthy metals, such as calcium, magnesium, and aluminium, be reduced from the change, and the more impure (or poorer in iron) will the pig-iron thus obtained be. But since the increased temperature of blast, as well as the increased amount of silicon in the pig-iron, promotes the separation of carbon as graphite, the pig-metal receives a greater inclination to become gray as the temperature of the blast is more elevated. Since also manganese belongs to the class of bodies requiring a very high temperature for their reduction, it will occur, in case the charge is manganiferous, that the heated blast will contribute to the production of a manganiferous pig-iron. Finally, the removal of sulphur from iron is promoted by a high temperature, and passes as calcium sulphide into the cinder. Therefore, the hotter the blast is when used, the freer from sulphur will the pig-iron be; the more so as from the saving in fuel produced by the heated blast, less of the sulphur contained in the fuel will be charged, which may be of some importance, especially in the case of sulphurous coke.

After these explanations, it would not be justifiable to entirely deny, as is sometimes done, the influence of the hot blast on the character of the pig-iron. But, on the other hand, the influence in question is more commonly too highly estimated; so that in some localities, from fear of a deterioration of the pig-iron, the advantages of the hot blast and consequent economy of fuel and more easy regulation of the working of the furnace have been entirely renounced, although these advantages become perceptible at a degree of temperature of the blast at which the action on the quality of the pig-iron is not to be reasonably assumed. For, although the amount of gas produced per weight-unit of the ore-burden is very soon perceptibly changed by the hot blast, still there is in the blast furnace, if not an actual excess, at least such a richness of reducing gases present, that a small decrease in the amount of gas cannot possibly exert a perceptible influence on the quality of the pig-iron. If, however, the temperature of the blast is very high, then indeed such considerable changes take place in the quantity of reducing gases, as also in the concentration of heat, that by the otherwise unaltered working of the furnace it cannot be expected to produce a pig-iron as poor in silicon as when using cold blast and the same mixture of ores. If, on the contrary, it be desired to produce as nearly *as* possible the same quality of pig-iron from two dissimilar charges, it will naturally follow that of the two the more basic charge will be able to stand a higher temperature than the more silicious one.

XXXV. If it be assumed that the coefficient of expansion of the air is 0.00367, and that with a temperature of blast increased to t°C. the same number of charges are carried by the furnace, the volume of blast forced into the furnace must be 1 4+ 0.00367t times greater than with cold blast. If, therefore, hot blast is to be used, it be comes necessary to adopt more powerful blowing-engines. It will first of all be discussed, presupposing that an unlimited amount of blast is at disposal, whether the number of charges has been modified in one way or another by heating the blast.

In the preceding it has been indicated how the slightest consumption of coal in a blast furnace is dependent on the number of charges, which under the given conditions preserve the equilibrium, so to speak, between the different zones, in such a manner that if from any cause this number of charges be perceptibly increased or diminished, the consumption of coal will in either case be greater: by a diminution in the number of charges, since a certain quantity of coal must be sacrificed to properly heat the lower portion of the furnace (the hearth), and also by an increase, as the reduction thus diminished in the upper portions of the furnace occasions a loss of coal. Since it has also been shown that the reduction is impaired by heating the blast, on account of the diminution in the quantity of the reducing gases, it is evident that increasing the number of charges and heating the blast must exert an unfavorable influence upon it in this respect. It consequently follows that in order to preserve so far as possible a uniformity in the quality of the pig-iron, it becomes necessary to diminish the number of charges in proportion as the blast passes into the furnace at a more elevated temperature. It must not be supposed from this that the number of charges is diminished in such a proportion as to produce the same quantity of pig-iron in any unit of time, since the ability of carrying a greater burden of ore due to the heated blast may somewhat increase the production of pig-iron, iron, although not to the same degree as if the number of charges remained unaltered.

In order to more clearly explain the views just stated, attention is once more called to the fact that we have started with the assumption that a definite number of charges is the most serviceable in a blast furnace working with cold blast to produce the quality of pig-iron desired. If this is not the case, and it becomes necessary, when using cold blast, to be satisfied with a less number of charges, for some particular reason, it is evident that the number of them, when using a highly heated blast, is not only to be left unchanged, but under some circumstances that an increased number can be useful. These peculiar circumstances may be: such a refractory mixture of ores and fluxes that, when blowing with cold blast, it is scarcely possible to keep the tuyeres clear; or the existence of too weak a blowing-engine, which is, however, rendered more effective by the introduction of heated blast.

Finally, some examples of working results, taken from ,*Jern- KontoreCs Annaler,* are here reproduced, which have been attained by the use of hot blast in various Swedish blast furnaces.

In five blast furnaces of the Norberg mining district, which had an average capacity of 146 tons* (132 to 164), the average results given in the row 1 were obtained in 1854, by the use of cold blast, while those given in 2, are the results of five other furnaces of the same district, having an average capacity of 160 tons, and were worked with a blast heated to 160° to 200° C.

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* The translator is uncertain whether the author means the Swedish ton equal to 5.1 cubic feet, or the Prussian ton equal to 7.75 cubic feet, or the Austrian equal to 11.2 cubic feet___F. P.

	Consumption of coal, per cwt. pig-iron,	Pig-iron produced from the charge.	Production of pig-iron in 24 hours.	Amount of fuel consumed.
1.	2.20 tons.	38.2 per cent.	102.8 cwt.	246.2 tons.
2.	1.75 "	40.4 "	131.5 "	232.1 "

From these figures it appears that in these small blast furnaces of the Norberg district, by heating the blast to 160° to 200° C., and by a slight increase of the capacity, there has been 24.5 per cent. Fuel saved, and an increased production of 28 per cent. While on the other hand the same increase of capacity has diminished the amount of coal consumed (i e., diminished the number of charges) 5.7 per cent.

The seven blast furnaces in the Diocese of Nora, which began to use hot blast in 1851, whose temperature is not, however, given, showed an average decreased consumption of coal of 22.8 per cent., compared with the four furnaces of the same diocese, using cold blast,

XXXVI. It has already been shown in the preceding discussion, that in proportion as the blast is hotter, the pig-iron produced will contain more silicon and earthy metals, as well as manganese, if the latter is contained in the burden. As the earthy metals usually occur in very small quantities in the pig-iron, compared to the silicon, and as the amount of manganese in the charge is rarely larger than is desired in the pig-metal, then—leaving the influence of the hot blast on the manner of occurrence of carbon in the pig-iron out of account—there is every reason for the assertion that, to attain as great a saving in coal as possible, the blast should generally be as high as appears permissible with respect to the amount of silicon wished for in the pig-iron.

It is assumed to be a well-known fact, that the amount of silicon in the pig-iron depends not only on the temperature to which the blast is heated, but also on the quantity of silica present in the charge. That consequently, in order to produce a certain quality of pig-iron, the blast can be more highly heated in proportion as the charge is more basic (contains less silica).

— XXXVII. From the principle last laid down it follows that in the production of Bessemer pig with charcoal it must be advantageous to blow with a much higher temperature of blast than has hitherto been the case, since the pig-iron will thus become hotter (although in consequence of the increased amount of graphite it will be more viscous and consequently more inclined to cool), and consequently will contain more silicon and manganese, which is of great importance in using this quality of pig, as they contribute more than any other bodies to increase the temperature in the Bessemer process.

That this influence of an increased amount of silicon in the pig-metal, universally recognized outside of Sweden, has not been so generally confirmed in Swedish Bessemer works, is probably due to the weak motors of the Bessemer blowing-engines, since an increased amount of silicon in the pig probably decreases the rapidity of refining it in such a manner that an increased pressure of blast together with a simultaneous elevation of the bath of pig-iron becomes necessary, and since, too, the temperature is dependent not only on the amount of the heat-producing body, but on the time within which the combustion takes place. It follows from this that in case the blowing-engines are not powerful enough to force in the amount of blast necessary to rapidly conclude the refining period in the pig-metal rich in silicon, the process can easily be prolonged, that the *blow*, on account of the cooling caused by radiation, not only is not hotter, but may even be cooler, than if the pig could be more readily refined; the more so as pig-iron, rich in silicon, generally contains more graphite, and is, therefore, more viscous, and consequently offers more resistance to the blast. This is, however, a difficulty which can be overcome by the use of more powerful blowing-engines ; and when this has been done, it will undoubtedly be found everywhere in Sweden, that an increased amount of silicon in the pig-iron promotes a hot *blow* in the converter.

XXXVIII. A high temperature of blast (about 500° C.) seems to be also very advantageous in the production of pig-iron which is to be remelted and used for the production of ordinary castings; since a large amount of graphite and at least one per cent, of silicon is desirable in this kind of pig. It is, indeed, true that such a foundry- pig does not possess so great a strength as a lower grade of pig-metal, as the former contains less chemically combined carbon and more graphite mechanically disseminated through it, which diminishes the density, and since the larger amount of silicon it contains probably diminishes its strength. But, on the other hand, the absolute strength is of but little value for ordinary castings as compared with avoiding a too hard, brittle condition. This brittleness can best be prevented when the pig-iron contains so much silicon and graphite that on remelting and at once casting it in thin portions, it does not harden and become white. Besides this, the pig-iron, rich in silicon and graphite, possesses the property, much valued at most foundries, that in proportion as it contains more of these substances it will permit a greater addition of old iron and refuse when remelting it in cupolas.

XXXIX. If, on the contrary, a pig-iron to be used in large castings is desired, requiring the greatest possible strength, then the blast should be forced into the furnace at a less elevated temperature, especially when these are to be cast directly from the blast furnace. Such a pig-iron should contain but little silicon or graphite, and should be of such a quality that the castings produced from it should appear minutely speckled on a surface of fracture, or show a minute network of gray meshes, with small light, although not perfectly white, interstices. Besides which, the graphite, which is present in this sort of pig-iron, should be in very small particles, imperceptible to the eye, and not in large, lustrous scales, which are apparently caused, for the most part, by a high degree of heat in the iron, especially when this is accompanied by a slow solidification and cooling.

XL. No kind of pig-metal is probably so sensitive to the influence of the heated blast as that used for malleable cast-iron; since although the amount of silicon it contains is not very inconsiderable, it ap- pears that the pig-iron, which before being softened is white, is much inclined during the process named to segregate a gray kernel in its interior, to which circumstance is due the fact that many kinds ofpig-iron are unsuitable for this process.

XLI. In order to determine the amount of silicon which is suitable for the pig-iron to be used in puddling, at least as this process is conducted at Motala, a number of experiments have been made, from which it appears that in such a pig-iron the most suitable amount of silicon is between 0.22 and 0.5 per cent. The same appears to be true in those kinds of pig-iron which are to be subjected to the finery process by means of the Franche-Comte and German Finery Forges; in the production of which sorts of iron a very high tem-perature of blast appears to be scarcely suitable. On the other hand, the pig-iron destined for the Lancashire Forge must be made with a low temperature of blast, and the amount of silicon it contains should be between 0.2 and 0.3 per cent., and in producing such iron a high temperature of blast can therefore scarcely come in question. According to the author's views, if the character of the charge is not more than usually basic, the temperature *of* blast of 200° C ordinarily employed in Swedish blast furnaces, cannot be judiciously much exceeded.

XLII. Since the largest amount of iron produced in Sweden at the present time is used in the Lancashire Forge, it would seem as if the hot-blast ovens used in that country entirely answered their purpose. But, on the other hand, it has just been shown that with several of the other varieties of pig-iron, also produced at the Swedish works, a far higher temperature of blast is permissible; and it is further evidently of great advantage, in order to maintain a uniform working of the furnace, that the hot-blast ovens should be sufficiently powerful to elevate without difficulty the temperature of the blast a few hundred degrees above that at which it is ordinarily heated, in case of any disturbance in the working of the furnace.

What an excellent means of regulating the working of the furnace can be obtained by the heated blast is best seen from the preceding calculations, from which it seems to be proved that with a blast furnace working under the conditions assumed, elevating the temperature 100° C. adds at least as much heat to the furnace as a corresponding increase of 8 per cent, of the fuel used. In this case, therefore, an increase in the temperature of blast of 100° C. over that previously used must exert the same influence as would be attained by diminishing the ore-burden 8 per cent., or 64 pounds. There is, however, the very essential difference that the elevation of the blast at once exerts its powerful influence, while the diminished burden of ore can only attain to full action on its arrival in front of the tuyeres. If, therefore, it were possible at any time to elevate the temperature of the blast as needed, it would be possible to produce a very uniform quality of pig-iron, and to control a number of considerable and from their effects, costly disturbances in the working of the furnace. Unfortunately, most of the hot-blast apparatus at present existing in Sweden is, in this respect, so weak that one must be glad if, with an irregular working of the furnace, the temperature of the blast can be maintained at its ordinary height. In blast furnaces with whose hot-blast apparatus it is possible, under normal conditions, to attain any considerable increase in the temperature of the blast above that with which the furnace is ordinarily worked, it is as a rule not only impossible to elevate the temperature of the blast, but on the contrary, in case any disturbance occurs in consequence of the decreased amount of furnace-gases, due to the irregular working, the temperature of the blast is diminished. Instead of possessing in the hotblast apparatus a means of controlling the disturbances in the working, under such conditions it is only a means of increasing them. It cannot therefore be doubted that even those Swedish furnaces which produce pig-iron to be used exclusively in the Lancashire Hearth should erect more powerful hot-blast ovens than those hitherto employed; and it therefore seems proper here to examine what faults belong to the existing apparatus, and how these can most readily be remedied.

XLIII. The most striking fault of the Swedish hot blasts is, without question, their small dimensions, in consequence of which the heating-surface for the blast is much too small. Hitherto the necessity of having a hot-blast apparatus corresponding in size to the amount of blast appears to have had far too little attention paid to it; this is, nevertheless, of the greatest importance. Since the greater the quantity of blast to be heated, so much the greater must be the heating-surface of the apparatus, in order to attain, without straining or overheating it, the same temperature of blast which the same apparatus would, without any difficulty, communicate to a less amount of blast. The greater the heating-surface, the less excess of heat over the desired temperature of blast will be necessary and the more lasting will the apparatus be. This condition is most apparent in pipe-apparatus; for if the same temperature of blast is to be attained in two ovens possessing an unequal surface of pipes, it is evident that in the smaller one not only the inner side of the pipes, *i. e.*, the heating-surface of the blast, must be maintained at a hotter temperature than in the larger apparatus, but it is also requisite that the difference of temperature between the inner and outer sides of the pipes must be kept greater in the smaller oven than in the other one, which subjects the pipes of the smaller apparatus to a much more rapid destruction. In addition to this the difference in temperature between the inner and outer sides of the pipes naturally increases with the thickness of the latter, and it is disadvantageous rather than useful to make these thicker than is in other respects necessary.

From what has been stated it is evident that in order to attain a comparatively higher temperature of blast with small pipe-apparatus these are very rapidly destroyed, and it was for this reason that in most Swedish hot blasts the cold blast was conducted into the lower portion of the oven, where the heat is greatest, and the exit of the hot blast was at the upper portion of the apparatus, where the heat is least. If, however, the fuel used to heat the apparatus is to be most fully utilized, then the blast should be conducted in the opposite direction; and it is only by this mode of construction that a corresponding advantage can be gained by increasing the size of the customary ovens. The ovens used in Sweden arc, with few exceptions, of the Wasseralfinger type, which consists of horizontal pines the ends of which are connected by elbows.

XLIV. In comparison with the more usual kinds of pipe-ovens used in other countries, consisting of vertical pipes, the Wasseralfinger apparatus has this disadvantage,—that in consequence of the horizontal position of the pipes a large quantity of dust accumulates on the upper sides, which diminishes their power of conducting heat, the more so as the porous character of this deposit renders it a very poor heat-conductor. If, however, this disadvantage of the Wasseralfinger apparatus is overlooked, which can be much diminished by properly purifying the furnace-gases from the dust they carry with them, and the use of elliptical pipes having their longer axis in a vertical position, it offers, when properly used, the considerable advantage over ovens with vertical pipes that in the former the heat produced in the combustion-chamber can be more fully utilized than is possible in the case of the furnace with vertical pipes.

This is due to the circumstance that it is not possible in hot-blast ovens with vertical pipes to send the blast in a direction opposed to the heat of the oven, *i. e.*, to conduct it in such a manner that the blast successively passes from the coolest portions to the hottest, us may be done in the Wasseralfinger apparatus. It is easy to see that this direction of the blast is best adapted to fully utilize the heat present in the apparatus. If the blast, when being heated, is conducted in the same direction as that in which the heat of the pipes diminishes, it will absorb this more rapidly in proportion as the difference of temperature is greater between the heat-giving and heat-absorbing bodies; but in its farther course this difference of temperature rapidly decreases, and the absorption of heat by the blast must diminish just as rapidly. It would be of no advantage, therefore, with this direction of the blast, to give the apparatus any considerable height, since the products of combustion escaping from the hot-blast ovens will always be hotter than the highest temperature communicated to the blast. The heat of the gases of combustion can therefore never be properly utilized in a hot-blast apparatus of this kind: and in order to obtain a proper heating-surface of blast, there remains no other means than to extend the oven in length or breadth. In order in this way to attain the desired increase in the temperature of the blast, there must be an increased quantity of gas at disposal corresponding to the increased horizontal extension.

The case is different when the direction of the blast is such that it enters the apparatus at the point where this last is coolest, and passes out from the oven at the point where the temperature is highest. Since so long as the pipes are hotter than the blast, this last will absorb heat, and the products of combustion escaping from the apparatus can be so far deprived of their heat as to possess but a slight excess over the cold-blast entering the oven. In an apparatus of this kind the blast is continually being wanned as it descends, commencing on its entrance into the apparatus, and only ending on its exit.

It is thus only necessary in order to attain a high temperature of blast that the apparatus should possess a suitable height, and that the elliptical pipes should be sufficiently lengthened in the direction of their longer axis to prevent the blast from passing too rapidly through them. In such a hot blast the temperature could be forced almost to the height produced by the fuel used in the combustion-chamber, were it not that a lower limit must be set on account of the durability of the heating-pipes. In any case, a considerable effective increase would be attained in an apparatus possessing this direction of blast, even with an unaltered quantity of gases, by suitably increasing its height.

From what has been stated it is evident, without any further remark, that the lower a Wasseralfinger apparatus is, the smaller must be the advantage which will be attained by the direction of blast, from above downward, just shown to be the proper one. That even very small hot-blasts will act more powerfully with this correct direction of blast, than by the opposite one, from below upwards, as is most commonly practiced in Sweden, is evident from the statistics of sixteen furnaces, in ten of which the blast passed in an upward direction, and the rest in a downward one, the latter giving by far the best results. A rational direction of blast becomes particularly evident in the hot blast used at Westanfors, since although in this apparatus the heating-surface of blast is only 0.176 square foot for every cubic foot of blast forced through per minute, there is no other apparatus of the remaining fifteen which affords such a high temperature of blast, with the single exception of that recently erected at Schisshyttan, which has a heating-surface of 0.373 square foot (more than double that of the former) for every cubic foot of blast passing through per minute.

The hot-blast apparatus used in Sweden are very small compared to those employed in England; in the latter 1 to 1.25 square feet of heating-surface are allowed for every cubic foot of blast passing through per minute, while in Swedish iron-works this does not generally exceed 0.15 square feet.

XLV. The hot-blast ovens now common in Sweden, which consist of 3 to 5 horizontal rows of pipes, one above another, should contain, for the reasons stated, a much larger number of rows of horizontal pipes. The heating-chamber should also be considerably elevated, and the usual direction of the blast should be reversed, so that the cold blast enters at the top of the oven and escapes heated below. Besides which the pipes should be oval, and not round. in order that less dust may be deposited on them, and that there may be a greater heating-surface for the blast, and a greater cross-section so as to produce a slower motion of the blast without causing that portion of it which is in the middle of the pipes to be too distant from the heating-surface.

Since the heating power of the gases is much more fully utilized in hot-blast apparatus of this kind than in the ordinary ones, it is self-evident that a much higher temperature of blast must be attained with the same consumption of gas. But it is on the other hand just as evident that the greater the amount of blast forced into the blast furnace per minute, so much the greater must be the length of the horizontal pipes, and consequently of the whole apparatus, and so much the more gas must be burnt in order to attain the same high temperature of blast.

It is also self-evident that in every kind of hot blast, the temperature of the blast depends on the amount of gas at disposal. And since, when the furnace is working badly, the amount of gas is diminished, due to the increased resistance of the cinder to the blast. it happens, when the hot blast has to be used as a regulator to the working of the furnace, either that the amount of gas is so great that when the furnace is working properly, a much higher temperature of blast can be produced than is desired in the case of any irregularity, or that a closed top or some other means of retaining the gas must be applied, so that the greater portion of the gases produced in the blast furnace can be disposed of at pleasure.

XLVI. In order to be able to attain a higher temperature in the hot-blast apparatus it is not enough to have a sufficient supply of gas, but care must also be taken that all the gas conducted into the oven be burnt, which is only possible with a proper access of air If the air conducted into it does not suffice to burn the gases properly, not only that heat is lost which could be obtained by burning the excess of gas, but the unconsumed gases absorb a portion of the heat of the products of combustion. The temperature is, in a like manner, diminished when an excess of air above that necessary for combustion is conducted in. Care must, therefore, be taken that both the supply of gas and air can be regulated at pleasure.

A portion of the Swedish hot-blast apparatus is so small and narrow that in case more gas is allowed to enter, in order to attain a higher temperature, it is not possible to suck in the air necessary to its perfect combustion; under such circumstances an increased access of gas diminishes the temperature of the blast instead of increasing it. In such small, narrow ovens the gases, when an increased supply is admitted, readily attain such a pressure that the air can only be drawn in at the lower openings, while at the upper ones, instead of the air being sucked in, there can only be observed the escape of partially burned gases, while at the same time a portion of them is consumed in the draught-chimney, and at its top, without producing any useful effect. This evil can, indeed, be in a great measure avoided by increasing the height of the oven. But if there is no means of forcing the air of combustion into the apparatus, which is not necessary in properly constructed ovens, care must be taken that the combustion-chamber be constructed of sufficient width to enable the gas as well as the air to rise in it without obstruction; since if the apparatus is so narrow that the necessary quantity of gas and air can only be sucked in by a tall chimney, these pass through the apparatus with such rapidity that there is not sufficient time for them to impart the desired heat to the hot-blast pipes.*

It is scarcely necessary to mention that in order to attain this end, the chimneys should always be provided with dampers or valves, which are excellent means of regulating the draught.

Finally, in order to obtain good results, if the hot-blast ovens are provided with sufficient quantities of air and gas, these must be conducted into the former in such a manner that there is no excess of gas at one point and of air at another. If, therefore, the air of combustion finds access through openings in the side walls, the apparatus must not be built too wide nor should there be too many horizontal sets of pipes, but these should be made longer, in order to obtain the necessary amount of heating-surface. If this is impossible, owing to local conditions, it should be the endeavor to conduct the air

* For this reason the hot blast at Trummelsberg, when first erected, gave very unsatisfactory results, but after widening it and thus diminishing the pressure of the gases, so that sufficient air could be drawn in, much better results were obtained.

toward the centre of the apparatus by bringing air-canals along the bottom of the hot blast, or by some other means to the same end.

XLVII. So long as the blast is heated in cast-iron pipes, the temperature is kept within bounds by the danger of too rapidly destroying the apparatus; in order to avoid which, endeavors have been made, since the use of Siemens's regenerative principle, to apply this to heating the furnace-blast. The apparatus constructed of this type must always be in pairs (or threes), so that one (or two) is being heated by the burning gases while the other one is heating the blast. And when this last has cooled to such a degree that the temperature of the blast has perceptibly decreased, the direction of the blast and gases is changed so that the gases pass into the oven which has just been cooled by the blast, while this last is forced through the apparatus previously heated by the gases.*

[Before closing, I will here condense some of the more important portions of Tunner's Introduction to the German Translation, it being understood that wherever the first person is used it refers to Tunner.—F. P.]

I believe that I am able to claim, without conceit, to have been the first to controvert the theory, recently prevailing, of the exclusive formation of carbonic acid in the hearth, in the so-called combustion zone of the blast furnace. The more astonishing does it seem, therefore, that I am now compelled to protest against the assumption that only carbonic oxide and no carbonic acid is present in the lower portion of the furnace, as is assumed by Bell, Akerman, and others, in their calculations, since they assert that the carbonic acid formed at the first moment is at once and completely decomposed by the surrounding coals, glowing at a white heat, to carbonic oxide. Nor can I accept the assumption of Schiuz, that equal portions of carbonic acid and carbonic oxide are formed.

I am convinced that there is no section of a blast furnace, nor (to which I call attention) of a cupola furnace, in which only carbonic oxide or carbonic acid are found, but that both these gases are present in varying proportions, dependent on various conditions, and that usually the upper portions of the furnace contain, as gas analyses

* I have been informed that the quality of the pig-iron produced in blast furnaces whose blast is heated by ovens of this type, is very variable, owing to the constantly changing temperature of the blast. No hot-blast ovens of this type have, I believe, as yet been constructed in the United States, although they are to be placed in new furnaces soon to be built at Port Henry on Lake Cham plain.—F. P.

show, the greater amount of carbonic acid, due to the commencing reduction of the iron ores.

This very varying proportion between carbonic acid and carbonic oxide renders it impossible to calculate accurately the temperature produced in the lower portions of the furnace, and I can only in so far recognize this calculation to be correct as the whole temperature produced in the furnace-shaft is based on a reliable determination of the tunnel-head gases and the portion evolved from the fuel and the charge, as Bell has done. The determination of the furnace gases, by calculations based on certain assumptions, is theoretically very interesting, and much less troublesome than a reliable determination of the average composition of the gases; but it cannot establish much confidence, for the reasons stated.

The carbonic acid evolved from the charge, especially from the linfestone flux, is calculated in different ways. While Bell assumes that the whole of this carbonic acid is only expelled at a temperature at which it will be converted to carbonic oxide by the surrounding coal, Akerman leaves this influence entirely out of his calculation, as he asserts that it is impossible to state how much of this carbonic acid is changed to carbonic oxide, and in so far as this does take place, it is already contained in the twelve per cent. of coal charged, which has been assumed in his calculations to be altered during the reduction to carbonic oxide. It seems to me that Bell's plan is the best one of the two, as it gives a more detailed insight, which is the chief aim of the whole calculation, and since, too, if not the whole, certainly by far the greater portion of the carbonic acid is in fact converted to carbonic oxide. I asserted, in 1859, in consequence of experiments I had made, that the carbonic acid expelled in the blast furnace from uncalcined spathic iron, was almost completely altered to carbonic oxide, at the expense of the surrounding charcoal. If this is the case with spathic iron, so much the more must it be with limestone, since a somewhat higher temperature is required for its perfect decomposition than for that of spathic iron.

Akerman has very properly taken into account the heat necessary for the reduction of the silicon. While in the calculation for Swedish furnaces only 15 H.U. are consumed, in English furnaces, where pig-iron is produced containing 2 per cent. and more of silicon, 15 X8 =120 H.U., and more, are rendered latent. It would have been better if the amount of heat consumed by the decomposition of the gasified water, introduced by the blast, had been stated separately instead of subtracting this *together* with the blast from the heat produced by the combustion of the coal. This is the more to be desired, as the ill effects of a moist blast would have been rendered more prominent. The amount of heat carried off by the escaping gases must be considered as a more or less questionable quantity, both with respect to the quality and quantity of the gases, as well as the heat brought into the calculation. This must depend on the cooling produced by the sides and bottom of the furnace, the fore-hearth and tymp, as well as the water used for cooling the tuyeres, although this last could easily be determined by direct experiments. The sum total of heat consumed is too small by several per cent., according to my views, as the whole calculation is based on the production of carbonic oxide alone.

Akerman correctly remarks that hitherto, in the determination of heat gained by heating the blast, the fact has been entirely left out of account, that the heat is brought into the furnace with the blast, to distinguish it from the heat produced in the furnace by burning the coal with the blast, without any increase of gas, which last, when escaping from the top, carries off more heat from the furnace. In § XXXIII, it was shown that with a temperature of blast of 205° C., while the heat brought directly into the furnace by the heated blast amounted to 10.2 per cent. of all the heat which is produced in the furnace, a still further amount of heat is utilized, due to the decreased amount of gases, of 5.67 per cent., or a total of 15.87 per cent. But since in § XXXV, it was shown that the average results of five furnaces in the Norberg district, with a temperature of blast of only 160°-200° C., and an inconsiderable increased capacity, were a saving of fuel of 24.5 per cent., it is evident that the saving in fuel must be due to some other influence of the hot blast than the one just stated. This influence is the more active combustion which is produced by the heated blast, which Akerman does not deny, but does not give the prominence to which his own data actually show.

In my opinion this essential increase in the effect of the heated blast is to be sought for in the circumstance that in the zone of fusion of the blast furnace, in which the highest temperature is necessary, a considerably higher temperature is actually produced. This increased temperature is not only due to the heat brought into the furnace by the hot blast, but is also a result of the more active combustion, together with the formation of a larger quantity of carbonic acid, which is not so instantaneously and completely again altered to carbonic oxide as Bell and Akerman appear to assume. It does not necessarily follow from the use of hot blast that a greater quantity of carbonic acid must be found in the tunnel-head gases ; it suffices if this is present in the lower portion of the furnace, where, especially with refractory charges, it is often difficult to attain the desired temperature, while there is no difficulty in effecting the reduction and carburization preceding it. The blast furnaces in the Ural mountains have very recently afforded a proof that by using a hot blast the temperature is actually more concentrated in the lower portion of the furnaces, since the introduction of hot blasts there has failed, owing to the furnace walls not being refractory enough. In other localities also, the use of a hot blast has only been attainable by properly cooling portions of the hearth, and in some cases even of the boshes, with water-boxes.

I concur in Akerman's views with respect to the influence of the heated blast on the quality of pig-iron produced; but cannot agree with him in the idea that a higher temperature of blast than that hitherto used is not advisable when making pig-metal to be used in puddling or fining. It is indeed true that by increasing the temperature of the blast a pig-iron would be produced richer in silicon and less suitable for the finery process, were not care at the same time taken to make the charge more basic, and also to diminish the pressure of the blast, and in some cases to have a greater diameter of hearth. Since it has been possible in Styria and Carinthia with a temperature of blast of more than 500° C., to produce a very good grade of white to mottled pig, it is evident that this is an assured fact. If the higher temperature of blast is admissible without injuring the quality of pig-iron, it appears to be shown that the greatest advantage can be attained by thus economizing in fuel.

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