Cost of making Pig iron in Alabama is less than anywhere in the world — see p1
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List no. 23

ALABAMA

GEOLOGICAL SURVEY

EUGENE ALLEN SMITH, PH. D., Director.

IRON MAKING IN ALABAMA.

SECOND EDITION

BY

WILLIAM BATTLE PHILLIPS, PH. D.,

Consulting Chemist and Metallurgist.

MONTGOMERY, ALA.:
ROEMER PRINTING CO., STATE PRINTERS AND BINDERS.
1898.

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To His Excellency,

JOSEPH F. JOHNSTON,

Governor of Alabama:

DEAR SIR: I have the honor to transmit herewith a Second Edition of Dr. Phillips' Report on Iron Making in Alabama.

Very respectfully,

EUGENE A. SMITH,

State Geologist.

University of Alabama,

October 1st, 1898.

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LETTER OF TRANSMITTAL.

(First Edition.)

Dr. Eugene A. Smith,
Director, Ala. Geol. Survey,
University, Ala.

SIR—I beg to transmit herewith a report on Iron Making in Alabama, prepared for the Geological Survey.

No systematic attempt has yet been made to bring this industry to the attention of the general public. Numerous article, have appeared in the technical papers in this and other countries during the last ten years, dealing with special phases of the subject, and many of them possess great merit. In particular may be mentioned the following:

The Iron Ores and Coals of Alabama, Georgia, and Tennessee. Jno. B. Porter, Trans. Amer. Inst. Min. Engrs., vol. xv, 1886–87, pp. 170–208.

Comparison of some Southern Cokes and Iron Ores. A. S. McCreath and E. V. D'Invilliers. Trans. Amer. Inst. Min. Engrs., vol. xv, 1886-87, pp. 734–756.

General Description of the Ores used in the Chattanooga District. H. S. Fleming. Trans. Amer. Inst. Min. Engrs., vol. xv, 1886–1887, pp. 757–761.

The Pratt Mines of the Tennessee Coal, Iron and Railway Co. Erskine Ramsay. Trans. Amer. Inst. Min. Engrs., vol. xix, 1890–91, pp. 296-313.

Notes on the Magnetization and Concentration of Iron Ore. Wm. B. Phillips, Trans. Amer. Inst. Min. Engrs., vol. xxv, 1895–1896.

A series of articles by E. C. Pechin, in the Iron Trade Review in 1888, and by the same author in the Engineering & Mining Journal, vol. lviii, 1894. The Proceeding of the Alabama Industrial and Scientific Society, 1891-1897, contain many valuable papers, as also the files of the Engineering & Mining Journal, the Iron Age, the Iron Trade Review, the Tradesman, Dixie, and the American Manufacturer & Iron World.

But the very fact of their appearing in technical publications has caused the general reader to neglect them, not on account of indifference, but because they were not readily accessible. The files of the great industrial journals, and the Transactions of the American Institute of Mining Engineers are not available to many who wish to know what has been already done in Alabama, and what the future may confidently be expected to unfold.

After careful consideration, it was decided to prepare a little book of 150-200 pages which should present the matter as it is to-day and chiefly from the standpoint of raw materials. Very little has been said as to furnace practice, because it was not in mind to prepare a Text-book of Iron Making. The book is intended for general distribution by the Geological Survey, and while the main purpose is to supply the average reader with easily digestible information, it is hoped that those who are actively engaged in the business may find in it some suggestions not altogether unworthy of their attention.

Very truly yours,

Wm. B. Phillips.

Birmingham, Ala., May 1896.

IRON MAKING IN ALABAMA.

BY

WILLIAM B. PHILLIPS.

INTRODUCTION TO FIRST EDITION.

During the last twenty-five years so great an improvement in the manufacture of pig iron and its utilization in more or less finished products has taken place in Alabama that it is now thought expedient to describe, as briefly as possible, the conditions that have compassed the industry and that are still in force.

In 1872, Alabama produced 11,171 tons of pig iron; in 1892, 915,296 tons. In 1880, the state produced 60,781 tons of coke, and in 1892, 1,501,571 tons. In the census year of 1870 the amount of capital invested in the iron business, including mining, was $605,700, and excluding mining, $566,100. In that year the total production of pig iron was 6,250 tons, valued at $21,258, and there were used 11,390 tons of ore valued at $30,175. In the census year of 1890 the capital invested in the mining of iron ore alone was $5,244,906, the amount of ore mined and used being 1,570,319 tons, valued at $1,511,611.

The Southern States generally sell their entire iron product for purposes other than steel making. The iron goes to foundries, mills, and pipe works. It was not until recently that any considerable amount found its way into steel works. It is not probable that more than one-twentieth of the iron made in the South goes to the steel maker. Alabama offers no exception to this rule. It was not until the last few months that any fairly large shipments of iron made here were sent to steel plants. The significance of this statement will appear when it is remembered that the total amount of iron produced in the United States in 1895, not intended for steel making, was about 3,000,000 tons. At the present time Alabama is producing 35% of the iron used in the foundries, mills, and pipe works of the country. The growth of the industry has been conditioned chiefly by three great factors :

First, the cheapness with which the ores can be mined and delivered.

Second, the proximity of the ore to the flux and fuel.

Third, the tendency of pig iron consumption towards the interior.

The cheapness of an ore is not always to be measured by its cost at the furnace. There are also to be considered its quality in respect of its content of metallic iron and the presence of ingredients which determine the use to which the pig iron made from it can be put. The lower the percentage of iron in an ore the cheaper must it be mined and transported in order that a market for the pig iron may be secured and held. A very rich ore may allow of mining and transportation costs that would prevent the use of an ore less rich. The same principle applies to the quality of the ore as regards its freedom from injurious substances. If it be free from phosphorus and sulphur, for instance, it may be highly acceptable to the steel plants. If at the same time it be rich in iron we may have the conditions that allow of maximum cost at the furnace. In Alabama we have ores of moderate content of iron, and they must therefore be mined at a low cost. They also contain too much phosphorus to allow of the pig iron being used for making Bessemer steel.

The principle on which the makers of pig iron in Alabama have had to proceed is the utilization of local ores, and the production of suitable coke from native coal. It all seems plain sailing to us now that the yearly output of coke exceeds one and a half million tons, and the yield of pig iron is above 800,000 tons ; but twenty years ago it was by no means certain that good coke could be made from Alabama coal on a large scale, and the use of Red Mountain ores was a vexed question. As late as 1883, so-called representative analyses of Alabama hematite were published showing 56 % and 61 % of iron on the one hand, while on the other it was said that pig iron made from Alabama ore and coke was so brittle that it ought to be kept under glass as a curiosity. Both these statements were equally removed from the truth. When finally it became known that with but few exceptions the Red Mountain ores could not be expected to contain more than 47 % of iron as mined and that the fifty-six and sixty-one per cent. hematite ores could be exhausted in a single day, the situation rapidly improved. So far as the ores were concerned, the problem narrowed down to the single question whether they could be successfully used in conjunction with cokes of domestic production. From that day to the present the question has changed but little, the main difference being that the price of ore has steadily diminished, reaching its lowest point in 1895, and that the coke is better and cheaper. During a part of this year the price of soft red ore, analyzing about 46 per cent. of iron, was fifty cents per ton, stock house delivery. It was during this year also that the cost of making pig iron in Alabama was at the lowest, less than $6 per ton. No more striking illustration of the great change that has come over the manufacture of pig iron in Alabama during the last years can be adduced than to say that the total cost of production is now less than the cost of the raw materials five years ago. This has been rendered possible not only by reductions in the cost of the raw materials, but also and particularly by improvements in furnace practice and a closer alliance between the chemist and the superintendent. There is a large iron company in the State which three years ago had no chemist, and the laboratory which had formerly been tenanted had been allowed to take care of itself for two years. The company has now four chemists in its employ and one of the best equipped laboratories in the country. Three years ago it was content to have some of its materials analyzed perhaps once a month; now the number of analyses per month is close upon four hundred. Chemical inspection of the stock goes hand in hand with inspection of the product, and there is now not a single thing used or made whose composition is not known. A great amount of material is bought and sold on analysis, and the inevitable tendency is towards the extension of this system to all materials. The most progressive companies in the State are now recognizing the value of close chemical inspection of the ores, fluxes, and fuels. In this respect the change that has come over the industry during the last five years is particularly noticeable and must be regarded as one of the most hopeful signs of the time.

Another agreeable improvement in the business is the willingness of the iron masters to exchange information and opinions, to visit competitive establishments, and cultivate the more social side of trade. There need not be rankling jealousies between those engaged in similar enterprises in the same district. To refuse to impart information is to refuse to acquire it, and the day has long since passed when in the mind of any one man is to be sought correct knowledge on all phases of the same matter. Without such cordial interest in what may be for the general good, this sketch of the materials used in making iron in this State, however imperfect it may be and doubtless is, could not have been undertaken in any hope of success. My own acquaintance with the district dates from 1887, and since that time I have accumulated nearly 10,000 analyses of every kind of material used in making iron in the State, coming partly from my own laboratory and partly from the records of companies actively engaged in the production of iron. The deductions that will be met with in the body of this report are founded upon analyses that were made in the interest of those prosecuting the iron business, not upon analyses of stray fragments or hand specimens. They represent hundreds of thousands of tons of ore, limestone, dolomite, coal, and coke, the samples being drawn from the stockhouses during a period extending over many years. In numerous instances samples of the ore were taken direct from the mines, foot by foot down the seam, and from mine and railroad cars. The constant effort has been not to include in the pages of this report any conclusions that were not based upon the actual practice in the State and district, and the reader is assured that no pains have been spared te accomplish this end.

To those who have most generously given the information desired of them, I would express my hearty thanks. It is a source of great pleasure to me that the replies to requests of this nature should have been met so fully and so courteously, and that I trust that the interest in what the State has to offer to the makers of iron may be deepened and broadened from this attempt to set in order the results already attained.

According to Swank (History of Iron in all Ages, 2nd Ed., p. 293, et seq.), who quotes from Leslie, the oldest furnace in Alabama was built about 1818. It was a charcoal furnace, and was situated a few miles west of Russellville, Franklin County, doubtless to use the brown ore of the Russellville belt, which is of excellent quality and is now used by the coke furnaces at Sheffield. It seems to have been abandoned about 1827, and from that date until 1888, a period of 60 years, this deposit of ore remained undeveloped and unused. Not long since there came to hand evidence of the existence of this old furnace in the shape of a piece of very impure iron which was brought to the writer from that part of Franklin county by a person who supposed it was iron ore.

From 1827 until 1843, there is no record of any furnace building in the State, the next one being at Polksville, Calhoun County; then one at Shelby, Shelby County, in 1848; and one at Round Mountain in 1853.

Charcoal iron has been made at Shelby almost continuously since 1848, and the reputation of the iron has not been excelled from that day to the present time.

The furnace was built by Horace Ware, who afterwards added a foundry and a mill for cotton ties and bar iron. This furnace was burned in 1858, but rebuilt at once. A larger mill was built in 1859, and iron rolled April 11th, 1860. This mill was very active during the war of the Confederacy, and was burned by the Union troops under General Wilson in 1865. It has not been rebuilt, but a part of the machinery was used in constructing the rolling mill at Helena in 1872. It may not be amiss at this point, while briefly considering this historic furnace and mill to quote a very interesting letter written by Mr. E. T. Witherby, assistant secretary of the Shelby Iron Company to Mr. Swank in 1888. "The first blast furnace erected here went into blast in 1848. Horace Ware was its proprietor. In 1854, Mr. Robert Thomas made iron in a forge near here. This iron was sent to England and returned in razors and knives. In 1859 Mr. Ware began the erection of a rolling mill. It was completed and started in the spring of 1860. In 1862 Mr. Ware sold his property to the Shelby County Iron Manufacturing Company, which erected a new furnace, the one which we have recently torn down, and on whose site we are erecting a new stack. The rolling mill was enlarged in 1863, and was operated continuously until March 31st, 1865, when it was destroyed by General Wilson of the Union army. It was in this mill, in 1864, that the plates were rolled for the armor of the iron clad ram *Tennessee.* Judge James W. Lapsley, one of the stockholders and directors of the present Shelby Iron Company, was made a prisoner by the Union forces in 1863, while in Kentucky looking for puddlers for this mill.

"When I came here, nearly twenty years ago, we had plates, merchant bars, and strap rails on hand made entirely of Shelby iron and rolled in this mill. Some of the plates, known to us now as the "gun boat iron" are still in our store house, but they have been slowly disappearing under the demand of our blacksmiths for "an extra good piece of iron for" "this job," or that "particular place." Some of these plates are 8 inches by 3 inches, and othes 11 inches by 5 inches, and of various lengths; originally, they were, perhaps, 10 feet long. Shelby pig iron was also shipped to the Confederate arsenal and foundry at Selma, Alabama, in 1864, where the *Tennessee* was constructed and fitted out. This iron doubtless went into guns and other castings for this vessel. Catesby ap Jones was superintendent of the arsenal, and with his senior in rank, Franklin Buchanan, both pupils of that sea-god, Matthew Calbraith Perry, wrought out the *Tennessee*. They were as full of progressive ideas regarding steam and armor as their master, and nothing but the scanty means at their disposal prevented a much more formidable iron-clad than the *Tennessee* from being set afloat.

"Car-wheel makers are the exclusive users of our iron."

It is interesting to note in connection with the Confederate States foundry at Selma, that it used coke made from the Gholson seam mined at Thompson's Lower Mine, on Pine Island branch, in Sec. 10, T. 24, R. 10 E., Bibb County, and elsewhere in the vicinity, as we are informed by Eugene A. Smith (Ala. Geol. Survey Report of Progress for 1875, pp. 32 and 33.) This was about 1863, and is probably the first use of Alabama coke for foundry purposes.

"In 1863–64 Capt. Schultz of the Confederate army made a large quantity of coke from seams in the Coosa coal field, getting it to market by floating it down the river in flats to the railroad bridge across the Coosa River, whence it was carried by rail to Montgomery and Selma. The coke was said to be the finest ever made in the State, and to equal the very best English cokes." (Smith ut supra, p. 38.)

In 1825, there was a bloomary near Montevallo, Shelby County; several in Bibb County in 1830–1840; one in Talladega County in 1842; two in Calhoun County in 1842. In 1856 there were enumerated 17 forges and bloomaries, about one-half being in operation and producing 202 tons of blooms and bar iron. The total product of charcoal pig iron in 1856 was 1,495 gross tons.

In 1876 the Eureka Coke Furnace was built at Oxmoor, Jefferson County, by Col. J. W. Sloss, one of the most active iron-masters in the State, and the founder of the coke iron industry. This was the first furnace to go in on coke, and was followed in 1880 by the Alice furnace, built at Birmingham in 1879–80, by H. F. DeBardeleben, another noted name in the history of the iron trade in Alabama. Then followed the first of the Sloss furnaces at Birmingham, built by Col. J. W. Sloss in 1881-82. and put in blast April 12th, 1882.

Space would fail us to enumerate the names of those concerned in the early history of the coke iron trade in Alabama, but J. W. Sloss (who died in 1890), H. F. DeBardeleben. T. T. Hillman, and Geo. L. Morris, who are still enjoying the fruits of their foresight and energy, will always be first called to mind by the historian of the days, not long past as we measure years, but removed from us by a continuous series of splendid achievements.

Si monumentum quæris, circumspice.

WM. B. PHILLIPS.

BIRMINGMAM, ALA., May 1896.

INTRODUCTION TO THE SECOND EDITION.

The very kind reception this little book has met with from the public has so nearly exhausted the first edition that a second is now thought necessary. It was the first systematic attempt to set in order the conditions under which the manufacture of pig iron has been possible in Alabama, and although none realized its imperfections more keenly than the author, yet they were errors of judgment and not of fact. With the exception of the introduction of double and in one case treble the usual number of tuyeres, the blast furnace practice has not altered, materially, since the publication of the first edition in 1896. The same ores are being used, and the same coke. The use of dolomite, as flux, has steadily increased, so that it has now become the main fluxing material in the Birmingham district. The cheap soft red ore is becoming notably scarcer, and there is more interest felt in deposits of brown ore, and in the possibility of employing larger amounts of hard, or limy ore.

At least one new brown ore deposit has been opened in the Birmingham district, by the Sloss Iron and Steel Co., and is of great promise. The brown ore deposits near Russellville, Franklin County, now supply the Sheffield furnaces, and excellent results have been reached by Mr. J. J. Gray in the use of these ores. The brown ore deposits near Anniston have been reopened, and the Woodstock furnaces have been making a good record. The Pioneer Mining and Manufacturing Company, with two furnaces at Thomas, have opened a new soft ore mine on Red Mountain, near Bessemer, and new openings on Red Mountain have been made by J. W. Worthington & Co. This latter company continues to mine excellent dolomite from the Dolcito quarry, six miles from Birmingham. The Jefferson Mining and Quarrying Co., also mines excellent dolomite, somewhat nearer the city, and the dolomite at North Birmingham has also been opened by The Sloss Iron and Steel Co. The Solvay Process Company, Syracuse, N. Y., is building 120 Semet-Solvay Recovery coke ovens at Ensley, to be operated in connection with the blast furnaces there, owned by the Tennessee Coal, Iron and Railway Co. It is thought that they will be in operation by the close of 1898. Messrs. Stein & Boericke, of Philadelphia, have built for the Jefferson Coal and Railway Co., at Lewisburg, four miles from Birmingham, a very complete coal washing plant, capacity 40 tons per hour. It is designed to wash slack, and as the company owns 137 bee-hive ovens it will enter the market for picked lump coal and washed coke.

So far as concerns coke the Birmingham district is now well equipped. The Tennessee Coal, Iron and Railway Co., continues to use the Robinson-Ramsay washer at Pratt mines for Pratt Coal, and at Johns for Blue Creek Coal. The Standard Coal Co., at Brookwood, Tuscaloosa county, uses the Stein washer. The Sloss Iron and Steel Co., uses the Robinson-Ramsay, as does also the Ivy Coal and Coke Co., at Horse Creek, Walker county, and the Howard-Harrison Iron Company, at Bessemer.

The Campbell washer has been used by Messrs. Elliott & Carrington, at Jasper, Walker county.

All the coke used in Alabama is from the bee-hive oven, but on the completion of the by-product ovens at Ensley some recovery oven coke will be used.

So far as concerns the ore supply it is not possible to add to what has already been written. The chapters on ore will, therefore, not be materially changed. I have added, however, the paper on the magnetization of Iron Ore, read at the Atlanta meeting of the American Institute of Mining Engineers, October, 1895, and an abstact of a report made to the Wetherill Concentrating Company, 52 Wall Street, New York, on the magnetic concentration of the non-magnetic ores of the Birmingham district.

The writer regards this latter process as full of promise for Alabama, as it appears to be entirely feasible to increase the iron in the low grade soft red ores from 38% or 40% to 53% or 55%, and to make proportionally as good a showing for the low grade limy ores, and the low grade brown ores.

No attempt at concentrating the red ores is now being made, but it seems to be not out of place to detail what was done. That these ores will some day come into use through some method of concentration seems probable.

The chapter on Fuels has been entirely recast, and a large amount of information gathered by the writer in his own laboratory in regard to the chemical and physical quality of the various cokes has been added.

A new chapter on Pig Iron has also been added, and many analyses of the various grades have been inserted, and a new chapter also on Coal Washing, additional information as to the coal industry, compiled from the reports of Mr. James D. Hillhouse, State Mine Inspector, has also been inserted, including the number of mines operated, the number employees, &c., &c.

Having been consulting chemist for the Birmingham Rolling Mill and Steel Works since the building of their first basic open hearth steel furnace, the opportunity of adding a chapter on Steel Making has been presented.

My sincere acknowledgments are due to the above company for its kindness in permitting the publication of information not hitherto given to the public. Mr. David Hancock has been associated with me in the steel laboratory, and has been of the utmost assistance.

In connection with the making of steel there will be found a full description of the manufacture of basic iron in Alabama, so far as concerns its chemical aspect, which is republished from The Mineral Industry, Vol. V, through the courtesy of the Scientific Publishing Co., New York. There has also been added a chapter on the cost of making pig iron in the State.

This has been done to correct an impression that iron is made here for less than $5.00 a ton. It is no longer a question that the cheapest pig iron made in the world is made in Alabama, and it has been thought that a brief statement of facts in regard to the matter would not be out of place.

The exportation of 218,633 tons of iron to England, Continental Europe, Japan &c, during 1897, as against 65,000 tons in 1896 marks a new and hopeful development of outside markets for Alabama iron.

WM. B. PHILLIPS,
Birmingham, Ala., May 1898.

IRON MAKING IN ALABAMA.

CHAPTER I.

THE ORES: GENERAL DISCUSSION.

The ores used in the production of pig iron in Alabama fall naturally into two classes, and for convenience of reference the local names will be used with full explanations under each. They are either limonites, the so-called "brown ores," or hematites, the so-called soft, and hard ores. There are deposits of blackband ores and of magnetites, none of which, however, come into use. Efforts have been made to use the more or less bituminous blackband ores, both raw and calcined, but they were not successful. Several years ago an attempt was made at one of the coke furnaces to employ the raw blackband ore found in association with one of the coal seams in the northern part of Jefferson County, but the furnace worked badly, probably owing to the very bituminous nature of the ore, and the experiment was discontinued. The same ore was afterwards calcined in piles in the open air and a portion of the resulting material was of fair quality. But owing, it is thought, to the lack of care in the management of the business there was a gooddeal of trouble from the caking of the ore. In places it resembled impure iron and was almost malleable. Nothing has been done in this direction for some time, as the available supply of ores that do not need such treatment is still very large. Practically all of the iron made in the State has been produced from limonite, hematite, or a mixture of the two.

For special purposes, as for instance, car wheel iron or some particular kind of iron destined for the pipe works, brown ores alone are used, although at times some admixture of hematite is permitted even then. For ordinary foundry and mill irons, and of late for basic iron, the common practice is to use a mixture of brown and hematite ores, the proportion of brown ore being for the most part about 20 per cent. of the ore burden, although there are some important exceptions to this rule.

It seems best to take up the ores under separate headings, that a fuller understanding of the subject may be reached, but before doing so some observations on the ores in general may not be out of place.

In Alabama a vast deal of prospecting has been carried on for more than twenty years to ascertain if it were possible to find richer ores or ores of cheaper accessibility. During the flush times several chemical laboratories were in active operation in more than one town and thousands of analyses were made of almost every known deposit. In many cases the samples were taken by interested persons and in many others by persons wholly unacquainted with the first principles of sampling ore seams. In the writer's own experience it has happened many times that a single piece of ore, not larger than the fist, would be brought in as representing the seam. In one case of the kind it happened that the ore showed a comparatively small amount of phosphorus, with some 46 per cent. of iron. Whereupon the report was circulated that a large deposit of Bessemer ore had been discovered and for a while speculators were busy. If there be any large deposit of Bessemer ore in the State it has not yet been found. There are places where some of the brown ores show phosphorus below the Bessemer limit, but fifty feet away they are liable to carry from

0.20 per cent. to 0.50 per cent. of this element. The same observation applies to certain seams of fine grained soft red hematite. Many seams have been carefully sampled and many analyses made in the search for ore that would not show phosphorus above the Bessemer limit, i. e., not over 0.05 per cent. for 50 per cent. of iron. But the conclusion has finally been reached that for the present we shall have to confine ourselves to ores that contain from 0.10 to 0.40 per cent of phosphorus per 50 per cent. of iron, and in many of the brown ores we may expect a considerable increase over these figures. It will not be denied that for a small furnace and with great care in the selection of the ore, the chemist being constantly employed in analyzing for phosphorus, it might be possible to make Bessemer iron in this State from some of the brown ores, but no one could be advised to undertake the project with present lights. The attempt has been made and several thousand tons of iron with less than 0.10 per cent. of phosphorus were produced, but the enterprise languished and has not been revived.

The treacherous nature of brown ore with respect to the continuit y of the deposit, is enough to forbid reasonable hope of success.

The hematite ores, on the other hand, carry phosphorus much above the Bessemer limit. They carry generally from 0.30 % to 0.40 % of phosphorus, although there is in the district contiguous to Birmingham a small seam of red hematite that carries 5.41 % of phosphorus and another 2.31 %, the metallic iron being about 38 %.

In the early days of iron making in the Birmingham district it was the rule, according to one of the contractors, "to mine anything that was red," and what was mined went into the furnace. The difference between good, bad, and indifferent may have been known, but was not a factor with the contractor or with the furnace manager.

The following table page 20 taken from the excellent report of Mr. John Birkinbine on "The Production of Iron Ores in 1897, U. S. Geological Survey, Division of Mineral Resources," shows the production and valuation of iron ore by states in 1896 and 1897.

From this table it will be seen that Alabama ranked third in the production of iron ore.

When one considers that Alabama converts practically all of her ore into pig iron she is easily first among the states in the local consumption of her product. The amount of iron made in the state from outside ore is insignificant. Michigan, the largest producer of ore, made in 1897 only 132,578 tons of pig iron, and Minnesota, the second largest producer made none at all.

Alabama is also third in the production of red hemalike ore, Michigan and Minnesota being first and second. Virginia is the first in the production of brown hematite, and Alabama second, with Tennessee a close third.

No magnetic ore or carbornate ore is mined in the State, although there are considerable deposits of both these varieties.

It is of special interest to know that the group of mines on Red Mountain between Grace's Gap and Reeder's Gap, including the Alice, Fossil, Muscoda, Redding, and Ware's was the largest single producer in the United States in 1896 with 945,805 tons.

In connection with this table it would be of interest to give one showing the pig iron produced in 1896 and 1897 by states, from the report of Mr. James Swank, manager American Iron and Steel Association, 1897.

TABLE I.

PRODUCTION OF DIFFERENT VARIETIES OF IRON ORE IN 1896 AND 1897 BY STATES. TONS.

State.	Red Hematite.		Brown Hematite.		Magnetic.		Carbonate.		Total.	
	1896	1897	1896	1897	1896	1897	1896	1897	1896	1897
Michigan	5,635,997	6,041,597	....	....	70,739	45,866	....	....	5,706,736	6,087,463
Minnesota	4,283,880	5,601,429	....	....	....	....	....	....	4,283,880	5,601,429
Alabama	1,694,648	1,738,583	346,845	360,038	....	....	....	....	2,041,793	2,098,621
Virginia	31,271	13,570	828,195	667,553	....	....	....	....	859,466	711,128
Pennsylvania	24,030	19,515	226,669	256,573	494,517	441,556	2,568	6,098	747,784	723,742
Wisconsin	607,405	554,155	....	....	....	....	....	....	607,405	554,155
Tennessee	207,752	260,550	326,932	343,947	....	....	800	....	535,484	604,497
New York	10,789	7,664	12,288	20,059	346,015	296,722	16,385	11,280	385,477	335,725
New Jersey	....	....	....	....	264,999	554,235	....	....	264,999	254,235
Colorado	14,274	21,500	189,943	165,814	11,602	....	....	....	215,819	187,314
Ga. & North Carolina	46,756	131,540	121,506	73,099	7,069	....	....	....	175,331	204,639
Ohio	....	....	....	....	....	....	58,480	54,417	58,480	54,417
Montana, New Mexico, Utah and Wyoming.	13,287	10,151	14,724	8,705	16,585	21,100	....	....	44,59	39,956
Kentucky	1,824	12,464	26,584	....	....	....	1,688	....	30,096	12,464
Conn. and Mass	....	....	27,289	22,573	....	....	....	....	27,2	22,573
Maryland	....	....	....	....	....	....	11,502	11,500	11,502	11,500
Texas	.....	....	4,777	13,588	....	....	....	....	4,777	12.588
Missouri	4,075	600	460	....	....	....	....	....	4,535	600
Total.	12,576,288	14,413,318	2,126,212	1,961,954	1,211,526	1,059,479	91,423	83,295	16,005,449	17,518,
Per cent. of total.	78.58	82.2	78.58	11.2	7.57	6.10	0.57	0.50		

TABLE II.

PRODUCTION OF PIG IRON IN 1896 and 1897, BY STATES. TONS OF 2,240 LBS.

	1896	1897.
Pennsylvania	4,024,166	4,631,634
Ohio	1,196.326	1,372,889
Illinois	925,239	1,117,239
Alabama	922,170	947,831
Virginia	386,277	307,610
Tennessee	248,338	272,130
New York	206,075	253,304
Wisconsin	158,484	103,909
Michigan	149,511	132,578
West Virginia	108,569	132,907
Maryland	79,472	193,702
Kentucky	70,660	35,899
New Jersey	59,163	95,696
Colorado	45,104	6,582
Georgia	15,593	17,092
Missouri	12,548	23,883
Connecticut	10,187	8,336
North Carolina	2,151	....
Massachusetts	1,873	3,384
Texas	1,221	6,175
Total	8,623,127	9,652,680

The largest production of pig iron in any one year was in 1897.

The principles underlying the valuation of iron ores are but little used in the State, the old system of purchasing by the ton still being maintained. The value of an ore is the price at the mine, for, unless the miner also pays the freight, he has already added to the cost of mining all the legitimate costs that should apply to a ton, including royalty. If his contract require that he pay the freight, he cannot reasonably add the freight to the value of the ore, for this varies with the distance it has to be transported.

With the exception of some brown ores, which are purchased on the unit basis, but which constitute a small part of the ore used, and some special contracts relating to hematite, the ores in Alabama are bought by the ton without regard to their composition. The price is so much per ton, whether they carry forty, or forty-three, or forty-seven, or fifty per cent. of iron.

This system has but little to recommend it, except a mistaken notion of economy in the saving of laboratory expenses and sampling. A close inspection may be kept on the ore as received and daily reports made as to its composition, but unless there is a penalty attached to the shipping of poor ore, there is really no way in which it can be stopped. The price is uniform, no matter what the ore may be. It may be improperly mined, it may contain unusual amounts of water, or clay, or chert, but the price is the same to the furnace. A car load of ore may contain 47 % of iron to-day, to-morrow the ore from the same mine may contain only 43 %, yet the price is the same. A brown ore may reach the furnace with its customary 7 % of water, to-morrow it may have 13 %, yet the ore is sold by the ton and the water is counted as ore.

There are two main results from this system: First, the contractor is not impelled to furnish ore any better than would be accepted. His sole aim is to avoid disputes with the furnaceman by sending ore that indeed could be better but still will pass muster. There may arise under this condition of affairs a tendency towards careless mining, and if the line between acceptable ore and bad ore be an arbitrary one, as is frequently the case, there is a temptation to "put the shot down" a little bit deeper than the line of separation. In the mining of the soft red ores by open cut, the over-burden having been removed, it is practically impossible to distinguish between ore of 46 % iron and ore of 40 % simply by the eye. The chemist alone can decide the question. It is a fortunate circumstance, in the Birmingham district, that for the most part the contractors are fully alive to the advantages of shipping ore that will cause no dispute. Under the present system it is difficult to see how they could ship better ore than they do. But the system itself is wrong in principle. The administration of it may be as fair to the contractor as to the furnace, but this does not do away with the main objection to it, which is, that the same price is paid for ore that is barely usable as for ore that is really good. It cannot be denied that this objection is valid and that until it is removed the true principle underlying the valuation of ores can not be put into practice.

The second result from the system of purchasing ore by the ton and not on analysis is that the furnaceman cannot know that his ore to-day is of the same composition as it was yesterday and will be to-morrow. The purchase of ore on analysis does not necessarily condition regularity of stock, but it is a long step towards this most desirable end. It is more than probable that under it there would be a tendency towards the higher grades of ore, for these would be more profitable to the contractor than the lower grades.

The irregularity in the stock is one of the most serious obstacles with which the Alabama iron master has to contend, especially when he is using Red Mountain ores.

The most untiring vigilance is demanded in order that the entire make of the furnace shall not be injuriously affected. It is of course the fact that a great deal of excellent iron has been made in the State without calling into constant requisition the services of a chemist. But this is no more than saying that many a case of illness has been cured without the care of a regular physician. We venture the assertion that even under the present insufficient system a lower cost account for the making of iron would be shown by the companies employing chemists than by the others. By far the greater amount of iron now made in Alabama is the product of companies with well equipped laboratories, and some of the most important sales of iron ever consummated in the State were, to a great degree, brought about by the fact that the laboratory could be depended upon not only for the inspection of the product, but also and particularly for the inspection of the stock.

Uniformly good iron can not be made at a uniformly low cost with irregular stock, and variations in the cost of the iron are to a considerable extent due to variations in the composition of the raw materials. Pay close attention to what goes into the furnace and tapping hole will take care of itself. It is a poor policy to fill the furnace with almost anything that may be to hand and trust Providence to look after the cast-house.

There is nothing in the nature of the ores used that forbids their sale on analysis, and as this system is already applied to nearly all the flux used, and to a not inconsiderable quantity of coke and ore, the extension of it would not appear to offer insurmountable difficulties. The greater part of the cost of making iron is borne by raw materials. The quality of these materials, therefore, and their regularity of composition are of vital importance. As respects composition, there is a point beyond which it is not possible to make iron profitably, no matter what the price of the materials may be. How low this point may be will depend, *ceteris paribus*, upon the difference between the cost of the iron and its selling price. When this difference is considerable, as was the case in this State ten or fifteen years ago, iron may be made at a profit from very inferior materials. But when the margin of profit is narrow, as has been the case of late years, the use of inferior materials becomes impossible. With increasing competition and a narrowing selvage of profits, the necessity for using better and better ore becomes more and more pressing. To keep the furnaces in blast and avert disaster from the district, it may happen that the price of ore will fall below the figures at which it can be mined profitably, unless the operations be conducted on a very large scale and long time contracts can be made, assuring a steady output for a number of years. Under such conditions some concessions may be made by the furnacemen in respect to quality, but at the same time they would be warranted in holding out for uniformity of composition. One would be inclined to consider the uniformity of composition as more important than the quality, provided always that this would not entail too much handling of stock per ton of iron made. When ore is sold for stock-house delivery at a fraction over a cent per unit of iron, it would seem that no further reduction in price could be expected.

Under all circumstances, except such as embody the sale of the ore at so much per unit of iron, there will be complaint by the furnaceman that the ore is not as good as it might be, and it will be met by the miner with the assertion that it is as good as it can be at the price paid for it. This may, indeed, be true, but at the same time it is not to be hastily concluded that for more money the miner is willing to guarantee better ore. For the most part his endeavor is to get the largest possible returns from the smallest possible outlay, a resolution in the highest degree laudable but apt, at times, to cause more or less friction as to shipments. To him a ton of ore is a ton of ore. It weighs 2,240 pounds, and whether it contains fifty per cent. of iron or forty-five he receives the same pay. But to the furnaceman, who has to consider the amount of iron he can get from that ton and the ease with which he can do it, the question is of another kind.

There is a side of the matter not yet touched upon, but which can not be neglected. If the higher grade ore only be mined, the exhaustion of the deposit is certainly set forward. It rarely happens that all of a deposit is high grade ore. and if only the best be in demand one has to cut his cloth to suit the pattern. The miner may have incurred large expense in opening the mine and in equipping it with proper machinery under the expectation that his output would be profitable to him. If he be restricted to a certain portion of the ore and this be below the amount required to yield a profit on the investment, he would be subjected to hardships not tolerable under ordinary conditions. He is quite willing to encourage the belief that it is cheaper to use a large amount of low priced, low grade ore than to pay more for better ore of which not so much is used. In the minds of some whose opinions should be worthy of consideration the value of a fifty per cent. ore is proportional to the value of a forty-five per cent. ore, and they argue that as the lower grade material can be bought for fifty cents per ton, or 1.11 cents per unit of iron, the better grade material is worth proportionally more, or 55.5 cents per ton. They forget that the value of an ore increases very rapidly as one nears the fifty per cent.

mark. As a matter of fact, if a forty-five per cent. ore be worth fifty cents, a fifty per cent. ore is worth 83 cents, that is, it will cost as much to make a ton of iron from the one at 50 cents as from the other at 83 cents. Above fifty per cent. the difference becomes even more striking.

Attempts at improving the quality of the ores used in the State have been confined so far almost entirely to the brown ores, although it is possible to better the soft red ores to a very considerable extent also. A description of the methods in use will appear under each kind of ore, so that it is merely necessary here to direct attention to the matter in a general way.

The ore that most readily lends itself to processes of beneficiation, without any very heavy expense, is the limonite or brown ore. Occurring, as it does, as more or less isolated masses imbedded in clay, it was comparatively easy to devise machinery that would treat the entire mass of stuff, removing the clay by suspension in water and passing the cleaned ore over screens of appropriate sizes. In this matter the clay, unless it was of a very plastic nature, was removed from the ore, the wash water being collected in settling dams and again used, after the clay had been deposited. The process was crude at first and the ore was insufficiently cleansed, but of late years it had been much improved and can now be depended on to furnish fairly good ore from even the more tenacious clays.

At some establishments it has been customary to improve the brown ores still further by calcining the washed ore in open piles with wood or charcoal "breeze" as fuel, and, later, in gas fired kilns. In this manner the ordinary water is completely removed, and the combined water, which does not go off under a full red heat, to an extent depending on the temperature and the duration of the firing. Washed brown ore carrying 44 per cent. of iron has been greatly improved by calcining, the iron in the calcined ore being as high as 54 to 56 per cent. over a period of several months.

While it is now customary to wash nearly all the brown ore used in the State, but little calcining is done. The reasons for this practice will appear under the discussion of the brown ores, and it will be shown that unless the deposit is known to be large or the demands upon it not very exacting as to quantity, the erection of calcining kilns could not be expected to yield much return on the investment.

For improving the soft red ores several plans have been proposed, but none of them have worked their way into actual use on a large scale, although at least one of them may now be said to have passed the experimental stage. It was proposed to wash the lower grade soft red ores in such a manner as to remove the more ferruginous material from the more sandy portion and to recover the ore in setting dams. Some experiments were very successful as regards the possibility of concentrating the ore, but the large amount of water required at points where it was expensive to get and the impracticability of handling large quantities of damp ore that would certainly fall into the finest powder as soon as it was charged into the furnace have caused the investigation to be postponed.

During the last two or three years extensive experiments have been made with the hope of concentrating these ores magnetically. Two plans have been proposed. First, to render the ore magnetic by raising it to a full red heat in a properly constructed kiln and then passing a reducing gas over it so as to convert the ferric oxide into the magnetic oxide. Subsequent crushing and sizing would bring the ore into a condition in which it could be treated over a magnetic separator, the sand, etc., being removed by centrifugal action.

The other plan for magnetic concentration of these low grade soft ores is to dry them thoroughly, crush and size and pass over a magnetic belt which will pick up the more ferruginous portions and allow the more sandy portions to fall away into suitable receptacles.

Both there processes will be described in the chapter on The Concentration of Ores.

On the whole, therefore, it may be said that in actual practice the only ores subjected to a process of beneficiation on a large scale are the brown ores. Practically all of the pig iron made in Alabama is obtained from native ores. In this respect the situation is quite the reverse of that found in Ohio, which with a pig iron production of 1,463,789 tons in 1895, and 1,196,326 tons in 1896, probably did not derive more than 3 % of it from native ore. The only ores brought into Alabama for any purpose are some brown ore from Georgia, a little "spathite" ore from Tennessee, and Lake ore for use as "fix" in the rolling mills.

The production and value of the ore mined in the State, so far as can now be ascertained, are given in the following table, compiled from the reports of Mr. John Birkinbine to the United States Geological Survey, Division of Mineral Resources, from the census returns and from independent sources.

TABLE III.

PRODUCTION AND VALUE OF IRON ORES IN ALABAMA AND THE UNITED STATES.

	ALABAMA.				UNITED STATES.		
	Tons.	Value.		Per cent. of Production.	Tons.	Value.	
		Per Ton.	Total.			Per Ton.	Total.
1850	1,838	$ 3.68	$ 6,770	0.12	1,579,318	$ 4.23	$ 6,981,679
1860	3,720	5.31	19,765	0.15	2,401,485	5.31	12,757,848
1870	11,350	2.66	30,175	0.21	5,302,952	5.63	29.843,420
1880	171,189	1.18	201,865	2.3	7,497,509	3 09	23,156,955
1881	220,000	1.30	286,000	2.4	9,094,369	2.97	27,000,000
1882	250,000	1.20	300,000	2.8	9,000,000	3 60	32,400,000
1883	385,000	1.20	462.000	4.6	8,240,594	3.00	24,750,000
1884	420,000	1.00	320,000	5.1	8,200,000	2.75	22,550,000
1885	505.000	1.00	505,000	6.6	7,600.000	2.50	19,000,000
1886	650,000	0.96	624.000	6.5	10,000,000	2 80	28,000.000
1887	675.000	0.96	648,000	6.0	11,300.000	3 00	33,900,000
1888	1,000,000	0.96	960,000	8.3	12,060,000	2.40	28,944,000
1889	1,570,000	0.96	1,507,200	10.9	14,518.041	2.30	33,351,978
1890	1,897,815	1.00	1,897,815	11.8	16,036.043	2.20	35,279,394
1891	1,986,830	1.00	1,986,830	13.6	14,591,178	2 10	30,641,473
1892	2,312,071	1.06	2,442,575	14.2	16,296.666	2.04	33,204,896
1893	1,742,410	1.86	1,490,259	15.0	11.587,629	1.66	19,265,973
1894	1,493,086	0.83	1,240,895	12.6	11,879,679	1.14	13,577,325
1895	2,199,390	0.80	1,759,512	13.8	15,957,614	1.14	18,191,679
1896	2,041,793	0.69	1.417,451	12.8	16,005,449	1.42	22,788,069
1897	2.098.621	0 74	1.546.543	11.9	17.518.046	1.08	18,953.221

For a number of years Michigan has held the first place as a producer of iron ore, Minnesota coming up from the 6th place in 1890 to the second place in 1894, 1895 and 1896.

It is not likely that Alabama's rank as third in the production of iron ore will be interfered with for some years.

She held the second place from 1889 till 1894, when she was surpassed by Minnesota, and Pennsylvania the third place until 1892 when Minnesota came up to the second place. It is not likely that the relative positions will be changed for some years. The immensity of the Mesabi ore deposits and the cheapness with which they are mined will, perhaps, keep Minnesota in the second place for the next two years, if indeed she does not push Michigan for first place within that time. Michigan does not produce much pig iron, the output being 132,578 tons in 1897. Minnesota made no iron in 1894, nor in 1895, nor 1896. The difficulty of procuring good coke at that distance from the coal fields has hitherto prevented these States from converting their ore into iron, and the tendency seems to be more and more to reduce the cost of these ores to Illinois, Ohio, and Pennsylvania furnaces. But it is a wise man who prophesies concerning the iron trade in this day of rapid industrial changes. It would appear, however, that Alabama will have to face competition from furnaces much nearer than Michigan and Minnesota. It is just here that questions of transportation play the really vital part. So long as the rich Lake ores can be hauled to Ohio and Pennsylvania furnaces and converted into pig iron which can be sold profitably for half a cent per pound, the situation in Alabama will be one in which the cost of transporting the iron to market after it is made is the main question. With the Northern and Eastern furnaces the great question is the cost of gathering the raw materials into the stockhouse. In Alabama the great question is the cost of marketing the pig iron. With better ore, better coke, and better furnace practice it may be possible even in Alabama to reduce the cost of making iron, but the transportation companies will control the situation then as they do now, unless a closer union can be effected between the two interests.

According to the Iron Trade Review, Cleveland, Ohio, the Lake shipments of iron ore in 1892, were 8,545,313 tons; in 1893, 5,836,749 tons; in 1894, 7,621,620 tons; in 1895, 10,234,910 tons; in 1896, 9,916,035 tons, and in 1897, 12,457,002 tons. These figures mean that considerably more than half of the total amount of iron ore mined in the United States is transported by water to the vicinity of the furnaces using it. Were it not for this fact the enormous development that has been reached in the Lake regions, with respect to the mining of iron ore, could not have been attained within so short a time, if at all.

In order to exhibit the relation that Alabama sustains to the other iron ore producing states, in respect to the value of the ore mined, the following table taken from the reports of Mr. John Birkinbine to the U. S. Geological Survey, Division of Mineral Resources, is appended.

TABLE IV.

Total Valuation and Average Value Per Ton of Iron Ore Produced in the United States in 1889, 1892, 1893, 1894, 1896, 1897.

STATES.	1889. Valuation.		1892. Valuation.		1893. Valuation.	
	Total.	Per Ton.	Total.	Per Ton.	Total.	Per Ton.
Alabama	$ 1,511,611	$ 0 96	$ 2,442,575	$ 1 06	$1,490,259	$0 86
Colorado	487,433	4 47	587,903	4 15	514,312	3 00
Connecticut and Mass.	a. 265,091	3 01	249,198	3 27	122,475	3 01
Georgia and N. Car.	334,025	1 29	262,517	1 25	203,682	1 09
Kentucky	135,559	1 75	63,172	1 25	47,746	1 30
Maryland	f 68,240	2 32	88,691	2 21	25,585	1 85
Michigan	15,800,521	2 70	16,587,521	2 20	8,611,192	1 84
Minnesota	2,478,041	2 87	3,090,942	2 46	2,321,204	1 55
Missouri	561,041	2 11	237,827	2 01	160,532	2 07
Montana, N. Mexico & Utah	b. 269,164	3 12	c. 97,121	2 16	d. 103,545	2 67
New Jersey	1,341,543	3 23	1.388,875	2 98	909,458	2 55
New York	3,100,216	2 49	2,379,267	2 67	1,222,934	2 29
Ohio	532,725	2 09	148,288	2 01	104,879	1 54
Pennsylvania	3,063,534	1 96	2,197,028	2 03	1,374,313	1 97
Tennessee	606,476	1 28	505,359	1 24	392,771	1 05
Texas	19,750	1 52	20,890	0 91	25,997	1 01
Virginia & West Virginia	935,290	1 83	1,428,801	1 91	1,050,977	1 70
Wisconsin	1,840,908	2 20	1,428,921	1 81	584,094	1 33
Total	$33,351,978	$ 2 30	$33,204,896	$2 04	$19,265,973	$1 66

TABLE IV—Continued.

Total Valuation and Average Value Per Ton of Iron Ore Produced in the United States in 1889, 1892, 1892, 8893, 1894, 1896, 1897.

STATES.	1894. Valuation.		1896. Valuation.		1897. Valuation.	
	Total.	Per Ton.	Total.	Per Ton.	Total.	Per Ton.
Alabama	$1,240,895	$0 83	$ 1,417,451	$ 0 69	$ 1,546,543	$ 0 74
Colorado	676,141	2 70	524,915	2 43	485,009	2 59
Conn. and Mass	71,191	2 35	63.286	2 32	i. 56,141	2 49
Georgia and N. Car	166,228	0 95	150,018	0 86	166,704	0 81
Kentucky	54,379	1 28	38,256	1 27	12,464	1 00
Maryland	17,809	2 25	23,004	2 09	23,000	2 00
Michigan	5,844,995	1 32	10,143,918	1 78	8.347,615	1 37
Minnesota	2,165,802	0 73	5,286,664	1 23	4,029.077	0 72
Missouri	105,235	1 28	12,880	2 82	600	1 00
Mont., N. Mex., and Utah	e. 67,538	1 52	g. 96,486	2 16	j. 67,922	1 70
New Jersey	568,056	2 05	528,759	2 00	491,838	1 93
New York	396,456	1 63	780,932	2 03	642,838	1 91
Ohio	65,792	1 12	72,019	1 23	64,235	1 18
Pennsylvania	643,459	1 21	920 916	1 23	851,079	1 18
Tennessee	288,005	0 98	432,932	0 81	479,485	0 79
Texas	11,521	0 75	h. 3.583	0 75	10 870	0 80
Virginia	873,305	1 45	1,220,619	1 42	974,031	1 37
Wisconsin	320,518	0 92	1,071,511	1 76	703,770	1 27
Total.	$13,577,325	$1 14	$22,788,069	$ 1 42	$18.953,221	$1 08

a Including Maine b. Includ'g Oregon Washington & Idaho, c. Includ'g Oregon. d. Includ'g Oregon & Idaho. e. Includ'g Nevada. f. Includ'g Delaware. g. Includ'g Wyoming. h. Va. alone. i. Includ'g Vermont. j. Includ'g Nevada & Wy.

CHAPTER II.

THE ORES: SPECIAL DISCUSSION:

THE HEMATITES.

In the discussion of the hematite ores we shall have to exclude the brown hematites as they properly belong to the limonites, although often mis-called by the former name. The limonites are locally termed "brown ores" and the output is about 25 per cent. of the total ore production of the State. They will be discussed under their proper heading.

The hematite ores are, for convenience, classed under two heads:

First, the soft red ores, carrying but little lime and

Second, the "hard red" ores carrying from 12 to 20 per cent. of lime and in many cases self-fluxing, that is, they carry enough lime to flux the silica contained in them.

In order that a clear understanding of the matter may be had at the outset the following brief description of the geological and topographical feature of the deposit of hematite ores so largely used in the State is given here.

They belong to the Clinton formation of the Silurian, which extends with some breaks, from the middle portion of Alabama to the northern part of Maine. They are overlaid by chert, sandstones, and clays, the overburden at places reaching a depth of forty and fifty feet. The seams now worked vary in thickness from 3 to 25 feet, run in a north-east direction and dip towards the south-east at angles varying from 15 to 22 degrees, the dip increasing as one goes towards the south-west. For the most part they occupy the crests of the hills, the outcrop forming a striking and persistent feature of the landscape for several miles in the vicinity of Birmingham.

The Soft Ores.

As a rule, to which, however, there are some important exceptions, the outcrop is "soft red," a term of comparative significance only as the ore is quite firm and has to be won by regular blasting operations. It is soft as compared with the limey or "hard red" ore. The soft ore may extend from the outcrop for a distance of 300 feet on the dip, depending on the thickness and imperviousness of the cover, although the hard ore comes to the surface at more than one place.

In winning the soft red, the overburden is removed and the ore mined, at day, by benches. Under cover the ore becomes limey and hard and is mined from inclines on the dip by drifts and slopes.

The soft ore is the hard ore with the lime removed by atmospheric influences and is richer in iron the poorer it is in lime, When the overbruden is stripped off there is found a seam of ore quite soft and seemingly disintegrated, of a deep red or purple color, the so-called "gouge." It may be only a few inches thick but often runs to 24 and even 36 inches, and comprises generally the best part of the ore. Underneath this begins the more solid ore diminishing in content of iron according to the vertical depth. The best quality of "gouge" will carry 52 per cent. of iron while ten feet below its line of demarcation the iron falls to about 46 per cent. Between the "gouge" and the ore proper there is often a thin seam of yellowish clay, which, however, is by no means constant in strike. In the more solid ore, beneath the "gouge," there are seams of the same clay, sometimes as much as two inches thick but for the most part not above half an inch thick. In the early days of iron making in the Birmingham district it was the custom to mine 15 to 20 feet of the soft ore and to send the whole material to the furnace. Of late years, however, the mining has been restricted to ten feet, including the "gouge" as it was found that below this depth the ore rapidly became siliceous and unfit for use. Taking the content of metallic iron in the "gouge" at fifty per cent, as mined, the loss in iron according to vertical depth, is about one-half of one per cent. per foot. This would bring the iron in the first ten feet of the seam to forty-five per cent. and in the next ten feet to forty per cent. A large number of analyses extending over several years show that when the mining is limited to the ten foot mark the iron content is a little over 47 per cent. in the ore as mined, i. e., with seven per cent. of water, and including the "gouge." The rapid increase of the silica in the ore below the ten foot mark is shown by the fact that to get even 47 per cent. of iron in the upper ten feet from one-fifth to one-third of it must be composed of the "gouge," with its 50 per cent. of iron.

The following successions of materials has been observed at East No. 2 mine on Red Mt. south of Grace's Gap, and about 4 miles from Birmingham. The overburden here was 24½ feet thick, and was removed before any of the ore was mined. In places the overburden is not so heavy, and in other places it is heavier. There is no general rule in regard to the thickness of the over burden or its nature. Within two miles of this locality towards the southwest the overburden is a great deal thicker, and of a different character.

SECTION I.

VERTICAL SECTION AT EAST NO. 2 MINE, RED MT. SOFT RED ORE.

	Ft.	In.
Soil and red clay	6	0
Sandstone	3	0
Clay	0	1
Sandstone	1	0
Clay	0	2
Ore	0	6
Clay	0	2
Ore	0	3½
Clay	0	1
Ore	0	4
Clay	0	4
Ore	0	4
Clay	0	½
Ore	1	1
Clay	0	2
Ore	0	10
Clay	0	1
Ore	0	2½
Clay	0	½
Ore	0	½
Clay	0	1
Ore	0	2
Clay	0	½
Fine grained ore	0	2
Clay	0	2
Fine grained ore	1	4
Slate	0	½

Fine grained ore	0	5
Clay	0	1
Fine grained ore	0	7
Slate	0	1
Fine grained ore	0	4
Slate	0	2
Sandy ore	0	1
Slate	0	1
Sandy ore	0	2
Slate	1	0
Sandy ore	0	6
Slate	0	1
Sandy ore	0	7
Slate	0	1
Limy ore	0	2
Slate	0	½
Limy ore	0	2
Slate	0	½
Limy ore	0	8
Clay	0	½
Sandy ore	0	6
Slate	0	3
Sandy ore	0	3
Slate and sandy ore	0	6
Sandy ore	0	1
Clay seam	0	½
Sandy ore	0	3
Slate	0	1
Sandstone	0	6
Good ore	10	0
Poor ore	12	0
Yellow slate bottom	46	7

The occurrence of thin seams of limey ore above the big seam of soft ore is noteworthy, as also thin seams of sandy, lime-free ore and limey oreare interstratified, being separated by thin partings of slate. It is also remarkable that the fine grained ore carries much less phosphorus than the ordinary soft ore of coarser texture, and the limey ore. Whatever phosphorizing agencies were at work when these ores were deposited, or subsequently, they do not seem to have affected all the ore alike. For instance, the ordinary, medium and coarse grained soft ore carries generally from 0.30 % to 0.40 % of phosphorus, but the fine grained ore carries not more than one-half this amount, and has been found with only 0.10 %. Furthermore, there is a 2 to 3 foot seam of soft ore, near Village Springs, 20 miles northeast of Birmingham, that carries 5.40 % of phosphorus in one place and 2.30 % in another. At Lone Pine Gap, opposite Birmingham. soft red ore has been found with 46 % of iron, and 0.06 % of phosphorus. In any one particular kind of ore the phosphorus appears to be of uniform distribution, but in the same vertical section where thin seams and thick occur, where fine grained and coarse grained ore is found, different amounts of phosphorus are met with. The matter is chiefly of scientific interest, but has not been fully investigated. It must not be suppposed that the succession of material, as already given, is always the same. Within 2 miles of East No. 2, towards the southwest at the Fossil mines quite another arrangement may be seen. With the exception of the limey ore, which does not appear in the overburden at the place examined, the materials are the same, but the succession and the development are different. The object of the mining at both places was the same, viz., to win the soft red ore. At East No. 2 the overburden wast 24½ feet thick, at Fossil it was 66 feet, the dip of the ore at East No. 2 was 19 degrees to the southeast and at Fossil 22½ degrees.

The thickest single stratum at East No. 2, above the ore was 3 feet of sandstone, while this material had increased in thickness to 26 feet at Fossil. At East No. 2 again the overburden was composed of no less than 56 separate strata in the 24½ feet, while at Fossil, in 66 feet there were also 56 separate strata. The fine grained ore and the limy ore in the overburden at East No. 2 are lacking at Fossil. It was difficult to get the vertical section at Fossil, as the writer had to be let down with a rope alongside the face, but it is thought that it is approximately correct.

SECTION II.

VERTICAL SECTION AT FOSSIL, RED MOUNTAIN, SOFT RED ORE.

	Ft.	In.
Soil and red clay	4	0
Sandstone	26	0
Clay	0	2
Sandstone	1	4
Clay	0	2
Sandstone	1	2
Clay	0	1
Sandstone	1	7
Clay	0	1
Sandstone	2	2
Clay	0	6
Sandstone	1	1
Clay	0	1
Sandstone	0	8
Clay	0	7
Sandstone	1	4
Clay	0	8
Sandstone	2	0
Ore	2	0
Sandy ore	3	0
Clay	0	3
Sandy ore	1	6
Clay	0	2
Sandy ore	1	0
Clay	1	0
Sandy ore	0	3
Clay	0	3

	FT.	IN.
Sandy ore	1	0
Clay	0	3
Ore	0	9
Clay	0	2
Sandy ore	0	1
Clay	0	6
Sandy ore	0	2
Clay	0	3
Ore	1	0
Clay	0	2
Ore	0	9
Clay	0	1
Ore	0	2
Clay	0	5
Ore	0	5
Clay	0	8
Ore	0	8
Clay	0	6
Sandy ore	0	2
Clay	0	1
Sandy ore	0	1
Clay	0	1
Sandy ore	0	4
Clay	0	2
Good ore	2	0
Clay	0	5
Ore	0	6
Clay	0	2
Good ore	3	0
Clay	0	1
Good ore	6	4
Clay	1	5
Good ore	9	0
Intermixed ore and clay	6	0
Yellow shale bottom		
	91 ft.	

In Vol. XV. 10th U. S. Census, Mr. A. A. Blair gives some very detailed analyses of the soft red ore used in the Birmingham district. An average of those quoted is herewith given:

	Dry basis %
Silica	13.66
Sulphur	0.11
Phosphorus	0.43
Alumina	6.13
Lime	1.26
Magnesia	0.37
Manganese protoxide	0.30
Iron protoxide	0.32
Iron peroxide	75.05
Carbonic acid	0.08
Carbon in carbonaceous matter	0.03
Water of composition	1.62
Metallic iron, 52.87 per cent.	99.36

Specific gravity 4.

This average shows a greater amount of alumina and metallic iron, and much less silica than is usually the case with this class of ore.

An average analysis of stock house samples shows:

		Dry.
Iron	47.24	50.80
Silica	17.20	18.50
Alumina	3.35	3.60
Lime	1.12	1.20
Water	7.00	

For practical purposes it is not necessary to go so fully into detail, and it is customary to determine merely the insoluble matter and the iron. With a few ores of this class which carry unusual amounts of alumina this ingredient is also determined. But for every day practice and with slags of 33 to 36 per cent. silica the alumina is considered as silica and reported with it as "insoluble." It is a fortunate circumstance that the soft red ores, when finely ground, yield their iron to acid solution without fusion, the insoluble residue being of a creamy white appearance and carrying seldom more than 0.20 per cent. of iron. For blast furnace purposes and where the ore is not sold on the unit system the easy solubility of the ore is a point of great importance, especially when many analyses must be made within a short time. About one-half of the alumina present goes into solution with the iron but may be neglected under the conditions that obtain in the district with respect to the variation in the composition of the cinder. In calculating furnace burdens the error arising from neglecting the alumina and reckoning it as silica is comparatively slight, as the ratio between the silica and the alumina is as 1 to 0.87.

The insoluble matter in most of the soft red ore as used in the State is 23 per cent., and the iron 46 per cent., with water at 7 per cent. The ordinary ratio between the metallic iron and the insoluble matter varies from 1 to 1.50 to 1 :2. To illustrate.

Water 7%.

Iron.	Insoluble. Matter.	
40	35.00	For each 1 per cent. increase in the iron the insoluble matter falls 2 per cent.
41	33.00	
42	31.00	
43	29.00	
44	27.00	
45	25.00	
46	23.00	
47	22.00	For each 1 per cent. increase in the iron the insoluble matter falls 1.50 per cent.
48	20.50	
49	19.00	
50	17.50	
51	16.00	
52	14.50	
53	13.00	
54	11.50	

It is not necessary to carry the list further, as the supply of fifty-four per cent. soft red ore is limited. It is not claimed that this ratio is absolutely correct, but a large number of analyses substantiate its reliability for ordinary purposes. The ratio from 40 iron through 46 iron is as 1 :2. Beginning with iron 47 and insoluble 22, the ratio appears to be nearer 1 :1.50 than 1 :2, for with iron 48 the insoluble matter is about 20.50. It may, therefore, be said with a fair degree of accuracy that a soft red ore carrying 40 per cent. of iron may be expected to contain 35 per cent. one with 45 per cent. of iron 25 per cent. and one with 50 per cent. of iron 17.50 per cent. of insolute matter. There are, of course exceptions to this rule and it does some times occur that an ore with 46 per cent, of iron will be found to carry 22 per cent. and one with 48 per cent. of iron will have 21 or 22 per cent. of insoluble matter. But on the whole the fact remains that an ore with 45 per cent. of iron will carry 25 per cent. of insoluble, and one with 50 per cent. of iron from 17 to 18 per cent., and the list may be used as an approximation to the truth.

In texture, the soft red ore is a mass of minute siliceous pebbles held in a ferruginous cement. The pebbles are seldom larger than a No. 4 shot, and are frequently much smaller. They are all more or less rounded and stained reddish–brown. The cementing material is softer than the pebbles, and on sizing even a very lean ore the material passing a screen of fifty meshes per linear inch is much richer in iron than the material remaining on a 10 or a 20,mesh screen. A soft red ore of 40 per cent. iron, on being ground to pass a ten mesh screen, will yield through a fifty mesh 53 per cent. of iron, and the amount passing the 50 mesh screen is from 25 to 30 per cent. of the ore, by weight.

So far as concerns their physical structure, this is one of the points of differentiation between the soft red and the so-called brown ores, for these, on being sized, show a steady loss of iron the finer the screen. The fact of increasing richness in iron the finer the screen renders the concentration of the low grade soft red ores much simpler than would otherwise be the case, as the "fines" can be briquetted without further treatment, and the troublesome question of handling them becomes comparatively easy. The rounded form of the more siliceous pebbles also occasions less wear on the shutes, screens, and conveyors; a point of no little moment in concentrating works.

The better grades of the soft red ore do not occur at every point on Red Mountain, nor is it possible to mine even ten feet profitably everywhere along the ridge. It is frequently the case that the inferior ore sets in, as the saying is, "at the grass roots," and even the richer "gouge" is sometimes absent. Mining operations can not be undertaken without careful prospecting and many analyses, for the difference between a fairly good ore and one that is not passable is often so slight as to deceive even the most experienced man who grades merely by the eye. After having become accustomed to a particular kind of ore, one may judge of its quality by the appearance with a reasonable degree of accuracy. While for the most part the soft ores are of the same general texture and color, it not infrequently happens that serious mistakes may be made unless the services of a chemist are called into requisition. When freshly mined the ore is of a deep red color, inclining to purplish red in the richer portions, but on drying there is assumed something of a brownish tint. For ordinary stockhouse delivery the ore contains on the average 7 per cent. of hygroscopic water, which, owing to the coarse-grained nature, soon dries out under cover.

In the early days of iron making in the Birmingham district, before the real value of the limy or hard ores was generally accepted, the furnace burden was composed almost entirely of the soft ores. Of late years, however, the tendency is decidedly towards a greater and greater proportion of the limy ore, the proportion rising at times to above 90 per cent. of the ore burden. It is still to some extent a mooted question as to the relative reducibility of the two ores, but a careful investigation of the subject would, we think, show that in this respect the limy ore has the advantage. When the soft ore descends into the zone of reduction in the furnace, it does so without losing its firmness of texture. Even after it has become red hot, or white hot, it maintains its shape, except as this may be changed by friction during the descent. The reducing gases act upon it in the lump, and if the lumps be of considerable size the reduction to metallic iron may be delayed and the ore may appear before the tuyeres.

The case is quite otherwise with the limy ore. The lime is present as carbonate, (except such as may be combined with the phosphorus as phosphate of lime, an amount rarely exceeding 0.50 %,) and when this reaches a point in the furnace at which its carbonic acid begins to come off, the ore begins to fall to pieces. The friction of the other materials aids this tendency quite as much as, and perhaps, more than in the case of the soft ore. The reducing gases can and do have a greater ore surface to work on and the result is that for a given weight of coke and a given composition of the gas there is greater reducing action. The soft ore is more fusible than the limy ore, but this does not necessarily mean that it is more easily penetrated by the reducing gases within the furnace. On the contrary a fused crust on the outside of a piece of soft ore interposes considerable opposition to the passage of the gases, and as this crust becomes thicker and thicker the gases penetrate with more and more difficulty. In the case of the limy ore as soon as it begins to part with its carbonic acid it begins to disintegrate, and this very fact of disintegration enables it to receive to better advantage the reducing power of the gases.

In comparing the two ores another circumstance must not be lost sight of, and that is the intimate commingling of the ore and the lime that is to flux it. This is a distinguishing characteristic of the lime ores. It would be impracticable to effect by artificial means such an intimate mixture of ore and lime as Nature has already provided in these ores. This circumstance is of the greatest importance in any discussion of the relative value of the soft and the lime ores, for while these latter require a higher heat for fusion they are not therefore to be considered less easily reducible.

The reducibility of an ore depends far more upon its permeability or porosity than upon its fusing point. For the most part the loss of energy in a furnace is chargeable to lack of reducing power rather than to lack of fusing power.

The tendency now is more and more towards the use of the limy ores; for the enormous demand that has been made on the better quality of the soft ore within the immediate vicinity of Birmingham has begun to make itself felt.

Three courses of action may be open: First, the increasing proportion of limy ore in the burden may induce the furnacemen to look towards the use of eighty or ninety per cent. of it, the difference being made up with soft and brown ore. Second, other sources of soft ore may be utilized. Third, the lower grades of the soft ore, now remaining in the ground, may be concentrated and made to take the place of the ore that has been removed. It is not thought that the proportion of brown ore used will be materially increased.

Under the existing conditions it would appear advisable to begin at once to increase the proportion of limy ore used, so as to establish on the basis of wider experience the economic relation that this burden would sustain to former practice, or to push the work of concentrating the lower grades of soft ore to some definite result.

The experiments on concentrating soft ore, to which some allusion has already been made, showed the possibility of taking an ore of 40% iron and 35% silica and bringing the ore to 57% and the silica to 15%, on the average. In this process two tons of raw ore were required to make one ton of concentrates. The matter is fully discussed in Chapter VII on the Concentration of Low-grade Ores.

The Limy, or so-called Hard Ore.

The ore sets in sometimes at the outcrop but much more frequently it is found only under cover and is the continuation of the soft ore in the direction of the dip. For distances varying from nothing to 300 feet on the dip the ore is soft, then the hard ore begins and continues to depths not yet ascertained but certainly very considerable. In other words, as has been already stated, the hard ore, which originally appeared at the surface, has been deprived of its carbonic acid by atmospheric influences and converted into soft ore along the dip to varying depths, the lime having been removed by leaching. Relatively the same differences that are to be observed in the soft ore from various places are also found in the hard ores. There are points along the mountain where the minable seam of soft ore is better than at others, and there are places where the hard ore is better than at others.

On a vertical section of the soft ore the content in iron decreases downward, the rate being about one-half of one per cent. per foot. The rule holds good for the hard ore on a vertical section. The mining on the big seam of soft ore is now confined for the most part to the upper ten feet, the mining on the hard ore is also the same, and below the ten-foot mark the hard ore also becomes too siliceous for economic use. The hard ore derives its value from two circumstances, first there is a great deal more of it than of the soft ore, because it extends to very considerable depths, and second because of the intimate admixture of carbonate of lime with the ferruginous material. The best hard ore carries more lime than is required to flux its silica, while in the ordinary grades the ratio of one of silica to one of lime is generally conserved. When this is the case the ore is termed ''self fluxing'' and in burdening a furnace exclusively with hard ore of this type it is not necessary to add limestone to flux the ore. When the burden is composed of hard and soft ore, or of hard and brown, or of hard, soft, and brown the amount of limestone to be added is calculated from the silica of the ore other than hard, the silica of the fuel and of the stone itself. The increase in the use of hard ore would tend to diminish the consumption of limestone by an amount represented by the limestone in the ore and if a strictly self-fluxing ore were used the consumption of limestone would be greatly diminished. There is a kind of hard ore, termed semi-hard, which contains from one-third to one-half of the lime in typical hard ore, but of this sort very little is used, and it is not mined regularly.

Within the last three years the use of crushed hard ore has become quite common in the Birmingham district. The soft ore does not lend itself readily to crushing unless thoroughly dry. With the amount of water it usually contains it becomes somewhat like clay in the crusher, i. e. more or less gummy, and the machine soon becomes choked.

A general average of the hard ore used shows:

	PER CENT.
Water	0.50
Metallic Iron	37.00
Silica	13.44
Lime	16.20
Alumina	3.18
Phosphorus	0.37
Sulphur	0.07
Carbonic acid	12.24

Adding the alumina and the silica together we have for silica plus alumina 16.62%, the lime is 16.20%, and the ore may be termed self-fluxing. It cannot be said that all of the hard ore used is self-fluxing, as some of it contains 5% more of lime than of silica plus alumina. Taking a general average, however, of analyses of all kinds of hard ore extending over several years this ore carries enough lime to flux the silica plus alumina. It may be urged that aluminous soft ore needs silica as a flux for the alumina, and this is indeed true. But we have to flux the silicate of alumina with lime, and it is merely a question as to whether all the bases of the burden shall be calculated as lime, and all the acids as silica, or whether we shall regard the silica plus alumina as requiring so much lime. In either case the type of slag to be made has to be considered, and for any one type the two calculations lead to the same result so far as concerns the consumption of limestone per ton of iron.

The question has been raised as to whether the hard ore, on the dip, may not gradually lose its content of iron and become a more and more ferruginous limestone until finally the iron will not exceed 20 or 25%. The matter is one of scientific rather than practical moment, and some information has been collected. Taking the iron in the soft ore at 47% at the outcrop, and in the hard ore at 37% 100 feet on the dip the rate of decrease for the iron would be one per cent. per hundred feet. This rate seems to be maintained at some localities, but at others it varies so that no rule can be given. This comparison is between the soft and the hard ore. When the hard ore begins it maintains a fairly uniform composition on planes extending in the direction of the dip.

As to the minimum amount of iron that a hard ore can carry and still be considered an ore, opinions may differ. But if the iron in the hard ore should fall to 25%, the lime increasing in the same proportion, it is not likely that it could be used. The silica and alumina appear to remain somewhat stationary, so that the question would be whether or no material carrying 25% of iron, from 16 to 20% of silica, and from 24 to 28% of lime can be profitably used. It will be many years, however, before this question will arise, and it is not necessary to discuss it now. It is bound up with geological and topographical considerations which are still in abeyance.

The beneficiation of the limy ore by calcining it is discussed in the chapter on Concentration of Ores.

THE LIMONITE, OR, SO-CALLED BROWN ORES.

As a rule these ores constitute the best material for iron making in the State. Practically all of the charcoal iron is produced from this class of ore, and although there has been of late years a marked decrease in the output of charcoal iron, following a general tendency throughout the country at large, the total amount made from 1872 to the close of 1897, was 1,000,000 tons.

The yearly amount of brown ore mined is about 26 per cent. of the total production of all kinds of ore.

The deposits do not occur in regular seams, except as the gossan of underlying pyritiferous veins which furnish very little of the ore used, but as pockets in the clay. These pockets are of greater or less extent, sometimes going down to 75 or 100 feet, or even deeper.

They do not appear to follow any known rule of occurrence, and each deposit has to be judged by itself alone. It is a common saying that no one knows much about a brown ore bank beyond the length of his pick. To-day one may be in good ore, to morrow there may be none in sight, and to know which way to turn one must know the particular deposit he is mining,

The ore is of two kinds, lump and gravel. There is no rule as to the proportion in which each may be present, even in the same 'bank.' The lump ore is generally better than the ordinary gravel ore unless this latter is carefully washed from adhering clay. And yet it often happens that the presence of chert, or sandy inclusions, in the lump ore, as also the clay-filling of the interstices and small holes, makes the lump ore objectionable. The lumps vary in size from that of the fist to large masses of several tons weight.

The large lumps are broken by hand, if of unusual size by means of small charges of dynamite, and loaded on the car without further treatment. By far the greater amount of brown ore is comprised within the sizes of a pigeon's egg and a goose egg.

Excluding the large lumps, the method of mining is briefly as follows: The bank is cut away in benches, the entire mass being taken down either by hand, or steam-shovel. The stuff is loaded on trams and conveyed to ordinary log-washers, single or double as the case may be, where it is subjected to thorough disintegration and stirring in large excess of running water. The clay, &c., is removed by suspension in water, and is run into settling dams for the recovery of the water. The heavier particles of sand are screened out over $\frac{1}{8}$ inch screens revolving in a mild current of water, and the washed ore delivered over the screens into the railroad cars, and sent to the furnaces. Where the clay holding the gravel is friable and does not 'ball' under the action of the washer, and where abundance of water can be secured, this method of preparing brown ore is fairly successful There is great variation in the character of the clay, some of it being easily disintegrated and therefore yielding its ore readily, and some of it being extremely tenacious and putty-like. In this case there may be serious loss of the finer ore particles, the balls of clay picking them up, enwrapping them, and finally carrying them to the waste dump.

It is customary at some establishments to remove the clay balls by hand, boys being employed for the purpose. Jigging is resorted to but rarely, the results not warranting the additional expense.

A method of washing that has given good satisfaction is to discharge the trams from the 'bank' into a head-box in which play two powerful streams of water. The lower end of the box, which is of triangular shape and inclined about 30 degrees, opens into a long wooden trough lined with castings of iron fitted snugly at the bottom. This trough in turn discharges into the washer at the foot of the hill.

The advantages claimed are contact of the material with water under pressure, and the better separation of ore and clay from the tumbling motion down the trough. Even the tenacious clays may, in this manner, be made to yield their ore. But if the clay be extremely tenacious, as is sometimes the case, even this mode of treatment fails to disintegrate it. In fact it rather tends to increase the 'balling' by carrying the material down an incline. The friable and easily disintegrated clays, on the other hand, are speedily removed in this process, and the washer is called upon merely to complete what has been already pretty well done. No washing system can succeed without plenty of water, and unsparing use of it. If the best results are to be reached there must be no half-handed and mistaken economy in the consumption of water, and as a large part of the water used is recovered in settling dams the loss of water is chargeable mostly to evaporation and seepage. The first can not be prevented, but seepage can be controlled by properly constructed dams.

The amount of material moved per ton of ore obtained varies within wide limits. It may be 1 :1, 4 :1, or 10 :1. Even the same bank shows very considerable differences in this respect, so that no rule can be given. It is a matter that can not be determined before hand, and is liable to change from day to day. Variations in the composition of the ore from the same bank, while observable, do not, as a rule, offer serious obstacles to successful mining. A given bank is apt to afford ore of the same general composition, and variations in the composition of stock-house samples are to be explained by insufficient treatment in the washer, due to lack of water or changes in the nature of the clay.

Brown ore mining is attractive because of the higher price paid for good brown ore, but should be entered upon only after the most thorough examination of all local conditions.

The average composition of the brown ore of the State, stock-house delivery, is as follows:

DRY BASIS.

Metallic Iron	51.00
Silica	9.00
Alumina	3.75
Lime	0.75
Phosphorus	0.40
Sulphur	0.10

The amount of water it contains varies according to circumstances. Thus, if the washer be placed at a short distance from the furnace the water, not having had time to drain out, is more than if the haul were longer So also if the ore be not properly washed the clay retains water. Under a haul of 25 to 50 miles the ore, sampled from the cars in the stock-house, contains on the average 7% of hygroscopic water. Following is an average analysis of a good quality of brown ore:

Hygroscopic water	7.00
Combined water	6.00
Metallic Iron	48.54
Silica	11.22
Alumina	3.61
Lime	0.84
Phosphorus	0 38
Sulphur	0.09

Selected brown ore may carry as much as 56% of iron, on a dry basis, and at one establishment the ordinary ore as charged carries 53%, after washing and calcining. The sale of brown ore on analysis has become the custom in the Birmingham district for outside ores. The basis of sale is 50% of Iron, and 10% of insoluble matter, or silic , as the case may be. The price per ton is started, let us say, at $1.00, for ore carrying 50% of iron, and 10% of insoluble matter. Then for each one per cent. above 50% 5 cents per ton is added to the price. If the insoluble matter at the same time decrease 1%, being 9% instead of 10%, 2½ cents per ton additional is added. An ore carrying 51% of iron and 9% of insoluble matter would be worth $1.075 per ton, and so on. If, on the contrary, the percentage of metallic iron should fall to 49%, 5 cents per ton would be taken off, and if at the same time the insoluble matter should rise to 11%, 2½ cents per ton more would be subtracted. Thus an ore carrying 49% of iron and 11% of insoluble matter would be worth $0.925 per ton. The starting price is not always the same. It may be $1.00, $1.05, $1.10 &c., according to circumstances, but the valuation of 5 cents per unit of iron, and 2½ cents per unit of insoluble matter is generally adopted. In this scheme no account is taken of hygroscopic or combined water, or of sulphur, phosphorus, or alumina.

The basis of valuation is the amount of metallic iron and insoluble matter. The ore may contain 5%, or 10% of ordinary water, yet no account is taken of it. It would be much better if a deduction could be made for all water above a certain percentage, although the condition of the weather, as in the case of heavy rains while the ore was in transit, might prevent satisfactory agreements.

The water a brown ore may contain is a small matter compared with the clay it may, and too often does, contain. The ordinary water is easily enough evaporated in the upper part of the furnace, but the clay requires flux and stone for its removal.

Well washed ore, free from clay, seldom holds more than 4% of water, and the increase in the amount of water follows closely upon the increase in the amount of clay.

There is a circumstance in connection with brown ore that merits attention, not only because of its contradistinction to the soft red ore but also and particularly because of its bearing upon its improvement, whether by simple screening or by some magnetic process. It has been stated that even the lower grades of soft ore on being dried and crushed yield more metallic iron in the material passing a 50 mesh screen than in the coarser stuff. In such ores there is a marked increase in the iron the finer the screen up to and including a 50 mesh.

This is not true of the brown ore. The finer the screen, up to and including a 50 mesh, the poorer in iron is the material passing through.

Not only have laboratory experiments shown this but actual work on a large scale has substantiated the general truth of the proposition that on crushing brown ore, whether by machines or by the attrition of ore on ore in a kiln the fine stuff carries less iron than the coarse stuff. Attention is drawn to this matter because of the custom at some kilns to draw the ore over screens into the furnace-buggies. There is considerable loss of material in this practice, and it is not to be recommended unless the ore carries an unusual amount of clay, which, of course, is removed over the screens. It may happen that as much as 10 per cent. by weight is lost, even over a ½ inch screen. Some experiments were undertaken to establish the actual loss, and how much iron was present in the various sizes of ore from a kiln.

Several hundred pounds were taken, the samples being drawn over several days and put together, so as to represent the ore fairly. The results of the investigation were as follows:

	Iron	Silica.
Raw ore	44.63	13.82
Calcined ore	50.20	15.10
Calcined ore—		
On ¼ inch screen (68 per ct.)	52.95	10.25
Through ¼ inch screen (32 per ct.)	49.30	15.90
On ⅛ inch screen (77 per ct.)	52.75	11.05
Through ⅛ inch screen (23 per ct.)	42.85	21.80

It can not, of course, be said that all brown ores act in this way, but the ore under examination fairly represented the second grade brown, and it is likely that other ores of the same class would give results comparable to these.

Screening over a ¼ inch screen gave 68 per cent. on the screen, with, say, 53 per cent of iron, and 32 per cent. through the screen with 49.50 per cent. of iron. Screening over a ⅛ inch screen gave 77 per cent. on the screen with 52.75 per cent. of iron, and 23 per cent. through the screen with 42.85 per cent. of iron. Screening can not be recommended, except for clayey ore, and the clay should be removed in the washer. There is practically but little difference between the 'overs' on a ¼ inch and ⅛ inch screen in respect of iron, while there is a difference of 9 per cent. in weight in favor of the coarser screen. The loss of ore through either screen is too large for profitable work, except under unusual circumstances requiring the use of the best ore obtainable.

MILL CINDER.

Another material used in the Birmingham district, as a source of iron, is mill cinder.

It is a product from puddling furnaces, and is worth from 90 cents to $1.00 a ton, delivered.

The composition varies somewhat, as the following analyses show:

Equal parts, by weight, of heating furnace and puddle cinder; metallic iron, 56.59 per cent.

Equal parts, by weight, of cinder made with coal, cinder made with gas, and puddle cinder; metallic iron 51.33 per cent.

Equal parts, by weight, of flue and tap cinder; metallic iron, 50.08 per cent.

The average composition of ordinary mill cinder is about as follows:

	Per cent.
Metallic iron	50.00
Silica	20.00
Alumina	1.50
Lime	0.50
Sulphur	1.50
Phosphorus	0.60

It is not used regularly, but in broken doses, as a "scouring" material.

BLUE BILLY, PURPLE ORE.

Residue from pyrite burners in sulphuric acid works. This material has been used in Alabama, having been purchased from the sulphuric acid factories in Atlanta, Pensacola, &c. It generally carries more than 60% of iron, but the content of sulphur is quite variable, and may be as much as 2.50%.

CHAPTER III.

THE FLUXES.

The material used for flux in the State is either limestone, dolomite, or a mixture of the two in varying proportions. It is now very largely sold on analysis, samples being drawn from each car received. The basis of sale is the percentage of silica, some of the contracts starting at 2.50 per cent. and others at 3.50 per cent. When the stone is sold on analysis it is customary to employ a sliding scale, as has already been explained under the brown ore. Suppose the base is 3.50 per cent. of silica. The scale is so arranged that for each quarter of one per cent. above 3.50 per cent., two-tenths of a cent per ton is taken off, and for quarter of one per cent. below 3.50 per cent. of silica two-tenths of a cent is added. Thus if the delivery price be 60 cents per ton for a 3.50 per cent. stone, and the silica should run to 3.75 per cent., the price would be 59.8 cents per ton, and if the silica should fall to 3.25 per cent., the price would be 60.2 cents per ton. If the silica should rise to 5 per cent. the price per ton would be 68.8 cents, and if it should fall to 2.00 per cent. the price would be 61 cents.

The average analysis of the limestone used in the state may be stated as follows:

Silica	4.00%	
Oxide of iron and alumina	1.00	
Carbonate of lime	94.60	Lime 53.00%

It not infrequently happens that the stone is much higher in silica than this average. Instances are on record in which the silica was 8.00 per cent. In such cases the production of iron is attended with considerably higher cost than when the better stone is used.

Considerable shipments of limestone from Bangor have been made in which the silica was less than 0.60 per cent.

Until the last few years limestone was the only flux used. During the last two years the use of dolomite has largely increased. In the manufacture of basic iron intended for the open hearth steel furnace it was soon found that the use of dolomite was a decided advantage, especially in the elimination of sulphur. Whether this result was due to the fact that the dolomite carried only 1.25–1.50 per cent. of silica as against 4.00 for the limestone, or whether the presence of magnesia was of real benefit, so far as concerns the elimination of the sulphur, is still in dispute. The fact, however, remains that in the production of basic iron, sold on analysis under severe restrictions as to quality, only dolomite is used. Aside from its low silica content, the dolomite possesses the further advantage of great uniformity of composition. This is a point very much in its favor. My own experience with limestone in this state covers something like 22,000 cars, and with dolomite about 5,000 cars. The former is subject to considerable variation in respect to silica, while the latter, in so far at least as concerns the lump stone, is of remarkable uniformity. The highest amount of silica observed in the lump dolomite is a trifle over 1.50 per cent., the ordinary range being from 0.75 to 1.25 per cent.

Extensive deposits of both limestone and dolomite exist within eight miles of Birmingham. The haul for limestone is, however, about thirty miles, only the dolomite being worked within the immediate vicinity. So far as my observation goes, the average composition of the dolomite used may be taken as follows:

Dolcito Dolomite........		
Silica....................	1.50%–2.00%	
Oxide of iron and alumina	1.00%	
Carbonate of lime.......	54.00%	Lime 30.31%
Carbonate of magnesia..	43.00%	Magnesia 20.71%

The dolomite mined by the Sloss Iron and Steel Company at North Birmingham seldom carries as much as 0.40 per cent. of silica.

The proportion between the magnesia and the lime does not vary much from 1 :1.50.

Both the limestone and the dolomite carry small amounts of sulphur, the maximum so far observed being 0.11 per cent.

As in the limestone quarries there are layers of siliceous material interfering with the quality of the material, so in the dolomite quarries there are ledges of almost pure silicia, white as porcelain. They seem to be flinty concretions occurring in more or less regular bands, from one-half an inch to three inches in thickness. It is customary to separate these flinty nodules from the stone by hand before it is shipped. They do not seriously interfere with the quality of the dolomite if care is used in the separation. Otherwise they are extremely objectionable.

The impure limestone is of a much darker color than the good stone, but the impure dolomite is generally much lighter in color than the remaining portion. There is a kind of dolomite that occurs in some of the quarries that is very deceptive to the eye. It looks not unlike coarse brown sugar, has the same damp appearance and glistens in the sunlight. To the hand it feels sandy, but on analysis it is found generally to be the best stone in the quarry. Some samples have given only 0.25 per cent. of silica. Not all of this loose, sandy looking dolomite is good, however, for it sometimes happens that it carries more than 3.00 per cent. of silica, and one sample was found to contain nearly 4.00 per cent. It does not form a large proportion of the material in the quarry, and is mined and shipped with the other stone.

Both the limestone and the dolomite are quarried on the face, no underground work being required. Crushed stone or lump is shipped as occasion may demand.

The amount of stone used per ton of iron varies, of course, with the quality of the stone, with the nature of the ore and fuel, and, to some extent, with the grade of the iron required. The range is from 0.30 to 0.80. This subject will be discussed in the chapter on Furnace Burdens, which will be devoted to the general practice throughout the State, different types of burdens being selected with reference to the consumption of raw materials per ton of iron and the cost of the same.

No attempt has been made on any considerable scale to use calcined stone, whether limestone or dolomite, except in so far as the calcination of hard ore may be considered as an attempt to calcine the carbonate of lime contained in it.

It is necessary here merely to state the question in general terms. As has been already remarked, in the discussion of the hard ore, we have in this State an intimate mixture of oxide of iron, silica, and carbonate of lime. The best of it contains on the average 37 per cent. of iron, 13.44 per cent. of silica, and 15.45 per cent. of lime. The admixture of these materials is far more perfect than could be attained by any practical mechanical means, although some of the ore is not self-fluxing. This being the case we can ask ourselves if it is more economical to employ this ore, in which the flux is already so well mixed with the silica, than to use an ore of far less content of lime and therefore requiring the addition of flux. At the first glance it would appear that it is better to avail ones self of whatever advantages Nature herself has conferred upon us in the way of an ore carrying its own lime. But the matter can not be settled out of hand and without careful investigation of all the data bearing upon it. From the standpoint of the furnace man, if he could depend on securing self-fluxing ore regularly, the matter resolves itself into the simple consideration as to whether he can make as much iron and as cheap iron in the one way as in the other. He may, indeed, go a step farther and ask if he make iron more cheaply in the one way than in the other. Having settled this, he has no further concern with the matter. If he can make iron more cheaply by using a greater and greater proportion of hard ore than by using an ore which requires the addition of extraneous flux, it is his duty to do it. This, however, is a one-sided view. There are other investments in the State that must be regarded as well as investments in furnaces. How is it with the contractor for ore and flux? Would his business be hindered by the substitution of hard ore for stone? If his profit on the ore were the same as his profit on the stone, no great hardship would follow the increase in the use of the one and the decrease in the use of the other. But if it should happen that his profit in mining stone were greater than his profit in mining hard ore, and there should be such an increase in the consumption of hard ore as to destroy the value of his stone quarry, he would not be apt to appreciate the advantages of the change. In this respect this iron district differs from any other in the country, and the relations of stone to ore burden vary perhaps more widely than elsewhere. The ability of the furnaces to diminish at will the consumption of limestone, places them in a very independent position. If the price of stone be too high, they can run on increased proportions of hard ore. If they succeed in obtaining the stone at reasonable cost, they take off hard ore and put on soft or brown. For instance, a certain coke furnace during a certain month in 1895 made about 5,000 tons of iron with an ore burden composed of 50.9 per cent. hard, and 49.1 per cent. soft ore. The total burden was as follows:

Hard ore	27.7	per cent.
Soft ore	26.7	"
Limestone	15.5	"
Coke	30.1	"
	100.00	"

The consumption per ton of iron was:

Ore	2.36	tons (2240 lbs.)
Stone	0.67	"
Coke	1.32	"
	4.54	

And the cost per ton of iron was, for raw materials:

Ore	$1.32
Stone	0.34
Coke	1.83
	$3.49

The consumption of coke per pound of iron made was 1.32 lbs., and practically all of the iron was of foundry grades.

Shortly before, the same furnace was running on 33.4 per cent. hard, 65.3 per cent. soft, and 1.3 per cent. brown ore. The total burden was:

Hard ore	17.0	per cent.
Soft ore	33.1	"
Brown ore	0.6	"
Limestone	16.9	"
Coke	32.4	"
	100.00	

The consumption per ton of iron, of which something over 4,600 tons were made, was, in tons of 2,240 lbs.:

Ore	2.20
Limestone	0.73
Coke	1.41
	4.34

The cost per ton of iron was, for raw materials:

Ore	$1.26
Stone	0.43
Coke	1.83
	$3.52

The consumption of coke per pound of iron was 1.41 lbs., and in this case also practically all of the iron made was of foundry grades. In these two cases there was a saving of nine cents per ton of iron by increasing the proportion of hard ore and lessening the amount of limestone added. The ore cost six cents a ton of iron more than when the larger proportion of soft ore was used, so that the net gain was three cents per ton of iron, $3.49 for the hard ore burden, and $3.52 for the other.

But with the lesser amount of hard ore the furnace made 358 tons of iron more than with the greater amount. This has to be set to the credit of the soft ore burden.

Perhaps no positive conclusions can be drawn from one or two instances, and as the whole matter will be fully discussed under Furnace Burdens, it may be best to defer any further remarks.

Enough, however, has been said in this chapter on the fluxes to direct attention to the importance of the considerations advanced. The future of the iron industry in the State depends not on any one circumstance or condition, howsoever vital it may seem, but upon the resultant of a number of forces, some of whose effects may be at the present but dimly foreseen. It is possible that the relation between hard ore and limestone, or dolomite, is one of these.

Mr. C. A. Meissner was the first furnace manager in the Birmingham district to make use of dolomite regularly and systematically. While manager of the Vanderbilt furnace he began to prospect for workable deposits of dolomite, and succeeded in locating and opening the quarries now belonging to the Jefferson Mining & Quarrying Co., about 2 miles from North Birmingham. This was the first quarry of dolomite opened and the first shipments were made in 1890 to the Sloss Iron and Steel Company.

This quarry is still in active operation, and yields excellent stone. All of the output is taken by the Sloss Iron & Steel Company.

Following the successful operation of this quarry J. W. Worthington & Co. opened the Dolcito dolomite quarry along the same deposit towards the North-east. The Dolcito quarry was opened in July 1895, the first shipments being made about August 1st. to the Tennessee Coal, Iron & Railroad Co. This quarry furnished 425,000 tons of stone to the close of 1897, and has a fine equipment, power drills, wire-rope transmission from the face to the crusher, &c. It has a daily capacity of 500 tons of crushed stone and 500 tons of lump stone. The average analysis of the Dolcito dolomite has already been given.

From its North Birmingham quarry the Sloss Iron & Steel Company is now obtaining dolomite that averages less than 0.50% of silica.

After Mr. Meissner had shown that good dolomite could be obtained within the immediate vicinity of Birmingham and in almost any quantity. Mr. E. A. Uehling, manager of the Sloss Iron & Steel Company, took the matter up. In an article written for the Alabama Industrial & Scientific Society (see Proc. Vol. IV, 1894, p. 24) Mr. Uehling described at some length the nature of this stone, and compared its value with that of the ordinary limestone of the district.

This paper was published in full in the first edition, and from it is taken the following:

"In determining the value of a stone as a flux, it is not only necessary to deduct the impurities it contains, but in addition to that, as much of the base as is necessary to flux these impurities. What remains only can be considered as available flux, and has value in the blast furnace. To get at the available flux, we must deduct 2 per cent. from the carbonate of lime for each unit per cent. impurity in the stone. Taking the limestone at 96 per cent. of carbonate of lime and deducting from this 8 per cent. to take care of its own impurities, we have left for available flux 88 per cent. of carbonate of lime.

"As the average dolomite contains only 2 per cent. of impurities and 43 per cent. of carbonate of magnesia with 55 per cent. of carbonate of lime, we will have, after deducting 4 per cent. from the carbonate of lime, 51 per cent. of this material, and 43 per cent. of carbonate of magnesia.

Reducing the carbonate of magnesia to its equivalent in fluxing power of carbonate of lime, we have, because the fluxing powers of the two carbonates are to each other as 84 to 100,

$$\frac{43\text{x}100}{84}\text{x}51=102.19.$$

The relatiue values of the two available fluxing materials of the district are, therefore, to each other as 88 is to 102.19. That means that 88 tons of dolomite will do as much work in the blast furnace as 102.19 tons of limestone. Put into dollars and cents, this means that if dolomite can be bought for 69 cents a ton, limestone is worth only 52 cents a ton; or if limestone costs 60 cents, dolomite is worth 69.5 cents a ton.

There is only one valid objection that can be brought up against the use of dolomite as a flux in the blast furnaces, and that is that magnesium has less affinity for sulphur than calcium has, and dolomite is therefore less efficient as a desulphurizer than limestone, to the extent that caustic lime is displaced by magnesia.

This object, however, becomes quite insignificant where the ores are free from sulphur, as is the case in the Birmingham district. When a considerable proportion of hard ore is used in the mixture, its lime, in connection with what is contained in the dolomite itself, is ample to take care of the sulphur contained in the coke.

One-quarter to one-half dolomite has been regularly used in the Sloss furnaces for nearly two years, and, at intervals, as high as three-fourths have been put on with the best results. The ore mixture being half hard and half Irondale (soft) at the city furnaces, and from one-fourth to one-third brown with, generally, equal proportions of Irondale (soft) and hard at the North Birmingham furnaces.

The coke used contained considerably above the average amount of sulphur found in the coke of the district.

The iron was of as good quality as could have been produced with all limestone as a flux, and the furnaces have worked more regularly than they did prior to the use of dolomite. The assertion that the use of dolomite has a tendency to make light colored iron is not sustained by fact. Some of the most celebrated foundry irons are made with all dolomite as a flux. The writer had used it for years, while in charge of the blast furnaces of the Bethlehem Iron Company, prior to coming down here, and experienced no difficulty in keeping the sulphur within the required limits, even with ores containing as high as 1.5 per cent. of that element.

The Illinois Steel Co. are also using dolomite exclusively in their Joliet Works. They are doing very good work, and have no trouble with the sulphur whatever.

The deficiency of dolomite to carry off sulphur is probably very much exagerated. There are impure dolomites as well as impure limestones; but when of good quality and used intelligently and without prejudice, it always gives good satisfaction. In addition to its superior fluxing power there is decidedly less tendency to 'hanging' with dolomite than with carbonate of lime."

We can not agree with Mr. Uehling that dolomite is a less efficient desulphurizer than limestone. Experience here with all kinds of burdens in the manufacture of basic iron, in which it was required that the maximum sulphur should be 0.050%, has shown the contrary. When limestone was used exclusively it was with difficulty that the specifications as to sulphur were met, and the percentage of casts with maximum sulphur 0.050% was very much less than when dolomite was used exclusively. These conclusions are based on the analysis of some 1500 casts. Speaking with reference to the manufacture of low-silicon, low-sulphur iron if any one thing was abundantly proved it was that limestone failed to give any thing like such good results as dolomite, not only with respect to silicon, but also and especially with respect to sulphur. This whole matter was carefully worked over by the writer in an article on "The Manufacture of Basic Iron in Alabama," published in *The Mineral Industry*, Vol. V. 1896.

It may be regarded as practically settled that as a desulphurizer in the blast furnace dolomite is quite as efficient as limestone for ordinary grades of iron, and much more efficient for basic iron requiring unusually low-sulphur.

With respect to the effect of dolomite on the silicon of the silvery and the soft irons we are not prepared to make a positive statement at this time. By some the low silicon that has characterized these irons during the last two years has been attributed to the prevailing use of dolomite. And yet some furnaces that do not use dolomite at all are troubled in the same way.

The low silicon in the 'hot' irons may be due in part, at least, to the increasing amount of limy ore that is being used. A very basic slag requires a very high heat for perfect fusion, and it makes no great difference whether the lime is in the ore, or is added in the shape of limestone. The more basic the slag the greater the heat required to melt it, and the more pronounced the tendency towards exceeding the point at which the silicon enters the iron.

There is a point at which silicon fails to combine with iron because the temperature is not sufficient for the reduction of silica. May there not also be a point at which silicon fails to enter the iron because (a) the temperature is too high, or (b) the slag is too basic? If silica is deoxidized the resulting metalloid alloys with iron, and in the measure in which the deoxidation goes on in the same measure will high-silicon irons be produced.

Ten years ago when there was less limy ore used than is the case now, there was no special difficulty in making silvery and soft irons. The difficulty was in keeping the silicon down, for Mr. Kenneth Robertson informs us. (Trans. Amer. Inst. Min. Engrs., Vol. XVII, 1888-1889, P. 94 et seq.) that No. 1 Foundry iron carried 3.66% of silicon, while No. 1 Mill, which was also called No. 3 Foundry, carried 2.87%. Unfortunately Mr, Robertson does not give the analysis of the irons according to the burden on which they were made. He does say that 54.81% of the total make was foundry-iron, but analyses are what is needed for a discussion of this kind, not calculations as to the proportion of foundry grades made, for the grades included under this classification are not the same now as they were then.

It would require a great deal of labor to look over the records of those days with a view to ascertaining the effect of the burden on the silicon content of the iron, if indeed the investigation would lead to any definite information, for chemical analyses were not then carried on with this purpose. There has not been very much improvement in this respect of more recent years, and even today chemists here are not expected to examine the furnace records. Still, enough information has been gathered to warrant one in saying that the tendency of limy ore burdens is towards decrease of silicon.

The subject is referred to here because it is not a matter of indifference as to whether the flux shall go in with the ore or be added as limestone.

In the light of the experience of the last two years it begins to look as if furnace managers would do well to examine into the effect of dolomite on the content of silicon, and to cultivate the laboratory more systematically. A chemist who is made to feel that he has nothing to do with the burdening of the furnace soon restricts himself to the merest routine work, and regards the questions of more lime or less lime, more hard ore or less hard ore, limestone or dolomite with an indifference born of repeated rebuffs.

In the chapter on Furnace Burdens there is given a blank form which has proved to be extremely useful. It may, of course, be modified to suit any emergencies. Properly filled out with additional information as to the amount and heat of the blast, silicon content of the irons &c., it would enable the chemist to be of far greater value to the furnace than he can ever be if regarded merely as an analyst whose business begins and ends with the grinding out of a certain number of results every day. If a chemist is worth anything at all he is worth trusting. If he can not be trusted with all kinds of information as to the working of the furnace he should not be trusted to make analyses, and unless he can know what goes into the furnace his knowledge of what comes out is of no use to him, and but little to any one else.

CHAPTER IV.

FUEL.

The fuel used in the blast furnaces of the State is coke and charcoal. There are no known seams of coal that could be used without coking, as is done in Ohio in this country, and in Scotland, particularly, abroad.

Coke.

There is, perhaps, no subject connected with the iron business that gives rise to more discussion than that of coke. There are so many different kinds made, and so great diversity among them in respect of chemical and physical properties, that it is almost a hopeless task to attempt to set the matter forward in a manner satisfactory to all concerned. In this State, which produces about 10 per cent. of the coke made in the United States, there is a very considerable difference in quality between the various grades of this fuel.

This chapter is not a treatise on coke, nor is it necessary to enter upon the subject beyond what is required to explain the situation.

Three kinds of coke are made here, from lump coal, run of mines, and washed slack, and each of these three may be 48 hr. or 72 hr. coke. Regarded in this way, and excluding mixtures, of which there may be endless variety, we have six different kinds to-wit:

48 hour—	72 hour—
Lump,	Lump,
Run of mines,	Run of mines,
Washed slack,	Washed slack.

The ordinary practice is to use 48 hr. coke, and perhaps 90 per cent. of the coke is of this kind. The chief difference between the 48 hr. coke and the 72 hr. coke is in the strength, or the ability to resist abrasion and crushing, the latter having somewhat the advantage in this respect.

The following table gives the results of some experiments undertaken to establish the crushing strain of some of the principal cokes used for blast furnace and foundry purposes. The table given in the first edition of this book gave tests on coke made here in 1891–92. Since that time there have been many improvements, and it has been thought best to substitute a new table for the old one. The later results represent the present composition of the cokes, and in addition the composition of the ash. It is much to be regretted that all the Alabama cokes are not represented, but it has been impossible to secure the proper samples. Enough, however, is given to show the quality of some of the chief varieties of this fuel now used in the State.

TABLE VI—48 HR. BEE-HIVE COKE, MADE FROM BLUE CREEK WASHED SLACK.

NO.	Apparent Specific Gravity.	True Specific Gravity.	Per Cent. of Cells by Volume.	Volume of Cells in 100 parts by weight	Compressive Strain. Lbs. per Sq Inch	Ash.	Sulphur.	COMPOSITION OF ASH.					
								Silica.	Oxide of Iron.	Alumina.	Lime.	Magnesia.	Sulphur
1............	0.806	1.723	53.20	66.34	369	10.60	0.90	40.30	23.15	33.42	1.20	0.44	0.16
2............	0.848	1.755	51.67	60.92	400	11.80	0.93	42.30	19.25	34.70	1.50	0.60	0.14
3	0.847	1.739	51.30	60.58	375	9.15	0.85	42.55	17.71	35.94	1.82	0.54	0.14
4........ ...	0.839	1.830	54.17	64.58	362	11.70	0.91	43.70	18.71	33.04	1.68	0.74	0.15
5............	0.952	1.709	44.58	45.92	650	12.02	1.00	42.40	19.43	33.84	1.71	0.74	0.15
6	0.835	1.788	54.59	63.83	675	9.70	0.87	42.76	17.15	35.92	1.86	0.62	0.14
7........ ..	0.842	1.805	55.75	69.00	487	12.40	1.10	42.00	21.50	34.00	1.10	0.35	0.12
Average .	0.853	1.764	52.18	61.59	474	1.05	0.94	42.29	19.56	34.41	1.55	0.57	0.14
48 HR. BEE-HIVE COKE MADE FROM WASHED PRATT SLACK.													
8........... ..	0.951	1.793	46.94	49.36	537	11.20	1.05	44.00	24.00	27.74	2.50	0.40	0.12
9........... ..	1.062	1.776	40.21	37.90	550	11.60	1.04	44.50	23.60	28.00	1.90	0.45	0.14
10	1.060	1.816	41.24	38.64	540	10.80	0.98	44.60	22.50	28.30	2.00	0.30	0.11
11............	1.196	1.860	35.31	29.50	406	7.60	0.68	43.90	22.80	29.10	2.30	0.40	0.17
12............	1.013	1.855	45.40	44.78	575	11.30	0.92	43.74	24.25	29.51	2.65	0.50	0.11
13...........	1.133	1.855	38.93	34.37	350	6.10	0.90	44.25	23.70	27.95	2.45	0.35	0.16
14............	0.982	1.857	47.14	48.03	488	9.50	1.00	44.60	24.30	27.35	2.10	0.40	0.18
15...	1.046	1.830	42.83	40.94	388	5.80	0.96	44.40	23.80	27.60	2.35	0.55	0.15
16	1.114	1.870	39.20	34.10	375	7.25	0.98	44.00	23.65	27.55	1.98	0.62	0.17
17	0.904	1.880	52.47	57.33	430	10.50	0.99	43.80	23.00	29.54	2.24	0.42	0.13
Average	1.046	1.839	42.96	41.49	464	9.16	0.95	44.17	23.56	28.26	2.24	0.43	0.14

TABLE VII.

72 HR. BEE-HIVE COKE, MADE FROM WASHED PRATT SLACK.

No.	Apparent Specific Gravity.	True Specific Gravity.	Per ct. of cells by Volume.	Volume of cells in 100 parts by Weight.	Compressive Strain Lbs. per sq. in.	Ash.	Sulphur.
18	1.153	1.848	37 60	32.60	550	13.10	0.90
19	1.131	1.881	39.80	35.30	575	13.20	0.95
20	1.057	1.821	41.98	39.72	537	8.70	1 31
21	1.013	1.855	45 40	44.78	575	11.30	0.92
22	0.701	1.810	46.41	48.00	725	9.10	1.10
23	1.217	1.861	34 63	27 28	550	6.50	0.98
24	0.971	1.891	48 63	50.06	675	8.30	1.05
25	1.155	1.890	38.60	33.40	450	7.40	1.15
26	0.967	1.810	46 54	48.11	700	7.70	1.00
27	1.071	1.813	40 94	38.22	600	9.40	1.04
28	0.862	1.850	53.30	61.80	431	8.50	0.90
29	0.840	1.765	54.20	67.60	420	9.00	0 94
30	0.910	1.805	50.25	55 30	460	9.25	0.97
Aver.	1.003	1.838	44.48	44.77	558	9.34	1.02

48 hr. Disintegrated Pratt Nut. Not Washed.

31	0 866	1.667	48.00	55.34	325	11.55	1.30
32	0.812	1.359	40 55	49.62	400	14.02	1.40
Aver.	0.839	1.513	44.27	52.48	362	12.78	1.35

72 hr. Disintegrated Pratt Nut. Not Washed.

33	1.355	2 593	47.77	34 25	550	10 50	1.20
34	1.351	2 542	47 00	53 10	587	10.30	1.25
Aver.	1 353	2.567	47.38	53.67	568	10.40	1.22

TABLE VII—Continued.

48 hr. Washed and Disintegrated Pratt Slack.

No.	Apparent Specific Gravity.	True Specific Gravity.	Per ct. of cells by Volume.	Volume of cells in 100 parts by Weight.	Compressive Strain Lbs. per sq. in,	Ash.	Sulphur.
35	0 996	1.850	46.10	46.20	650	10.10	0.98
36	0.861	1 839	56.20	69.40	400	10.30	1.00
37	1.000	1 805	44 40	44.10	575	10.30	1.03
38	0.862	1.695	49 12	56.96	700	10.70	1.06
39	0.828	1.818	46.00	45.50	500	9.00	0.96
40	1.100	1 850	40.30	36.60	675	11 20	1 10
41	0.920	1.630	44 20	48.80	625	9.90	1.00
Aver.	0.938	1.784	46 62	49.65	589	10 12	1.02

72 hr. Washed and Disintegrated Pratt Slack.

42	1.330	1.850	38.20	41.00	750	9 30	1.04
43	0.956	1.822	47.60	50.00	750	9.25	1.02
Aver.	1.143	1.836	42 90	45.50	750	9.27	1.03

Black Creek— 48 hr.

44	0.900	1.84	46.20	52.00	400	3.90	0.79

Milldale (Standard C. & C. Co.,) 72 hr.

45	0.961	1.88	47.00	52.50	545	7.60	0.80

Jefferson C. & C. Co., Lewisburg.

46	0.84	1.764	52.46	62 54	531	10.20	0.68

Gas Carbon.

47	1.25	2.10	40.50	43.00	600	5.90	1.23

The analyses here given show that these cokes fall naturally into two main groups, characterized by the porosity (cell space) and the size of the cells. With regard to this principle of classification we have coke in which the percentage of cells by volume is just above 50, and coke in which the percentage of cells by volume is just above 40. To the first group belongs the Blue Creek coke, and to the second the Pratt coke. The figures given are in each case averaged from a number of determinations on separate prices, not less than 5, and in most cases 10. For 48 hr. Blue Creek coke made from washed slack the averages are:

Apparent specific gravity	0.853
True “ “	1.764
Per cent. of cells by volume	52.18
Volume of cells in 100 parts by weight	61.59
Compressive strain	474 lbs.
Ash	11.05
Sulphur	0.94

For 48 hr. Pratt coke made from washed slack the averages are:

Apparent specific gravity	1.046
True “ “	1.839
Per cent. of cells by volume	42.96
Volume of cells in 100 parts by weight	41.49
Compressive strain	464 lbs.
Ash	9.16
Sulphur	0.95

There is a marked difference in these two cokes, the one exhibiting a large cell, and the other a small cell, while in strength they are about equal. For determining the specific gravities, and the cell space the method first proposed by Dr. T. Sterry Hunt in 1863, and modified by Dr. F. P. Dewey was used with certain changes. Instead of using the air pump, which is indeed is not necessary, the samples were boiled in water for 16 hrs. and allowed to stand 16 hrs. in water before weighing. For the compressive strain one inch cubes were accurately cut from sound pieces of coke with a hack-saw, and a Star blade, using a miter-box. This was very tedious, and some of the cubes required as many as 6 blades. Coke is very destructive to steel saws. Perhaps the best tool would be one of the diamond wheels used in preparing specimens of rocks for the microscope.

In each case at least 3 cubes were cut, and care was taken to have them free of cracks and pieces of slate.

They were crushed in a standard Riehlé Testing Machine, operated by hand, and reading to 3,000 lbs. It was observed that now and then some cubes of 72 hr. and 96 hr. coke withstood more than 3,000 lbs. stress, but this does not often occur, and is immaterial as a coke testing 3,000 lbs. is certainly strong enough.

It must be understood in all discussions of the physical qualities of coke that great differences may be found in samples from the same oven, and indeed in samples from the same part of the oven. Too much importance should not, therefore, be laid upon such investigations, for one may very easily be mislead, and draw entirely erroneous conclusions. In connection with chemical analyses physical tests may be relied upon, in comparing one coke with another, to give fairly accurate data, but they should be accepted only if based upon a long series of determinations in which the conditions of manufacture are positively known. The size of the coal coked, the amount of water it holds. the rapidity of the coking process and its duration, the amount of water used in quenching, and whether inside or outside watering is used are some of the factors to be considered. Within certain limits the chemical composition of the coal appears to be of less influence upon the physical qualities of the coke than the factors just mentioned.

The 72 hr. bee-hive coke made from washed Pratt slack does not differ materially from the 48 hr. except as to its strength, giving 558 lbs. as against 464 lbs. It is especially adapted for foundry purposes, the increase of strength being of greater benefit here than in the blast furnace. In respect of strength the 48 hr. unwashed, but disintegrated Pratt nut is much inferior to the 72 hr. The disintegration of Pratt nut coal, unwashed, and subsequent coking, whether for 48 hrs. or 72 hrs. appear to yield a coke of about the same percentage of cells by volume as the 48 hr. and 72 hr. washed slack, but the volume of the cells is much larger, viz., as 53 to 41. The strength of the unwashed disintegrated Pratt nut of 48 hrs. is inferior to that of the 48 hr. washed slack, while that of the 72 hr. unwashed, disintegrated nut is somewhat above the strength of the 72 hr. washed slack. In other words, disintegrating the unwashed nut coal gave a coke of about the same percentage of cells by volume, and increased the size of the cells, but failed to better the coke with respect to crushing strain.

Washed and disintegrated Pratt slack, whether coked for 48 hrs. or 72 hrs,, makes a fine coke in every respect. In order to compare these cokes with standard Pennsylvania and Virginia cokes we append results obtained by Mr. John Fulton, and given in his excellent Treatise on Coke.

The average standard Connellsville coke shows:

True specific gravity........................	1.77

Per cent. of cells by volume	45.87
Volume of cells in 100 parts by weight	54.13
Compressive strain	279 lbs.
Ash	10.58
Sulphur	0.81

Two cokes from Big Stone Gap, Va., showed on the average:

True specific gravity	1.64
Per cent. of cells by volume	44.78
Volume of cells in 100 parts by weight	55.22
Compressive strain	285 lbs.
Ash	5.61
Sulphur	0.87

Pocahontas coke gave:

Apparent specific gravity	1.83
Per cent. of cells by volume	52.07
Volume of cells in 100 parts by weight	47.93
Compressive strain	236 lbs.
Ash	5.88
Sulphur	0.73

Mr. Fulton gives also the results from an examination of Blocton coke, Ala., as follows:

True specific gravity	1.75
Per cent, of cells by volume	49.97
Volume of cells in 100 parts by weight	50.03
Compressive strain	409 lbs.
Ash	6.94
Sulphur	0.74

The writer found the average of two samples of Blocton coke, 48 hr. bee-hive:

True specific gravity	1.65
Per cent. of cells by volume	44.46
Volume of cells in 100 parts by weight	45.98
Compressive strain	737 lbs.
Ash	5.80
Sulphur	1.35

And a sample of Pocahontas (Stonega) coke gave:

True specific gravity	1.84
Per cent. of cells by volume	53.83
Volume of cells in 100 parts by weight	63 01
Compressive strain	588 lbs.
Ash	6.50
Sulphur	0.75

Coke made at Earlington, Kentucky, by the St. Bernard Coal Company, gave for 48 hr. bee-hive:

True specific gravity	1.69
Per cent. of cells by volume	53.47
Volume of cells in 100 parts by weight	67.67
Compressive strain	275 ℔
Ash	14.60
Sulphur	1.74

Not to protract this matter further, although many more tests could be given, we close with a 72 hr, bee hive coke, made at Brookside, Ala., by the Sloss Steel & Iron Company, of washed slack:

True specific gravity	1.87
Per cent. of cells by volume	55.00
Volume of cells in 100 parts by weight	65.20
Compressive strain	320 lbs.
Ash	10. 0
Sulphur	1.25

Some investigations have been made as to the effect of carbonic acid on red hot coke, but other and more pressing work prevented their completion. Some high authorities, among them Sir I. Lowthian Bell, have recommended that the action of carbonic acid on red hot coke be included among the determining factors in the valuation of coke for blast furnace purposes. But the writer is not disposed to think that such data are of much, if any, importance. The gases in a blast furnace are mixtures of carbonic acid, carbonic oxide, hydrogen, oxygen, and nitrogen, with aqueous vapor also. It is not known what effect, if any, is produced by carbonic acid in the presence of these other gases. It is not as if carbonic acid were the only gas that would or could act upon the coke, for as a matter of fact it is always accompanied by other gases in greater or less quantities. Doubtless the dissolving action of carbonic acid upon red hot coke is an important phenomenon, and one well worthy of study, but until it is known whether the other gases exert a neutral, an accelerating or a deterring effect upon this dissolving tendency it does not appear that much practical information is gained. The matter of zone reactions in the furnace also complicates the question, as well as that of the occlusion of gases in coke.

The average composition of the cokes used in the State is as follows:

Coke from Run of Mines Coal.

	PER CENT.
Moisture	0.75
Volatile and combustible matter	0.75
Fixed carbon	84.50
Ash	14.00
	100.00

Sulphur..................0.90—1.60 per cent.

Coke from Washed Slack.

Moisture	0.75
Volatile and combustible matter	0.75
Fixed carbon	88.50
Ash	10.00
	100.00

Sulphur................0.80—1.10 per cent.

Coke from Lump Coal.

Moisture	0.75
Volatile and combustible matter	0.75
Fixed carbon	87.00
Ash	11.50
	100.00

Sulphur................1.00—1.30 per cent.

In chemical composition there does not seem to be any material difference between the 48 hr. and the 72 hr. coke.

The composition of the ash of the various cokes in use may be given as follows:

Run of Mines.

Silica	47.03
Ferric oxide	12.46
Alumina	33.62
Lime	1.53
Magnesia	1.69
Sulphur	0.15

Washed Slack.

Silica	45.10
Ferric oxide	12.32
Alumina	31.60
Lime	1.50
Magnesia	Trace.
Sulphur	0.14

Lump.

Silica	46.00
Ferric oxide	12.00
Alumina	32.00
Lime	1.00
Magnesia	0.50
Sulphur	0.16

It would be interesting to know if the amount of ash and its composition influenced the strength of the coke, or whether the treatment of the coal, prior to charging the ovens, and the duration and temperature of the process should alone be looked to in explanation of this point.

It does not seem probable that the amount of ash or its composition, *per se*, would influence the strength of the coke as much as the distribution of the ash constituents in the coal.

That is, if the coal was finely pulverized before charging there would be a more equable distribution of the ash-constituents with consequent uniformity of composition in the coke. But uniformity of composition, however desirable, does not necessarily imply increase in strength. Granting that there would be increase in strength is this effect beneficial when the coke is already strong enough? If the coke made from any coal, without pulverizing, were already strong enough, the only advantage in pulverizing would be in the greater uniformity of composition. But some coals do not yield strong coke unless they are pulverized. Whether this is due to the irregularity of the distribution of the ash, or the bituminous matter, or the relation between the coking and the non-coking constituents of the coal, is not known. When, however, such coals are pulverized they often make excellent coke.

The composition of the ash of coke, by affecting its fusibility, may affect also its strength, the size and shape of the cells and the thickness of the cell walls. But of such matters very little is known.

It requires a great deal of time to make such investigations, as well as skill and perseverance.

The composition of the ash of coal, whatever effect it may have on the quality of the coke made from it, certainly has an important bearing on furnace practice. It must influence the fusibility of the burden, and to a greater or lesser degree affect the consumption of limestone, whether this be the carbonate of lime in the hard ore, or extra stone. The more acid the ash the more base is required for fluxing.

The amount of coke used per ton of iron varies, of course, with the nature of the coke, and of the other constituents of the burden; with the kind of iron made, the shape and size of the furnace, the rate of driving, and other circumstances grouped generally under the term "furnace practice." The range is from 1.16 to 1.72 tons of 2240 pounds. From an examination of 150,000 tons of iron made from 1890 to 1895 under varying conditions the lowest consumption for a period of one month was 1.16 tons per ton of iron. In this particular case the furnace was working on all brown ore, the burden being composed of brown ore 52.9, limestone 20.4, and coke 26.7. The tons of iron made per charge was 1.53 tons, number of charges 1802, total iron made 2766 tons, of which 99.1 per cent. was of foundry grades.

The consumption of materials per ton of iron made was ore 2.31 tons, stone 0.89 ton, and coke 1.16.

The particular case in which 1.72 tons of coke were used per ton of iron made was when a furnace was running on the following mixture, stated as percentages, hard ore 53.7, soft ore 34.2, brown ore 12.1. The entire burden was composed as follows, in percentages, hard ore 28.5, soft ore 18.2, brown ore 6.3, limestone 10.6, coke 36.4. The iron made per charge was 1.88 tons, number of charges 1819, total iron made 3418 tons, of which 92 per cent. was of foundry grades. The consumption of material in tons per ton of iron was as follows:

Ore	2.51
Stone	0.49
Coke	1.71

The average consumption of coke per ton of iron may be taken at 1.41 tons of 2240 pounds. This would mean that for producing the 835,851 tons of coke iron in 1895 there were used 1,179,375 tons of coke and that 250,000 tons of coke made in the State during that year were diverted to some other purpose.

The average for the best coke made in the State may be taken at 1.30 tons of 2240 pounds for a ton of iron of 2240 pounds. A pound of iron has been made in the State with less than a pound of coke, but for a very limited period.

This matter will be taken up more fully in the chapter on Furnace Burdens, as tables have been prepared based on more than 83,000 charges and an iron production of nearly 150,000 tons over a period of several years.

There has been a notable decrease in the consumption of coke per ton of iron since the introduction of coke made from washed slack coal. It is much superior to ordinary coke both in structure and composition, and might be still further improved by pulverizing the coal before charging the oven, as in this way a better distribution of the ash is rendered possible as well as a stronger coke.

No constituent of the burden responds as readily to variations in furnace practice as coke. It forms generally more than a third of the burden, and always more than half of the total cost of the materials entering into a ton of iron is chargeable to coke. It is not only the most costly single ingredient, it is more costly than the ore and the stone taken together.

Economy in the use of coke is, therefore, the most important economy that can be set on foot and carried out in connection with the manufacture of pig iron in this State. Better ore and better stone are needed if there is to be no better coke. To improve the ore and the stone is to increase the yield of iron per charge, and to decrease the consumption of the most costly material entering the furnace, i. e. coke.

The following table gives a bird's eye view of the coke industry in Alabama from 1880 to the close of 1897, and is compiled from the reports of Joseph D. Weeks to the United States Geological Survey, Division Mineral Resources, with additional statistics for 1896 and 1897.

The greatly lamented death of Mr. Weeks, on the 26th of December, 1896, removed from the industrial world one of the best statisticians, and one whose contributions to the manufacture of coke were always especially recognized and appreciated.

TABLE VIII.

COKE OVENS IN ALABAMA.

Year.	Establishments.	Ovens.		Coal Used, Tons	Coke Produced, Tons.	Yield in Coal in Coke per ct.	Value of Coke.	
		Built.	Building				Total.	Per ton.
1880	4	316	100	106,283	60,781	57	$ 183,063	$3.01
1881	4	416	120	184,881	109,033	59	326,819	3.00
1882	5	536	....	261,839	152,940	58	425,940	2.79
1883	6	767	122	359,699	217,531	60	598.473	2.75
1884	8	976	242	413,184	244,009	60	609,185	2.50
1885	11	1,075	16	507,934	301,180	59	755,645	2.50
1886	14	1,301	1,012	635,120	375,054	59	993.302	2.65
1887	15	1,555	1,362	550,047	325,020	59	775.090	2.39
1888	18	2,475	406	848,608	508,511	60	1,189,579	2.34
1889	19	3,944	427	1,746,277	1,030,510	59	2,372,417	2.30
1890	20	4,805	371	1,809.964	1,072,942	59	2,589.447	2.41
1891	21	5,068	50	2.144,277	1,282,496	60	2,986,242	2.33
1892	20	5,320	90	2,585,966	1,501,571	58	3,464,623	2.31
1893	23	5,548	60	2.015,398	1,168.085	58	2,648,632	2.27
1894	22	5,551	50	1,574,245	923,817	58.7	1,871,348	2 25
1895	22	5,658	50	2,459,465	1,444.339	58.7	3,033,521	2.10
1896	24	5,363	....	1,769,520	1,038,707	58.7	2.181,284	2.10
1897	25	5,365	120	2,451,475	1,443,017	58.8	3,094,461	2.14

The average value of the coal used in making coke in 1895 was 87½ cents per ton; in 1896, 79 6-10 cents; and in 1897, 83½ cents. There were no new ovens built in 1896 or 1897.

Mr. Jas. D. Hillhouse, State Mine Inspector, makes the production of coke in 1896, 1,689,307 tons, and the number of ovens 4,494.

As of interest in connection with coke and coking operations, there is given here an article, by the author, on coking in a Bee-hive oven, published in the Engineering and Mining Journal, N. Y., and also part of a report made to the Sloss I. & S. Co. on the use of Pratt washed slack coal in the Otto Hoffman oven, published in the American Manufacturer and Iron World.

COKING IN A BEE-HIVE OVEN.

(The Engineering and Mining Journal, Vol. LXIV, Nos. 25 and 26, and Vol. LXV, No. 3.)

It has for several years been of interest to me to observe the progressive changes that took place in a bee-hive oven from the moment of charging the coal to the withdrawal of the coke. The opportunity of observing and noting these changes from hour to hour was presented lately, and gladly accepted, and for nearly 48 hours the oven was closely watched. The observations were taken in person. The coal used was washed slack, from the Pratt seam.

The oven was of the usual bee-hive type, of 12 feet diameter, the spring of the arch beginning at 26 in. from the floor. The door was 2½ ft. wide and 3 ft. high. The trunnel head was 14 in. deep and 14 in. in diameter. The weight of washed slack charged was 11,575 lbs., but as it contained 5% of moisture the dry weight was 11,024 lbs. The oven was charged at 11:50 a. m., and, after leveling, the top of the coal was 4 ft. below the bottom of the trunnel head. The door was bricked up at once. A charge of coke had been drawn from the oven during the morning, so that it was hot. Within a few minutes after charging there was an odor of light hydrocarbons from the door and from the trunnel head, and in 20 minutes, after charging, this odor became quite perceptible. For the first two hours there was no flame, but the evolution of a grayish-black smoke became more and more intense. At 2:30 p. m., 2 hours and 40 minutes after charging, the first flame appeared and burned with a decided reddish tinge until 3:30, or one hour, when it became yellowish. For the next two hours the flame from the trunnel head was yellowish and smoky. On top of the coal the flame was yellowish, streaked with grayish-black bands of smoke, which seemed to lie rather closely to the coal. By six o'clock, six hours after charging and 3½ hours after the first ignition, the flame from the trunnel head was 4 ft. high and of a decided yellowish color. At seven o'clock, 4½ hours after ignition, the oven was perceptibly hotter, the flame was burning fiercely, and there were wisps of blackish-gray smoke in the oven. There were but few signs of fritting, although the smoke in the oven might have obscured them had they been present. Shortly after seven o'clock I was unfortunately called away and could not return for two hours, so there were no observations until at 10 o'clock, 7½ hours after ignition; the flame had then lost its distinctive yellowish cast and was decidedly whitish. It was still 4 ft. out of the trunnel-head and the oven was much hotter. The top of the coal was fritted, cracks of considerable size had appeared: there was not much smoke in the oven, but white flames were issuing from the cracks and burning in a flickering, lambent manner. There was no perceptible swelling up of the coal, but on top it was uneven and jagged. The cracks did not seem to lie in any special direction, nor to be of any uniform size or depth. The play of the flames from the cracks was most beautiful. None of them burned steadily, although none went out. There was no appearance of "blows" of gas or any sudden outburst at any spot. Now and then a white flame would seem to be sucked back into the depths of a crack and to vanish, but at no time did any of them go out entirely. There were no wisps of smoke in the oven. The flames seemed to burn with about the same intensity and there was a remarkable uniformity in their height and general appearance.

Nine hours after ignition.—The flame from the trunnel head was still from 3 to 4 ft. high, but had not changed much in appearance, being still decidedly whitish; it was thinner than before. Inside the oven the cracks in the coal were wider and deeper and the coal was much more broken and jagged. In several places, noticeably beneath the trunnel head, the coal had sunk, and there were crater-like depressions, from which flickering white flames issued and had a slightly bluish tinge. The oven was much hotter than at the last observation. Bright white flames burned in jets over the surface of the coal, the so-called "candles" of the coke burner. They were distributed irregularly over the surface of the coal, burned intermittently, died down and came up again from the same place, or close by. About 12 inches of the coal from the top seemed to be burning, as the door was hot for this depth, but cool below.

Ten hours after ignition.—No apparent change beyond the further development of cracks in the coal, and its further subsidence. The oven was hotter.

Eleven hours after ignition.—No apparent change except that the oven was much hotter, approaching a white heat. The bluish tinge of the flame inside was entirely gone.

There was no specially noticeable change at the 12th and 13th hours after ignition, but at the 14th hour the oven was of a clear white heat, the inside flames were thin and white, and the flames from the trunnel head had begun to drop. The cracks in the coal were larger and more numerous. The coal had burned down to the 24-inch mark on the door.

Fifteen hours after ignition.—Flames from the trunnel head much thinner, burning fiercely and swiftly in a somewhat streaked fashion. Within the oven the heat was very intense, the cracks in the coal were larger and white flames of a slightly bluish tinge played irregularly over the surface.

At the 16th, 17th, 18th, 19th and 20th hours after ignition there was not much apparent change; but at the 21st hour the flame from the trunnel head was much thinner than at the 15th hour, and had receded much more. By the 22d hour the flame was decidedly thinner than at the 21st hour, and from this until the 28th hour it gradually became thinner and thinner, and burned swiftly with a striated appearance. Inside the oven the cracks were still developing, and white flames played over the top of the mass. The heat was now well along toward the bottom of the oven.

Thirty-fourth hour after ignition..—There were no special changes in the flame from the 28th to the 34th hour, except that it became thinner all the while, and at the 34th hour was just out of the trunnel head. From this time to the 40th hour the flame gradually drew back into the oven, until it could no longer be seen. But when the oven was opened for drawing, at the end of the 46th hour, there were thin jets of bluish white flame now and then on top of the coke. The door of the oven was taken down at the end of the 46th hour after ignition, and the coke watered inside the oven for 18 minutes. The oven was drawn by two men in one hour. The yield of coke over a fork of 14 tines, 21 inches wide, with spaces 1½ inches in the clear, was 5,875.80 lbs., or 58.78% of the weight of the dry coal. The weight of the dry breeze through the fork was 322 lbs., or 5.13% of the weight of the coke over the fork. The proximate analysis of the coal used was, on a dry basis: Volatile and combustible matter, 32.43%; fixed carbon, 60.91%; ash, 6.66%. The sulphur was 1.91%. The composition of the coke over the fork was, on dry basis: Volatile and combustible matter, 1.51%; fixed carbon, 88.90%; ash, 9.59%. The sulphur was 1.37%. The composition of the breeze and ashes passing the fork was, on dry basis: Volatile and combustible matter, 1.47% ; fixed carbon, 56% ; ash, 42.53%. The sulphur was 1.14 per cent.

The composition of the black ends of the coke, the so-called "black-jack," was on a dry basis: Volatile and combustible matter, 1.82 per cent; fixed carbon, 89 per cent; ash, 9.18 per cent. The sulphur, 1.29 per cent.

By screening the breeze and ashes over a 1-inch screen there was recovered 25 lbs., or 8 per cent of material that had the following composition, on a dry basis: Volatile and combustible matter, 1.25 per cent; fixed carbon, 88.40 per cent; ash, 10.35 per cent; sulphur, 1.30 per cent; while the 297 lbs., or 92 per cent, passing the 1-inch screen was of the following composition on a dry basis: Volatile and combustible matter, 1.25 per cent; fixed carbon, 61.40 per cent; ash, 37.35 per cent; sulphur, 0.85 per cent. Passing the breeze and ashes over a ½-inch screen gave 35 per cent over and 65 per cent through. The material over the ½-inch screen gave, on dry basis: Volatile and combustible matter, 1.20 per cent; fixed carbon, 80.80 per cent; ash, 18 per cent; sulphur, 1 per cent; while the material passing the ½-inch screen gave, on dry basis: Volatile and combustible matter, 0.80 per cent; fixed carbon, 51.90 per cent; ash, 47.30 per cent; sulphur, 0.80 per cent.

It is usual in the Birmingham district to fork coke over a 1½-inch opening, and the amount of breeze and ashes left is often a considerable item. It depends to a great extent upon the coal itself, but also upon the skill of the coke-drawer, the manner in which the oven is watered having a great deal to do with it. Coke made of washed coal gives much less breeze than the same coal unwashed, the difference at times rising to 50 per cent in favor of the washed coal. Irrespective of the difference in the quality of the coke made from unwashed and from washed coal, which of course is the most important matter, the difference in the yield of furnace coke, as between the two, is well worth considering.

A second oven was charged with a similar coal on the same day, and was operated for 96-hour coke. Weight of dry coal charged, 11,024 lbs., the coal containing 5 per cent of moisture. The yield of dry coke over a 1½-inch fork was 6,350 lbs., or 57.51 per cent of the dry coal, or 54.86 per cent of the coal as charged. Time of watering, 20 minutes; time of drawing, one man, 1 hour 57 minutes weight of breeze and ashes, dry, 240 lbs., or 2.17 per cent of the dry coal charged. The analysis on dry basis was:

	Coal.	Coke.	Breeze and ashes.
Vol. and combust. matter	32.46	1.06	2.68
Fixed carbon	60.86	89.63	69.79
Ash	6.68	9.31	27.53
	100.00	100.00	100.00
Sulphur	1.89	1.34	1.23

Over a 1-inch screen there was recovered from the breeze and ashes 14 lbs. (=5.8 per cent) of material of the following composition, dry: Volatile and combustible matter, 1.56; fixed carbon, 86.55; ash, 11.89. The sulphur was 1.20 per cent. The material passing the 1-inch screen was not analyzed.

A third oven was charged on the same day with a similar coal, and operated for 72-hour coke. Time of watering, 17 minutes; time of drawing, two men, 55 minutes; weight of dry coal charged, 11,024 lbs., or with 5 per cent moisture, coal charged, 11,575 lbs.: weight of dry coke, 6,590 lbs., over a 1½-inch fork, or 59.7 per cent by weight of the dry coal and 56.93 per cent of the coal as charged; weight of breeze and ashes, 285 lbs. dry, or 2.58 per cent of the weight of the dry coal charged and 4.33 per cent of the weight of the coke over a 1½-inch fork. The analysis was as follows:

	Coal.	Coke.	Breeze and ashes.
Vol. and combust. matter	32.55	1.71	1.09
Fixed carbon	60.64	88.35	79.97
Ash	6.81	9.94	18.94
	100.00	100.00	100.00
Sulphur	1.93	1.31	1.21

The composition of the black ends of the coke was: Volatile and combustible matter, 2.26; fixed carbon, 86.52; ash, 11.22. The sulphur was 1.28 per cent.

Screening the breeze and ashes over a 1-inch screen gave 34 lbs. (11.9 per cent) of material of the following composition, dry: Volatile and combustible matter, 0.80; fixed carbon 87.64; ash 11.56; sulphur was 1.28 per cent. The material passing the 1-inch screen was of the following composition, dry: Volatile and combustible matter, 1.00; fixed carbon, 69.90; ash, 29.10; sulphur, 1.10 per cent.

The coal used in these three ovens was the same, washed slack, and was of practically the same composition. Each buggy of coal was sampled as it was discharging into the oven.

In the following table, which embodies the results, the composition of the coal is the average of the three analyses, and all the calculations are based on dry material:

TABLE IX.

SHOWING CHEMICAL CHANGES FROM COAL TO COKE. PROXIMATE ANALYSES.

	Vol and combust. matter.	Fixed carbon	Ash	Sulphur.	Yield of dry coal in coke.	Yield of breeze and ashes.	Increase of carbon from coal to coke	Increase of ash from coal to coke	Decrease of vol matter from coal to coke.	Decrease of sulphur from coal to coke.
	Per cent	Per cent	Per cent.	Per cent.	Per cent	Per cent	Per cent.	Per cent.	Per cent	Per cent.
Coal.	32.48	60.80	6.72	1.91	....	......	.....		.....	.....
48 hr coke	1.51	88.90	9.59	1.37	58 78	2.92	46 21	42.71	95.35	28.27
72-hr. coke	1.71	88.35	9.94	1.31	59.77	2.58	45.31	48.51	91.73	31.41
96 hr- coke	1.06	89.63	9.31	1.34	57.51	2.17	47.41	38.54	96.73	29.84

The average yield of dry coke over a 1½-inch fork, from dry coal, was 58.69 per cent. The average increase of the fixed carbon was 46.31 per cent and of the ash 43.25 per cent. The average decrease of the volatile matter was 95.94 per cent, and of the sulphur 29.84 per cent.

As a further contribution to this study, I give the ultimate analyses of the coal and of the coke, averaged dry basis:

TABLE X.

ULTIMATE ANALYSES OF COAL AND COKE.

	Coal.	Dense coke.	"Needle" coke.
Carbon	78.23	84.55	97.55
Hydrogen	4.51	1.33	1.12
Oxygen	8.98	4.33	1.23
Nitrogen	1.56	0.18	0.00
Ash	6.72	9.61	0.10
	100.00	100.00	100 00
Sulphur	1.90	1.31	0.27

The analysis of the needle coke will be commented upon later.

By comparing the proximate composition of the coal and of the coke with the ultimate composition several very interesting things are observable. What is termed "fixed carbon" in the proximate analysis of coal is a very different thing from the carbon obtained on combustion, being in the one case 60.80 % and in the other 78.23 %. In the proximate analysis the fixed carbon is the difference between the sum of the volatile matter and the ash and 100, on a dry basis. If the volatile matter is 32.48, and the ash 6.72, the fixed carbon is 100 —(32.48 plus 6.72) equals 60.80. But in driving off the volatile matter, even in a covered platinum crucible enclosed within another covered crucible, there is a serious loss of carbon because the volatile matter itself is largely composed of gaseous hydrocarbons together with more or less solid carbon going off in the smoke. The soot is not pure carbon, but contains some hydrocarbon compounds whose nature varies according to circumstances, such as the rapidity of the heating, the duration of the heating and the nature of the coal itself. But the question at once arises. Can any of these volatile hydrocarbons, reckoned as such in the ordinary proximate analysis, be used in the coke oven during the coking process, as a source of carbon ? The answer to this depends upon the nature of the hydrocarbons, the temperature of the oven and the thickness of the bed of coke over the still burning coal.

It is well known that certain hydrocarbon gases evolved from coal at a comparatively low temperature are decomposed at a higher temperature with deposition of carbon ; for example, olefiant gas, C_2H_4, and acetylene, C_2H_2, this latter gas, indeed, decomposing under certain conditions, at ordinary temperatures. But olefiant gas and acetylene do not occur in the destructive distillation of coal beyond a few tenths of 1 per cent., as shown by Dr. Fyfe several years ago in the *Journal of Gaslighting*, and Ebelmen found that after being in the oven 7½ hours coal gave only 1.667 per cent. of carburetted hydrogen in the gases collected. It is possible that reactions going on within the mass of burning coal and the mass of red-hot coke are of such a nature as to allow some of the hydrocarbons evolved to deposit carbon ; but it is almost impossible to calculate just how much of this deposited carbon there is in any one oven of coke. The very bright silvery needles and blades of coke found on bee-hive coke are composed of almost pure carbon, the combustion giving 97.55 per cent. But these blades and needles form an insignificant proportion of the coke, and a very thin coating of this silvery deposited carbon serves to improve the appearance of the coke. Deposited carbon may and probably does increase the yield of the coke, but to a very slight extent, and appears to enhance the appearance of the coke without adding much to its weight. Some time ago I had an opportunity of securing some very fine specimens of deposited carbon from a bee-hive oven. Some large lumps of limestone were thrown in on top of a charge to make lime. When the coke was ready to water these lumps were taken out before the water touched them. I examined them closely and found that in the cracks of the lower lumps, and indeed upon the surface of some of the smaller pieces, which, however, may have come from the larger lumps, there were sheets of almost pure carbon, the analysis giving about 98 per cent. The sheets were as thick as ordinary letter paper, and were somewhat flexible. There were countless little globules of bright, silvery carbon scattered all over the sheets, and under a $\frac{1}{8}$ inch objective these globules were seen to be covered with a network of fine lines, running hither and thither. On illuminating these globules with a focussing glass in bright sunlight, they presented a most beautiful appearance under the microscope, resembling great globes of silver floating in blackness. I have never seen a more beautiful sight than they exhibited.

It is a curious circumstance that the appearance presented by these globules under the microscope closely resembles that given by botryoidal limonite. There is the same network of fine lines, dividing the surface into many irregular shaped patches. Hair coke, the so-called "whiskers" of the coke burner, is also composed of almost pure carbon, and under a 1-12 inch objective are often found to be covered with little globules, adhering to the sides of the "hair" and looking like pearls strung on a silver wire.

Percy (*Metallurgy, Fuel, Etc.*, pp. 421–422) speaks of the hair-like form of coke and gives an explanation of its origin, through deposition of carbon in the inner surface of carbon tubes blown out by escaping gas. The hairs are sometimes completely filled with carbon, but at other times are hollow, as I have myself observed.

A study of this hair-coke by a competent microscopist would certainly be interesting. Now and then the hairs are covered with little curved projections, while again they resemble a thread partially untwisted so that the separate strands are visible. Occasionally they are pierced through by minute holes, a high magnifying power showing several holes in lines across the hair.

I have amused myself mounting many specimens of coke, deposited carbon, hair-coke, etc., for the microscope and in observing their peculiarities of structure and their exceeding beauty when finely illuminated. Dull and uninteresting as coke may seem to the naked eye, when properly mounted in balsam and the balsam from the upper part removed with gasoline there are few objects more beautiful under a $\frac{1}{8}$ inch objective, or even a $\frac{1}{4}$ inch.

It might be that a microscopic study of coke, and especially of the various forms of deposited carbon found on coke, would give us some valuable information, and I did begin such a study, but the pressure of other matters forced me to abandon the investigation at the time, and since then I have been unable to resume it.

My excuse for this degression must be that in these forms of carbon, whether sheets, or blades, or needles, or hair, we seem to have nearly pure forms of deposited carbon.

Percy (*ut supra*), has more or less to say about deposited carbon, and Fulton in his excellent book on *Coke* also speaks of it. But although all authorities agree that such action may and probably does take place in a coke oven the amount of carbon thus gained is not and cannot be stated with accuracy. As before remarked, a very thin coating of bright silvery carbon may serve to better the appearance of the coke without adding materially to the weight.

The 48-hour, 72-hour and 96-hour cokes from this investigation were examined for specific gravity, cell space and strength. The results were as follows:

TABLE XI.

SPECIFIC GRAVITY, CELL SPACE AND STRENGTH OF COKES.

	Appar. specific gravity.	True specific gravity.	Per cent. of cells by volume.	Volume of cells in 100 parts by weight.	Compressive strain = ¼ ultimate strength 1 in. cube.
48-hour	1.029	1.913	46 58	46.29	440 lbs.
72-hour	0.875	1.785	52.22	61.45	550 "
96-hour	0.921	1.839	48 84	54.30	660 "

It may be remarked in regard to the porosity of coke, as determined by the percentage of cells by volume and the volume of cells in 100 parts by weight, that single estimations are rarely of any value. During the last few years I have made many such estimations, and the variations in samples from the same oven are often very considerable, confirming Dr. Dewey's observations. One would naturally expect variations between the dense, well-bodied coke and the black ends, whether from top to bottom, but the variations I refer to are to be found in even the best coke from the same ovens. The results given in Table XI are averages from two samples taken from the best-looking coke.

In determining the apparent and the true specific gravity, the percentage of cells by volume, and the volume of cells by 100 parts by weight, I have used the method first suggested by Dr. Sterry Hunt ("Canada Geological Survey, 1863, 1866," pp. 281–283), and afterward improved by Dr. F. P. Dewey. ("Transactions. American Institute Mining Engineers, Vol. XII, p. 111). But not having a good air pump, I boiled the samples for 12 hours and allowed them to stand in the water for 12 hours more. The formulas used are as follows: a = weight of dry coke; b = weight of water absorbed; c = loss of weight in water of the saturated coke. Then: $c : a = 100 : x$ = Apparent specific gravity. $c - b : a = 100 : x$ = True specific gravity. $c : b = 100 : x$ = Per cent. of cells by volume $a : b = 100 : x$ = Volume of cells in 100 parts by weight.

The determination of the ultimate strength, which, divided by four, gave the compressive strain, was made in a Riehlé Standard Testing Machine on 1-in. cubes. The cubes were carefully sawed from the coke, and were cut so as not to include any cracks. An 8-in. hack-saw with "Star" blades does very well, although the destruction of the blades proceeds with distressing rapidity. A diamond saw, such as is used for preparing sections of minerals for microscopic examination, would doubtless be an excellent tool for this work. I have used as many as six and eight "Star" blades in sawing out a single cube. Coke is very destructive t steel saws even the very best soon becoming utterly useless, as might be expected from the nature of the material. Objection has been raised to this method of preparing coke samples for crushing, and Dr. Thoerner recommends cylindrical test pieces. But I have obtained closely concordant results by careful sawing out of 1-inch cubes, and the advantage is that the ultimate strength is given directly from the beam, the compressive strain being taken as one-quarter of the ultimate strength.

Dr. Dewey recommends taking as many as 15 separate samples from each oven, for determining specific gravity, etc., and in view of the wide variations in coke from the same oven, perhaps this number is not too large.

Speaking generally, Alabama cokes fall into two main divisions, so far as concerns the porosity, large-celled and small-celled, and the duration of the coking process does not seem to affect the principle of the classification seriously. With the exception of a few Thomas ovens in operation, all of the coke now made in the State is the product of bee-hive ovens. The Solvay Process Company, of Syracuse, N. Y., is building 120 by-product ovens at Ensley. The coal to be used will be similar to the coal of these experiments.

As a rule, 48-hour coke is used by the blast furnaces, the 72-hour coke going for foundry purposes. The chief difference between them is in the superior density and strength of the 72-hour product. There is also less breeze from the ovens.

Referring now to Tables IX and X: If all the so-called volatile matter should escape without depositing any of its carbon, and none of the so-called fixed carbon should be burned, but be changed to coke, one might expect to find in the coke itself 90.04 per cent. of carbon. Excluding the volatile matter of the 48-hour coke, 1.51 per cent. the actual amount of fixed carbon found in the coke was 90.26 per cent. It would thus appear that the carbon burned in the oven is counterbalanced by the carbon deposited from hydrocarbons. But the difficulty of ascertaining. by analysis of the escaping gases, just what amount of carbon is burned is so complicated that there is but little hope of arriving at even approximate accuracy. For instance, what are the products of the combustion of carbon, under the conditions maintaining in a beehive oven ? The entire consumption of the carbon would, of course, imply the free entrance of air, but the air is to a great extent excluded. Ebelmen found on collecting gas at three different times from cylindrical ovens, not recovering the by-products, the following, the figures being from Groves & Thorps "Chemical Technology," Volume I, "Fuels," by Mill & Rowan.

TABLE XII.

COMPOSITION OF COKE OVEN GAS—ELBELMEN.

	After 2 hours.	After 7½ hours.	After 14 hours.	Mean.
Carbonic acid	10.13	9.60	13.06	10.93
Carburetted hydrogen	1.44	1.66	0.40	1.17
Hydrogen	6.28	3.67	1.10	3.68
Carbonic oxide	4.17	3.91	2.19	3.42
Nitrogen	77.98	81.16	83.25	80.80

The composition of these gases varies widely, according to the period of coking, and there are doubtless other circumstances, apart also from the composition of the coal itself, which would cause variations—the rapidity of the firing, the thickness of the bed of coal and coke, the size of the coal charged, the quantity of air entering the oven, etc., etc.

Furthermore, changes are continual going on in the oven from the time the coal gets hot and begins to evolve gases until the coke is watered and drawn, and these changes are not necessarily the same in kind or in degree throughout the coking mass. At one point decomposable gases are being evolved, at another they are depositing carbon, at a third non-decomposable gases—non-depositing gases—are coming off, at a fourth gases are being evolved that under proper conditions would deposit carbon, but which, in fact, are escaping into the air. It has been said above that the deposited carbon counterbalanced the carbon that was burned in the oven. This presupposes that the fixed carbon of the coal is of the same nature as the fixed carbon of the coke; a supposition not always tenable. When the volatile matter is driven off from coal in a platinum crucible at the highest temperature of a blast lamp, it is certainly possible that some carbon is deposited in the mass of the coke thus formed. A closed platinum crucible within another closed crucible is a miniature coke oven, and if carbon is deposited in the large oven it should, also, other things being equal, be deposited in the very small one. Under the microscope carbon left in the crucible does exhibit evidences of the existence of deposited carbon, for the fine globules of bright silvery luster with the reticulated markings, so characteristic of deposited carbon, are sometimes observable under a $\frac{1}{8}$-inch objective, and now and then, but more rarely, under a $\frac{1}{4}$ inch objective.

But the conditions favorable to the deposition of carbon are more abundant and more pronounced in a coke oven than in a crucible, so that it is likely that the coke from an oven has relatively much more deposited (and therefore very pure) carbon than the residue in a crucible after driving off the volatile matter. Taking everything into consideration, it would appear that the fixed carbon, as determined in the ordinary method of analysis, is not of the same nature as the fixed carbon of the coke. But, practically, the difference is not of any moment and the subject has merely a scientific interest.

Deposited carbon, in pieces of considerable size, is sometimes obtained from the arch of recovery (by product) ovens.

Under this discussion it might be of interest to construct a table from Table X, which would show the changes in ultimate composition between the coal and the coke, as Table IX does for the ingredients determined by proximate analysis.

Table XIII.—Changes in Ultimate Composition from Coal to Coke.

	%Carbon.	%Hydrogen.	%Oxygen	%Nitrogen.	%Ash.	% Increase of carbon.	% Decrease of hydrogen.	% Decrease of oxygen.	% Decrease of nitrogen.	% Increase of ash.
Coal.......	78.23	4.51	8.98	1.56	6.72	....	.....	.....	.....	.....
Coke	84.55	1.33	4.33	0.18	9 61	8.07	70.51	51.78	88.46	43.00

Coke is very far from being pure carbon and ash-forming ingredients, as it is sometimes taken to be. Aside from the ash in this analysis there are present hydrogen, oxygen and nitrogen, the sulphur not being considered. Of these there may be nearly 6 per cent.

Parry made some determinations of the nature of the gases occluded in coke, and found that both carbonic acid and methane, were present, and he remarked that the carbonic acid probably arose from the oxidation of the carbon after the coke was made, and that an appreciable loss of carbon might result in this way. But this is a subject of which little is known. It presents many interesting questions to the metallurgical chemist, and is deserving of further investigation.

No investigations were made on these cokes as to the action of carbonic acid, as recommended by Sir I. Lowthian Bell, or of hydrogen, as recommended by Dr. Thoerner. In the employment of each of these reagents considerable loss takes place, and it has been proposed to use this loss as one of the elements entering into the valuation of coke for blast furnaces. There are many questions arising in connection with coke, and to examine into all of them would take much more time than is at the disposal of most metallurgical chemists.

The following results were obtained too late for incorporation in the body of this article. They relate to the yield of coke, over a 1½-inch fork, and 'ashes' (breeze and ashes) from Pratt coal in a bee-hive oven. The moisture in the coal was not given, but would be about 6%.

Washed Pratt slack: charged coal 12,650 lbs; obtained 72-hr. coke 7,080 lbs (=55.96%), and 'ashes' 348 lbs. (=2.75%).

Washed Pratt slack: charged coal 13,150 lbs.; obtained 72-hr. coke 7,725 lbs. (=58.74%), and 'ashes' 346 lbs. (=2.63%).

Disintegrated washed Pratt slack; charged coal 11,000 lbs; obtained 72-hr. coke 6,715 lbs. (=61.04%), and 'ashes' 271 lbs. (=2.46%).

Disintegrated washed Pratt slack: charged coal 11,300 lbs.; obtained 72-hr. coke 7,275 lbs. (=64.38%), and 'ashes' 230 lbs. (=2.04%).

In these experiments the disintegration of the coal was followed by a considerable increase in the yield of coke, and the waste in ashes fell off, in one case, from 2.63% to 2.04%.

The quality of the coke made from the disintegrated coal was in no wise inferior to that made from ordinary washed slack, and in fact the coke was stronger and denser than under ordinary circumstances.

Disintegration of coal, previous to coking, is not carried on to much extent in Alabama.

ALABAMA COAL

IN

BY-PRODUCT OVENS,

BY

WILLIAM B. PHILLIPS.

ALABAMA COAL IN BY-PRODUCT OVENS.

EXTRACT FROM A REPORT MADE TO THE SLOSS IRON AND STEEL CO.

(American Manufacturer, Vol. LXII, p 446.)

By

William B. Phillips.

It is proposed to give in this paper an account of the testing of 54,000 pounds of Alabama coal at the Otto-Hoffman by-product ovens of the Pittsburg Gas and Coke Co., near Glassport, Penn., undertaken with the view of ascertaining to what extent this coal would lend itself to the recovery of by-products, and the production in a by-product oven of coke suitable for use in the blast furnace.

The works at Glassport have been in successful operation for more than a year under the superintendence of Dr. F. Schniewind, who introduced the system into this country. They consist of 120 ovens, in four batteries of 30 ovens each. The capacity of each oven, when fully charged, is about 7.5 tons of coal. The works are well provided with condensing chambers, ammonia apparatus, exhaust pumps, etc. The testing of this coal did not in any wise interfere with the usual operations there, except in so far as it was necessary to weigh and measure the products obtained. The conditions of the test did not vary materially from those under which large and regular operations are carried on every day. The results, therefore, do not represent what might be obtained from a special test under special conditions, but it is believed that they can safely be used as the basis of calculations as to future work.

The coal used was slack from the mines of the Sloss Iron and Steel Co., Jefferson County, Ala., washed in a Robinson-Ramsay washer. It came from the Pratt seam and was of the usual quality of this coal, when washed, as the following average analysis will show:

Proximate analysis of Pratt washed slack coal. Drs. Mason and Luthy, Pittsburg Gas and Coke Co.

Moisture	5.95
Volatile matter	32.69
Fixed carbon	54.33
Ash	7.03
	100.00
Sulphur	0.94
Phosphorus	0.0117

The ultimate analysis of this coal, as made in the Phillips Testing laboratory, Birmingham, is as follows:

Ultimate analysis of washed Pratt slack coal, made by the Phillips Testing Laboratory, Birmingham.

Analysis on dry basis:

Carbon	76.50
Hydrogen	4.90
Oxygen	10.15
Nitrogen	1 25
Ash	7.20
	100.00

This amount of nitrogen is equivalent to 1.15 per cent. of ammonia, and the disposable hydrogen would be 3.61 per cent. The coal, as charged, contained, on the average, 5.95 per cent. of moisture, but for convenience it will be best to consider it as dry and to base all the results and calculations on dry coal. Four separate charges were tried in an oven fitted up for the purpose and used in testing various coals that have been sent to the works. A very careful watch was maintained over the entire operation and especial thanks are due, not only to Dr. Schniewind, and to Mr. W. P. Parsons, Assistent Superintendent, but also to the gentlemen comprising the laboratory force, and to Messrs. Thos. G. Littlehales and Wm. Speakman for the very kind and unremitting attention given to the test throughout its entire duration.

The first charge contained 13,067 pounds of dry coal, and the coking time was 34 hours and 35 minutes. The coke was pushed in 1 minute after taking down the doors and was watered on the outside. When ready to load the coke contained 1.80 per cent of moisture. The yield of dry coke, over a 1½ inch fork, was 8,490 pounds or 64.9 per cent. of the weight of dry coal. The dry breeze weighed 320 pounds, or 2.45 per cent of the dry coal, so that the total weight of coke obtained was 8,810 pounds, or 67.3 per cent. of the weight of the dry coal.

The yield of sulphate of ammonia was 19.2 pounds, per ton of dry coal. It was decided not to weigh the tar from each separate charge, but to wait until the test was completed. The highest candle power observed during the first test was 18.8, and the average was 13.2. The average specific gravity of the gas was 0.471. The highest calories were 6649, equivalent to 748.0 British Thermal Units, which will be referred to hereafter in this paper as B. T. U. The average heat units during the first tests were 651.8, or 5794 cals.

The second charge of coal represented 13,509 pounds of dry coal. The coking time was 29 hours and 30 minutes. The yield of dry, forked coke 9,275 pounds, or 68.6 per cent, and of breeze 582 pounds, or 4.3 per cent., a total yield of coke of 9,857 pounds, or 72.9 per cent. The yield of sulphate of ammonia was equivalent to 23.9 pounds per ton of dry coal. The highest candle power observed was 16.3, the average being 11.1. The highest calories were 6617, equivalent to 744.4 B. T. U., the average being 5352 cals., or 602.1 B. T. U.

The specific gravity of the gas was 0.411. The amount of moisture in the coke, when ready to load, was 3 per cent.

The third charge represented 13,882 pounds of dry coal, and the coking time was 30 hours and 5 minutes. The yield of dry, forked coke was 9,029 pounds, or 65.4 per cent., and of breeze 600 pounds, or 4.3 per cent., a total yield of coke of 69.7 per cent. When ready to load the coke contained 3.0 per cent. of moisture. The highest candle power observed was 17.8, the average being 11. The specific gravity of the gas was, on the average, 0.454. The highest calories were 6330, equivalent to 782.1 B. T. U., the average being 5429 cals., or 618.1 B. T. U. The yield of sulphate of ammonia was 26.9 pounds per ton of dry coal.

The fourth charge represented 14,171 pounds of dry coal, and the coking time was 32 hours and 20 minutes. The yield of dry, forked coke was 9,608 pounds, or 67 8 per cent., and of breeze 708 pounds, or 5.0 per cent , a total yield of coke of 72.8 per cent. When ready to load the coke contained 4.30 per cent. of moisture. The highest candle power observed was 12.6, the average being 10.3. The average specific gravity of the gas was 0.426. The highest calories were 6576, equivalent to 739.6 B. T. U., the average being 5765 cals., or 648.8

B. T. U. The yield of sulphate of ammonia was 25.5 pounds per ton of dry coal.

The average amount of moisture in the coke, when ready to load, was 3.02 per cent. The average yield of dry, forked coke from dry coal was 66.7 per cent., and of breeze 4.0 per cent., a total yield of 70.7 per cent. The average yield of sulphate of ammonia was 23.9 pounds per ton of dry coal. The yield of tar was 90 pounds per ton of dry coal. The average quality of the tar from the seal-pot may be stated as follows:

Moisture	3.93
Oil	1.52
Specific gravity	1.211

The average quality of the tar from the exhauster was as follows:

Moisture	2.04
Oil	2.04
Specific gravity	1.211

The average analysis of the coke (Drs. Mason and Luthy) was as follows, on a dry basis:

Volatile matter	0.98
Fixed carbon	90.22
Ash	8.80
	100.00
Sulphur	1.28

I will not, at this time, enter upon the subject of the adaptibility of this coke for blast furnaces. There is no information to hand respecting its use in the Alabama furnaces, but experiences elsewhere has shown that per unit of carbon it has nothing to fear from the competition of bee-hive coke, especially when to the making of coke is added the saving of by-products. If it were merely a question of coke making, without reference to by-products, perhaps there is no system any better than the bee-hive. In structure, the bee-hive coke has the advantage over by-product coke in that it is more uniform, but in carbon duty there is not much if any thing to choose between them. By-product coke is apt to contain more moisture and to be somewhat more brittle than bee-hive coke, but under conditions allowing of the utilization of the gas, tar and ammonia, the loss in quality of the coke is more than counterbalanced by the profits accruing from the sale of these substances.

The average yield of this coal in the bee hive oven is somewhat below 60 per cent. counting breeze as coke, so that in this respect the by-product oven has an advantage of 10 per cent to 12 per cent. greater yield. It is doubtful if the difference will amount to 15 per cent. or 16 per cent. as some would claim. If we accept the statement of Sir Lowthian Bell that bee-hive coke is 10 per cent. more useful in the furnace than by-product coke, or that Mr. John Fulton that it is 7 per cent. more useful, we should be prepared to anticipate a balancing of carbon duty against greater yield, one off-setting the other. But so much depends upon the class and condition of the stock, and the actual furnace practice that generalization is hazardous.

The gas from this coal is well adapted for illuminating purposes, but would have to be enriched in some carburetting apparatus to bring it up to the requirements ordinarily made in regard to candle power. During the first 24 hours of the process the candle power did not fall below 8, and went as high as 18.8. The average candle power during the first period of 12 hours was 13.1, and during the second period of 12 hours it was 10.8. By operating a sufficient number of ovens in series, so as to keep the candle power at about the same figure, it would doubtless be possible to reach 15 or 16, leaving from 6 to 7 candle powers to be added by the carburizer.

The gas is well adapted for fuel purposes, the heat units ranging from 141,379,700, per 1,000 cubic feet, in the second period of 12 hours to 165,178,770 in the first period. These figures are less than for natural gas, as this may go to 209,979,000 heat units, per 1000 cubic feet. The yield of gas was 9,600 cubic feet per ton of dry coal, of which 3,000 cubic feet would be surplus gas.

At the meeting of the Alabama Industrial and Scientific Society, held in Birmingham, December 21st, 1897, Mr. W. H Blauvelt, Engineer for the Solvay Process Company, Syracuse, N. Y., read a paper on The Semet-Solvay Coke Oven and Its Products, Mr. Blauvelt had previously discussed the subject in The Mineral Industry, Vol. IV., 1896. He has recently republished the important parts of these two articles in pamphlet form. Considering that the Solvay Process Company is now erecting 120 of the Semet-Solvay ovens at Ensley, Ala., and will soon have them in operation, and that Mr. Blauvelt is thoroughly versed in the construction and conduct of this oven, it does not seem to be out of place to introduce here his latest remarks upon the subject. Aside from the utilization of the hot air from some beehive ovens for raising steam under boilers usually fired with coal, the only product from the coke ovens in this State has been the coke. But besides the coke there are other valuable products to be obtained from coal as it is being changed into coke, as, for instance, ammoniacal compounds, tar, and gas suitable for heating and illuminating purposes. These can be and in many places are now recovered from the coal without prejudice to the coke. Their recovery and subsequent utilization marks one of the great and beneficent departures from the former way of making coke. The system is peculiarly adapted to Alabama coals, as they are rich in tar, ammoniacal compounds, and gas, all of which can be recovered and used. From the tar may be made pitch and ordinary light and "dead" oils, and a great number of products now recognized as coal-tar products, numberless dyes and flavoring extracts and medicines. From the ammoniacal compounds sulphate of ammonia is made, a very valuable material used in the manufacture of fertilizers, anhydrous ammonia now so largely used in the South in ice-making establishments, and other substances more or less largely employed in the arts. The surplus gas may be used for all kinds of heating purposes, for cooking, and heating residences; and, by enrichment, for lighting purposes. Instead, therefore, of throwing away these by-products they will be utilized, and the plant at Ensley—the first of the kind in the South—will enter upon this work within the present year.

Mr. Blauvelt's pamphlet—which is here republished by permission—is as follows:

THE SEMET-SOLVAY COKE OVEN AND ITS PRODUCTS.*

BY WILLIAM H. BLAUVELT.

[Extract from proceedings of the winter meeting of the Alabama Industrial and Scientific Society, held in Birmingham, Ala., December 21, 1897.]

Gentlemen of the Alabama Industrial and Scientific Society:

The plant of by-product retort ovens, which is being erected at Ensley, is only the sixth installation of by-product ovens in this country. In Continental Europe such ovens have become quite an old story, and, in fact, practically no bee-hives are built there, except in small or isolated plants. So few years have passed since by-product ovens were first introduced in America, that they are still a novelty to very many, even of those who are well acquainted with the use of coke and its manufacture in the old fashioned way. It has, therefore, been suggested that a brief description of the plant at Ensley, and a comparison of these new ovens and their products with the old bee-hive type, will be of interest to your Society.

The plant of ovens now under construction at Ensley will consist of 120 retort ovens, with their accompanying apparatus for collecting the by-products from the distillation of the coal. It is probably unnecessary to say that retort ovens are essentially different in shape from the bee-hive oven, the coking chamber being usually about 30 feet long and 6 feet high, and varying in width from 15 inches to 30 inches or more, depending upon the coal to be coked, and the type of oven. The coal is

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*Portions of this paper are taken from an article by the writer, which was published in "The Mineral Industry," Vol. IV., 1896, which is a copyrighted work, and such extracts are here used by the special permission of the Scientific Publishing Company, the proprietors of "The Mineral Industry."

charged through three or more holes in the top, in the same manner as in a bee-hive oven, except that the oven is filled with coal to within about eight inches of the top. The coal is heated and the volatile matter driven off by means of the heat generated by the combustion of gas in the flues or passages in the side walls of the ovens. A fourth opening in the roof of the oven is connected with a pipe or main, which carries the gas, as it comes off from the coal, to the by-product apparatus.

The Ensley ovens are of the Semet-Solvay design. This oven is the principal exponent of what is known as the horizontal flue type, in contradistinction to the vertical flue type, the principal representative of which is the Otto-Hoffman oven. In the vertical flue type the gas is burned in two horizontal flues, or combustion chambers, at each side of the ovens at the bottom, which extend half way toward the other end. The products of combustion ascend through some sixteen small vertical flues, which reach to the top of the oven, where they deliver into another horizontal flue, which reaches the whole length. This connects with a similar set of small flues, which deliver the hot gases into a horizontal flue, or combustion chamber at the bottom, like the first, and thence to a regenerator of the familiar Siemens type. Every hour the travel of the gases is reversed, hot air being supplied for the combustion of the gas from the regenerators, as in an ordinary Siemens furnace.

In the horizontal flue ovens there are three horizontal flues, one above another, on each side of each oven, extending the full length of the oven, and connected with each other at the ends, so as to form a continuous flue for the gas and flame. The travel of the gases is from above downward; that is, through the top flue, then backward through the second, etc., the bottom flues being connected with a passage to the chimney. A small amount of gas is introduced at the ends of the top and second flue, along with a sufficient amount of air for its combustion. This air is preheated by a simple arrangement in the bottom of the ovens, and the combustion goes forward continuously without any attention, often for weeks at a time, it being only necessary to see that the proportions of gas and air remain the same, and are of sufficient quantity to keep up the necessary heat in the ovens. The gases after leaving the ovens are carried under boilers, and supply steam for operating the machinery of the plant. These gases go to the stack at a temperature of not much over 200° C, so that from the point of view of heat economics these ovens are very efficient.

The Semet-Solvay ovens are usually about 16 inches wide, and contain about 4½ tons of coal per charge. This charge is coked in about twenty-four hours, and when the gases are all driven off, the doors at each end of the ovens are opened, and the whole charge of coke is pushed out with a steam pusher, or ram, in a minute or two. As soon as the ram has been withdrawn and the doors are closed, the oven is ready for another charge, and practically no heat has been lost, as the quenching is all done on the outside of the oven. The whole process of discharging and recharging an oven can readily be completed in fifteen minutes.

As the gas which is distilled from the coal leaves the ovens it enters a large flue known as the hydraulic main. This extends the whole length of the block of ovens, and is partially filled with water. The gas bubbles through the water, and a portion of the tar and ammonia is condensed out. From the main the gas passes to the condensers. These are large vertical cylinders filled with tubes through which water is made to circulate. The gas passing around these tubes is cooled, and a further portion of the tar and ammonia condenses. Rotary exhausters occupy the next place in the series of apparatus, their use being to draw the gas from the ovens through the pipes and condensers, and to discharge it into the next following apparatus, which is the ammonia washer. In this vessel the final traces of ammonia are removed, and the gas thus cooled and washed is free from condensable matter and ready to be used for heating or lighting. A portion of it is usually withdrawn at this point and used to heat the flues of the ovens, but if there is sufficient demand for the oven gas for other purposes, ordinary producer gas may be substituted for it, and the whole amount produced will be available for sale. This amount varies with the coal, but is usually from eight to ten thousand cubic feet per ton of two thousand pounds. The quality of this gas is more fully described later, where the by-products of the ovens are discussed somewhat at length.

THE PRODUCTS OF THE BY-PRODUCT OVEN.

Coke.—An investigation of the subject will immediately show that the essential distinction between the operation of the retort oven and that of the ordinary beehive is that in the former the coal is coked without the admission of air, by heat applied from the outside, while in the latter the air is admitted to the oven and the combustion takes place immediately over the body of coal. The result is that in one case the hydro-carbons are simply distilled off, with a certain breaking down and deposition of carbon on the coke, so that a yield of coke greater than the so-called "theoretical" can be counted on, while in the other case the most of the hydrocarbons are burned in the ovens, some carbon is deposited, and some of the fixed carbon of the coal is burned, resulting in a yield of coke less than the theoretical. As an illustration of the difference in yield resulting from this difference in method of coking, a good yield of coke from Connellsville coal in a beehive oven is 65 per cent., while in a good retort oven it is easy to get 75 per cent., an increase of about 10 per cent. Of course this increase reduces proportionately the percentage of ash, phosphorus, etc., remaining in the coke, so that the retort oven yields more coke and a purer coke than the beehive from the same coal. This increase in yield varies with the proportion of fixed carbon, ash, etc., in the coal.

The quality of the coke made in the by-product ovens has long been a subject of discussion, especially among the blast furnace men of Europe. The English authority, Sir Lowthian Bell, made a series of careful tests a number of years ago and pronounced against the coke in comparison with that made in beehive ovens, and his conclusions were accepted by English ironmasters. But improved construction and practice have combined to produce a better coke. and it is reported that Sir Lowthian Bell has modified his views to such an extent that a plant of retort ovens is now being built at his own works—those of Messrs. Bell Brothers. On the Continent retort oven coke is now the standard, and in this country we are just beginning to realize that a coke not made in the old beehive oven and not having the famous silvery gloss of coke quenched in the oven is proving itself quite equal to it in fuel value.

The essential difference between beehive and retort oven coke lies in its hardness and shape, caused by the different application of the heat in the oven. In the beehive the coal is spread out in a layer 23 or 24 inches thick over a surface some twelve feet in diameter. The bottom of the oven having been cooled by the quenching of the previous charge and by contact with the new one. the coking begins at the top and extends downward, reaching the bottom in from 32 to 34 hours. The coke has ample opportunity to swell and develop a cellular structure in accordance with the composition of the coal, and entirely independent of any attempts at control. The typical form of beehive coke is therefore long finger-like pieces, widening toward the bottom of the oven and with an inch or two of spongy coke at each end. The inability to control the formation of the cells makes it essential that just the right coals are used, or the requisite hard body, resistant alike to pressure and the action of hot carbonic acid in the blast furnace, cannot be obtained. The fact that the coal from the Connellsville district gives just the requisite structure when coked in the beehive oven is the reason for its present pre-eminent position as a blast furnace fuel in America.

In the retort oven the coal lies in a high narrow mass, about 5 feet high and from 16 to 20 inches wide. The previous charge having been pushed out rapidly by machinery and quenched outside, the oven is hot when the fresh charge is introduced and the evolution of gases begins immediately from the coal lying in contact with the hot sides. The flow of gases being from the sides, they meet in the center and rise to the top, where they escape, forming a sort of cleavage plane midway between the two walls. Thus the pieces of retort coke are stouter than the long, slowly developed ''fingers'' of the beehive oven, and are a little shorter than half the width of the oven. The end of the piece next the wall is denser and the end next the cleavage plane is more spongy than the main body.

The cellular structure is more compressed than beehive coke, principally on account of the narrow retort that permits no expansion in the direction of the flow of the gases, and also because the depth of the charge is usually about two and one-half times as great as in the beehive. The cellular structure of retort coke is dependent somewhat on the proportions of the ovens, the temperature and the time of coking.

The ability of the retort oven to coke coals that cannot be used in the beehive is due to the more rapid application of the heat, fixing the pitchy or coke-making portion of the coal before it has time to escape, and the formation of a firm cellular structure by the pressure.

During the past year a conclusive test has been made indicating the relative values of retort and beehive coke made from the same high grade coal, of a quality adapted to both the retort and beehive practice. For a year or more a blast furnace has been run either entirely or largely on retort coke made from the Connellsville coal. The furnace was blown in on retort coke, and run for some months without any signs indicating anything unusual in the fuel. Subsequently a portion of beehive coke was used in the fuel charge, and from time to time the fuel was changed from all retort coke to all beehive coke, or to a portion of each, without any indications in the working of the furnace that there was any difference in the fuel.

It is probable that prolonged and accurate comparisons would show that the hardness of the retort coke would result in a somewhat lower fuel consumption and a cooler furnace top, owing to the weaker action of the furnace gases on the harder coke; also, that the blast pressure would have to be slightly higher than with the beehive coke.

It is quite within the bounds of possibility that some of our American coals, equal in chemical purity to the Connellsville, yet inferior to it in adaptability to the conditions of the beehive oven, may prove to make a coke in the retort oven that will be of equal value in every respect with the Connellsville beehive coke. Indeed, experiments already made would seem to point in that direction.

Objection has been made to the retort coke on the ground that it is watered outside the oven, thereby destroying the carbon glaze found on coke quenched within the oven and increasing the percentage of moisture in the coke. Careful tests have proved that retort coke is somewhat more resistant to the action of hot carbonic acid in the top of the furnace than is beehive coke from the same coal, which seems to show that the carbon glaze has in practice no value. The absence of a glaze on retort coke is no indication that carbon is not deposited from the gases, for in the first place the yield of coke is always higher than the so-called "theoretical" yield, and in the second place, as the coke is leaving the oven the glaze can plainly be seen, but its brightness is destroyed by the water. A long series of tests have shown that coke properly quenched outside of the oven need not contain over ¼ to ¾ per cent. of moisture, but the amount of moisture in the coke after its arrival at the furnace is altogether another question, and depends more on the time it is on the road and on the humidity of the atmosphere than on the method of quenching.

The effect of moisture in the upper part of a blast furnace is an open question. Experiments have been made by leading furnacemen which indicate that its cooling action on the ascending gases saves the coke in a measure from solution in the hot carbonic acid and permits more coke to reach the zone of fusion, with the result that the fuel consumption is noticeably lowered.

The Connellsville beehive coke is, perhaps, the most perfect blast furnace fuel in the world, and it is not claimed that retort coke made from this coal is a superior fuel to the beehive product. But to the great bitum nous coal fields of this country, to which the Connellsville district does not bear the relation of one to the hundred, the retort oven comes with a promise of help. Many coals that, although pure enough chemically for metallurgical use, make a soft coke in the beehive oven, when coked in the retort oven give a structure so hardened and strengthened that the product is an entirely acceptable metallurgical fuel. In other cases, when the impurities are too great for furnace or foundry use, or the structure is hopelessly weak, or when the coal is dry and lies dead in the beehive without a suggestion of coking, a coke can often be made in the retort oven that is easily salable for domestic purposes, brewers' and malsters' use, and for many other uses where a clean-burning fuel, free from smoke, is desired. The demand for coke for these purposes is growing rapidly, and the supply of this market should be very profitable in a properly located and designed plant, from which the gas and other by-products would have a ready sale.

The ability of the retort oven to coke coals that have hitherto been considered non-coking, brings into prominence the subject of laboratory tests of coals for coking purposes and of the coke made. A chemical analysis of the coal or coke, while important, does not fully indicate its value, and physical tests are quite as important.

The coking qualities of a coal are hardly shown at all by an ordinary chemical analysis, and an actual test in the oven is the usual method for determining this point. A laboratory method for making this test has been recently developed by Louis Campredon in the laboratory of the Vignac Works, France. His method is similar to that used in ascertaining the binding power of cement. The principle is the mixing of the coal with an inert body and carbonizing the mixture in a closed vessel; the greater the binding or coking power of the coal the more inert matter will it bind into a solid mass. The practical operation of the method is as follows: Pulverize the coal finely, passing it through a sieve of fine mesh. A suitable inert body is a fine siliceous sand of uniform grain, but somewhat coarser than the coal. Several equal portions of coal (say of 1 gm. each) are mixed with variable weights of sand, and the mixtures are heated to a red heat in closed porcelain crucibles, so as to carbonize the coal. After cooling, either a dry powder or a more or less hard coked mass is obtained. After a few trials it is easy to determine what maximum weight of sand a coal can bind together.

Taking the weight of coal as unity, the binding power will be given by the weight of the agglomerated sand. The binding power is nil for a coal giving a powdered coke, and it has been found to be 17 for the most binding coal yet tried by the experimenter, while pitch is 20. Experiments by this method show that there is no relation between the proximate analysis and the binding power of coals, confirming actual oven experience.

THE BY-PRODUCTS.

These consist primarily of ammonia, tar and gas, and in addition to the increased yield of coke are the sources of profit from the by-product oven which are wholly lost in the ordinary beehive. Some retort ovens, such as the Otto-Coppée, for example, are without the by-product apparatus, and burn the gas to heat the ovens without washing it. These recover no ammonia or tar, but use the excess gas for raising steam, evaporating about 1.5 pounds water per pound of coal coked. But the by-products are so easily saved and the profits therefrom make such an acceptable addition to the right side of the ledger that they can hardly be neglected. A brief consideration of each one may be of interest.

Ammonia.—This substance is given off from the coal in the oven very slowly at first, but as the temperature of the charge rises the quantity increases, and after some ten hours the evolution is quite rapid. As the coking approaches completion the yield becomes much less and stops altogether, although usually a quarter or more of the nitrogen originally in the coal still remains in the coke. The yield of ammonia varies very much in different coal, and depends partly on the amount of nitrogen and oxygen in the coal. It varies also with the temperature at which the coal is coked. Perhaps the most reliable method to determine the yield from any coal, except by an actual oven test, is by the distillation of a sample of the coal in a small retort, under the same temperature and conditions as are present in the oven. But the results are liable to be misleading unless the operation is conducted by an experienced person, as it is hard to maintain the proper conditions.

The ammonia from the ovens is collected in the hydraulic main and condensers, along with the tar, by the cooling and scrubbing of the gas. The ammonia occurs in two forms in the liquor: "fixed" and "volatile;" the former containing the sulphates, chlorides, cyanides, etc., while the latter contains the carbonates, sulphides, and, according to some, free ammonia. The bulk of the fixed salts is condensed first and the volatile later. The ammonia liquor is quite weak when it is first drawn from the tar, usually containing from ¾ to 1 per cent. of ammonia. This weak liquor may be either converted directly into sulphate, and sold as fertilizer, or by purification and concentration it may be converted into aqua ammonia or anhydrous ammonia, which is used so largely through the South and elsewhere in refrigerating and other apparatus.

Ammonia liquor was formerly valued by the hydometer, but this method is deceptive, as the density of the liquor is affected by the condition in which the ammonia occurs. The more accurate method is the distillation of the liquor with some caustic lime or soda, which drives off all the ammonia, volatile and fixed. The distilled ammonia is absorbed in standard acid, and the excess of acid is afterward titrated with a standard alkali solution. The yield of ammonia is usually reckoned as ammonium sulphate, although it may be sold as liquor or sulphate, or in a more concentrated form, according to the market.

The yield of ammonia from the coals in the vicinity of Pittsburg is from 16 to 22 pounds of sulphate per ton of coal.

Tar.—Since the manufacture of illuminating gas by the water-gas process has attained prominence the market for tar is very much improved. Very large quantities are used for roofing, paving, etc., and in Europe much is distilled and separated into pitch and the various lighter oils, which are further treated for the almost endles number of valuable substances which they contain. In this country but little of this is done as yet, and the tar is used mainly for the cruder purposes. Properly developed, its manufacture into the more valuable products should yield very satisfactory profits. Our chemical manufacturers are beginning to realize this fact, and plants for the distillation of tar are growing in number and in importance. The rapid increase of by-product ovens, and the consequent large amount of tar which will be put on the market in the near future makes it necessary to find another outlet for it than the cruder uses, and it is probable that tar distillation will be an important industry in this country before many years.

The main products of the distillation of tar are, light oil, creosote or heavy oil, naphthalene, anthracene and pitch.

The yield and quality of tar from retort ovens depend on the coal and also on the temperature at which the distillation takes place. The tar from the leading retort ovens is usually of excellent quality and commands the best price. The yield of the coals in the vicinity of Pittsburg is from 70 to 80 pounds per ton of 2,000 pounds of coal. Some coals yield as much as 100 pounds or more.

Gas.—The gas that is obtained from retort ovens is a by-product, the value of which varies greatly with the locality in which the ovens are situated. When the ovens are at the coal mine the gas is frequently valuable only for steam raising purposes, and at the usual prices of coal at the mines would be worth but a very few cents per thousand feet. An intermediate condition would be when the ovens are adjacent to an iron or steel works, where the gas could be used for heating furnaces, soaking pits, etc., where it would supplant producer gas being much more conveniently applied and easily freed from all impurities. The most favorable locations for obtaining a good value for oven gas are those adjacent to large towns, where there is a demand for illuminating or fuel gas. The discovery and use of natural gas in the country has caused a great demand for fuel gas, especially for domestic purposes, and many hundreds of thousands of dollars have been spent in attempt to supply this demand. But while these experiments have been going on the bee-hive coke ovens of Pennsylvania alone have been quietly burning to waste nearly 1,000,000,000 feet a week of a very superior quality of fuel gas without exciting any special attention.

Cokeoven gas from properly managed retort oven is approximately the same article as that from the retorts of a gas house, the processes of manufacture being similar. It usually contains rather less illuminants, however. Its quantity and composition vary with the coal used and the temperature of distillation, but made from good gas coal it may be used for illuminating purposes after being passed through the ordinary lime boxes to remove the sulphur, etc. If from the nature of the coal the illuminating power of the gas is low, it can either be enriched by any of the well known methods or burned with incandescent burners or used as a fuel gas; for the lack of 1 or 2 per cent. of illuminants will not appreciably affect its fuel value.

In arranging and oven plant for the supply of fuel or illuminating gas, it is necessary either to provide a holder of rather large dimensions or with a smaller holder, to have not less than, say, twenty-five or thirty ovens, that shall be drawn in rotation at approximately even intervals; for in common with other substances containing hydrocarbons, when coal is distilled in an oven or elsewhere the gases given off are not at all uniform in composition, but change constantly as the distillation progresses.

The following are analyses of retort-ovens as from European and American coals:

TABLE XIV.

	Percentage by volume				
	I.	II.	III.	IV.	V.
Carbonic acid	3.0	0.90	1.4	3.27	.3
Carbonic oxide	8.8	4.90	6.5	7.95	7.4
Hydrogen	58.0	58.57	53.37	52.77	51.7
Nitrogen	2.4	5.74	0.5	1.99	5.5
Methane	24.7	27.56	36.1	31.45	32.3
Olefines	3.1	2.33	2.2	2.57	2.8
Totals	100.0	100.0	100,0	100.0	100.0

It is often asked—what is the difference between coke oven gas and natural gas? This is readily answered by a comparison of the above analyses with the following, which is from gas sold in Alleghany and Pittsburg by the natural gas companies:

Carbonic acid	0.3	per cent.	Nitrogen	0.2	per cent.
Carbonic oxide	0.0	"	Methan	96.9	"
Hydrogen	0.0	"	Olefines	0.8	"

It will be noticed that this latter gas is almost pure methane, or marsh gas, while the coke oven gas is practically a mixture of methane with hydrogen. The natural gas of the above analysis contains about 980 British thermal units per cubic foot, while the coke oven gas usually contains from 560 to 590 heat units. It is a familiar fact to those who have seen natural gas burned for lighting purposes that the large amount of methane causes it to burn with a smoky flame, and the light from it is therefore poor, although the proportion of olefines or illuminants, is not always as small as in the analysis given above. It has been stated by good authorities that when a gas having such a large proportion of methane is burned in the ordinary way without regeneration of the air by the products of combustion, that the available heat units are not greater than those from a gas of similar composition to the coke oven gases given above, owing to the fact that such a very large amount of air is necessary to burn the methane, and the amount of heat absorbed in bringing the inert nitrogen up to the temperature of the combustion chamber is so great that it counterbalances the superior heating value of the gas. Of course, if the heat carried away in the products of combustion were returned to the furnaces by regeneration, this loss would not be nearly so great.

The principle source of luminosity in the gas is benzol. This substance is separated from the gas in some of the German by-product works, and is used for the manufacture of the aniline colors. It is a highly volatile substance, somewhat similiar to the naptha products of petroleum distillation, and is very difficult to transport. Its removal from the gas renders the latter useless for illuminating purposes, but does not materially affect its fuel value. Benzol is also obtained in the distillation of tar, but not in large quantities.

To sum up briefly, then, it will be seen that the coking of coal in the by-product retort oven differs in the results obtained in the following particulars from the same operation in the bee-hive: From the bee-hive oven we obtain coke. The article is of excellent quality if the coal is just adapted to the purpose, but the yield is from 5 to 20 per cent. lower than the analysis of the coal shows should be gotten.

In addition to the coke there is a great deal of smoke, but those living near the ovens hardly look on this as a valuable product.

From the by-product retort oven, we have coke again, and always more than the analysis of the coal indicates. It has yet to be proven that any coal which makes good bee-hive coke will not make equally good retort oven coke. Moreover an excellent metallurgical coke can be made from many coals that are worthless for the bee-hive. In fact it is largely for this reason that retort ovens have been so widely introduced in Continental Europe. In addition to the increased yield of coke we have from a ton of coal, from 16 to 22 pounds of sulphate of ammonia, from 70 to 100 pounds of tar, and from 3,000 to 10,000 cubic feet of gas.

The manufacture of coke is about the only metallurgical operation that we Americans, proud of our wonderful progress in all the mechanical arts, still conduct after the manner of our ancesters before the Revolutionary war. Let us introduce the by-product retort oven into the chain of iron manufacture, confident that it will not be unworthy to be linked with the mining and haulage of our coal by electricity, the digging of our ore by steam shovels, and our blast furnaces smelting 700 tons of iron in a day.

CHAPTER V.

Coke Furnaces.

The largest furnaces in Alabama are 80 feet high, and 19 feet 6 inches wide in the bosh, or widest part. The greatest amount of pig iron ever made in a furnace in one day in this State was 265 tons,* and for its production there were required 588 tons of ore, 62 tons of limestone and 265 tons of coke, all of 2,240 lbs.

It is by no means unusual for a furnace to make 200 tons of iron a day, and for this there would be required 480 tons of ore, 280 tons of coke, and 25 tons of stone, if the proper amount of hard ore were used. The average number of tons of material handled per ton of iron made is about 4.44 in coke furnaces, so that for the 835,851 tons of coke pig iron made in 1895, there were handled 3,711,178 tons of material, of which 2,089,627 tons were ore, 442,176 tons were stone (limestone and dolomite), and 1,179,375 tons were coke. These are approximate figures. The amount of ore required to make a ton of iron varies from 2.10 tons to 2.87 tons, the average being close to 2.50. The average amount

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*This output has been exceeded by about 50 tons since the introduction of 16 tuyeres.

of coke used per ton of iron made is 1.41 tons of 2240 pounds, the range being from 1.16 to 1.60.

The average amount of stone used per ton of iron made is about 0.53 ton, the range being from 0.10 to 0.88.

The amount of each material entering the furnace per day is not a matter of guess, or of indifference, but is carefully determined from the chemical analysis. It is customary to fill the furnace and keep filling it by "charges," each "charge" being composed for the most part of ore, coke and stone. Thus, for instance, a "charge" may be composed of 5,600 lbs. of coke 10,080 pounds of hard ore, 2,749 pounds of soft ore, and 620 pounds of limestone, and the furnace will take from 80 to 90 charges per day, and should yield 200 tons of iron. The proportion between the various elements of the charge, as well as the total weight of the charge, and the number of charges per day, are all subject to change, but unless there is urgent necessity the daily alterations should be very slight. Having once established the proper burden, it is not advisable to change it, nor is it necessary to do so if the materials can be provided in sufficient quantity and with sufficient regularity, and uniformity of composition. But changes of burden are very frequently made, so frequently in fact that the necessity for them constitutes the greatest obstacle in the path of successful furnace management in this State. It is the lion in the way, unchained at that. In comparing furnace practice in Alabama with furnace practice in Pennsylvania, for instance, one is impressed at the outset with the frequent and in many cases violent changes in the burden in the first place, and in the second with the large tonnage handled per ton of iron. This tonnage is referrable to the raw materials going into the furnace, and to the cinder which, of course, has to be removed. This condition of affairs will remain as it is now until better ore can be obtained, as the ore comprises about 56 per cent. by weight of the burden, being more than the stone and the fuel together, and is subject to wider variations in physical and chemical composition than either the stone or the fuel.

In discussing furnace burdens, therefore, it must be understood that we do so with some reservations. To present the matter briefly and in a general way, as becomes the character of this publication, and yet truthfully as far as we shall go, is difficult. Generalizations can be accepted only with the grain of salt, and should be based on a certain set of conditions. Given these we may derive valuable information, but to utilize them to the best advantage one must know more than appears on the surface.

It may be advisable to take up the subject first from the standpoint of the coke furnace, and then discuss, briefly, the charcoal practice.

We will divide the coke practice into two main heads:

1st. Burdens composed, so far as concerns the ore, of hard ore and soft ore, the proportion of the hard ore rising from 48.2 per cent. to 100 per cent.

2d. Burdens composed, so far as concerns the ore, of hard ore, soft ore, and brown ore, the proportion of brown ore rising from 1.30 to 100 per cent.

1st. Burdens composed, so far as concerns the ore, of hard ore and soft ore, the proportion of hard ore rising from 48.2 per cent. to 100 per cent.

In order that the same basis of comparison may be used, we have taken the delivery prices of the raw materials as follows:

Per ton of 2,240 lbs.		
Hard ore	67.5 cts.	per ton.
Soft ore	55.4 "	"
Limestone	63.4 "	"
Coke	$1.75 "	"

These prices are very close to the averages for shipments during 1895.

The table that has been prepared is based on actual furnace records, and comprises results obtained from the examination of 32,917 charges, the amount of pig iron represented being 50,360 tons. The years selected were 1889, 1890, 1893, 1894 and 1895. The tons referred to are of 2,240 lbs. The table includes the year, the private number, the number of monthly charges, the percentage composition of the ore burden and of the total burden; the iron made, per charge, and for each month, and the percentage of foundry grades (including F. F. or 4 F., but excluding gray forge, mottled and white); the consumption of ore, stone and coke in tons per ton of iron made; the cost of the ore, the stone and the coke per ton of iron; the percentage distribution of this cost; and the pounds of coke required to make a pound of iron. The calculations have been somewhat laborious but the results are extremely interesting and important. They do not cover as much ground as could be wished, but the pressure of other matters compelled an abridgement of the original plan.

We will give a table of results from the same furnaces, consecutive months and at certain intervals. It contains the results of 32,917 charges, and 50,360 tons of iron.

Each horizontal line of figures represents monthly returns Four furnaces are represented, the ore, stone and coke being the same for any one furnace during the period, and all tons of 2,240 pounds.

TABLE XV.—ILLUSTRATIVE OF COKE FURNACE PRACTICE WITH HARD AND SOFT RED ORE.

Increasing percentage of Hard Ore in Ore Burden of Hard and Soft. Delivery Prices: Hard, 67.5 Cts.; Soft, 55.4 Cts.; Stone, 63.4 Cts.; Coke, $1.75.

Results from the Same Furnace. Consecutive Months. Tons of 2,240 Lbs.

			Per cent of Ore Burden.		Per cent. of Total Burden.				Iron Made.			Consumption: Tons per Ton of Iron.				Cost per Ton of Iron.				Per cent of Cost Per Ton of Iron				
Year.	Number.	Charges.	Hard.	Soft.	Hard.	Soft.	Stone.	Coke.	Per Charge.	Total.	Perc't. of Foundry Grades.	Ore.	Stone.	Coke.	Total.	Ore.	Stone.	Coke.	Total.	Hard.	Soft.	Stone.	Coke.	Pounds of Coke per Pound of Iron.
1895	16	2954	50.9	49.1	27.7	26.7	15.5	30.1	1.66	4912	99.2	2.39	0.68	1.34	4.41	$1.47	$0.44	$2.31	$4.22	19.5	15.4	10.3	54.8	1.34
1895	17	2870	50.9	49.1	28.1	27.1	15.8	29.0	1.72	4943	96.2	2.51	0.72	1.32	4.55	1.55	0.45	2.31	4.31	19.8	15.7	11.4	53.1	1.32
1895	20	3029	52.3	47.7	27.2	24.8	16.0	32.0	1.62	4932	90.2	2.27	0.69	1.39	4.35	1.48	0.44	2.44	4.36	19.6	14.2	11.3	54.9	1.39
Average.		2951	51.3	48.6	27.7	26.2	15.7	30.4	1.67	4929	95.2	2.39	0.69	1.35	4.43	$1.50	$0.44	$2.35	$4.29	19.6	15.1	11.0	54.3	1.35

Results from the same Furnace. Consecutive Months.

1895	19	2742	51.1	48.9	26.5	25.3	15.8	32.4	1.47	4037	88.6	2.42	0.73	1.52	4.67	$1.48	$0.45	$2.66	$4.59	18.1	14.2	11.3	54.9	1.52
1895	18	2708	50.9	49.1	27.0	26.1	15.6	31.3	1.54	4155	68.3	2.54	0.77	1.47	4.78	1.55	0.48	2.58	4.61	18.4	14.9	10.8	55.9	1.47
1895	21	3003	52.3	47.7	26.2	24.1	16.6	33.1	1.49	4495	87.0	2.32	0.73	1.52	4.57	1.43	0.46	2.66	4.55	18.0	13.4	10.4	58.2	1.52
1895	13	2872	48.2	51.8	24.0	26.3	17.2	32.5	1.45	4157	83.9	2.26	0.79	1.57	4.62	1.60	0.49	2.67	4.76	8.7	14.7	10.6	56.0	1.57
Average:		2831	50.6	49.4	25.9	25.4	16.3	32.4	1.49	4211	81.9	2.39	0.75	1.52	4.66	$1.51	$0.47	$2.64	$4.62	18.3	14.3	10.8	56.6	1.52

Results from the same Furnace. Consecutive Months.

1890	30	1508	65.9	34.1	36.6	19.0	10.3	34.1	1.97	2970	95.7	2.48	0.45	1.52	4.45	$1.58	$0.28	$2.67	$4.53	24.4	10.3	6.5	58.8	1.52
1890	28	1343	65.9	34.1	36.4	18.7	10.0	34.9	1.95	2615	87.8	2.51	0.46	1.60	4.57	1.58	0.29	2.79	4.66	23.9	10.2	5.3	59.7	1.60
1890	29	1512	65.9	34.1	36.9	19.1	9.7	34.3	1.92	2898	93.2	2.57	0.44	1.58	4.59	1.62	0.28	2.75	4.65	24.4	10.4	6.1	59.1	1.58
Average.		1454	65.9	34.1	36.6	18.9	10.0	34.5	1.95	2828	92.2	2.52	0.45	1.57	4.54	$1.59	$0.28	$2.74	$4.61	24.2	10.3	5.9	59.6	1.57

Results from the same Furnace. Consecutive Months.

1893	36	1995	91.5	8.5	57.3	5.2	2.3	35.2	1.96	3901	83.9	2.78	0.10	1.56	4.44	$1.82	$0.13	$2.76	$4.71	36.9	2.8	1.5	58.8	1.56
1893	34	1805	80.7	19.3	47.4	11.2	5.7	35.7	1.83	3315	93.8	2.68	0.26	1.63	4.57	1.93	0.16	2.89	4.99	33.1	5.1	4.0	57.8	1.63
1893	38	1576	100	....	63.8	....	...	36.2	1.91	3005	59.4	2.87	..	1.63	4.50	1.94	.....	2.85	4.79	40.5		...	59.5	1.61
Average,		1792	90.7	9.3	56.2	5.5	2.6	35.7	1.90	3407	79.0	2.78	0.12	1.61	4.51	$1.89	$0.10	$2.83	$4.82	36.8	2.6	1.8	58.8	1.61

A critical examination of this table will show :

1st. The amount of ore used per ton of iron made increases with the per centage of hard ore in the burden, rising from 2.39 tons with 51 per cent. to 2.52 tons with 66 per cent., and 2.78 tons with 90 per cent.

2d. The amount of limestone used per ton of iron made decreases with the increase of hard ore, falling from 0.69 ton with 51 per cent., to 0.45 ton with 66 per cent. and 0.12 ton with 90 per cent. With 50 per cent. of hard ore in the ore burden the consumption of stone is 1545 lbs. per ton of iron made, with 66 per cent. of hard ore it is 1008 lbs. and with 90 per cent. of hard ore it is 269 lbs. In one furnace for a period of three months the consumption of stone per ton of iron was 0.75 ton.

3d. The amount of coke used per ton of iron made increases with the increase of hard ore, rising from 1.34 tons with 51 per cent. to 1.57 with 66 per cent. and 1.61 with 90 per cent. In the case of one furnace carrying 50.6 per cent. hard the consumption of coke per ton of iron made for a period of three months was 1.52 tons.

Coke is always the most costly ingredient of the burden. In the table under discussion it does not fall below 53 per cent. of total raw material cost per ton of iron. The tendency towards increasing consumption of coke with increasing amounts of hard ore leads, therefore, to increase cost for raw materials to a ton of iron.

The consumption of coke per ton of iron, the quality of the coke, ore and stone being the same, depends to a very great extent upon the amount of air and its pressure and temperature, which is blown into the furnace per unit of time. Instances are on record in Alabama where the consumption of coke per ton of iron with very heavy lime burdens over considerable periods did not exceed 1.25 tons, but the furnace was well equipped as to boilers, engines and stoves. Under such circumstances it has been said by one of the best furnacemen in the Birmingham district that he could use all hard ore (of the best self-fluxing type) and make iron with 1.25 tons of coke without impairing the quality of the iron.

It must, however, be said that the use of crushed hard ore tends to diminish the consumption of coke, for hard ore in large lumps is not easily penetrated by the reducing gases. When a large piece, weighing from 50 to 75 lbs. is exposed to the heat of the furnace in descending the outside of it is first effected. The carbonic acid is removed, the oxide of iron begins to part with its oxygen, and processes of disintegration are set up which continue until the ore is broken into small fragments.

It may be assumed that the oxide of iron is not completely reduced until each piece is exposed to the deoxidizing gases. This takes place with comparative rapidity if the ore is porous, as with certain kinds of brown ore, or if the fragments of ore are sufficiently small. They must not be too small, else the current of gas is checked, the burden packs and the furnace "hangs." But if the size of the ore particles be small enough to allow of easy gas-penetration while not so small as to cause irregularities in the descent of the burden, we should have comparatively favorable conditions for reduction. It would appear that the hard ore has a twofold advantage over the soft ore, first as regards the admixture of lime for making a self-fluxing ore, and second in having the lime combined with carbonic acid. The first advantage renders possible the saving of extraneous lime. Using 80 per cent. of hard ore and 20 per cent. of soft ore in the ore burden there are required 582 lbs. of limestone, as against 1,680 lbs. for 50 per cent. hard and 50 per cent. soft, a saving of 31 cents per ton of iron in favor of the heavier hard ore burden. This saving, however, may be more than counterbalanced by the greater amount of ore and coke required in the heavier hard ore burden. It may not be possible to obtain better ore, i. e., so far as concerns its iron-content, but it can be improved by crushing. Crushing does not increase the amount of iron, but it does increase the reducibility of the ore by enabling the gases from the coke to act upon a larger surface of iron-bearing material. It does more than this. It furthers the evolution of the carbonic acid in the ore, and this renders the ore more porous.

Crushing and calcination have a common purpose, viz., to increase the reducibility of the ore by increasing the amount of iron-bearing surface exposed to the reducing agencies.

The use of crushed hard ore is rapidly extending in Alabama, and it will not be long before the advantages attending it use will force themselves upon those who seem at present to be indifferent to the matter.

In a paper on "Large Furnaces on Alabama Material," (Transactions American Institute Mining Engineers, Vol. XVII, p. 141. 1889). Mr. F. W. Gordon said that the results at Ensley proved the possibility of making a pound of iron with a pound of coke. Since that time and with a better coke than was then used it has happened for a day or so that a pound of coke made a pound of iron, but the coke iron that has been made in the Birmingham district with a ton of coke per ton of iron is insignificent in amount, and there is no reasonable expectation that it will be increased in our day. The present consumption for the best coke is 1.34 lbs. per pound of iron.

If any hopes were entertained as to the possibility of any one of the Ensley furnace making a pound of iron with a pound of coke even for a week at a time they must long since have been abandoned in the cold light of facts.

4th. The tendency of the percentage of foundry grades of iron is towards a decrease with the increase of hard ore. While this is not strongly accentuated still it appears to be too evident to be neglected. Individual cases may be cited wherein the percentage production of foundry grades during a month was higher when the percentage of hard ore rose to 80 per cent. than when it was at 52 per cent., as by numbers 34 and 20. But on the other hand when the ore burden was composed entirely of hard ore, as in No. 33, the percentage of foundry grades touched its lowest point, viz., 59.4.

The influence of increasing amounts of hard ore on the quality of the iron is of the utmost importance in the discussion of this subject. Too much stress can not be put on it, for it determines the price at which the product must be sold. The higher the percentage yield of foundry irons the more valuable is the output. Any thing, therefore, that tends to interfere with the make of foundry iron should be most carefully investigated, and conclusions drawn from authentic records must be the chief evidence.

Thirteen cases have been examined, the number of charges being 32,917, and the amount of iron 50,360 tons. Three cases in which the percentage of hard ore in the ore burden was 50.9 per cent., 50.9 per cent. and 52.3 shows the following percentages of foundry grades respectively, 99.2 per cent., 96.2 per cent., 90.2 per cent., the average being 95.2 per cent.

The total number of charges was 8,853, and the total iron made 14,798 tons.

Four cases in which the percentage of hard ore in the ore burden was 48.2, 50.9, 51.1, and 52.3, show percentages of foundry grades, respectively, 83.9, 68.3, 88.6, and 87.0, the average being 81.9. The number of charges was 11,325, and the iron made 16,845 tons.

In these cases the average percentage of hard ore in the ore burden was 50.6, as against 51.3 in the first case, while the average percentage of foundry grades was 81.9, as against 95.2. While there was a very small difference between these two cases in respect of the amount of hard ore used there was a marked difference in the percentage of foundry grades made, 95.2 per cent. and 81.9 per cent.

Three cases were examined in each of which the percentage of hard ore in the ore burden was 65.9. In one of them with 1,508 charges and 2,070 tons of iron, the percentage of foundry grades was 95.7. In another with 1,343 charges and 2,61 tons of iron the percentage of foundry grades was 87.8. In the third with 1,512 charges and 2,898 tons of iron the percentage of foundry grades was 93.2. The average of 4,363 charges and 8,483 tons of iron was, in foundry grades, 92.2 per cent.

Finally, three cases were examined in which the percentage of hard ore in the ore burden rose from 80.7 to 100. In one of these with 80.7 per cent. hard there were 1,805 charges, 3,315 tons of iron, and 93.8 per cent. of foundry grades. In another with 91.5 per cent. hard there were 1,995 charges, 3,901 tons of iron, and 83.9 per cent. foundry grades. In the third with 100 per cent. of hard there were 1,576 charges, 3,005 tons of iron, and 59.4 per cent. of foundry grades.

Averaging the results from the two furnaces carrying about 50 per cent. of hard ore in the ore burden we find that with 20,178 charges and 31,643 tons of iron the percentage of foundry grades was 88.5.

Comparing this with the results from the furnace carrying 65.9 per cent. of hard ore, with 4,363 charges, 8,483 tons of iron and 92.2 per cent. foundry grades, there seems to be an advantage of 3.7 per cent. foundry grades for the higher percentage of hard ore.

Taking these two together and comparing with them the results from the burden averaging 90 per cent. of hard ore there is found to be a decided falling off in the percentage of foundry grades.

Perhaps all that can now be said is that there seems to be a tendency towards inferior grades of iron when the percentage of hard ore in the ore burden passes 66. The smaller the yield of iron from the furnace the higher is the percentage of foundry grades, and this seems to be independent of the amount of hard ore carried. Out of 8 cases in which the monthly yield was between 3,900 and 5,000 tons there were 37.5 per cent. in which the yield of foundry grades fell below 87 per cent. In 5 cases in which the monthly yield was between 2,500 and 3,500 tons there was only 1, or 20 per cent. in which the percentage of foundry grades fell below 87.

Whether we may conclude from this that rapid driving on a hard ore burden tends to lower grades of iron is not quite clear. Provided that the furnace has sufficient engine power to furnish the requisite blast and stoves enough to furnish the requisite heat there does not seem to be any good reason why she should not work off on foundry grades satisfactorily, even with a very heavy hard ore burden. But to attempt to make high grade iron with hard ore (limy) burdens and insufficient blast, or heat is apt to cause numerous disappointments.

ORE BURDENS COMPOSED OF HARD, SOFT AND BROWN ORE, THE PRODUCTION OF BROWN RISING FROM 1.3 PER CENT. TO 100 PER CENT.

The table embodies the results from 40,270 charges, and 66,653 tons of iron. The delivery prices for the raw materials are as follows, per ton of 2,240 lbs.

Hard ore	67.5 cents.
Soft ore	55.4 "
Brown ore	1.00 "
Coke	1.75 "

They are the same as for the table giving the results from ore burdens of hard and soft ore, except that, in addition we have brown ore.

They are not assumed prices but such as was actually paid in the Birmingham District during 1895. Three furnaces are represented, the ore, stone and coke being the same for any one furnace during the period. Each horizontal line of figures represents monthly returns:

TABLE XVI—ILLUSTRATIVE OF COKE FURNACE PRACTICE WITH HARD AND SOFT RED ORE AND BROWN ORE.

Increasing Percentage of Brown Ore in Burden of Hard, Soft and Brown. Delivery Prices: Hard, 67.5 cts; Soft, 55.4 cts.; Brown, $1.00; Stone, 63 4 cts.; Coke $1.75. Tons of 2, 240 lbs.

Same Furnace. Consecutive Months.

Year.	Number.	Charges.	Percent. of Ore Burden.			Perct. of Total Burden					Iron Made—Tons.			Consumption: Tons per Ton of Iron.				Cost per Ton of Iron.				Percent. of Cost per Ton of Iron					Pounds of Coke per Pound of Iron.
			Hard.	Soft.	Brown.	Hard.	Soft.	Brown.	Stone.	Coke.	Per Charge.	Total.	Per cent. of Foundry grades.	Ore	Stone.	Coke.	Total.	Ore.	Stone.	Coke.	Total.	Hard.	Soft.	Brown.	Stone.	Coke.	
1894	7	2687	33.4	65.3	1.3	17.0	33.1	0.6	16.9	32.4	1.69	4568	95.8	2.22	0.73	1.44	4.39	$ 1.33	$ 0.47	$ 2.50	$ 4.30	11.7	18.2	0.6	11.5	58.0	1.44
1895	12	2945	47.1	51.5	1.4	24.4	26.7	0.6	16.8	31.5	1.57	4635	97.9	2.37	0.75	1.45	4.57	1.47	0.48	2.54	4.49	16.8	15.0	0.7	10.7	56.8	1.45
1894	15	2690	48.5	50.0	1.5	26.5	27.3	0.7	15.9	29.6	1.79	4818	99.7	2.29	0.64	1.24	4.17	1.41	0.39	2.17	3.97	18.8	15.8	0.8	10.1	54.5	1.24
1895	11	2962	46.6	50.0	3.4	23.2	21.9	1.6	18.7	31.6	1.69	5002	97.6	2.11	0.78	1.34	4.23	1.32	0.49	2.35	4.16	15.9	14.0	1.2	12.6	56.3	1.34
1895	14	2957	48.4	46.8	4.8	25.1	24.3	2.5	16.6	31.5	1.65	4886	99.5	2.23	0.72	1.37	4.32	1.48	0.45	2.37	4.30	12.3	15.0	2.4	15.2	55.1	1.37
1895	10	2833	42.4	50.8	6.8	22.1	26.5	3.7	17.1	30.6	1.64	4659	99.2	2.35	0.77	1.38	4.50	1.49	0.49	2.42	4.40	15.2	15.0	3.6	11.3	54.9	1.38
1895	9	2847	42.1	50.7	7.2	21.8	26.3	3.7	17.6	30.6	1.63	4678	94.5	2.34	0.78	1.38	4.50	1.49	0.51	2.41	4.41	15.0	14.3	3.6	12.5	54.6	1.38
Average.		2833	44.1	52.1	3.8	22.9	27.0	1.9	17.1	32.1	1.67	4745	97.2	2.28	0.74	1.38	4.40	$ 1.43	$ 0.47	$ 2.39	$ 4.29	15.1	15.3	1.8	12.0	55.8	1.38

Same Furnace, Consecutive Months.

1890	25	1635	57.1	42.5	0.4	31.9	23.8	0.3	10.6	33.4	2.01	3291	83.1	2.48	0.47	1.48	4.43	$ 1.54	$ 0.29	$ 2.59	$ 4.42	21.5	13.1	0.2	6.7	58.5	1.48
1890	22	1819	53.7	34.2	12.1	28.5	18.2	6.3	10.6	36.4	1.88	3418	92.0	2.51	0.49	1.72	4.72	1.69	0.30	3.01	5.00	18.2	9.5	6.0	8.2	60.1	1.72
1890	32	1713	70.3	9.3	20.4	40.0	5.2	11.6	6.4	36.8	1.88	3209	86.9	2.55	0.29	1.61	4.45	1.88	0.18	2.98	4.96	24.6	2.6	10.6	3.7	58.5	1.61
1890	26	1609	58.5	20.4	21.1	32.3	11.2	11.7	8.4	36.4	1.89	3011	90.0	2.50	0.44	1.52	4.49	1.80	0.22	2.79	4.81	20.3	5.8	10.9	5.9	57.1	1.52
1890	23	1994	53.7	19.2	27.1	29.9	10.7	15.1	9.7	34.6	2.01	3990	89.2	2.40	0.41	1.49	4.30	1.77	0.26	2.58	4.61	18.8	5.5	14.1	5.9	55.7	1.49
Average.		1754	58.6	25.1	16.3	32.5	13.8	9.0	9.1	35.6	1.93	3386	88.2	2.49	0.42	1.56	4.47	$ 1.73	$ 0.25	$ 2.77	$ 4.75	20.7	7.3	8.3	6.1	57.5	1.56

TABLE XVI—ILLUSTRATIVE OF COKE FURNACE PRACTICE WITH HARD AND SOFT RED ORE AND BROWN ORE.

Increasing Percentage of Brown Ore in Burden of Hard, Soft and Brown, Delivery Prices: Hard, 67 5 cts.; Soft, 55.4 cts.; Brown, $1.00; Stone, 63.4 cts.; Coke, $1.75. Tons of 2,240 lbs.

Same Furnace. Consecutive Months.

			Percent. of Ore Burden.			Per ct. of Total Burden					Iron Made—Tons			Consumption: Tons per Ton of Iron.				Cost per Ton of Iron.				Percent. of Cost per Ton of Iron.					
Year.	Number.	Charge.	Hard.	Soft.	Brown.	Hard.	Soft.	Brown.	Stone.	Coke.	Per Charge.	Total.	Per cent. of Foundry grades	Ore.	Stone.	Coke.	Total.	Ore.	Stone.	Coke.	Total	Hard.	Soft.	Brown.	Stone.	Coke.	Pounds of Coke per Pound of Iron.
1895	3	1904	17.3	35.1	47.6	8.9	18.2	24.6	19.2	29.1	1.34	2569	92.8	2.37	0.88	1.32	1.57	$ 1.86	$ 0.55	$ 2.32	$ 4.73	5.8	9.7	23.8	11.8	48.9	1.32
1894	4	1900	18.3	33.3	48.4	10.0	17.6	25.3	18.6	28.5	1.29	2456	99.9	2.45	0.87	1.35	1.68	1.91	0.55	2.38	4.84	6.2	9.3	24.3	11.4	48.8	1.36
1895	5	1983	21.0	28.1	50.9	10.5	14.0	25.3	20.0	30.2	1.37	2708	99.2	2.16	0.86	1.31	1.33	1.73	0.54	2.30	4.57	6.7	7.3	23.9	11.9	50.2	1.31
1895	6	1909	23.8	24.8	51 4	12.4	13.0	26.8	18.2	29.6	1.23	2369	92.1	2.50	0.87	1.41	1.78	2.04	0 55	2.48	5.07	7.9	6.8	25 4	11.0	48.9	1.41
1895	2	2076	16.0	17.7	66.3	8.8	9.8	36.7	18.1	26.6	1.37	2844	98.1	2.68	0.88	1.28	1.84	2.33	0.55	2.24	5.12	5.6	5.1	34 7	10.9	43.7	1.29
1895	1	1802	..	...	100	...	....	52.9	20.4	26.7	1.53	2766	99.1	2.31	0.89	1.16	4.36	2.31	0.56	2.04	4.91	...	....	47.0	11.5	41.5	1.16
Average.		1929	16.1	23.1	60.8	8 4	12.1	31.9	19.1	28 5	1.35	2619	96.9	2.41	0.87	1.30	4.58	$ 2.03	$ 0.55	$ 2.29	$ 4.87	5.3	6.3	29.8	11.4	47.2	1.30

A careful examination of the table will show:

1st. The amount of brown ore used per ton of iron made varies from 2.28 to 2.49 tons. In 1880 the brown ore was not as good as in 1894 and 1895, and the consumption of ore per ton of iron rose to 2.49 tons, although the average percentage of brown ore in the ore burden was 16 3.

With 44.1 per cent, of hard, 52.1 per cent. of soft and 3.8 per cent. of brown the comsumption of materials per ton of iron was as tons:

Ore	2.28
Stone	0.74
Coke	1.38
	$4.40

and the cost of the material was:

Ore	$1.43
Stone	0.47
Coke	2.39
	$4.29

When the proportions were:	PER CENT.
Hard	58.6
Soft	25.1
Brown	16.3

the consumption of material was, in tons per ton of iron:

Ore	2.49
Stone	0.42
Coke	1.56
	4.47

and the cost per ton of iron was:

Ore	$1.73
Stone	0.25
Coke	2.77
	$4.75

When the proportions were:

Hard	16.1
Soft	23.1
Brown	60.8

the consumption, in tons per of iron, was:

Ore	2.41
Stone	0.87
Coke	1.30

and the cost per ton of iron was:

Ore	$2.03
Stone	.0.55
Coke	2.29
	$4.87

2d. The amount of limestone used per ton of iron varies according to the amount of hard ore used, being 0.42 ton with 58 per cent. 0.74 ton with 44 per cent., and 0.87 ton with 16 per cent. It may be instructive to compare these figures with corresponding results from an ore burden of hard and soft. With 48 per cent. hard in such a burden, which is the nearest to 44 per cent. as above, the consumption of stone in tons per ton of iron was 0.79, as against 0.74 with 44 per cent. of hard in a burden carrying brown ore. The nearest figure in the hard-soft burden to the 58 per cent. hard in the hard soft brown burden is 65.9 per cent., and this required 0.45 ton of stone per ton of iron, as against 0.42 ton in the brown ore burden carrying 58 per cent. of hard ore.

It is important to note that a hard ore burden with 100 per cent. of hard required no stone, while in the brown ore burden with 100 per cent. of brown the amount of stone required per ton of iron was 0.87 ton, the highest consumption of stone to be observed in these tables.

3d. The amount of coke used per ton of iron decreases with the increase of brown ore, except in the case of the furnace in operation in 1890, and using 58.6 per cent. of hard ore. In this case the consumption of coke was much in excess of the returns for 1894 and 1895, and the general increase of coke with increase of hard ore is borne out also by this table.

4th. The percentage production of foundry iron from brown ore burdens is impaired by increasing the amount of hard ore. With 44 per cent. of hard and 3.8 per cent. of brown ore the average percentage of foundry grades was 97 2. With 58 per cent. hard and 16 per cent. brown it was 88.2 per cent, With 16 per cent. hard and 60 per cent. brown it was 96.9.

As might be expected from the more complex nature of the burden the admixture of hard, soft and brown ores gives rise to greater variations in the economies of production than in the case with burdens of hard and soft ore. The variations are traceable to the fluctuations in the quality of brown ore, for they exhibit wider ranges of composition than either the hard or the soft ore. Then again in physical qualities they are apt to show rapid oscillations. The condition in which brown ore from the same mine and washer reaches the stockhouse has to be observed personally before one can fully appreciate what these may be, and often are. When the brown ore "bank" is in fairly good ore, and the clay is easily disintegrated, and water is abundant the ore comes in clean. When the clay is "tough," the ore cherty, and the water scanty, the ore comes in wet, and seriously hampered with clay, or with too much insoluble matter.

In spite, however, of these obstacles, which at times may cause trouble, the fact remains that the use of brown ore is highly advantageous. There are very few furnaces that are not glad to get it, and now and then to pay a good deal more than $1.00 per ton for it.

Instances are on record where as much as $1.50 per ton has been paid in the Birmingham District for brown ore of 55 per cent. iron. although the average price is much lower. Good brown ore always commands a ready sale at fairly remunerative prices.

With the exception of a few furnaces that are not favorably located with respect to hard and soft ore, but are within easy reach of brown ore, the proportion of brown ore used in the coke frunaces rarely exceeds 25 per cent. and for the most part is not above 20 per cent. The ore burden is arranged in various ways, 50 per cent. hard, 25 per cent. soft and 25 per cent. brown; 40 per cent. hard, 45 per cent. soft and 15 per cent. brown; &c· &c.

Under special conditions, such as a large order from pipe-works, &c. the proportion of brown ore is increased until the ore burden may be composed entirely of it. But by far the greater amount of iron made from burdens carrying brown ore is made with about 20 per cent. of brown, hand picked, and washed but not calcined.

The practice could be greatly benefited by using washed *and* calcined ore but so far as is known not a single coke furnace is in operation on this kind of material, exclusively or in admixture with hard, and soft ore.

What has been said as to furnace burdens is true in a general way, It is not our purpose now to go into the details of furnace practice, nor to discuss the manner in which the raw materials may be used to the best advantage. This, after all, must be left to the judgment of the furnace manager, which in turn is based on actual experience under varying conditions. It not infrequently happens that one man will take the same materials and the same furnace and produce better iron at a less cost than another, whose theoretical knowledge may be of the best but whose practical acquaintance with the art of making iron has not qualified him to manage a furnace successfully.

There are excellent furnace-men whose knowledge of the difference between silicon and silica is somewhat hazy, and who would find it extremely tiresome to calculate the cubical area of a furnace, They have acquired their information by hard knocks and the exercise of common-sense and a tenacious memory. We have in mind now a good furnace-man who will probably die in the belief that carbonic acid is a combustible material, and who could not calculate the formula of a cinder containing 50 lime, 35 silica and 15 alumina if he was to suffer decapitation the next day.

Iron making is not only a science, it is an art, and one too calling for the constant display of very considerable knowledge and skill, and of untiring patience.

So long as the furnace is working satisfactorily all is well, but to know what to do and when to do it in case something goes wrong, this is what makes or mars the furnace manager.

A furnace may work along weeks at a time on the same burden and produce its normal quantity of iron, and that of a good quality, when some subtle change may take place, discernible only by an experienced eye, and what is to be done must be done at once.

There is one circumstance in connection with iron making in Alabama that renders the daily life of a furnace-man anything but ''skittles and beer.'' It is the wide and at times rapid variation in the quality of the raw materials. The coke is of fairly uniform composition, but the ore is often quite irregular.

There lie before us certain furnace records giving the daily charges of ore, stone and coke over a considerable period. We will take a certain month when the make of iron was 5,719 tons, 77 per cent. being foundry grades. There were used 2,503 charges, during the month, a daily average of 80.7.

The furnace was using 80 per cent. of hard ore, and 20 per cent. of soft. During the 31 days the amount of ore in tons per ton of iron varied from 2.62 to 2.19, or 963 lbs. This was during the entire month. From one day to the next there were differences of 600 lbs. of ore per ton of iron. In other words, if the furnace could have been charged every day with ore carrying 45.6 per cent. of iron, as was the case on one day, the yield of iron in the month could have been 6,620 tons instead of 5,719, a difference in favor of the better ore of 901 tons for the month. The daily production of iron could have been 213 tons instead of 184 tons.

Furthermore. Not only is the daily yield of the furnace seriously hampered by such irregularities in the ore, the percentage of foundry iron in the make is also lessened, and there are opportunities for an increased consumption of coke and greater costs of production.

In burdening a furnace it is in every way better to have a leaner ore of regular composition than a richer ore of variable and varying composition.

There would be fewer and more restricted variations in the cost accounts, and less interference with the production of the better grades of iron in the one case than in the other.

The question of securing ore of more constant composition is one that can not be brought too forcibly to the attention of iron makers in Alabama. It dominates all other considerations, and is to-day the most vital problem confronting them. No other single question is at once so important and so little studied, the interest in it seeming to be in inverse proportion to its gravity.

As a further contribution to the study of this subject, there is given a table showing what is probably the best practice with coke furnaces using brown ore ex-clusively. The consumption of coke is remarkably low, being 0.87 lb. per pound of iron, or 1948 lbs. for 2240 lbs. of iron. The percentage of foundry grades made was 100, and the cost of raw materials, per ton of iron, was $4.28. The coke was high in ash, 15.7 per cent., and the limestone contained 2.0 per cent. of silica.

The furnace was banked for three days, and yet during the period made 239 tons of iron per 24 hours.

This is certainly good practice, and it is doubtful if anything better, if indeed anything so good, has been recorded in the State.

TABLE XVII.

ILLUSTRATIVE OF COKE FURNACE PRACTICE WITH ALL BROWN ORE.

Delivery Prices: Tons of 2,240 lbs. Ore, $1.00; Limestone, 50 cents; Coke, $2.47.

Year.	No.	Pr. ct. of Ore Br'dn	Per cent. of Total Burden			Iron Made Tons.		Consumption Tons Per Ton of Iron.				Cost Per Ton of Iron.				Per cent. of Cost Per Ton of Iron.			Pounds of Coke per Pound of Iron.
		Brown.	Brown Ore.	Stone.	Coke.	Total.	Per cent of Foundry Grades.	Ore.	Stone.	Coke.	Total.	Ore.	Stone.	Coke.	Total.	Ore.	Stone.	Coke.	
1897	51	100	58.3	16.1	25.6	6696	100	2.01	.55	.87	3.43	$ 2.01	$ .27	$ 2.00	$ 4.28	46.9	6.2	46.9	0.87

CHARCOAL FURNACE BURDENS.

The reputation of the charcoal iron made in the State has been most excellent, especially that of Shelby furnaces, and even now in these times of depression the Shelby iron is sought for by those who still desire a high grade charcoal iron.

The charcoal used is made for the most part in the old way, in mounds and heaps, the attempt to recover by products in specially constructed kilns being confined to the Round Mountain Company in Cheroke county.

By far the greater amount of charcoal iron is derived from the brown ores, the consumption of ore per ton of iron being from 1.80 to 2.03 tons.

The following table exhibits the furnace burdens in good practice over a period of 4 months, with brown ore:

TABLE XVIII—CHARCOAL FURNACE PRACTICE.

YEAR.	Number.	Percentage of total burden.			Iron Made.	Consumption: Tons per ton of iron; bushels for coal.			Cost per ton of Iron.				Ponnds of Coal per Pound of Iron	Per cent of yield of iron Nos. 1 to 5 inclusive.	Per cent. of cost Per Ton of Iron.		
		Ore.	Stone	Coal	Total	Ore.	Stone.	Coal.	Ore.	Stone.	Coal.	Tota.			Ore.	Stone.	Coal.
1893	46	58.2	9.8	32.0	1712	1.84	0.31	100.8	$ 1.78	$ 0.26	$ 6.55	$ 8.59	0.99	78.0	20.7	2.7	76.6
1894	47	60.0	10.6	29.4	1753	1.95	0.34	97.2	1.72	0.26	5.73	7.71	0.96	90.4	22.3	3.4	74.3
1895	48	59.6	10.9	29.5	1789	2.03	0.37	101.8	1.65	0.28	5.85	7.78	1.00	97.7	21.2	3.6	75.2
1896	49	58.3	9.6	32.1	1893	1.80	0.30	100.7	1.50	0.24	5.63	7.37	0.99	88.9	20.3	3.3	76.4
Average	. . .	59.0	10.2	30.8	1787	1.90	0.33	100.1	1.66	0.26	5.94	7.86	0.99	88.7	21.1	3.3	75.6

In this table 2748 cubic inches are taken as one bushel. and the weight per bushel is taken at 22,4 lbs., so that 100 bushels equal one ton of 2,240 lbs.

According to these returns the average percentage, furnace yield, of iron in these brown ores was 52.6, the average consumption of ore per ton of iron being 1.90 ton; the average consumption of limestone was 0.33 ton, or 739 pounds; and of charcoal 100.1 bushels.

The ore was partly washed and calcined, partly merely washed, No. 46 being washed and calcined.

Investigations that have been carried on for some months, but which are not yet to be published, have shown that there is a marked decrease in the amount of charcoal required per ton of iron and a decided increase in the output of the furnace consequent upon the use of washed and calcined ore. This may not appear from the examination of the returns of a single month, as for instance in No. 46. But after comparing the same ore under these different conditions, the other elements of practice being the same; there is no room for doubt.

The charcoal furnaces have the advantage over the coke furnaces of much better ore, but their fuel is far more costly than coke, and the percentage cost of the fuel is considerable more than with coke iron.

Charcoal iron is worth more than coke iron, the present selling price being about twice as much for the one as for the other. The entire product is consumed by manufacturers of car wheels, and those who make a specialty of tough, chilled castings. In the old days a great deal of charcoal iron was used in boiler plates, but the increasing use of soft steel for this purpose has gradually destroyed this business, and very little of it now goes to boiler works.

CHAPTER VI.

PIG IRON.

No Bessemer iron is produced in the State, as the ores so far exploited carry entirely too much phosphorus. Putting the maximum phosphorus allowed in Bessemer iron at 0.10 per cent., an ore containing 50 per cent. of iron and 0.05 per cent. of phosphorus would give pig iron with 0.10 per cent. of phosphorus. As a rule the ores used in the State do not contain as much as 50 per cent. of iron, for by far the greater amount of iron is made from the soft red and the limy ores of less richness. There are brown ores that carry 50 per cent. of iron, and even more, but with the exception of the furnaces at Shelby, Anniston, Round Mountain and Sheffield, with a maximum yearly capacity of about 200,000 tons, there are no furnaces using brown ore exclusively. The brown ores in actual use carry not less than 0.30 per cent. of phosphorus, and taking their content of iron, on the average, at 52 per cent., there would be found in the pig iron not less than 0.47 per cent. of phosphorus, nearly five times as much as the maximum allowed in Bessemer iron. When it comes to mixing brown ore with soft and limy (hard) fossil ores, as is the usual practice, the actual amount of iron in the ore as charged is dependent on the proportions of the various ores used. It certainly will not exceed, on the average, 44 per cent., if indeed it be not nearer 42 per cent. With 0.30 per cent. of phosphorus in the ore burden, this would mean at least 0.68 per cent. of phosphorus in the iron. There is not much iron made in the State that carries less than 0.70 per cent. of phosphorus, and the lowest phosphorus that any iron-producing company would be warranted in specifying would be 0.75 per cent.

There are some brown ores near Talladega, belonging to the Alpine Mountain district, that have been shown to carry less than 0.05 per cent. phosphorus per 50 per cent. of iron. Several years ago the furnace at Talladega contracted to supply Bessemer, iron made from these ores, to a Pennsylvania steel company, and some 3000 tons were shipped. But for some reason the enterprise languished, and has not been revived. It is almcst a hopeless undertaking to make Bessemer iron from these ores. In places they are very low in phosphorus and great expectations have been based on them. But they are variable in phosphorus, showing here very low phosphorus, there a good deal more, and at no great distance 0.10 per cent., 0.20 per cent., and 0.30 per cent. They are very good ores, so far as their content of iron is concerned, but the phosphorus is liable to great variations, and on this account they can not be successfully used in the manufacture of Bessemer iron.

Now and then attention is directed anew to some seam, or deposit of ore that carries phosphorus below the Bessemer limit, but such ores have not come into market.

Next to some of the low-phosphorus brown ores come certain magnetic ores of Clay and Talladega counties. They have been explored very little, and not much is known of them. They have been already mentioned in the chapter on Ores.

It would not have been thought necessary to say even this much as to Bessemer iron in this State had not the writer received many letters from abroad in reference to the subject. It may be said once for all that little or no iron is made here with less than 0.50 per cent. of phosphorus, and it is not thought that Bessemer ore, in quantity, exists here. The pig iron made in Alabama is for foundries, rolling mills, and pipe works, where the percentage of phosphorus is not of so much importance. Within the last two years some of the iron made has also gone for the manufacture of steel by the basic open hearth process, and this is referred to in the chapter on Steel.

The coke pig iron is graded according to a certain system which has grown up in the Birmingham district, and has very little, beyond custom, to commend it. It is illogical, cumbersome, and ridiculous. These faults might be overlooked if it possessed a fair degree of accuracy, but it has not even this merit, and exists by virtue of a certain inertia acquired during the past several years. Whatever usefulness it may once have had it has sloughed off, and it now remains as a monument of absurdity, whose distorted outlines are not even softened by the hand of time, for it is not yet 20 years old.

There are now eleven grades of coke iron, and happy is the grader whose unerring skill enables him to discriminate between them. He is indeed a *rara avis!* These eleven grades are, proceeding from the 'hot' to the 'cold' irons:

Open Silver Gray.
Close Silver Gray.
No. 2 Soft.
No. 1 Soft.
No. 1 Foundry.
No. 2 Foundry.
No. 3 Foundry.
No. 4 Foundry (Foundry Forge).
Gray Forge.
Mottled.
White.

The first eight are generally grouped under the term "foundry irons," and the last three under the term "mill irons." Iron for pipe works is for the most part No. 3 and No. 4 Foundry.

The article by Mr. W. H. Brannon, on Grading Iron in the Birmingham District, which appeared in the first edition, is still pertinent, and is re-published here. There is no better grade in the State than Mr. Brannon, so far as knowledge of the iron is concerned, and no more conscientious man in the discharge of the onerous and delicate duties that devolve upon him.

The article in question was prepared partly for this publication, and partly for the Alabama Industrial and Scientific Society, in whose Proceedings it may also be found, Vol. VI, 1896, pages 11–14.

So far as concerns yard grading there is nothing more to be said. Mr. Brannon has covered the ground thoroughly, and his paper is recommended to those who wish to know the best practice in the Birmingham district:

THE GRADING OF SOUTHERN COKE IRON WITH SPECIAL REFERENCE TO THE BIRMINGHAM DISTRICT.

(*Proc. Ala. Indust. & Sci. Soc., Vol. VI, 1896, pp. 11-14.*)

By W. H. Brannon, Bessemer, Ala.

Eight years ago there were in the Birmingham District 15 grades of iron, viz:—1 Foundry; 2 Foundry; 2½ Foundry; 3 Foundry; Extra No. 1 Mill; No. 2 Mill;

Mottled; White; No. 1 Bright; Medium Bright; Close Bright; No. 1 Silvery; No. 2 Silvery; and Silvery Mill;

This list was revised in 1888, and to-day we recognize 11 grades, viz:—No. 2 Silvery; No. 1 Silvery; No. 2 Soft; No. 1 Soft; No. 1 Foundry; No. 2 Foundry; No. 3 Foundry; No. 4 Foundry; Gray Forge; Mottled; and White.

In 1888 very little attention was paid to chemical analysis, the irons being graded almost entirely by color and granulation. In addition to having a fair knowledge of the principal chemical ingredients of pig iron the grader now must be thoroughly familiar with the four points in uniform grading, viz:—color, granulation fracture and face.

No. 2 Silvery contains from 5 to 5.50 per cent. of silicon, has very little or no granulation, and is almost smooth, with a galvanized appearance. No. 1 Silvery has some granulation, and a smooth face, and contains from 4.50 to 5 per cent. of silicon. Both these irons are weak in fracture, and show a fine, silvery lustre on a fresh face, and are flaky. They should exhibit no dark spots, and the crystallization is obscure. They are what they purport to be "Silvery Irons," and the difference between them, on the yard, is mainly, one of granulation. They are the hottest irons, and contain much more silicon and much less combined carbon than any of the other grades. Their carbon is almost wholly in the shape of graphite, but the large excess of silicon prevents this ingredient from conferring a dark color on the iron.

No. 2 Soft contains 3.50 to 4.0 per cent. of silicon. No. 1 Soft from 3.0 to 3.5 per cent. They are both of a light color, smooth face and weak fracture. A distinct granulation begins to be apparent in No. 2 Soft, which is more pronounced in No. I Soft, but in neither of these grades is the granulation so marked as in the Foundry irons.

The Soft irons are darker than the Silvery irons, but lighter in color than the Foundry irons, and the granulation is not so jagged as in these latter grades. In particular they do not show a silvery appearance, and are not flaky. The increasing ratio of graphite to silicon begins to manifest itself in the Soft irons in the darkening of the color as compared with the Silvery irons.

No. 1 Foundry contains from 2.50 to 3.0 per cent. of silicon, has a very open and regular granulation extending through the entire face, and a dark gray color. The crystallization is marked, and the face is rough to the feel. The difference between this and No. 2 Foundry, which contains from 2.25 to 2.50 per cent. of silicon, is the same in kind as exists between the two silvery, and the two soft irons, and is chiefly one of granulation. In No. 2 Foundry the grain is not so open as in No. 1 Foundry, nor is the crystallization so coarse. The color may be as dark in one as in the other, but in No. 1 Foundry there is a deep blackish gray color which is absent in No. 2 Foundry.

No. 3 Foundry contains from 2.0 to 2.25 per cent. of silicon, and resembles No. 1 and No. 2 Foundry in structure, but the granulation is much less marked. The crystallization is finer than in No. 2 Foundry, and the color, while still dark gray, is not so pronounced.

No. 4 Foundry, recently called Foundry Forge, shows the dark gray color of the other foundry irons, but the granulation is closes and the crystallization finer. It carries from 1.75 to 2.0 per cent. of silicon. Taken together the Foundry irons are distinguished by dark gray color, open grain, and well marked crystallization, three points which are seen to the best advantage in No. 1 Foundry.

Gray Forge is the old No. 2 Mill. It has 1.50 to 1.75 per cent. of silicon, and shows a pebbled granulation in the center, with mottled edges about one-quarter of an inch deep all around. It has a blistered and pitted face, and is frequently honey-combed on the fractured end, some of the holes being an eighth to a half an inch deep.

Mottled iron has from 1.25 to 1.50 per cent of silicon, shows no granulation, and has a pepper and salt appearance on a fresh face. It begins to show an increasing amount of combined carbon, about one-half of the total carbon being in this condition.

White iron has from 1.0 to 1.25 per cent. of silicon, shows no granulation, and is often as white as bleached linen. It carries very little graphite, and is usually high in sulphur. It is very hard, often resisting the drill, and on this account it is difficult to sample properly.

In sampling pig iron one of two methods may be used, the choice depending on the extent of the subsequent analysis. When silicon, sulphur, phosphorus, manganese and total carbon are to be determined the iron is best sampled from the runner, from 4 to 6 small ladles full being taken during the cast and shotted in a bucket of cold water. When graphite, and combined carbon are also to be determined boring must be restored to. In this case two methods may be used. In the first, the face of the pig is bored in three places to the depth of ½ to 1 inch along a line drawn diagonally across the face, the borings being mixed. In the second, the pig is bored diagonally almost entirely through in one place.

In boring pig iron care must be taken to prevent the intermixture of sand from the pig with the borings, and it is well to put a careful man in charge of the drill. In boring chilled pig, and in sampling from the runner, there is, of course, much less danger of adhering sand getting into the borings. A neglect of this matter may often mislead the grader, as sand in the borings shows up as silicon in the pig, and a No. 3 Foundry may be classed as a No. 1 Soft. It is a difficult and tiresome matter to separate sand from borings by means of a magnet, and at the best entails a good deal of extra and unnecessary labor upon the chemist.

The tendency of the trade is now strongly towards a closer chemical inspection of the irons offered for sale, and the grader who intends to keep up with his profession must take this fact into consideration. He must, therefore, acquaint himself with the effect of the chief constituents upon the various irons in respect of color, granulation, fracture and face. He is called upon every day to decide questions involving a great deal of money, and as it sometimes happens that he cannot wait for an analysis he must be prepared to grade without it. But he should by all means cultivate the closest intimacy with the laboratory, and have the grades analysed as often as possible, and not neglect to inform himself as to the influence of the burden, heat and pressure upon the product under his care.

(This paper was prepared for the Birmingham meeting of the Alabama Industrial and Scientific Society, May, 1896.

At that time the prices, f. o. b. furnace Birmingham district, for the grades given were about as follows, per ton of 2,240 lbs.:

Open Silver Gray	$8.75
Close " "	8.50
1 Soft	7.75
2 Soft	7.50
1 Foundry	8.25
2 Foundry	7.75

3 Foundry	$7.25
4 Foundry	6.90
Gray Forge	6.75
Mottled	6.75
White	6.25

No one is more competent than Mr. Brannon to speak of this matter, and it is gratifying to hear him acknowledge his dependence upon the chemist. He says, speaking of the yard grader, "He should by all means cultivate the closest intimacy with the laboratory, and have the grades analysed as often as possible."

But even when this is done, and after the grader has re-standardized his eyes by constant afflliation with the chemist, it is impossible for him to grade accurately, unless the furnace is running uniformly.

For instance, any one at all familliar with the recent course of events in the Birmingham district knows that it has become difficult to make high-silicon iron. Open silver gray, close silver gray, and No. 2 soft are scarce, and No. 1 soft carries the silicon of No. 3 Foundry.

The irons that formerly carried from 3 to 5 per cent. of silicon now carry from 2 to 3 per cent., and this without having suffered a notable change in appearance. Perhaps it should be said that the changes in appearance by which the grader is guided are not of such a character as to enable him to seize upon and use them for his purposes.

Be the explanation what it may, the conscientious grader is brought to face this practical difficulty, the former high-silicon irons have changed their composition without changing their appearance, correspondingly.

An iron that looks like a No. 2 soft, or a No. 1 soft, and which, according to ordinary yard grading, would be classed as such, is found in the laboratory to contain less than 2.50 per cent of silicon, and may contain only 2.0 per cent. These are not exceptional instances, but happen every day, and have been happening for a year or more.

Could anything show more strongly the utter absurdity of the present system of grading? Companies that do not seem to care what they make, and that have not had analyses made for months can not be expected to take a very lively interest in a reform of what is so entirely bad as to merit almost any condemnation. Others that show an active interest in what is going on in different directions seem to hesitate to attack the ridiculous system in use. They should take courage, for formidable as it may appear it is really on its last legs and is propped up behind with rotten timbers.

But there must be something in the system to commend it, cumbersome as it is. The names of the grades are not altogether hocus pocus, as might well be imagined, but stand for certain qualities which are recognized in trade, and are found of convenient use. The different grades of iron must have names, and the names must signify qualities, or there would be endless confusion. The present criticism is not directed against naming the various grades, for this is indispensible, but against the needless multiplication of grades and names. The present ridiculous system has grown up on irregularities of furnace practice, and is continued because of some fancied economy. There is really no reason why there should be more than five or at most six grades.

When Mr. Kenneth Robertson prepared a paper on The Grading of Birmingham Pig Iron, (Trans. Amer. Inst. Min. Engrs., Vol. XVII, 1888-89, PP. 94-96) there were eleven grades, viz. No. 1 Foundry, No. 2 Foundry, No. 2½ Foundry, No. 1 Mill, No. 2 Mill, No. 1 C, No. 2

C, (Silvery Irons) No. 1 Bright, No. 2 Bright, Mottled, and White.

At that time No. 1 Foundry carried 3.66 per cent. of silicon, No. 1 Mill, which was also known as No. 3 Foundry, carried 2.87 per cent., and No. 2 C. as much as 7.09 per cent.

In ten years there has been a complete change in the composition of these irons, and yet the same system of nomenclature is retained. High silicon irons are seldom made, and the same may be said of No. 1 Foundry. The No. 1 Foundry of ten years ago would now be classed as a Soft iron.

The agreement made in 1888 by the chief producers of southern iron recognized nine grades, viz. Silver Gray, No. 2 Soft, No. 1 Soft, No. 1 Foundry, No. 2 Foundry, No. 3 Foundry, Gray Forge, Mottled, and White, and in 1893 a grade intermediate between No. 3 Foundry and Gray Forge was added, and called Foundry Forge. It is now called No. 4 Foundry.

Now and then it happened that a close, fine grained silvery looking iron would show on analysis not more that 2 per cent. of silicon, while again, without greatly altering in appearance, it would show from 2.90 to 3.10 per cent. silicon. If the silicon was about 2 per cent. the iron was termed Foundry Forge, as it is now termed No. 4 Foundry; if the silicon was about 3 per cent. it was and is yet, termed No. 1 Soft.

Ordinarily and when grading for the same furnace running on about the same burden, the competent grader comes very near the proper grade, and can be trusted to ship on his own judgment. But when complaints arise, as they do sometimes, and especially on a depressed market, the consumer has to be shown that the iron he objected to as not being No. 3 Foundry, for instance, does really contain from 1.75 to 2 per cent. of silicon, and falls within the limits for this particular grade. This much as to silicon. But how is it in respect to graphitic, and combined carbon? Is the iron to be graded solely by its silicon content? It is granted that for the most part iron can be fairly well graded on its content of silicon, and that the variation of this element confers upon the iron peculiarities of color, granulation, fracture, and face that are more strongly marked than peculiarities due to other elements. It is this fact that has rendered possible the present system of visual and tactual grading. It was quietly assumed that if the silicon was all right, the iron was all right, and this was supplemented by the further assumption that if the iron was all right the silicon was all right.

The easiest way of grading iron is by its silicon content, but it by no means follows that it is the best way, or the only way. Leaving out the content of sulphur, as not seriously affecting any of the grades above Gray Forge, there should be certain ratios established between silicon and combined carbon for the Soft and Foundry irons. The variation in the amount of silicon does, of course, influence the quality of the iron, and one might go even farther and allow that it influences the iron more than any other single element. But combined carbon is by no means to be neglected.

In 29 complete analyses of iron graded as No. 3 Foundry, I found that the silicon varied from 1.45 to 3.83 per cent., the average being 2.37 per cent. Five of the samples should have been graded as No. 1 Soft, as the silicon was between 3.04 and 3.17 per cent., and one should have been No. 2 Soft with silicon 3.83 per cent. These irons were all graded on the yard by a careful and competent man, yet in 6 cases out of 29, or 20.7 per cent., the iron graded as No. 3 Foundry was really Soft. Excluding those six, the average silicon in the other 23 was 2 16 per cent., a result not far wrong, if at all, as No. 3 Foundry may vary from 1.90 to 2.20 per cent. of silicon. In the six cases in which the silicon was over 3 per cent. the combined carbon was 1.04 per cent., and in the 23 others it was 0.82 per cent., the average of the 29 being 0.87 per cent.

The combined carbon in No. 3 Foundry does not usually run as high as 0.82 per cent., the average being about 0.40 per. cent. In the Soft irons it should not be above 0.40 per cent., but in some cases especially when the iron resembles No. 3 Foundry, it may go to 1.00 per cent.

We have then to discriminate between Soft irons with over 3 per cent. of silicon, and the normal amount of combined carbon, and irons which contain over 3 per cent. of silicon and upwards of 1 per cent. of combined carbon. Grading on fracture and appearance some of these latter irons would be put in No. 3 Foundry; grading on silicon content they would go in the Soft irons, with the understanding that the combined carbon was abnormally high.

The same principle holds good in respect of the other Foundry irons, although in a less degree. It is this tendency of the lower grades of Foundry iron to show higher percentage of combined carbon than is usually the case that renders grading by fracture and appearance somewhat uncertain. In case of doubt a silicon estimation will enable one to decide whether or no the iron should be put in the Soft grades, and an estimation of combined carbon will show whether or no it should be stated that this element is above the average.

The multiplication of grades may go on indefinitely according as the fancied needs of consumers increase in number.

There was recently completed an agreement between the chief producers of Alabama coke iron whereby certain uniform prices for standard grades were to be observed. It is a very good thing as far as it goes, but it does not go far enough, nor strike very heartily at the root of the trouble.

The main point is to secure uniform grading, and this can certainly not be gained merely by establishing uniform prices.

A local trade association could take the matter in hand, but a simpler and it seems to us a more satisfactory plan would be for the companies that made the agreement as to prices to make a similar agreement as to grading, and put a competent man in charge of it. The price depends upon the grading. It is not enough for the iron-masters to meet and say what the names of the grades shall be, nor to fix the price at which the grades thus named shall be sold. Unless there is at the same time an agreement as so what kind of iron shall be classed as No. 1 Soft, or No. 3 Foundry, the agreement as to uniform prices is of little use. It is sure to happen that permission to ask a special price for a special iron will be solicited, and unless it is known what this iron really is, what relation it bears to the grades whose prices are already fixed and agreed upon, how can there be any thing but confusion? One may say: "I am making an iron, which to all ordinary grading would be put in No. 2 Foundry. But it carries less than 1.50 per cent. of silicon and is therefore not a typical No. 2 Foundry and I wish to ask a special price for it." He has called in his chemist and knows that the iron is not No. 2 Foundry, although it closely resembles it in granulation, color, fracture, and face. He wishes to sell it on analysis, for this is really the gist of the whole matter.

By all means let there be uniform prices, but if the grading is not uniform what do the uniform prices amount to, after all? They are simply grade-splitters, and will inevitably lead to more confusion than at present exists, if they are not based on the chemical analysis of the irons.

Some people are inclined to regard the chemical grading of pig iron as a sort of Panjandrum, or Mysterious Monster, lying in wait for the unwary. But no chemist who understands the situation in Alabama can declare out and out for laboratory grading, as no chemist can doubt that the present system is out of date, illogical, and cumbersome.

The purpose to which pig iron is put depends absolutely upon its composition; the color, fracture, granulation, and face having nothing to do with it except in so far as they indicate the existence of certain ingredients, whose actual percentage can be determined only by the chemist. As regards grading the inferences to be drawn from data obtained on the iron yard are reliable only if confirmed by laboratory tests, and are to be accepted only when they are so confirmed.

What changes are to be suggested? First the maintenance of a chief grader, whose business it should be to regulate the grading under conditions imposed by the separate companies. Second, the establishment of a central laboratory devoted to pig iron analyses. Third, the diminution of the number of grades and the substitution therefor of not more than six grades, differentiated by the content in silicon, and combined carbon, and possibly sulphur. These six grades might be as follows:

	Silicon.	Combined Carbon.	Sulphur.
Silvery Irons,	5 to 6	0.10 to 0.30	0.01 to 0.04
Soft Irons,	3 to 5	0.20 to 0.60	0.01 to 0.05
Foundry Irons,	2 to 3	0.30 to 0.90	0.01 to 0.07
Gray Forge,	1 to 2	0.40 to 1.25	0.04 to 0.09
Mottled,	0.6 to 1	0.50 to 1.80	0.06 to 0.11
White,	0.1 to 0.6	1.00 to 2.50	0.08 to 0.30

This scheme, or some modification of it in line with its general provisions would retain the present nomenclature, and bring it into closer accord with laboratory results. It would do away with five grades, which are no more than side-grades at best, and would enable the grader to exercise better discretion in the yard. The rapidity and accuracy with which the estimation of silicon, and combined carbon can now be made render it possible to have the results from the cast-house by the time the iron is ready to break and pile. The estimation of silicon now leaves very little to be desired, and while the estimation of combined carbon in pig iron is not so accurate as in steel it is sufficiently so for the purpose in hand. If objection be made to such a radical change much could be done to improve the present system without decreasing the number of grades, or interfering with the nomenclature. If a systematic record of the pigs sampled were kept it would be possible to control the grading within narrower limits than now maintain.

The following plan is suggested for use by graders. Have stout manila envelopes prepared, 3x6 inches in size. On the front have the following blank form printed, viz :

........................Company.

.............Tons. Grade..............

No........Furnace. Division.............

Made........189.. Sampled.......189..

(Mark out the word that does not apply.)

Color, { Light.
Dark.

Fracture, { Weak.
Strong.

Granulation, Regular, } Fine.
Medium.
Irregular, } Coarse.

Face, { Smooth.
Pitted.
Blistered.

Chilled edge...........

(Signed) ...."

On the back of the envelope have the following blank form printed, viz:

Charges.......

Burden.	Pounds.
Hard Ore..........	
Soft Ore...........	
Brown Ore.........	
Stone { Limestone.....	
Stone { Dolomite......	
Coke	
Total...........................	....

To be taken before each cast.

	Time.				Average.
Revolutions of Engine Heat. Pressure.					

Such envelopes were prepared, after consultation with Mr. Brannon, and Mr. W. J. Sleep, manager of the American Pig Iron Storage Warrant Company in this (the Birmingham) district, and were used for a considerable period. They answered the purpose admirably, so long as there was co-operation on the part of all the officials concerned. But while the chemist was glad to have the information, and while the grader found that it was just what he needed, in many cases the samples were either not taken at all, or the blanks were not properly filled out. Orders sent out from the general office were not obeyed and samples that should have been taken were utterly neglected. One of the annoying things in connection with the study of Alabama pig iron is the curious indifference of furnace managers to the collection of systematic information in regard to their product. Most of the companies have their own laboratories, and the chemists are alive to the importance of the subject. The cost of the collection of such information as is outlined in the blanks is merely nominal. The grader fills out the blanks in regard to color, etc., when the samples are taken. It is done in less than five minutes. The additional information is obtained from the furnace office in five minutes more. But when the general office has sufficient interest in the matter to order that the blanks should be filled out the inexplicable indifference of the furnace superintendents may block the matter. Whether it is they think they do not need the information, or whether they regard the request and the order as an unwarrantable interference with their own particular business, or both, is not in evidence.

Two of the best judges of iron in the State, Mr. Brannon and Mr. Sleep, whose daily business brings them in close contact with all kinds of iron, and upon whose judgment large sums of money depend, are agreed that there is urgent need of more systematic information in the grading of iron. The composition of heretofore well recognized grades has changed, graders need to know what these changes are and how they may be recognized, the laboratories are well equipped and the chemists anxious to assist in every possible way the progress and success of the business. One of the chief officials of a large company has said: "For the enlargement of the domestic market, the most desirable thing to be done, in my judgment, is to secure uniformity in grading and naming iron, and selling it upon terms of uniformity. * * * * * It is scarcely too much to say that the whole question of grading iron is assuming a more complex condition." And yet the same old absurd conglomeration continues, and graders are asked to tell at a glace the chemical composition of eleven different kinds of iron. Of course they can not do it, and they should not be expected to do it.

If any of these observations apply to the domestic market, and in fact they all apply, with what greater force do they apply to the foreign market?

Great efforts have been made to secure a foothold for Alabama iron in England or the continent during the last two years, and a gratifying degree of success has been attained. Shipments on foreign orders for the year 1897 approximate 220,000 tons, and it is likely that the trade will grow, if the producers recognize the demands of the foreign consumers. Alabama iron going abroad has to compete with standard brands such as Eglington, or Clarence, or Middlesbrough No. 3, whose uniform composition has enabled the consumer to know just what to expect.

If he buys No. 3 Foundry, Alabama make, he has a right to expect that the silicon shall not be in excess of the amount present in the standard brands. The foreign market has grown up on pretty much the same foundation as the domestic market, viz., cheapness. In spite of irregularities of composition Alabama iron has been sold in this country because it was made at a less cost and could be sold for less money than other iron. Lack of uniformity does not distinguish all the coke iron made in Alabama, for there are companies in the State that are very careful in grading, but there has been and is now a good deal of complaint that our irons are irregular in composition. But this has not prevented the development of the pig iron industry, with domestic sales, and may not prevent the further extension of the foreign market. The cultivation of new markets, especially those situated at a great distance and which have only recently been compelled to look to us for some of their material, can be successfully undertaken only by the exercise of the greatest care. A consumer may for a time put up with what does not exactly suit him if he is buying it cheap. If for some reason, temporary or permanent, he finds his usual supply curtailed he must go elsewhere. The question of cost is, of course, the main one, but the requirements of his own market, i. e., for his own manufactured products, must be consulted, and he cannot continue to buy a cheap article if he can not use it to advantage. Within the limits of their own grades Alabama irons are known and appreciated in nearly all the States of the Union and in many foreign countries, and what is said here is not to be taken as captious criticism, for nothing could be further from the intention of the writer.

But it has seemed to him that the changes which have been slowly creeping into the grading of iron should be recognized at their full value. The names of the grades do not mean what they once meant, the names have remained, but the composition of the irons has changed. This is no secret. It is perfectly well known to those who have given the matter even cursory attention, and the only thing to do is to act upon the common knowledge. A system which almost every day in the year forces the yard grader to class as Soft as iron which does not carry over 2 per cent. of silicon has had its day, and should give place to a system founded on the actual chemical composition of the iron.

This is true no matter whether the iron is intended for home consumption or for the foreign market, but it is particularly true for those who wish to sell their iron abroad.

CHAPTER VII.

THE COST OF PRODUCING PIG IRON IN ALABAMA.

In January, 1894, there appeared an article in the Engineering and Mining Journal, New York, that gave the cost of making pig iron in Alabama at $6.37. The items were as follows:

TABLE XIX.

1¼ tons of coke @ $1.51	$1.89
2 1-5 tons of ore @ 0.67	1.48
¾ tons of stone @ 0.65	0.50
Labor	1.25
Repairs	0.50
Supplies	0.50
Selling expenses	0.25
Total	$6.37

This article was unsigned and the author is at present unknown. The closeness with which he approximated the real cost will appear later.

In June of the same year Mr. E C. Pechin, formerly editor of the Iron Trade Review, Cleveland, Ohio, published in the same Journal an article on the cost of making pig iron in Alabama, and expressed the opinion that it was then costing, at two plants, not above $6.50 per ton, and possibly less. The author of the unsigned article and Mr. Pechin were both very near the truth. It is now proposed to discuss the matter at some length and to submit figures that may be relied upon as the cost in detail of making pig iron in Alabama during 1894, 1895, and 1896. What the cost was in 1897 is another matter and will not be entered upon at this time. My excuse for discussing the matter must be that an erroneous opinion seems to be current in some quarters that pig iron can be and is made here for less than $5 per ton. It is possible that some iron has been made in the State at a cost closely approximating $5, but it is not thought that so low a cost has been possible for any length of time. During the years 1894, 1895, and 1896 the lowest cost that I am conversant with was $5.71, and I do not think that any company has maintained, for any length of time, say several months or a year, a cost account lower than this. It may be that some furnaces with exceptional conditions as to the supply of raw materials may approximate this amount by the year, and even, at times, have made iron at a less cost than $5.71.

In the report made by Mr. Carroll D. Wright, United States Commissioner of Labor, in 1891, as to the cost of making pig iron in this country, it is stated that, excluding interest, depreciation of value of plant, and charges for freight of product to places of free delivery, the lowest cost reached in any Southern State during the year 1889–90 was $9.16. At that time this was the lowest cost reported in the entire United States.

The details of this cost were made up as follows. Materials:

Ore	$1 96
Limestone	0 324
Coke	4 243
Total	$6 527

Other expenditures:

Labor	$1 737
Officials and clerks	0 156
Supplies and repairs	0 703
Taxes	0 038
Total	$2 634
Grand total	$9 161

An Alabama furnace in operation during this period was making iron at the following cost, arranging the items as above;

Materials:

Ore	$2.587
Limestone	0.397
Cinder, scrap, etc	0.099
Coke	4.471
Total	$7.554

Other expenditures:

Labor	$1.835
Officials and clerks	0.178
Supplies and repairs	0.283
Taxes	0 031
Total	$2.327
Grand total	9.88

At a certain furnace plant in the State, producing in 1890 about 140,000 tons of pig iron, the cost was as follows:

Material	$6.32
Labor	1.86
Sundries	0.83
Total	$9.01

The average cost of making iron in Alabama in 1889–90 was about $9.50, although it must be said that some furnaces made iron for about $9.

During the period of 1890–1897 the cost of making iron was about $3 less than it was in 1890, and the lowest cost reached over any considerable period was about $5.75, with a possibility that some furnaces were able to make it for about $5.50 over a limited period.

It is proposed, in the following pages, to give detailed cost sheets of the production of a very large amount of pig iron, and then to discuss, briefly, the reasons for the reductions of cost within the last six or seven years.

COST OF MAKING PIG IRON IN ALABAMA IN 1894, 1895, 1896.

TABLE XX.

LABOR ACCOUNT.

	1894. Cents.	1895. Cents.	1896. Cents.
Cast-house	11.7	19.3	19.4
Cinder-yard	4.2	5.4	5.7
Engines and boilers	4.4	8.0	8.3
Furnace office	2.8	1.0	1.1
Iron-yard	16.0	17.2	17.1
Laboratory	0.9	....	....
Lights	0.8	0 8	0.8
Locomotives	9.9	11.0	10.2
Salaries	3.3	2.6	2.5
Sand	0.9	0.1	....
Stables	0.8	0.8	1.2
Stock-house	26.6	29.5	25.9
Tracks	....	2.0	2.6
Water	1.2	1.1	1.4
Extra	....	1.0	0.4
Total	83.5	99.8	96.6

TABLE XXI.

SUPPLIES.

	1894. Cents.	1895. Cents.	1896. Cents.
Cast-house	5.5	8.0	9.2
Cinder-yard	1.4	1.7	1.8
Engines and boilers	3.1	4.2	4.0
Furnace office	0.8	0.8	....

Iron-yard	0.8	0.8	0.5
Laboratory	0.2	0.4	0.5
Lights	0.4	0.6	0.6
Locomotives	11.0	6.0	6.8
Sand	2.5	0.3	....
Stables	0.3	0.4	0.3
Tracks	1.0	1.7	1.4
Stock-house	2.4	2.4	1.3
Water	1.1	1.3	2.0
Extra supplies	2.4	2.3	3.0
Total	32.9	30.9	31.4

TABLE XXII.

CURRENT REPAIRS.

Cast house	5.2
Cinder-yard	1.4
Engines and boilers	4.8
Iron-yard	0.6
Locomotives	0.6
Stock-house	1.5
Tracks	2.0
Water	1.0
Extra	1.40
Total	18.5

Current repairs for 1895 and 1896 taken at 20 cents.

Putting these items together with the others that apply to the matter we have the following:

TABLE XXIII.

AVERAGE COST OF PIG IRON IN	1894	1895	1896
Ore	$1.86	$1.754	$1.716
Limestone	0.16	0.240	0.128
Coke	2.78	2.840	2.735
Total for materials	$4.800	$4.834	$ 4.579

Materials	$4.800	$4.834	$4.575
Labor	0.835	0.998	0.966
Supplies	0.328	0.302	0.314
Current repairs	0.181	0.200	0.200
General expenses	0.077	0.070	0.093
Relining	0.170	0.183	0.200
Taxes	0.026	0.025	0.080
Insurance	0.003	0.005	0.006
Bad debts	0.037	0.033	0.030
Total	$6.457	$6.650	$6.464

The lowest cost during 1894 was $5.71, the highest was $7.81, and the average selling price of No. 2 Foundry iron was $7.28. The lowest cost during 1895 was $5.84, the highest $7.02, and the average selling price of No. 2 F. was $7.15. The lowest cost during 1896 was $5.74, the highest $6.84, and the average selling price of No. 2 F. was $7.22.

The percentage distribution of the various items of cost is as follows:

TABLE XXIV.

	1894. Per Cent.	1895. Per Cent.	1896. Per Cent.
Ore	28.8	26.3	26.6
Limestone	2.5	4.0	2.0
Coke	43.1	42.6	42.3
Materials	74.4	72.9	70.9
Labor	12.9	15.0	15.0
Supplies	5.2	4.5	4.8
Current repairs	2.8	3.0	3.2
General expenses	1.0	1.0	1.2
Relining	2.7	2.7	3.2
Taxes	0.4	0.4	1.2
Bad debts	0.6	0.5	0.5
Total	100.00	100.0	100.00

The average cost of the raw materials during these three years was as follows, per ton, stock-house delivery:

	Hard Ore.	Soft Ore.	Brown Ore.	Limestone.	Coke.
1894...	$0.753	$0.566	$1.01	$0.605	$1.875
1895...	0 675	0.535	1.09	0.634	1.758
1896...	0.672	0.572	1.07	0.647	1.727

There was also used some mill cinder at an average cost, per ton, of 75 cents, and a little blue billy at an average cost per ton, of $1.71. But the proportion of these two materials was small, and the items may be neglected. We are now in a position to compare the costs of these years, one with another, so as to be able to observe the course of the industry at a time when it is likely that the costs were as low as they will be for some time to come. Unless large expenditures are made for improvements it is likely that these costs will stand as the lowest for quite a while.

The first thing that attracts our attention is the close agreement in the costs for the three years, the greatest difference being only 21 cents as between 1894 and 1895, while as between 1895 and 1896 there is a difference of only 1 cent, This close agreement may, in part, be due to the system of book-keeping employed, not, of course, with any intention of misleading but merely to harmonize the costs of one year with those of another in a general way. For instance, take the years 1894 and 1895, where there was a practical identity of cost In 1896 the cost of raw materials was 24 cents less than 1894 while the labor costs were 13 cents more. The cost in 1894 which were in excess of those in 1896 are as follows:

	Cents.
Ore	14
Stone	4
Coke	5
Supplies	1
Total	24

While those that were less in 1894 than in 1896 are as follows:

	Cents.
Labor	13
Repairs	2
General Expenses	2
Relining	3
Taxes	5
Total	25

There is certainly a very judicious balancing of accounts as between these two years that at the close of 1896 it should be found that there was a difference of but one cent. It leads to the supposition that arbitrary charges have been made, based, it may be, on the experience at that particular plant but liable to excessive variations.

The cheapness with which the raw materials are mined and delivered in the stock-house has conditioned the building up of the industry of iron making more than any other single circumstance, perhaps more than all other circumstances combined. It is this feature of the matter that has made progress possible, for the labor costs and other expenses are not as low as they are among the chief competitors of the State in the iron market. The furnace yield of iron from the ores, taking a general average, is 41%, and it takes 2.47 tons of ore to make a ton of iron. Handicapped with such low grade ore it has yet been possible to assemble this ore, with the limestone and coke, and make iron at an expense, for raw materials, of $4.57 over a period representing about 150,000 tons. This would not have been possible except for the topographical and geological features of the district. If one inquires as to the future of the iron industry in the State he can be best answered not by referring to what has been done, but by judicious investigations into the possibilities of continued cheap raw materials. On the average the percent of the total cost of making iron in Alabama borne by the raw materials during the three years we have selected was 72.7. During the census year 1889-90 it was about 74%, so that there has been of recent years a reduction in this most important item of 1.3%, and as much as 4% if we take the year 1896 as the criterion. In labor costs there has been a percentage reduction of 5%, as the labor cost, 7 to 8 years ago, was over 19% of the total cost, while during the period 1894 to and including 1896 it was 14.3%. The saving in labor has been nearly four times as much as the saving in raw materials. Realizing that the great advantage given by cheap raw materials was not the only factor in maintaining a position in the iron market, the producers of iron in Alabama set themselves to reduce the cost of converting these materials into pig iron, and as the labor cost was and is the most important after the materials strenuous efforts were made to diminish it. It may be possible, by introducing mechanical appliances around the furnaces, not only in the stock-house but also in the cast-house, to bring down the labor cost by twenty-five cents per ton of iron, so that it would not exceed, let us say, 60 cents. But this implies the expenditure of large sums of money and more care in the preparation of the stock before it reaches the furnace. The advantage of cheap raw material, we must remember, is one that is apt to create a false sense of security. Relying too much upon what nature has done leads one to neglect doing what he should do. Then too, cheap materials with an enormous drain upon them all the while, putting nothing back while taking a vast deal out, after so long a time—and the time may not be so very long, after all—fail to respond to the demands made upon them. Their inevitable tendency is to become dearer as they become scarcer. To counterbalance this tendency there must be economies in other directions, such for instance, as a more scientific and less wasteful system of mining, reductions in freight charges on raw materials, ownership and direct working of the mines and quarries, and, particularly, improvements at the furnaces for handling stock and products. Whether or no we have already seen the cheapest pig iron in Alabama is a question for the future to decide. I do not propose to enter upon it at present except to say that there has been too much reliance placed upon the cheapness with which materials have been assembled and a great deal too little upon improved methods. When cheap materials become dearer and no improvements have been made in other directions then the cost of making iron in Alabama will begin to increase, and many of the advantages she now enjoys will be lost.

The constant drain that has been made upon the so-called soft red ores, i. e. the ores that carry from 46 to 48 per cent. of iron with less than 1 per cent of lime and that can be delivered in the stock-house for 55 cents per ton, has already made itself felt. There is very little of such ore now left within easy reach of Birmingham and the furnace practice is in a state of transition. From this time on the ore mixture will be made up more largely of the limy ores and the brown ores (limonites.)

There are some furnaces of exceptional situation, as for instance at Ironaton and Shelby and possibly at Sheffield that can secure brown ore in the stock-house for 60 to 80 cents per ton, but this is by no means the general situation. The average cost of brown ore at the stock-house is close to $1, if indeed it be not nearer to $1.10. With hard ore at 70 cents and brown ore at $1 a mixture of 20 per cent brown and 80 per cent hard would cost per ton of iron, $1.91, taking the iron in the hard ore at 37 per cent. and in the brown ore at 50 per cent. The average cost of the ore mixture, with varying proportions of hard, soft and brown ore, during the years 1894-96, was $1.77, a difference of 14 cents per ton against the hard-brown mixture.

This disadvantage may, of course, be counterbalanced by using less limestone, but it may well be that more coke will have to be used, so that the difference is not likely to be less than 14 cents per ton and may be more. But the furnace practice, with progressive exclusion of the soft ore, has not been sufficiently extended as yet to permit a positive opinion, and the matter must await further developments.

The acquirement of limestone and dolomite quarries by the furnace companies and the direct working of them, without royalties, or profits to the contractors, has already resulted in notable economies in respect of fluxes.

The development of the by-product system of coking, with the result of giving cheaper coke, is also a most promising outcome of recent months in the Birmingham district.

In connection with the blast furnaces of the Tennessee Coal, Iron and Railway Company, at Ensley, near Birmingham, the Solvay Process Company is erecting 120 Semet-Solvay ovens, and expect to have them in operation by the close of 1898. The ordinary bee-hive coke is being improved, and we may, I think, expect that its quality will be still further insisted upon by those who buy in the open market. What ever the future may hold for the State in respect of the cost of making iron, one thing appears to be certain, viz. that the most rigid economies and the very best practice will be required to maintain as low a cost account as has been reached during the last few years.

The development of the home market for pig iron, while not a factor of its cost, is yet of no little importance as affecting the future of the industry. The capacity of the rolling mills now built in the State is 183,300 tons per annum. For this amount must be substracted 19,200 tons representing the capacity of mills which, in all likelihood, will not be in operation again. This leaves 164,100 tons as the total annual capacity of the mills that may be counted upon as consumers of pig iron. The pipe works making gas, water and soil pipe have a total annual capacity of 21,000 tons. If we allow 25,000 tons a year for axles, mine and car wheels, and iron used in the construction of railroad cars, &c. &c., we shall have 210,100 tons as the total annual capacity of the mills, pipe works, &c. To this may be added 23.000 tons as the annual capacity of the steel works now built. The grand total, therefore, is 233.000 tons per annum, and represents the amount of pig iron that can be worked up in the establishments in the State. But it is not likely that the amount of domestic pig iron so used is above 175,000 tons annually, or a little over 18 per cent. of the annual production of pig iron, and I am inclined to take it at not over 15 per cent., or about 142,000 tons. In the State there are 7 rolling mills, 2 steel works, 2 bridge works, 7 pipe works, 2 car axle works, and 4 car wheel works to use up nearly a million tons of pig iron. This statement does not include the foundries, but even with these included the capacity for finished goods does not reach 20 per cent. of the production of crude iron.

The State needs more extensive and better equipped foundries, machine shops, and other establishments for using what is made at home. From the Birmingham district alone there were shipped in 1897 749,065 tons of pig iron. During the year 2 8,633 tons were exported, as against 65,000 tons in 1896. The State exported 1.5 times as much pig iron as was used within her own borders. The home consumption has not kept pace with the home production, and the developments of the last ten or fifteen years have been in the direction of crude iron and not in that of finished goods. With respect to pig iron and its products the State is pretty much in the condition in which the Southern States were a few years ago with respect to cotton and cotton mills. There has been a great awakening with respect to cotton, why not with respect to pig iron? These two products, the one natural and the other manufactured, represent the crudest of crude materials, for neither can be utilized in the economic arts until it is transformed into something else, the cotton into cotton goods, the pig iron into castings, wrought iron, and steel. Unless there is a great change in the consumption of pig iron we shall continue to be hewers of wood and drawers of water for those whose intelligence is no greater but whose foresight is keener than our own.

CHAPTER VIII.

COAL AND COAL WASHING.

According to Dr. Eugene A. Smith, State Geologist, the area of the several coal fields of the State is as follows; in square miles:

Cahaba	400
Coosa	150
Warrior	7800
Total	8,350

By far the greater amount of coal is mined in the Warrior Field, the chief operations being in the counties of Jefferson, Walker and Tuscaloosa, in the order of prominence. In Bibb county the mines in and around Blocton furnished last year (1897) 671,077 tons. Adding to this amount the 84,673 tons mined in Shelby county, we have a total of 755,850 tons to be credited to the Cahaba field, or about 13 per cent. of the total production. The Coosa field produced 67,584 tons, or about 1 per cent. while the Warrior field produced 5,024,031 tons, or more than 85 per cent. of the total output. At present, and it may be for many years to come, the Warrior field is and will be the great source of the coal mined in the State. Its area is very much greater than that of the other two combined, the coal is certainly as good and the facilities for mining and transporting it are better than in the other fields. The best and largest seams of coking coal are in the Warrior field, but for steam and domestic purposes the Warrior coals are no better than those from the Cahaba field. Some of the Coosa coals are also well adapted for coking, steam, and domestic use, but they have not as yet come much into market.

The following tables, taken from the reports of Mr. E. W. Parker, Statistician of the Department of the Interior, will exhibit the condition of the coal industry in Alabama, during recent years.

TABLE XXV.

Coal Product of Alabama, by Counties from 1889.

Tons of 2000 Lbs.

COUNTIES.	1889	1890	1891	1892	1893	1894	1895	1896	1897
Bibb	500,525	221,811	619,809	793,469	806,214	401,061	653,732	710,842	671,077
Blount	.....	....	....	....	....	8,000	62,400	32,760	37,350
Jefferson	2,437,446	2,665.060	2,905.343	3,499,274	3,093,277	2,766,302	3,726,325	3,729,719	3,714,676
St Clair	40,557	33,653	66,096	24,950	72,000	43.517	30,806	33,368	67,584
Shelby	84,33	25.022	34,130	27.968	55.339	76.619	52.754	52.923	84,675
Tuscaloosa	16.14	65,517	142,184	168,039	167,516	191,081	208,117	205,223	234,488
Walker	488.22	767,34	980,219	1,103,612	927,349	891.953	946,241	952,642	1,037,516
Winston	...	......	....	....	3,200	4.634	4,500	2,140	8,238
Small mines	5.255	12 000	12,000	12,000	12,000	8 000	8,000	25,000	35,000
Total	3,572.983	4,090,409	4,759.781	5,529,31	5.136,935	4,297.178	5,693,775	5,748,697	5,893,770

Blount county produced 40 tons in 1893; Etowah 900 in 1895, 3,080 in 1896, and 3,168 tons in 1879 and Jackson 6,011 in 1894. These returns are included in the totals.

The two following tables, also from Mr. Parker's report, show the average prices for Alabama coal, f. o. b. mines, by counties, since 1890, and the statistics of labor employed and working time.

TABLE XXVI.

Average Price For Alabama Coal, f. o. b. Mines.

COUNTY.	1890	1891	1892	1893	1894	1895	1896	1887
Bibb...........	$ 1.10	$ 1.17	$ 1.08	$ 1.00	$ 1.00	$ 1.00	$ 0.89	$ 0.93
Blount		.....	.....	.....	.....	0.80	1.00	1.09
Jefferson	1.00	1.04	1.03	0.98	0.90	0.87	0.89	0.88
St. Clair.......	1.18	1.14	1.10	1.06	0.96	0.48	1.00	0.81
Shelby	2.50	2.60	2.61	1.82½	1.44	1.73	1.75	1.50
Tuscaloosa	1.05	1.03	1.07	1.05	1.06	0.97	1.13	0.93
Walker	1.00	1.03	1.02	0.98	0.91	0.90	0.85	0.79
Gen average...	1.03	1.07	1.05	0.99	0.93	0.90	0.90	0.88

TABLE XXVII.

Statistics of Labor Employed and Working Time at Alabama Coal Mines. Parker, ut supra.

COUNTIES.	1890		1891		1892		1893		1894		1895		1896		1897	
	Average working days	Average No of men employed	Average working days	Average No of men employed	Average working days	Average No of men employed	Average working days	Average No of men employed	Average working days	Average No of men employed	Average working days	Average No of men employed	Average working days	Average No of men employed	Average working days	Average No of men employed
Bibb	250	1,340	243	1,175	290	1,500	216	1,280	204	1,089	198	1,259	232	1,195	183	1,425
Blount	......	....	....	....		....	......	......		......	275	95	225	46	254	61
Jefferson	267	6,209	274	5,405	289	5,860	258	7,033	272	6,567	267	5,825	290	5,134	250	6,026
St. Clair	250	1.340	242	180	200	75	198	135	225	98	126	96	154	162	270	166
Shelby	200	150	265	200	225	150	200	255	114	405	169	198	139	302	179	376
Tuscaloosa	157	268	287	298	261	281	247	412	261	363	282	612	258	588	276	425
Walker	210	1,[illegible]00	219	2.014	217	2.209	187	2.15[illegible]	180	2,25[illegible]	210	2.231	189	2,403	[illegible]9	2.089
The State	217	10.642	268	9.302	271	10,075	237	11.294	238	10,859	244	10.346	248	9,894	233	10,579

The number of mines reported in the coal producing counties in 1896 and 1897 was as follows:

TABLE XXVIII

Giving the Number of Mines in the Coal Producing Counties, in 1896 and 1897.

COUNTIES.	Number of Mines.	
	1896	1897
Bibb	5	6
Blount	1	1
Cullman	1	
Etowah	1	1
Jefferson	32	40
St. Clair	2	2
Shelby	5	7
Tuscaloosa	6	6
Walker	26	23
Winston	1	2
Total	80	86

TABLE XXIX.

Bituminous Coal Product of the United States—1896. Parker, ut supra. Tons of 2,000 lbs.

	Total. Production.	Total Value.	Average Price per Ton f. o. b. Mines.	Average No. of Days Active.	Average Number of Employees.	Number of Mines	Area of Coal Fields in Square Miles.
Alabama	5,748,697	$ 5,174,135	$ 0.90	248	9,894	80	8,660
Arkansas	675,374	755,577	1.12	168	1,507	14	9,100
California and Alaska	93,776	220,523	2.35	291	177	5	....
Colorado.	3,112,400	3,606,642	1.16	172	6,704	88	2,913
Georgia and North Carolina	246 359	179,770	0.73	301	731	3	2,900
Illinois	19,786,626	15,809,736	0 80	186	33,054	330	36,800
Indiana	3,905.779	3,261,737	0.84	163	8,896	131	6,450
Indian Territory	1,366,646	1,918,115	1.40	170	3,549	21	20,000
Iowa	3,954,028	4,628,022	1.17	178	9,672	182	18,000
Kansas	2.884.801	3,295.032	1.15	168	7,127	96	17,000
Kentucky	3,333,478	2,684,306	0.78	165	7,549	112	4,500
Maryland	4,143,936	3,299,928	0.80	204	4,039	22	550
Michigan.	92,882	150,631	1.62	157	320	11	6,700
Missouri	2,331.542	2,518,194	1.08	168	5,982	128	26,700
Montana	1,543,445	2,279,672	1.47	234	2,335	21	....
New Mexico	622.626	930,381	1.49	172	1,559	16	....
North Dakota	78,050	84,908	1.09	166	141	10	....
Ohio	12,875,202	10,253,461	0.79	161	25,500	408	10,000

Oregon	101,721	$ 294,564	$ 2.90	191	254	8	....
Pennsylvania	49,557,453	35,368,249	0.71	206	72,625	569	9,000
Tennessee	2,663,106	2,281,295	0.86	211	6,531	45	5,100
Texas	544,015	896,251	1.65	187	1,953	16	4,500
Utah	418,627	500,547	1.20	202	679	15	....
Virginia	1,254,723	848,851	0.68	198	2,510	29	2,000
Washington	1,195,504	2,396,078	2.00	221	2,622	21	....
West Virginia	12,876,296	8,336,685	0 65	201	19,078	189	16,000
Wyoming and Nebraska	2,233,184	2,918,225	1.37	210	2,937	29	3 200
Total	137,640,276	114,891,515	0.83	192	237,665	2,599	210,073
Pennsylvania Anthracite	54,346,081	81,748,651	1.50	174	148,991	355	480
Grand Total	191,986,357	$ 196,640,166	$ 1.02	185	386,656	2,954	210,553

The coal product of Wyoming in 1896 was 2,229,624 tons, valued at $2,904,185. The average price per ton was $1.30; average number of days active 209; average number of employees 2,949; number of mines 28.

The coal product of Georgia, in 1896, was 238,546 tons, valued at $168,050. The average price per ton was $0.70; average number of days active 303; average number of employees 713, including 360 State convicts; number of mines 2.

The production and value of the coal mined in the United States, in 1897, is given by Mr. Parker, as follows.

TABLE XXX.

STATE.	Production Tons.	Value.	Average price per Ton.
Alabama	5,893,770	$ 5,192,085	$ 0.88
Arkansas	807,207	893,692	1.11
California	89,092	200.866	2.25
Colorado	3,303,449	3,772,520	1.14
Georgia	195,869	140,466	0.717
Illinois	20,072,758	14,472,529	0.72
Indiana	4,019,360	3,416,586	0.85
Indian Territory	1,321,840	1,800,924	1.36
Iowa	4,915,463	5,566,332	1.14
Kansas	2,694,242	3,230,666	1.20
Kentucky	3,906,458	3,170,811	0.81
Maryland	4,442,128	3,387,785	0 76
Michigan	221,792	322,266	1.45
Missouri	2,627,458	2,878,204	1.09
Montana	1,647,999	2.897,642	1.75
Nebraska	495	1,800	3.64
New Mexico	671,879	954,406	1.42

North Carolina	21,280	$ 27,000	$ 1.27
North Dakota	70,175	70,358	1.00
Ohio	12,219,193	9,508,870	0.78
Oregon	100,311	311,550	3.11
Pennsylvania (Bituminous)	53,842,800	37,964,496	0.70
Tennessee	2,880,994	2,316,239	0.80
Texas	619,602	950,713	1.53
Utah	549,646	651,555	1.19
Virginia	1,524,956	1,022,823	0.67
Washington	1,434,112	2,777,687	1.94
West Virginia	13,556,978	8,637,617	0.64
Wyoming	2,483,074	2,676,191	1.08
Total	146,134,380	$ 119,214,659	$ 0.816
Pennsylvania (Anthracite)	52,122,408	78,880,048	* $ 1.65
Grand Total	198,256,788	$ 198,094,707	

* Excluding "Colliery Consumption."

According to the report of Mr. James D. Hillhouse, State Mine Inspector, the following was the output of coal in Alabama in 1896, by counties and by classification, as also of coke, and the number of coke ovens.

TABLE XXXI.

Giving the Output of Coal and Coke in 1896, by Counties, and by Classification, Also the Number of Days Worked.

COUNTIES.	Coal.					Coke.		Days Worked.
	Lump.	Nut.	Slack.	Run of Mines.	Total.	Ovens.	Production.	
Bibb	65,691	27,266	27,279	590,606	710,842	467	52,019	235
Blount	16,380	8,190	8,190	....	32,760	.....	....	273
Cullman	....	....	....	1,000	1,000	.....	....	..
Etowah	200	80	....	2,800	3,080	.....	....	236
Jefferson	513,818	3,211	644,140	2,568,550	3,729,719	3,545	1,539,813	238
St. Clair	771	....	1,257	31,340	33,368	.....	....	153
Shelby	38,007	11,942	2,694	280	52,923	.....	....	148
Tuscaloosa	9,129	8,380	83,857	106,857	205,223	202	47,537	221
Walker	365,264	100,161	60,449	426,768	952,642	280	49,938	177
Winston	986	....	421	733	2,140	.....	....	155
Total	1,010,046 17.6%	159,150 2.8%	828,287 14.4%	3,748,134 65.2%	5,745,617	4,494	1,689,307	

The total number of mines was 80. The 70 mines reporting in the State in 1896 worked 14,814 days, an average of 211.6 days per mine. The highest number of days recorded was 312 in Jefferson County, and the lowest 42 in St. Clair County. Five (71 per cent.,) mines worked more than 300 days, 19 (27.1 per cent.) worked between 250 and 300 days, 23 (33 per cent.) worked between 200 and 250 days, 14 (20 cent.) worked between 150 and 200 days, 5 (7.1 per cent.) worked between 100 and 150 days, while 4 (5.7 per cent.) worked less than 100 days. The number of days worked, by counties, as given in the above table, is obtained by dividing the total number of days reported from each county by the total number of mines making the returns. It is not altogether fair to the mines working a considerable number of days to group them with mines working irregularly, or with small mines. Thus, by the table, Blount County has to its credit 273 days, but produced only 32,760 tons, while Jefferson County, producing 3,729,719 tons has 238 days to its credit. Perhaps a better insight into the business would be gained by dividing the total amount of coal credited to each county by the number of days worked.

Proceeding in this manner we have the following table, giving the amount of coal produced per day in the various counties during the year 1896.

TABLE XXXII.

Giving the amount of coal mined per working day per county in 1896:

	Tons.
Bibb	3,025
Blount	120
Etowah	13
Jefferson	15,671
St. Clair	211
Shelby	358
Tuscaloosa	929
Walker	5,382
Winston	13
Total	25,722

Dividing these figures, in turn, by the number of mines reported will give a general average of the tonnage output per day per miner per county in 1896.

TABLE XXXIII.

Giving a general average of the tonnage per day per miner per county in 1896.

Bibb	3.56
Blount	3.00
Etowah	1.00
Jefferson	4.14
St. Clair	2.24
Shelby	1.66
Tuscaloosa	2.25
Walker	4.02
Winston	0.30

Working the 8 ft. seam at the Blue Creek Mines, Jefferson, Co., 504 miners working 275 days produced, in

1896, 662,295 tons of coal, an average of 4.77 tons per day per miner.

On the 4 ft. seam at Pratt mines, Jefferson County, 338 miners secured 354,084 tons in 270 days, an average of 3.88 tons per day per miner.

On the thinner seams in the northern part of Jefferson Co., averaging 2½ ft., 273 men secured 93,348 tons in 196 days, an average of 1.74 tons per day per miner.

The amount of coal obtained per day per miner does not altogether depend upon the thickness of the seam. There are other circumstances as well, for instance the quality of the coal itself, its surroundings as regards ease of mining, whether it has to be blasted down, or can be under cut and wedged down, etc., etc. It does not follow because of the thickness of the seam that the miners make better wages, for the thicker the seam, other things being equal, the less is the rate paid per ton for mining.

According to the report of Mr. James D. Hillhouse, State Mine Inspector, the following was the output of coal and coke, and the number of coke ovens in Alabama in 1897, by counties and by classification.

TABLE XXXIV.

Giving the output of coal, and coke, and the number of coke ovens in 1897, by counties and by classification; also the number of days worked.

The total number of men employed was 7,743 miners; 2,270 inside day men, and 1,088 outside day men, a total of 11,101, as against a total of 9,894 in 1896, and 9,766 in 1895.

The total number of mines was 86.

TABLE XXXV.

COUNTIES.	Coal.						Coke.	
	Lump.	Nut.	Slack.	Run of Mines.	Total Tons.	Days Worked.	Ovens.	Product Tons.
Bibb	48,494	......	5,695	616,888	671,077	208	467	59,577
Blount	25,000	3,000	2,000	7,350	37,350	285	......	......
Etowah	107	.	114	2,947	3,168	192	......	......
Jefferson	689,509	10,839	926,091	2,088,237	3,714.676	227	3,713	1,221,326
St. Clair	552	1,163	......	65,869	67,584	253	......	......
Shelby	27,451	24,723	4,142	28,357	84,673	219	......	......
Tuscaloosa	8,983	13,640	109.191	102,674	234,488	248	202	61,288
Walker	285,918	90,422	94,290	566,887	1,037,517	198	280	53,061
Winston	3,860	1,500	498	2,380	8,238	...	......	......
Small mines	......	......	......	35,000	35,000	...	......	......
Total	1,089,974 (18.5)%	145,287 2.4%	1,142,021 19.4%	3,516,589 (59.7)%	5,893,771	... ...	4,662	1,395,252 ...

The 80 mines reporting in the State in 1897 worked 17,727 days, an average of 221.6 days per mine.

The highest number of days recorded was 312, in Jefferson county, and the lowest was 41, in Walker county.

Of the 80 mines reporting 7 (=8.8 per cent.) worked 300 days and over; 22 (=27.5 per cent.) worked between 250 and 300 days; 27 (=35 0 per cent.) worked between 200 and 250 days; 15 (=18.7 per cent.) worked between 150 and 200 days; 7 (=8.8 per cent.) worked between 100 and 150 days; while 2 (=1.2 per cent.) worked less than 100 days.

In 1897 the number of days worked was 2,913 more than in 1896, and the amount of coal mined was 148,154 tons more than in 1896.

The following table gives the amount of coal mined per day in each county during 1897:

TABLE XXXVI.

	Tons.
Bibb	3,305
Blount	131
Etowah	16
Jefferson	16,364
St. Clair	207
Shelby	386
Tuscaloosa	945
Walker	5,240

Winston county did not report number of days worked.

The amount of coal mined in each county, per day, per miner in 1897 was as follows:

Bibb	3.34
Blount	2.80
Etowah	0.80
Jefferson	3.47
St. Clair	2.28
Shelby	1.82
Tuscaloosa	2.94
Walker	4.10

COAL WASHING.

The washing of coal preparatory to the manufacture of coke is well established in the State. Very nearly one-half of the coal turned into coke is previously washed. The washing is confined mostly to the slack coal, *i. e.* the coal passing a screen of 1½ inch to 1¾ inch mesh, or space between bars.

The following table gives the name of the washers, location, and daily capacity. At the close of 1897 the Tennessee Coal, Iron and Railway Company was also erecting two 400–ton Robinson–Ramsay washers, one at slope 4, and the other at slope 5, Pratt mines.

TABLE XXXVII.

Coal Washing Plants—1897.

Name of Washer.	Location.	Daily Capacity. Tons.	Operated By.
Campbell.........	Jasper, Walker Co......	300	Elliot & Carrington.
Robinson-Ramsay	Blossburg, Jefferson Co.	600	Tenn. C., I. & R'y Co.
" "	Blue Creek, Jefferson Co	800	"
" "	Pratt Mines, Jefferson Co	(3) 1200	"
" "	Coalburg, Jefferson Co.	400	Sloss I. & S. Co
" "	Brookside, Jefferson Co.	400	"
" "	Blossburg, Jefferson Co.	400	"
" "	Birmingham, Jefferson Co	400	"
" "	Horse Creek, Walker Co	400	Ivy C. & C. Co.
" "	Bessemer, Jefferson Co.	400	Howard-Harrison Iron Co.
Stein...........	Brookwood, Tuscaloosa Co................	500	Standard Coal & Coke Co.
Stein............	Lewisburg, Jefferson Co	400	Jefferson Coal & Coke Co.
Total.......	12 Washers.	5,800	7 Companies.

Coal Washing.

As coal washing in the State is entirely incidental to the production of blast furnace and foundry coke, it might be best to include the remarks on this subject in the chapter on Fuel. But the importance of it warrants separate treatment, if, indeed, merely a short one. The growth of the industry has been very rapid. While it is true that in 1890 123,189 tons of slack coal were washed, yet, in 1891 the amount fell to 8,570 tons. It seems to have begun regularly in 1892, for since that time the amount of slack washed has steadily increased.

In some establishments, *e. g.*, at Brookwood, and at Lewisburg, the lump coal is hand-picked, on long picker-belts. In all the establishments now washing coal only the slack is washed.

While the industry is of very recent date, so far as large and continuous operations are concerned, yet it was begun in the State in 1875–76 at Oxmoor. A Stutz washer was used there on Helena coal, but the records cannot now be secured. It is of interest also to note that modified Belgian coke ovens were used there at that time. Both the washer and the ovens have been torn down these many years. For most of the coking coals here washing is not necessary, except for the slack. It was to utilize this that washing was undertaken, as otherwise the slack was of little value. A large amount of run of mines coal is made into coke, but the use of washed slack is steadily encroaching upon this, and recently another large plant has entered upon the business. We may expect that the future will show an increasing proportion of coke made from washed slack, as the demand for the better grades of domestic and steam coal will make the use of slack more and more necessary.

It is difficult to state exactly the amount of slack through a 1¾-inch screen yielded by coal mining operations. So much depends upon the nature of the coal itself, and that of the seam, as also upon the system of mining, screening, etc., that only general statements can be made. It varies from 35 per cent. to 65 per cent. of the output. A coal washing plant for handling 500 tons of slack per day of twelve hours will require the mining of not less than 800 tons of coal, and may require 1,400 tons.

A table showing the character of the coal made into coke in this State is given below. It is taken from the returns made to the Division of Mineral Resources, United States Geological Survey:

TABLE XXXVIII.

Year.	RUN OF MINES.				SLACK.				Total Tons.
	Unwashed.		Washed.		Unwashed.		Washed.		
	Tons.	Per ct.	Tons.	Per ct.	Tons.	Per ct.	Tons.	Per ct.	
1890..	1,480,669	81.8	....	......	206,106	11.3	123,189	6.9	1,809,964
1891..	1,945,469	90.6	....	......	192,238	9.0	8,570	0.4	2,144,277
1892..	2,463,366	95.3	....	......	11,100	0.4	111,500	4.3	2,585,966
1893..	1,246,307	61.8	51,163	2.5	292,198	14.6	425,730	21.1	2,015,398
1894..	411,097	26.1	7,429	0.5	477,820	30.3	677,899	43.1	1,574,245
1895..	1,208,020	49.1	....	......	32,068	1.3	1,219,377	49.6	2,459,465
1896..	1,292,191	50.2	70,125	2.7	51,674	2.0	1,159,723	45.1	2,573,713
1897..	902,310	36.8	120,420	4.9	91,200	3.8	1,337,545	54.5	2,451,475

In 1891, of the 2,144,277 tons of coal made into coke only 0.4 per cent. was washed slack, *i. e.*, of every 100 tons of coal sent to the ovens less than one-half a ton was washed slack. In 1893 there was fifty times as much washed slack used for coke as in 1891, and in 1895 more than 140 times as much as in 1891. There was a remarkable increase as between 1892 and 1893, viz.: from 4.3 per cent. to 21.1 per cent., as also between 1893 and 1894, viz.: from 21.1 per cent. to 43.1. From 1894 on the increase in the use of washed slack has not been so marked as in the previous years.

The use of washed slack enables the mine owners to avail themselves of what would otherwise be of little value, and to make a better coke of this material than is made of run of mines coal.

Results of washing slack coal from the Pratt seam. Amount represented about 5,000 tons.

TABLE XXXIX.

SLACK COAL—ROBINSON–RAMSAY WASHER.

Size	Through 1/8 in. to dust.		Through 1/4 in. on 1/8 in.		Through 3/8 in. on 1/4 in.		Through 1/2 in. on 3/8 in.		Through 3/4 in. on 1/2 in.		Through 1 in. on 3/4 in.		Through 1 3/4 in. on 1 in.	
	Unwashed.	Washed.	Unwashed.	Washed.	Unwashed.	Washed.	Unwashed.	Washed.	Unwashed.	Washed.	Unwashed.	Washed.	Unwashed.	Washed.
Per cent......	27	28	16	21	10	10	16	13	15	16	9	7	7	5
Volatile matter......	30.03	30.74	29.11	32.00	29.86	32.40	32.40	31.10	29.20	31.10	30.80	32.60	28.30	32.36
Fixed carbon.........	58.45	59.77	62.10	60.10	61.20	61.40	60.80	59.30	53.10	62.70	57.60	61.20	53.60	62.69
Ash...........	11.52	9.49	8.73	7.90	8.94	6.20	9.60	6.80	17.70	6.20	11.60	6.20	18.10	4.95
Sulphur......	1.71	1.46	1.47	1.29	1.51	1.37	1.74	1.20	1.63	1.49	1.77	1.29	1.82	1.18

CHANGES IN THE COAL—AS PERCENTAGES OF THE RESULTS FROM UNWASHED SLACK.

	Per cent.		Per cent.		Per cent.		Per cent.		Per cent.		Per cent.		Per cent.	
	Gain.	Loss.	Gain.	Loss.	Gain.	Loss.	Gain.	Loss	Gain.	Loss.	Gain.	Loss.	Gain.	Loss.
Volatile matter......	2.89	......	9.93	....	8.50	......	....	4.10	6.51	....	5.84	....	14.35	.....
Fixed carbon.........	2.26	....	....	3.22	0.32	....	....	2.46	18.08	......	6.25	....	16.96	....
Ash.........	.	17.62	....	9.51	....	30.56	......	29.16	....	65.00	....	46.58	....	72.65
Sulphur ..	....	14.62	....	12.24	......	9.28	.....	31.03	......	8.58	.	27.12	....	35.16

Disregarding the changes in the volatile matter and fixed carbon as not affecting the efficiency of the washing as much as the reduction of the ash and the sulphur, some important deductions may be derived from an examination of these tables. The Robinson washer does not size its materials; everything through a 1¾ inch screen, for instance, goes direct to the washer, and no attempt at sizing is made. The above sizes of coal were obtained by using hand-screens, but they were not sent to the washer by separate sizes. Of the material going into the washer—

27	per cent.	passed a	⅛ inch	screen.			
16	"	"	¼ inch	"	but was retained by a	⅛ in.	screen
10	"	"	⅜ inch	"	"	¼ in.	"
16	"	"	½ inch	"	"	⅜ in.	"
15	"	"	¾ inch	"	"	½ in.	"
9	"	"	1 inch	"	"	¾ in.	"
7	"	"	1¾ inch	"	"	1 in.	"

Calculating the average ash from the ash in each separate size we find it to be 11.90 per cent. This was the ash in the slack going into the washer. Of the material coming from the washer, excluding the refuse slate, sludge, etc.—

28	per cent.	passed a	⅛ inch	screen.			
21	"	"	¼ inch	"	but was retained by a	⅛ in.	screen.
10	"	"	⅜ inch	"	"	¼ in.	"
13	"	"	½ inch	"	"	⅜ in.	"
16	"	"	¾ inch	"	"	½ in.	"
7	"	"	1 inch.	"	"	¾ in.	"
5	"	"	1¾ inch	"	"	1 in,	"

Calculating the average as before we find it to be 7.47 per cent., and the reduction of the ash is 37.23 per cent. That is, this slack lost 37.23 per cent. of its ash by being washed, a result somewhat lower than is obtained by considering the slack as a whole without regard to the ash in the separate sizes. Using the same method for calculating the sulphur in the unwashed slack we find it to be 1.65 per cent., and in the washed slack 1.35 per cent. The sulphur, therefore, was reduced by 18.18 per cent.

In other words 100 parts of ash in the unwashed slack become 62.77 parts in the washed slack, and 100 parts of sulphur in the unwashed slack become 81.82 parts in the washed slack.

TABLE XXXV.

Refuse Slack. Robinson-Ramsay Washer. Sampled From The Tail Gate.

Through ⅛ in. to dust.			Through ¼ in. on ⅛ in.			Through ⅜ in. on ¼ in.			Through ½ in. on ⅜ in.			Through ¾ in on ½ in.			Through 1 in. on ¾ in			Through 1¾ in. on 1 in.		
P.C.	Sp. G	Ash	P. C.	Sp. G.	Ash.	P. C.	Sp. G.	Ash	P. C.	Sp. G.	Ash	P. C.	Sp. G.	Ash	P. C.	Sp. G	Ash	P. C.	Sp. G.	Ash
11.2	1.56	41.10	8.2	2.21	66.56	6.7	2.12	62.56	16.5	2.02	57.10	22.3	1.68	50.04	15.8	1.64	49.20	19.3	1.45	42.04

Refuse Slack. Robinson-Ramsay Washer. Sampled From Railway Cars.

P. C.	Sp. G.	Ash	P. C.	Sp. G.	Ash	P. C.	Sp. G	Ash	P. C	Sp. G.	Ash	P. C.	Sp. G	Ash	P. C.	Sp. G.	Ash	P. C.	Sp. G.	Ash
16.7	1.42	33.15	9.7	2.17	66.26	7.8	2.04	62.80	15.5	1.95	54.06	23.3	1.65	8.90	11.2	1.46	38.84	15.8	1.59	46.40

Average Analysis of Refuse Slack. Robinson Washer.

P. C.	Sp. G.	Ash	P. C.	Sp. G.	Ash	P. C.	Sp. G.	Ash	P. C	Sp. G	Ash	P. C.	Sp. G.	Ash	P. C.	Sp. G	Ash	P. C.	Sp. G.	Ash
13.95	1.47	36.34	8.95	2.19	66.41	7.25	2.08	62.68	16.0	1.97	55.62	22.8	1.66	49.47	13.5	1.57	44.85	17.55	1.52	44.00

The analysis of the sludge, corresponding to these results, was—

	Per cent.
Volatile matter	24.73
Fixed carbon	44.14
Ash	31.13
	100.00
Sulphur	4.12

The purest coal that could be picked out, by hand, from the coal here in discussion, had the following composition:

	Per cent.
Volatile matter	33.00
Fixed carbon	64.60
Ash	2.40
	100.00
Sulphur	1.25

In washing operations it is, however, impracticable, if not impossible, to obtain coal of this degree of purity. Owing to loss of coal, there is a point beyond which it is impracticable, to reduce the ash. This point varies with each coal, and to some extent also with the purpose for which the washed coal is intended. In this State only the slack coal is washed, and practically all the washed slack is made into coke.

Reverting to the statement already made that all of the material through a 1¾-inch screen is called slack, and is sent to the Robinson-Ramsey washer without further sizing, the question is: to what point shall the ash in the washed coal be brought in order that the washing may be considered satisfactory?

There are three elements entering into this question:

1. The amount of ash in the original slack.

2. The waste of coal in the operation.
3. The demand of the furnaces for a superior coke.

The maximum amount of ash to be left in the washed slack depends to a great extent upon the demands of the blast furnaces and foundries for coke, for if the demand is active and prices good the waste in the washing is not of so much importance. It is always *important*, and should be carefully looked after, but there are times when its importance is greater than at others. Considering all the elements entering into the question, the amount of ash to be left in the washed slack, whatever it may be, is to be termed "fixed" ash, and the difference between this and the total ash in the unwashed slack is removable ash. For instance, if the ash in the unwashed slack is 11.90 per cent., and the ash in the washed slack is 7.47 per cent., we may regard this latter as the fixed ash, and 4.43 per cent. is the removable ash. But in this particular case the reduction of the ash from 11.90 per cent. to 7.47 per cent. was not as good work as should have been done. With coal of this nature the ash should be reduced to 6.75 per cent. instead of 7.47 per cent., for the coke should not carry over 10 per cent. of ash.

The best results with this particular coal were to reduce the average ash by 43 per cent., and the sulphur by 26 per cent., taking the records over considerable periods. The four following analyses represent about the best practice on the large scale, using unwashed slack, and the Robinson-Ramsay washer. For convenience of comparison the average composition of the unwashed slack is also given :

UNWASHED SLACK—DRY.

	Per cent.
Volatile matter	30.06
Fixed Carbon	58.04
Ash	11.90
	100.00
Sulphur	2.40

WASHED SLACK—DRY.

	1 Per cent.	2 Per cent.	3 Per cent.
Volatile matter	32.43	32.46	32.55
Fixed carbon	60.91	60.86	60.64
Ash	6.66	6.68	6.81
	100.00	100.00	100.00
Sulphur	1.91	1.89	1.93

The reduction of the ash was 43.5 per cent., and of the sulphur 20.4 per cent. The yield of 48-hour coke, over a 1½-inch fork, from this washed slack was 58.78 per cent., or from 5 tons of coal 2.94 tons of coke.

There may be instances in which the Robinson-Ramsay washer, on coal of the kind herein described, has done, perhaps, somewhat better work than this, but it is not thought that under average conditions the results are any better than these.

TABLE XXXVI.

Coal Recovered From Refuse Slack by Solution of Sp. G. 1.35.

Through ¼ inch on ⅛ inch.		Through ⅜ inch on ¼ inch.		Through ½ inch on ⅜ inch.		Through ¾ inch on ½ inch		Through 1 inch on ¾ inch		Through 1¾ inch on 1 inch.	
Per Ct	Ash	Per Ct.	Ash	Per Ct.	Ash	Per Ct.	Ash	Per Ct.	Ash	Per Ct.	Ash
4.10	8.90	2.50	10.10	3.0	9.30	4.20	8.70	3.0	12.06	4.0	16.10

Coal Recovered From Unwashed Slack by Solution of Sp. G. 1.35.

Per Ct.	Ash	Per Ct.	Ash	Per Ct.	Ash	Per Ct.	Ash	Per Ct.	Ash	Per Ct	Ash
85	6.20	79	5.90	88	4.10	81	12.30	75	4.30	56	10.30

Coal Recovered From Washed Slack by Solution of Sp. G. 1.35.

Per Ct	Ash	Per Ct.	Ash	Per Ct	Ash	Per Ct.	Ash	Per Ct.	Ash	Per Ct.	Ash
87	4.60	86	4.01	81	5.20	88	4.20	95	5.30	88	3.05

The Robinson-Ramsay washer does very well on slack in which there is little or no bone coal, and where the difference between the specific gravity of the coal and the slate is considerable. For instance, the average specific gravity of the refuse slate, as from the above tables, is 1.71, the highest being 2.2 in the material through ¼-inch and left on ⅛-inch screen, the lowest being 1.42 in the material through ⅛-inch screen. The specific gravity of the pure slate, without intermixture of coal, may be taken at 2.40, but there is very little such material in the unwashed slack, for the refuse slate of highest specific gravity, 2.21, had with it 4 per cent. of coal which carried 8.9 per cent of ash.

In washing coal it is not so much a question of removing the pure slate from pure coal, because this can always be done, as of separating slate-carrying coal from coal of a greater or less degree of purity. The question as to what is coal, is not general, but special, and has to be answered in the light of each individual case. With the coal under discussion, and with this washer, the writer is inclined to think that material above 1.35 sp. gr. cannot well be considered coal, for the lowest ash in coal recovered from refuse slate by a solution of this specific gravity was 8.70 per cent. Perhaps the limit should not be above 1.30. Taking it at 1.30, and the specific gravity of the refuse slate, with coal attached to it, at 1.71, the difference in specific gravity is 0.41.

With this difference, and with this particular coal, this washer may be depended upon to handle a large amount of slack every day, and to do this work very well. But it is not designed to treat coal in which the specific gravity of the impurities, such as bone coal, etc., approaches that of the coal itself.

Possibly if the slack were properly sized, and each size sent to its own washer, better results could be obtained.

What was said to be the Luhrig system was introduced into the Birmingham district in 1890-91, but the machines were neither properly constructed nor properly managed, and the washing operations soon came to nothing. It is much to be regretted that this was the case, for when the Luhrig system is designed after a study of the coa itself, there is no better coal washing system. In Alabama, however, only two systems are in use, on a large scale, the Robinson-Ramsay and the Stein. The Campbell tables have been introduced to work some of the Walker county coals, and have given fair results. Until the fall of 1897 the Standard Coal & Coke Co., Brookwood, Tuscaloosa county, Alabama, was the only establishment using the Stein washer, but the Jefferson Coal & Railway Co., Lewisburg, Jefferson county, has recently had built, under the personal directon of Mr. Stein himself, a very complete washing plant of a capacity of 40 tons an hour. At Brookwood the Stein washer has given excellent results. It is to be regretted that no detailed investigations of the washing operations there are accessible. In the proceedings of the Alabama Industrial and Scientific Society, Volume VI., Part I., Mr. F. M. Jackson said in regard to

THE STEIN WASHER:

"It has enabled the Standard Coal Company to produce a coke of uniform quality and of extraordinary structure, the average analysis of which invariably runs below 10 per cent. of ash and 1 per cent of sulphur. The analysis for the last six months shows the average ash to be 8.80 per cent., and sulphur 0.74 per cent., whereas the coke formerly carried as much as 18 per cent., and never under 13 to 15 per cent., with sulphur 1.50 per cent. to 1.75 per cent. The loss in washing is from 6½ per cent. to 9 per cent. of the weight of the slack, and the loss in coal is never over 3½ per cent. under ordinary conditions, and often is as low as 2 per cent."

Mr. Jackson refers to Mr. John Fulton's book on coke for further information in regard to the Stein washer at Brookwood. From this authority we learn that it was the first of its kind erected in the United States, having been built in 1890, and has a daily capacity (10 hours) of 500 tons. The following analyses, taken from Fulton, show the reduction in ash :

	Ash			Per Ct. of reduction of ash in coal.
	Unwashed Coal.	Washed Coal.	Coke.	
	15.32	8.15	10.10	46.9
	14.10	7.50	9.50	46.9
	15.07	6.50	.....	56.8
	20.83	8.10	10.50	61.3
	17.18	7.60	10.50	55.5
	16.38	6.50	9.27	60.2
	20.90	5.50	.....	73.5
	17.37	5.40	.....	69.0
	18.63	7.15	.....	61.7
	21.12	4.81	6.10	77.5
Average...	17.69	6.72	9.33	60.93

This is certainly an excellent record. So far as concerns the making of coke from this coal the information is satisfactory, but inasmuch as the Stein system is based on the sizing of the coal before it goes to the jigs, it would have been more complete had the efficiency of the washing as referred to each size been given. We must, therefore, in the absence of specific data infer that these results are averaged from the separate results, and yet the variation in the efficiency of the washing forbids this assumption, for the removal of the ash varies from 46.9 per cent. to 77.5 per cent. The Robinson-Ramsay washer, on some coals, removes *from certain sizes* as high as 72.65 per cent. of the ash, but does not reach anything like so high a result, considering all the coal that goes into it. One may be permitted to doubt if the results at Brookwood represent all the sizes of coal. For instance, a certain coal had 21.12 per cent.

of ash before washing and 4.81 per cent. after washing, a reduction of the ash of 77.5 per cent., and the ash in the coke was 6.10 per cent. But one would like to know what size this was, and what proportion this particular size bore, in weight, to the total amount of slack sent to the jigs. Looked at from the standpoint of actual results, certainly these figures leave but little to be desired, and this, after all, is the main consideration. To remove 77.5 per cent. of ash from coal carrying 21.12 per cent. is certainly good work, but one cannot refrain from asking why this result was not reached with coal of 14.10 per cent. ash? If 77.5 per cent. of ash were removed from this kind of coal the resulting coal would carry only 3.18 per cent., instead of 7.50 per cent., which it did carry under a removal of 46.9 per cent.

Two facts stand out prominently from these analyses, viz.: the best results were from the dirtiest coal, and that from a coal practically useless for coke-making there was obtained a coal that makes excellent coke.

There are two points of view in coal washing operations—practical and scientific—and to some it might appear that if the practical results are satisfactory the scientific aspect of the matter may be left to take care of itself. But it will generally be found that the best practical results are reached by the aid of the best scientific information, and that there is a very real and a very vital connection between good practice and good theory. A careful study of what is going on very often leads to improvements; and from an examination of what *is* done we come to a decision as to what *should be* done.

At the Florida meeting of the American Institute Mining Engineers, 1895, Mr. J. J. Ormsbee had a paper entitled "Notes on a Southern Coal-Washing Plant." The analyses and tables in that paper were made by myself, but it is not necessary to repeat them here, as the foregoing analyses and tables were made (also by myself) in 1896, and show all that is required in a discussion of this kind. Almost the whole of Mr. Ormsbee's paper is taken up by material which was furnished by myself.

In 1890, when this State was visited by the British and German iron-masters Mr. Jeremiah Head, of England, was in the Birmingham district, and again in 1894, with his son, Mr. A. P. Head. In 1897 the elder Mr. Head published in the Transactions of The Federated Institution of Mining Engineers, Newcastle-Upon-Tyne, the results of his observations in the principal coal districts of the Southern States. What was said in regard to Alabama is reproduced here. The analyses he quoted are omitted, for the reason that those already given in these pages are sufficient to enable one to judge of the quality of the coal and coke in the State. Mr. Head's long familiarity with such matters, his openness of mind, and frank way of speaking render his remarks extremely interesting and important. His inference that the labor troubles of 1894 were in any wise connected with the employment of negroes in the mines is a mistake. It was not a question of negro labor but of the recognition of the Labor Unions. The effort was made to prevent not only the negroes but non-union white miners as well from working at the wages offered.

Mr. Head's remarks are as follows:

Birmingham District.—We now come to the important coal-fields in the State of Alabama, of which the city of Birmingham is the focus, and to which, to a great extent it owes its existence; as also does the neighbouring city of Bessemer, and several others. The principal Alabama coal-fields are :—

	Square Miles.
Warrior, estimated to extend over...	7,800
Cahaba " " ...	400
Coosa " " ...	345
Total	8,545

These coal-fields differ essentially from those already described, in that they do not exist as a succession of flat beds in mountains at a considerable elevation above the sea; but as a series of parallel elliptical synclinal basins below the ground-level, with their outcrops rising to it all around. The Forest of Dean coal-field is of the same nature, and in South Wales there are coal deposits of both kinds. The general strike of these coal basins is from northeast to southwest. The dip is naturally greatest at the outcrop, then gradually lessens and disappears; and finally rises in the same way on the opposite side.

The Warrior coal-field contains no less than fifty seams, of which twenty-five are thought to be workable, but only three are actually worked. The thickness of the coal in these varies from 3 to 14 feet.

The Cahaba deposit contains twenty coal-seams, of which three, from 2 to 6 feet in thickness, are worked.

The total production of the Alabama coal-field was :—

In 1870	11,000 tons.
In 1880	340,00 "
In 1886	1,800,000 "
In 1889	2,903,350 "

Since 1890, the coal and iron trades have been suffering from a terrible depression, from which they are only just recovering, and therefore recent statistics do not indicate the productive powers of the district.

The Alabama coal is mostly of a coking quality. In 1890, there were 4,647 coke ovens built, and 270 under construction; but, by the end of 1891 the number had increased to 6,000. With the exception of 64 Thomas coke-ovens, all the ovens are of the ordinary beehive type—10½ to 12 feet in diameter, and 5 to 7 feet high inside. The charge is usually 5 tons of small coal, which produces 3 tons of coke.

In the principal, or Great Warrior, coal-field there are numerous mines, for the most part with coke-burning plants attached. The following are typical ones—viz., Blne Creek, Pratt, Adger, Blocton, and Johns mines.

Average analyses of the coal of the Warrior coal-field, and of the coke made from washed and unwashed coal, are given below:—

	Coal.	Coke.	
		From unwashed Coal.	From washed Coal.
Fixed carbon.....	61.51	87.02	90.48
Volatile matter...	31.48	1.02	1.11
Ash..............	5.42	10.12	7.50
Sulphur..........	0.92	1.77	0.83
Moisture.........	0.67	0.07	0.08

With one exception, these mines are all worked from the outcrop, the winding shafts being at such an angle with the horizon as will admit of entrance and egress on foot. The tubs are hauled in and out by engines and wire ropes running on rollers. There are three entries at the Blue Creek mine, which are together capable of yielding 2500 tons of coal per day.

The one exception referred to is the Pratt mine, which has a shaft 200 feet deep, worked by a winding engine and head-gear in the usual way. Pumping is effected by a force-pump below, driven by air compressed at the surface. This mine alone produced over a million tons of coal in 1889.

Under the system of working prevalent in the Alabama districts, galleries are driven off the main slope at intervals of 300 feet. The intervening body of coal is worked out by driving stalls 40 feet wide, and 60 feet from centre to centre, for a distance of about 275 feet. This leaves a pillar of 20 feet between the stalls, which is worked back to the heading, as soon as the stalls are finished. In this way all the coal is taken out between the galleries, leaving pillars to protect the entries. When the galleries have been driven about 3,000 feet even these pillars are removed. By this means not more than 5 per cent. of the available coal is lost. Ventilation is usually effected with one continuous current, but sometimes a split-current is adopted. In that case a Guibal fan is placed at the air shaft, on each side of the main haulage slope, so that each side is independent of the other, and each gallery takes its supply of fresh air direct from the main-slope. The hewing is generally done by hand; but at the time of the writer's visit 13 Harrison pick machines were in use; they are able to undercut to a depth of 4½ feet along 90 feet of face, with one attendant per shift.

At the time of the writer's first visit to Alabama, in 1890, the coal-slack was nowhere submitted to a washing-process before being charged into the coke-ovens. The disadvantages arising from the comparatively poor calorific value of the resulting coke was felt to be a serious drawback to the development of the iron trade. Consequently great attention was given to coal-washing plant, and it was not long before the Robinson and Ramsay coal-washer was introduced and adapted to American requirements. The writer believed that all coke now used at Alabama blast-furnaces was produced from washed coal-slack. The beneficial results were shown in the comparative analyses which he had given, and had contributed materially to make possible the extraordinary development which was at present in progress in the Southern pig iron trade. At the Pratt mines coking-plant, flues, built in the walls between the ovens, and communicating with them, draw off a portion of the gases and convey them to the boilers, where they are burnt. It was claimed that no less than 375 tons of coal per week was saved by this arrangement.

If we take the area of the three principal Alabama coal-fields, at the estimate already given, viz., 8,545 square miles, which is equivalent to 5,468,800 acres, and reckon the workable coal at 8 feet 4 inches thick in the aggregate; and as yielding 100 tons per inch per acre, we shall find that the total quantity of coal is 54,688,000,000 tons, which consumed at the rate of the present total production of Great Britain (viz, 180 million tons per annum) fixed the duration of the Alabama coal-field at 303 years.

At the time of the writer's last visit to Alabama, viz., in the autumn of 1894, the price of coke delivered at the blast furnaces was about 6s. 9d. per 2240 pounds, or half the current price in England. Negro labor is mainly employed, the latitude being about the same as that of Morocco, and the climate being, therefore, almost tropical, the population requires less food and protection than in colder regions. Great efforts were made in the spring of 1894 by the leaders of the local trades unions to force the negroes into their organization. When they found that impossible, they endeavored to frighten them out of the trade. Several were shot, others maltreated, and for a time mine-managers went about armed with revolvers. By aid, however, of a loyal militia, headed by a capable and courageous governor, the trade unionists were eventually beaten; and thenceforth the south, having the benefit of cheap negro labor, has been able to compete advantageously in all parts of the United States.

The distance from Birmingham to the Gulf ports is 258 miles to Pensacola, and 276 miles to Mobile. The railway rate to the former port, including shipping charges, is 4s. 6d. per ton, or say 0.20d. per ton per mile. This rate enables coal-producers to put coal free-on-board at these ports, for, say, 8s. per ton, or as low as bunker coal at the northeastern ports of Great Britain. The railway facilities enjoyed by the Americans are in striking contrast with their absence here, British heavy products having to pay from three to five times the above rates per ton per mile.

It is not, however, in direct coal exportation that British producers need fear American competition. It is more in heavy goods, such as pig-iron, steel rails, and billets, which absorb in their manufacture from 1½ to 2½ times their own weight in fuel. In the case of such exports, only one railway and sea freight is paid on all material used in producing 1 ton of product carried. Such goods are also practically undamageable, and are not much affected by delays of transit; and being useful as ballast they are taken at low sea-freights along with cotton cargoes. Alabama pig iron so favored, is already arriving in considerable quantities in European markets; and for the time being at all events, coals, or the products into the manufacture of which they enter are being literally "carried to Newcastle," or right into several of the coal-producing districts of Europe.

Calorific Power of Coal.

The subject of the calorific power of Alabama coals and cokes has not received the attention its importance demands. It is very rarely that any interest is manifested in the matter.

So far as is known, Prof. O. H. Landreth of Vanderbilt University, Nashville, Tenn., was the first to make tests of the heating value of Alabama coals. This he did in the spring of 1885, and the following table, taken from *Mineral Resources of the United States*, 1886, p. 239, embodies his results.

TABLE XXXVII.

Heating Valne of Alabama Coals (Landreth.)

NAME OF COAL.	Water Evaporated Per Pound of Coal. Pounds.	Ash (After Combustion Under Boiler.) Per Cent.	Relative Heating or Steaming Values, Cumberland Coal Md being 100.
Blocton	7.37	5.7	89.8
Black Creek	7.63	4.0	92.9
Cahaba	7.65	5.0	93.2
Helena	7.58	7.7	92.3
Henry Ellen	7.25	5.2	88.3
Pratt	8.04	7.4	97.9
Warrior	7.73	4.6	94.2
Watts	7.11	13.2	86.6

During the last few years, as opportunity offered, the The writer has made ultimate analyses, and calorific tests of some of the principal coals of the State. The calories were determined by the use of Lewis Thompson's calorimeter, and the British Thermal Units from the calories.

This form of calorimeter is not adapted to scientific investigations, but is used, quite commonly, in England for approximate results. The figure obtained are offered as the best to be had, under the circumstances, and are subject to correction.

It is much to be regretted that no one has taken the trouble to look into this matter. Perhaps those who were inclined to do so were circumstanced as the writer has been, and those who had both the time and the means felt no concern whatever as to the matter. It has not been so long since the manager of a coal company denied that his coal had any carbon in it at all, or any other impurity. With this as an exponent of public interest one may readily believe that very few have the temerity to discuss the matter.

TABLE XXXVIII.

Ultimate Analyses, Calories, and British Thermal Units of Some Alabama Coals. (W. B. Phillips.)

DESCRIPTION OF COAL.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.	Sulphur.	Ammonia.	Disposable Hydrogen.	Calories (Lewis Thompson's Calorimeter.)	B. T. U.
Blue Creek Run	72.34	4.45	12.25	0.89	10.06	1.06	1.07	2.93	7378	13,280
" " washed slack	76.04	4.48	9.64	0.79	9.05	0.85	0.95	3.28	7687	13,836
Henry Ellen, lump	79.10	4.72	8.86	1.62	5.70	0.45	1.96	3.62	7960	14,220
" " nut	77.69	4.46	9.30	1.54	7.01	0.60	1.86	3.30	7775	13,995
Mary Lee, lump, top	76.18	5.54	8.93	0.55	8.90	1.15	0.66	4.33	7850	14,130
" " " bottom	76.30	5.39	9.99	0.52	7.80	1.10	0.63	4.15	7950	14,310
" " washed slack	75.30	5.31	5.94	1.49	11.96	0.78	1.80	4.57	7875	14,175
Pratt lump	75.38	5.46	12.29	1.08	5.79	0.98	1.30	3.93	7800	14,040
Pratt, run of mines	76.93	5.01	10.96	1.18	5.92	1.18	1.43	3.64	7500	13,500
West Pratt washed slack	78.23	4.51	9.13	1.56	6.57	1.90	1.87	3.34	7750	13,950
Disintegrated Pratt washed slack	78.32	4.27	7.50	1.38	8.48	1.57	1.67	3.43	7700	13,860

In Poole's excellent work "The Calorific Power of Fuels," Wiley & Sons, N. Y., 1898), are given many analyses of American and foreign coals, with data as to their calories and British Thermal Units.

For purposes of comparison a few of the Pennsylvania and West Virginia coals are here given, taken from Poole.

TABLE XXXIX.

Giving the Ultimate Composition of Some Pennsylvania and West Virginia Coals. Poole, Calorific Power of Fuels, 1898.

PENNSYLVANIA, BITUMINOUS COALS.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.	Sulphur.	Water.	Calories.	British Thermal Units.	Authority.
Beaver Creek	74.60	4.89	6.90	1.40	8.75	1.96	1.50	8201	14,762	Lord & Haas.
Clinton	73.57	4.86	7.87	1.24	8.05	1.86	2.55	8166	14,699	"
Carnegie	77.20	5.10	7.22	1.68	5.93	1.42	1.45	8304	14,947	"
Hoytdale No. 2	77.83	5.04	7.96	1.65	4.35	1.57	1.60	8278	14,900	"
West Virginia Coals	...	...	...	...	...		...		...	"
Pocahontas	85.40	4.20	3.18	0.85	4.80	0.62	0.65	8777	15,798	"
Thacker (Run)	78.90	4.98	5.64	1.42	6.50	1.16	1.40	8434	15,181	"
Pocahontas (Run)	83.75	4.13	2.65	0.85	7.25	0.57	0.80	8768	15,682	"

CHAPTER IX.

THE CONCENTRATION OF LOW-GRADE ORES.

As was stated in chapter 1. two processes for concentrating the low grade ores of the State have been tried on a large scale. The experiments, for the most part, were confined to the soft, or lime-free, red ores, and to the 'hard', or limy ores. They were based on two different principles, first the artificial magnetization of the of the ore, and subsequent separation over a special machine, and second the treatment of the ore, merely dried and crushed, in a saturated magnetic field, this process not requiring that the ore should be magnetic.

CONCENTRATION OF THE LOW-GRADE SOFT RED ORE.

The writer prepared for the meeting of the American Institute of Mining Engineers in Atlanta, October, 1895, a description of the experiments which he carried on with the magnetizing process, It was thought at the time that the results were very encouraging, but on experimenting with the Wetherill Concentrating Process during the following year it was found that it was not necessary to render the ore magnetic. It could be and was concentrated magnetically without being at all magnetic in the ordinary acceptation of the term.

But in order to contribute to the study of the Alabama ores, the red fossil ore in particular an abstract of the Atlanta paper is here given, and the results from the Wetherill machines also.

CONCENTRATION BY MAGNETIZING.

The deposit of red fossiliferous ore (Clinton) attains its maximum thickness in the immediate vicinity of

Birmingham, where the Eureka seam (now termed Ishkooda) is from 18 to 24 feet thick. The upper portion of this seam, near the outcrop, is what we term soft ore, inasmuch as the lime has been removed by leaching. Under cover the ore becomes hard and the amount of lime it carries varies from 12 to 25 per cent. In mining the soft ore it is customary to remove the over-burden and to take the ore from open cut, the tracks being at different levels to facilitate the handling. The over-burden varies in thickness from a few feet to 40 feet, and is stripped on the dip for distances varying from 50 to 300 feet from the crop. The dip of the seam increases as one goes towards the southwest, the average being close to 20 degrees. In the early years of iron-making in the district it was customary to remove from 15 to 20 feet of the ore and to send it all to the furnace, but of late the mining has been restricted to 10 or 12 feet and there has been left in the ground from 8 to 10 feet of ore. This lower portion of the seam is now considered too low in iron and too high in silica to permit its profitable use in the furnace. It carries about 40 per cent. of iron and about 35 per cent. of silica, the silica increasing with the vertical depth below the mining mark. Not less than 500,000 tons of this low-grade ore is now stripped, the upper 10 or 12 feet of workable ore having been removed and sent to the furnaces. Nothing remains now but to shift the tracks and to mine the lower portion also, thus making the entire thickness of the seam available for the furnace. With the exception of the Irondale seam, 5 feet thick and carrying about 53 per cent. of iron, at no point on the mountain can the entire seam be mined for furnace purposes unless the lower portions be subjected to some process of concentration. The Irondale seam is distinct from the big, or Ishkooda seam; it carries from 6 to 8 per cent. more of iron, also more alumina. and can be profitably mined from wall to wall. This, however, is not the case with the Ishkooda seam. It is not likely that, on the average, more than one-half of it can be used now for the manufacture of iron, and unless the remaining portion can be concentrated, it is practically of no use whatever. The stripping that has been done is chargeable to the ore mined and sold, so that the lower portion of the seam can be mined at a very slight expense. It can be loaded into the railroad-cars and laid down in any stock house in the vicinity of Birmingham for 40 cents per ton. This statement applies to such ore as has been already stripped, and from which the upper portion has been removed for use in the furnace, leaving the question of tracks and loading-appliances already provided for. It applies, therefore, to what may be considered a limited amount of ore, and it is so in a certain sense and as compared with the enormous deposit of such low-grade material along the mountain. A concentrating-plant taking 500 tons of ore per day and working steadily 365 days in the year would require nearly 3 years to use up what is now ready for mining; and when we consider that the mining of the upper portion is going on all the while, thus increasing the amount of the low-grade ore left, it is not likely that such a plant would be able to use the uncovered portion in five years, if the removal of the better ore should cease on the first day of October, 1895. So much for the Ishkooda opening; but there are several other mines along the mountain, within 2 and 3 miles of Ishkooda, that exhibit the same conditions, and I feel warranted in saying that the available supply of 25-cent. ore will not fall much short of 1,000,000 tons.

When one considers the immense amount of low-grade ore that has not been touched, from Grace's Gap to Gate City, a distance of 9 miles, one can not fail to be satisfied that for many years to come the supply of ore for a concentrating-plant will be ample. With a full knowledge of the subject and from an acquaintance of several years with the ore-situation in the Birmingham district, I have no hesitation in saying that a concentrating-plant of the capacity mentioned above, would not experience any serious difficulty in obtaining low-grade ores suitable for concentration and at a price that would leave a fair profit, for twenty years.

CRUSHING THE ORE.

The size of the ore most suitable for magnetization is that of a hen's egg, With such pieces the magnetization is through even to the center, and when the proper heat has been used there is no sign of louping, or incipient fusion. The ore is of a deep velvety black color. At times the grains of sand are somewhat whitened but for the most part they are coated with a film one of black magnetic oxide. The grains of sand are rounded in the original ore, and in the magnetized ore they are of the same physical nature. If the heat be too high the sand adheres closely to the ore, incipient fusion having set in, and the subsequent separation is not so good. We have frequently magnetized pieces of ore as large as a cocoanut uniformly to the center; but there is danger is using ore of this size; for when the interior is at a suitable temperature the exterior is apt to be too hot, and there may arise more or less tendency towards louping, We have found the most suitable heat is a full red and it is difficult to maintain a large piece of ore throughout at this temperature. The exterior may just right while the interoir of the lump will not be red-hot, and when broken will still be unreduced.

It has often happened that a large lump showed a magnetized coating on the outside extending a third or a half of the distance to the center. This coating would be of a dull black color, while the center would still show the original red color of the ore. I have examined a very large number of pieces from the kiln under varying conditions of work, but have not yet seen a piece that was magnetic at the center and non-magnetic on the outside.

It was our practice to charge the kiln with pieces as nearly uniform in size as possible, so that the gas currents should meet with about the same resistance as they traverse the space between the combustion-chamber and the draft-flues.

To this end we charged the lumps unmxied with fine ore, the cabs being loaded with forks. A certain amount of fine ore is necessarily made in the kiln itself by the friction of the ore against itself and against the walls of the kiln. This cannot be prevented. The fine ore is as magnetic as the lump, but no more so; and there would not be any serious objection to its presence in the kiln did it not back up into the gas-ports and obstruct the regular flow of gas across and through the lump-ore. It is noteworthy that there has been no louping of the fine ore, this being confined entirely to the lumps.

We used 3 tons of coal per day of 24 hours, so that we had some 390,000 feet of gas for 110 tons of ore, or 3,545 feet per ton. This amount of gas would heat the ore to a full redness and magnetize it. From four to six hours after starting the fires in the producer, the gas can be ignited all around the kiln at the several igniting doors. Analyses of the gas from the moment at which it will ignite until it is of a bright orange-red color, and is at its best, are herewith given. The samples were drawn from the producer immediately in front of the pipe conveying the gas into the kiln, care being taken that no air was drawn into the sampler. They were analyzed at once for carbonic acid, oxygen, carbonic oxide and hydrogen, acetylene not being determined, nor marsh gas, although this latter compound exists in producer-gas to the amount of some 3 per cent. Acetylene seldom occurs in producer-gas beyond a few tenths of one per cent., and may be neglected. As to marsh gas, it does not seem probable that this gas, in and for itself, can be used to magnetize ore, as the reactions that occur when it is passed over red-hot ore, no other gas being present, are theoretically not such as would lead to a magnetization of the ore. I am unable to speak with confidence on this point, however, as it is a matter of great difficulty to prepare this gas in a state of purity. The ordinary reactions by which it is prepared from sodium acetate yield a gas which is seriously contaminated with hydrogen, rendering it useless for magnetizing experiments, as the hydrogen is itself a powerful reducing agent, and the magnetic oxide produced by passing marsh-gas from this source over ore would be due to the hydrogen primarily. The question of the effect of pure marsh-gas on red-hot ore is one of scientific rather than of practical moment, as the producer-gas usually employed contains it only to the maximum extent of some 3 per cent.

It can, of course, be prepared pure from zinc methyl; but none of this substance could be procured from dealers in this country, and the question has been dropped for the present.

The effective agents in magnetizing ore are carbonic oxide and hydrogen and if the producer is operated under the best conditions there will be enough of these to do the work.

The average content of carbonic oxide while magnetizing was 25 per cent.; of hydrogen, 13 per cent.; of carbonic acid, 6 per cent.; and of oxygen, 0.40 per cent.

MAGNETIZATION AND CONCENTRATION OF IRON-ORE.

TABLE XL.

Analyses of the Producer-Gas Used.

Carbonic Acid.	Oxygen.	Carbonic Oxide	Hydrogen.	Remarks.
14.00	None.	8.46	5.93	Bed 4 inches; color dark gray; 1 hour after starting fire.
13.20	None.	6.00	5.60	Bed 6 inches; color dark gray; 2 hours after starting fire.
5.00	0.40	30.80	12.90	Bed 2½ feet; color grayish-red; burns well.
6.80	0.40	25.10	11.90	Bed 3 feet; color orange-yellow, exlent gas.
8.00	None	24.09	13.84	Bed 4 feet; color orange-red; good gas
4.30	1.83	22.18	12.63	
6.00	0.60	25.40	14.60	
9.00	0.40	21.40	10.05	Average.

The analyses of the waste gases showed that all the carbonic oxide and the hydrogen were consumed in the kiln.

After the gas been burning all around for 10 hours, the discharging of the kiln can begin. It will be understood that the first 10 or 15 tons, lying at the bottom of the kiln and thus beyond the limit of the heat, are not changed at all and must be sent back as raw ore. This happens only when the kiln is started, for, after this portion of ore has been removed so as to give place to ore that has been sufficiently heated and magnetized, all of the ore coming to the shutes has traversed the zone of highly-heated gas and has been exposed to its influence. As the ore is withdrawn from the shutes fresh ore is charged into the kiln, and the operation is continuous. When the ore comes down to the shutes red-hot, the current of gas is changed, and instead of passing into the combustion-chamber, it is passed into the magnetizing-chamber, from which it passes over the ore unmixed with air and therefore capable of reducing the ferric oxide in the ore into the magnetic oxide. In experimenting with the kiln, we found that even when the gas-valve leading into the combustion-chamber was closed and the valve leading into the magnetizing chamber opened, there was still too much air going into the kiln, and we luted the shute-doors with clay. It was extremely difficult to prevent the gas from burning in the ore and thus wasting its reducing power; but by constant attention and keeping the shute-doors well luted, we succeeded in preventing this to a great extent. The reducing-gas was passed over the ore for an hour, when one or two shutes were opened and a cab of ore withdrawn. It was at a full red heat when drawn, and was spread out on the ground to cool. It retained its heat for several hours, but when finally cool enough to handle was of a dull black color, and when coarsely powdered, highly magnetic. The temperature of the kiln, as measured by an Uehling-Steinbart pneumatic pyrometer of the latest construction, varied from 900 deg. to 1350 deg. Fahr., the average being 1100 deg.

One of the most trying difficulties we experienced was in getting the ore down to the shutes thoroughly and uniformly magnetized. Sometimes the greater part of a cab would be well magnetized while a portion of it taken from the same shute at the same time would not be magnetic at all. This was found to be due to the fact that it had not been exposed to the gas for a sufficient length of time. As proof of this, I took some of the gas that was going into the kiln and some of the non-magnetized ore from a cab, heated the ore to a full redness in a glass tube and passed the gas over it. It became magnetic in a few moments. After this, we allowed the gas to pass over the ore for a longer time, and found that when the shutes were well luted and the air excluded, we obtained better results. One thing was proved to our entire satisfaction, viz., that when the ore was exposed for a sufficient length of time at a full red heat to a current of producer-gas, it became highly magnetic, and that this effect was to a considerable extent independent of the size of the lumps. The difficulty already alluded to, the tendency of the larger lumps to loup, was hard to overcome. The outside of these pieces would be magnetic while the interior would not be changed at all, or at best would exhibit very feeble magnetism.

Now and then a lump as large as a cocoa-nut would come down in a very satisfactory condition, but on the whole it was found desirable to exclude these large lumps from the kiln and to use ore that was of the size of a hen's egg. Another serious difficulty was in the irregular manner in which the ore came down to the shutes. In a kiln of this construction it is very difficult to get a uniform heat all round. At times the kiln would be hot enough on one side, too hot on another and too cool somewhere else. When it became too hot on one side there was nothing to do but to draw ore from the shutes on that side and let the ore descend until the normal heat was restored. This naturally disturbed the course of the operation elsewhere in the kilns, and had a tendency towards allowing insufficiently-magnetized ore to come down to the shutes and in a measure to occupy a space outside of the area of magnetization. When the operation was proceeding satisfactorily, we got from the kiln 110 tons of ore per day of 24 hours, and worked in this way for several weeks. A part of the ore was magnetic, and a part was not. It was culled for separation. The separating machine could not treat half the ore that was magnetized every day; and the remainder was sent direct to the furnace without separation.

CONCENTRATION OF THE MAGNETIZED ORE.

This was effected over a Hoffman separator, at first, and afterwards over a Payne machine, which proved to be an excellent separator. The magnetized ore was first sent to a No. 3.

Gates crusher, screened over a revolving screen of 8 meshes per linear inch, the heads from the screen going into a pair of rolls and thence into the conveyor with the tails from the screen, and so on to the bin above the separator. Between the end of the conveyor and the bin there was another screen of quarter-mesh size to remove the small lumps that jumped the rolls or passed down between the ends of the rolls and the housing. All the material going to the separator passed this screen and nearly all passed a screen of 8 meshes per linear inch.

The fineness of this material is given in the following table.

TABLE XLI.

Fineness of Material Going to the Separator.

	Per cent.
Left on 8-mesh screen	3.00
Through 8- " " and on 10-mesh	6.50
" 10- and on 20-mesh	28.50
" 20- " 30- "	31.50
" 30- " 40- "	6.50
" 40- " 50- "	9.50
" 50- " 60- "	2.50
" 60- " 70- "	3.50
" 70- " 80- "	None.
" 70- " 100- "	3.50
" 100-mesh	5.00

This represents the average fineness of the material sent to the separator during the course of the experiments, as several determinations were made from time to time.

It was not found practicable to run the separator at a greater speed than would give about 700 pounds of heads per hour, as we had difficulty in disposing of our tailings in greater quantity than this, owing to the confined space in which we had to work. The separation was attended by a good deal of dust until we regulated the feed to this point, and even then it was far from pleasant. Special care has been taken of this in the plans for the alteration of the plant; and we shall remove the dust by means of an air-blast. The average content of iron in the ore sent to the separator was 45 per cent. and of silica 30 per cent The average content of iron in the heads was 58.86 per cent. and of silica 11.51 per cent.; in the middlings 51.12 per cent. of iron and 21 per cent. of silica.

At the very start we found that some portions of the ore were more highly magnetic than others, and that the less magnetic material manifested a strong tendency to go into the tails and not into the middlings. In other words, the tails contained magnetic ore that should have gone either into the heads or at any rate into the middlings. Adjustment of the machine and changes of the amperage enabled us to correct this to some extent; but we did not succeed in doing away with it entirely, and throughout the entire course of the work we were troubled with incomplete separation. Repassing the tails over the machine always resulted in obtaining more heads and middlings than in the first pass, and we finally concluded that it was practically impossible to get even tolerable tails by one pass. To this conclusion it seems that all have come who have tried magnetic separation, even of highly magnetic natural magnetite, viz., that it is in all cases advisable to use two machines or, better still, two drums, and to pass the middlings and tails from the first to the second, increasing it may be the amperage on the second machine or drum, and, perhaps, also regrinding the material from the first machine before sending it to the second. As by far the greater part of the expense in the magnetic separation of ore is incurred before the ore is sent to the separator, the additional expense of sending it to another machine, even should it be reground, is comparatively slight. It may be of interest to some to know the distribution of the iron and the silica in the heads according to the fineness. I give, therefore, in the following table some analyses covering this point. Numerous analyses have been made to show just where the best ore was, and if finer grinding would enable us to improve the quality of the heads. From these I select the following:

TABLE XLII.

Analysis of Heads According to Fineness.

Original Ore: Insoluble, 28 per cent.; Iron, 44 per cent.

	Per cent.	Insoluble.	Iron.
Left on 8-mesh screen..........	3.00	12.76	63.20
Through 8- on 10-mesh screen..	6.50	12.50	62.70
" 10- " 20- " ..	28.50	13.00	61.30
" 20- " 30- " ..	31.50	13.40	60.00
" 30- " 40- " ..	6.50	13.70	60.30
" 40- " 50- " ..	9.50	15.40	58.25
" 50- " 60- " ..	2.50	13.90	60.80
" 60- " 70- " ..	3.50	14.00	60.70
" 70- " 80- " ..	None.		....
" 70- " 100- " ..	3.50	14.70	60.00
" 100-mesh...............	5.00	16.10	57.00
Average..........		13.94	60.42

It might be inferred from these analyses that the amount of iron decreased with the fineness; but that this is not always the case will be apparent from the following analyses representing the heads at another period of the work:

TABLE XLIII.

Analysis of Heads According to Fineness.

Original Ore: Insoluble, 32 per cent.; Iron, 40 per cent.

	Per cent.	Insoluble.	Iron.
Left on 10-mesh screen............	2.90	12.65	59.15
Through 10- on 20-mesh..........	18.30	12.58	59.09
" 20- " 30- "	21.70	12.72	59.25
" 30- " 40- "	10.00	12.65	59.20
" 40- " 50- "	10.00	12.40	59.48
" 50- " 60- "	13.30	11.05	61.73
" 60- " 70- "	8.50	11.08	61.80
" 70- " 80- "	None.	.....	.....
" 70- " 100- "	10.00	11.45	61.40
" 100-mesh..................	5.30	10.80	62.00
Average..................		11.93	60.33

There does not seem to be any fixed rule as to this matter; sometimes the percentage of iron increases with the fineness and sometimes it does not. It may be chargeable to the nature of the ore, if easily pulverized or not, the degree of magnetism in the ore (about which very little is known, whether the ore be natural or artificial magnetite); the intensity of the current; the speed of the machine; or a combination of these causes.

So far, nothing has been said as to the removal of phosphorus. This element is present in the ore to about 0.30 per cent., but it is not removed in the separation. It seems to be present as phosphate of lime, entirely amorphous, and most intimately mixed with the iron. We have not been able to remove it, or even to diminish it to any considerable extent. No matter how finely the ore is ground, the heads still carry more phosphorus than is allowed in Bessemer ore. It can be entirely removed by chemical means, and brought from 0.30 to 0.008 per cent. at one operation. It has been found that dilute sulphuric acid will dissolve out the phosphorus from the heads without affecting the content of iron seriously, and in this manner heads carrying from 58 per cent. to 60 per cent. of iron and 0.008 per cent. of phosphorus have been prepared.

A word now as to the cost of carrying out this process on scale, let us say, of 100 tons of raw ore per day of twenty-four hours. We will assume that the plant is erected on the mountain in immediate proximity to the ore, and that the gravity system is employed for conveying the ore from the mine to the kiln and from the kiln through the various operations until the concentrates are loaded on the cars.

We will allow, also that it requires 3 tons of raw ore to 1 ton of concentrates carrying 55 per cent. of iron, and that the yield of such concentrates from one kiln is 27 tons per day of 24 hours. In other words, we allow that from a kiln holding 100 tons of raw ore we obtain daily 81 tons of magnetized ore fit for separation. The cost of producing 1 ton of concentrates of 55 per cent. iron will be about as follows:

3 tons of raw ore, at 25 cents,	$0.75
Crushing, including labor,	0 05
Discharging kiln	0 06
Crushing, rolling and screening,	0.05
Separating and disposing of tailings	0.05
Superintendence,	0.04
Night foreman	0.02
Engineers,	0.04
3 tons of coal for producer, at $1.25,	0 04
3 tons of coal for boilers,	0.04
Oil, supplies, etc.,	0 01
	$1.15

These are the estimates that have been made from our experience with the process at Bessemer, where we had to work under unfavorable conditions, and where the cost per ton of 55 per cent. concentrates was 40 cents higher than the above figures. If we are able to increase the percentage of iron in the concentrates, as we expect to do, the cost per ton will be lessened accordingly. On the other hand, should we not be able to do this, but have to allow for 3 tons of raw ore per ton of 55 per cent. concentrates, as above, the cost will not vary much from that given, viz., $1.15.

We come now to the question, is a ton of 55 per cent. ore of the fineness already given, worth $1.15 at the works, or $1.30 at the furnace? In valuing an ore for furnace practice, two methods may be used, the one based on the nature of the iron desired to be made from it, whether special high-grade Bessemer or basic open-hearth: the other, disregarding this feature of the question, as based on ordinary grades of foundry-, forge- and mill-iron made in this district. Both methods are in common use, and both are independent of the reducibility of the ore, this factor of the question not being generally considered.

The matter, then, narrows down to the question as to whether this ore, under the conditions now maintaining in the Birmingham district, is worth to the furnace $1.30 per ton delivered.

This may, perhaps, be answered to the best advantags if we inquire as to its value if it alone were to be used iin the furnace. As a matter of fact, unless it be made nto briquettes, eggettes, or other suitable shape, by means of some binding material, it can not be thus used; but for the purpose of this calculation we may assume that it can.

We will assume that the limestone to be employed as flux contains 3 per cent. of silica, that the coke used as fuel contains 10 per cent. of ash, or 5 per cent. of silica, and that the ore contains 55 per cent. of iron and 13 per cent. of silica. What will it cost to make to make a ton of iron with these ingredients, allowing 2400 pounds of ckke per ton of iron?

1.82 tons of ore at $1.30	$2.36
1.20 tons of coke at $1.75	2.10
0.66 tons of stone at 0.60	0.39
	$4.85

This cost is, of course, to be taken as representing the cost of the materials entering into a ton of iron, and does not include labor costs, repairs and interest. and is based on ordinary foundry-irons with slag carrying 35 per cent. of silica.

Aside, however, fron considerations affecting the cost of making iron, with or without these concentrates, in the Birmingham district, the success of the process will bring into use very large deposits of soft ore now practically worthless, and enable the owners of such ore-lands to realize more on their investment than they could otherwise hope to do. The supply of the better grades of soft ore is not indefinitely great, and even where the quality of the seams justifies mining, with the exceptio of some narrow seams of high-grade ore, very little more than half the seam is now being taken. It follows that the original cost of the ore-lands must be doubled if the lower part of the ore is not used, and in charging off the cost of the land this fact must be considered. If this process will enable us to utilize the whole seam, top, middle and bottom, all along the Red Mountain, the supply of soft ore is very greatly increased and the cost of making iron will continue lower than if we had to mine ore under ground.

To this paper may be added the following observations. The difficulty of effecting a uniform and regular magnetization in the Davis-Colby kiln, was to a great extent obviated by reconstructing the kiln, so as to provide 4 chambers each with its own in-take pipe from the producer and its own draft-pipe into the main connecting with the central stack built alongside the kiln. Each of these compartments held about 22 tons of raw ore. The advantage of thus dividing the kiln was at once apparent. Each compartment was a separate kiln, independent of all the others, and such reducing action as was desired could be carried on at will. If any compartment became too hot the amount of gas going into it was decreased by closing the valve, if not hot enough additional gas was let in. Each compartment being provided with its own discharging door it could be emplied without interfering with the others. There is no better kiln for calcining ore than the Davis-Colby, but when it came to magnetizing ore it was found necessary to reconstruct it.

In regard to the magnetization of the fossil ores. It has occurred to more than one person to endeavour to take advantage of the fact that they (in common with non-magnetic iron ores generally) become magnetic when exposed, at a sufficient temperature to the action of reducing gases. But so far as the writer is aware these were the first experiments on a large scale to improve the quality of the low grade ores of the Clinton formation, the so-called red fossil ores.

In March 1897 I received a very interesting communication from Mr. Jno. P. Hamlett, Wytheville, Va., detailing some experiments he made 10 years ago with the fossil ores of that part of Virginia, the S. W. portion. Mr. Hamlett wrote:

"About 10 years ago I examined these ores and concluded I would make an experiment with them, simply for my amusement. I took several pieces as large as my fist, and put them on an ordinary wood fire and left them there to roast all night. Next morning I pounded them up in an iron mortar to the size of ordinary blasting powder. I then took a small, cheap pocket magnet of the usual horse-shoe type, and was some what surprised at the ready way in which I could pick out the ore and leave the grains of silica. My little magnet would draw up every particle of the ore.

I then sent about 100 lbs. of the ore to Mr. Clemens Jones, of Penna., informing him of my experiment. I was aware of the fact that his attention had been turned to this subject of concentrating fossil ores by roasting them and using electricity as an agent in his work.

In due course of time I received a letter from him stating that he had made a very successful and encouraging test with the ores sent, him that they averaged 24.30 per cent. of iron as received, but that he had no difficulty whatever in concentrating them up to 48 per cent without crushing them too fine, etc., etc.

There the matter dropped, so far as I was concerned, and there it has remained until this hour so far as these ores are concerned.

Mr. Clemens Jones paper on the Magnetization of Iron ore'' was read at the New York meeting of the American Institute of Mining Engineers, September, 1890, but there is no mention in it of the Virginia ore, and he seems to have confined his experiments almost entirely to limonite (brown ore).

So far as the writer is aware Mr. Hamlett was the first to experiment even in a small way with the magnetization and concentration of the red fossil ores, and this fact would certainly have been mentioned in the Atlanta article had he known of it.

It was stated in that article that we used the Hoffman separator. We did so at first but afterwards used the Payne Separator, and obtained from it excellent results, making about 100 tons of concentrates. It was in every way superior to the Hoffman machine, and is certainly well adopted for concentrating magnetic ore. Taking every thing into consideration it was thought that the experiments conducted on so large a scale promised to develop into a valuable adjunct to the Birmingham iron industry. But hearing of the Wetherill process it was decided to try this also, as it held out hopes of our being able to dispense with the magnetizing of the ore, and this would be a great desideratum.

CONCENTRATION BY THE WETHERILL PROCESS.

So the concentrating plant was remodelled, and two full size Wetherill machines were put in. It is not our purpose to describe the Wetherill process. Briefly, it is based on the fact that when iron, bearing minerals, properly prepared as to size, etc., are brought into a saturated magnetic field they are attracted in proprotion to the strength of the current, and the amount of iron in the material. Non-magnetic ore is attracted just as if it wére magnetic, and for all practical purposes these machines, whose magnets are actuated by a current of electricity, act on red fossil ore as if it were magnetic. A report was made to the Wetherill Concentrating Company on the results of various trials lasting over sêveral weeks, and formed a part of a paper read before the Pittsburg meeting of the American Institute Mining Engineers. February, 1896, on "the magnetic Separation of Non-Magnetic material" by Messrs H. A. J. Wilkens and H. B. C. Nitze. Mr. Wilkens was present when the experiments were being conducted, representing the Wetherill Company as its general manager, and with the writer had charge of the work.

Messrs Wilkens and Nitze prepared a most excellent paper on the Wetherill process generally and from it is taken the following description of what was accomplished in concentrating the fossil ores of the Birmingham district.

"Clinton Fossil Ores—Of more general interest on account of the greater application of the process and the large extent of the field, are, perhaps, the results obtained on the red fossil hematite ores of the Birmingham district in Alabama.

The richer, soft ores of this district, such as are used in the furnaces, average from 45 to 48 per cent, in iron, and from 30 to 24 per cent. in insoluble matter. Such res occur, however, only in a few localities, which are limited in extent, and are now almost exhausted. By far the greater portion of the leached ore-beds consists of material running from 35 to 45 per cent, in iron and from 45 to 30 per cent. in insoluble matter. This latter class of ore cannot be used in the furnaces to advantage, and is therefore practically worthless, unless the percentage of iron be raised by concentration; and at the same time the insoluble matter be proportionately decreased.

Structurally, the ores as a rule fine-grained, the average size of the distinct particles being such as would pass through a 10 mesh screen.

On examining the product of separation it is seen that the ore consists of:

1. Rounded silica grains, which, owing to a coating of iron oxide, are found by analysss to contain from 10 to 15 per cent. of iron.

2. Rounded grains of more highly ferruginous material; running, perhaps, 30 per cent in iron.

3. A binding material of hematite, which in itself carries a varying amount of insoluble matter, depending upon the locality of the ore, fineness of grain, etc. Various working tests were made on material from a great number of localities, and the results were verified by some 500 analysis.

Space will not permit of a detailed account and discussion of the results; it is merely intended here to present a general idea of what was accomplished.

The previous magnetization experiments had been made entirely on the richer soft ores, such as are now being used directly in the furnace, and of the composition given above. Concentration tests on this material by the Wetherill process gave the following results (Calculated on a basis of 100 tons of raw ore):

	Iron.	Insoluble.
Original ore gave	48.03	25.20
57 tons of heads with	57.10	13.10
28. " " middling with	46.20	25.40
15. " " tails with	10.00	70.80

It was further found that about 20 per cent in weight of this ore could be brought up to:

Iron..........................59.15%
Insoluble.......................10.45

The above results compare most favorably with those previously obtained by the magnitizing roasting process, particularly in the proportional amount of heads that were produced and the comparatively small percentage of iron carried in the tails. For the purpose of comparison, the following results of the process are given, (calculated on a basis of 100 tons of raw ore):

	Iron.	Insoluble.
Original magnetized ore gave	49.05	22.05
15 tons of heads with	59.00	11.06
35 " middlings with	52.00	20.00
50 " tails "	44.00	28.00

Only the more perfectly magnetized material was used on the concentrating machines.

In the magnetizing process is to be considered not only the cost of roasting, but also the imperfections attending it, such as the incomplete magnetization, the louping of the ore-lumps, and the inability to use a large percentage of fines in the kiln.

There is no doubt, moreover, that the raw material is better adapted for concentration, on account of the uniformity in the magnetic properties and physical structure of the several ingredients.

The tests by direct concentration on the lower-grade ores showed a proportionately greater increase in the percentage of iron than those on the higher-grade material. The quality of the heads was, however, not as good, which shows that the hematite matrix in the low-grade ores shows a larger percentage of inherent insoluble matter than that of the richer ores.

Among others the following results were obtained: (Calculated on the basis of 100 tons of raw ore).

	Iron.	Insoluble.
Original ore gave....................	41.58	37.51
69 tons of heads with................	52.00	23.00
31 " tails "	18.40	70.00

About 25 % in weight of this original ore was raised to: iron, 56.40 %; insoluble, 17 %.

Tests were also made on the so-called "hard ore," which represents that portion of the ore-bed from which the lime has not been leached. The raw ore of this character, as used at the furnaces, averages: iron, 35.50; insoluble, 17.50; lime, 16 %.

From this were obtained from 50 to 60 % in weight of heads, containing: iron, 48; insoluble, 10.50; lime, 10 %."

In preparing this paper Messrs. Wilkins & Nitze had in view an account of the Wetherill process as applied to various ores, not only of iron, but of zinc, and manganese, and to monazite sands, etc. It was not the purpose to speak particularly of the results reached in the Birmingham district on the low-grade Clinton ores. Their paper, therefore, while fully indicating the lines along which work was carried on here could not deal in detail with every feature of it. As the writer is convinced that some such method of concentration will eventually be used here it may not be out of place to give other results reached in experimenting, on a commercial scale, with the Wetherill process.

The question was discussed by the writer in the Engineering and Mining Journal, New York, Vol. LXII, pp. 75, 105, 124, 151, and the description given here is taken partly from that publication, and in addition from his own note-books.

The Wetherill Inclined Magnet Machine, and the Flat Magnet Machine were used, sometimes one and sometimes the other. The soft red ore was passed through a 15-mesh screen, and fed to the machine running at 8 amperes and 100 volts.

	Iron.	Insoluble.
100 tons original ore gave	39.20	40.16
52.4 tons heads with	56.40	17.10
6.9 " middlings with	38.85	41.35
40.7 " tails with	16.70	74.10

The gain of the heads in iron was 43.8 % over the original ore, and the reduction of the insoluble siliceous matter was 57.4 %; number of tons of raw ore for 1 ton of 56.40 % concentrates, 1.91. That is to say, from 1.91 tons of raw ore carrying 39.20 % of iron there was obtained 1 ton of ore with 56.40 % of iron. This result given here were not obtained at a single operation, and the course of treatment was as follows:

1st pass. amperes, 10; volts, 100.

	Iron.	Insoluble.
100 tons original ore gave	39.20	40.16
59.3 " heads and middlings with	54.10	18.80
40.7 " tails "	16.70	74.10

The heads and middlings from the 1st pass were repassed at 8 amperes and 100 volts, and we obtained two products, viz.: middlings, 4 % of the original ore, with 31.40 % of iron, and 52.20 % of insoluble matter; and heads and middlings, 55 % of the original ore, with 54.10 per cent. iron, and 18.70 per cent. insoluble matter. Finally these second heads and middlings were repassed at 6 amperes, 100 volts, and two products obtained, viz.: middlings, 2.9 per cent. of the original ore, with 46.30 per cent. of iron, and 30.50 per cent. of insoluble, and heads (final heads) 52.4 per cent, of the original ore, with 56.40 per cent. of iron, and 17.10 per cent. of insoluble. We could have stopped with the first heads and middlings, and have had 59 3 per cent. by weight of the original ore, with 54.10 per cent. iron, and 18.80 per cent. of insoluble matter. We may say, then, that from an ore carrying 39.20 per cent. of iron, and 40.16 per cent. of siliceous matter we obtained at the first pass 59 per cent. by weight of concentrates with 54.10 per cent. iron, and 18.80 per cent of siliceous matter. The gain in the percentage of iron was 38 per cent. above the original ore, the reduction of the siliceous matter was 53 per cent., and for one ton of concentrates there was required 1.69 tons of raw ore.

One hundred tons of this raw ore would yield 59 tons of concentrates with 54 per cent. of iron, and 41 tons of tails with 16.70 per cent. of iron.

In our operations the amount of raw ore passing a 40-mesh screen was 33 per cent. of the ore, and this contained 49.4 per cent. of iron, and 26.5 per cent. of siliceous matter. The fines from this low-grade ore are much richer in iron than the coarse stuff. They carry from 49 per cent. to 54 per cent. of iron even when the original ore carries only 37 per cent. of iron.

The ferruginous portion of the ore is softer than the more sandy portions, and it is possible to effect a very considerable concentration merely by crushing the dry ore and screening over a 40-mesh screen. The amount of material passing through a screen of this fineness varies from 25 per cent. to 35 per cent., so that we might expect to get to 54 per cent. of iron in one-fourth to one-third of the raw ore simply by crushing and screening. There is an increase of iron in the material finer than 40-mesh, but hardly enough to merit attention.

The material through a 40-mesh screen was, therefore, called fines, and can be concentrated somewhat. In working on the fines we used the inclined-magnet machine, and obtained results as follows:

	Iron.	Insoluble.
Fines through 40-mesh	49.40	26.50
10 amperes, 100 volts, gave		
12.6 per cent. of heads with	55.30	17.12
22.8 per cent. of middlings with	51.75	21.10
64.6 per cent. of tails with	45.80	30.35

The gain of the heads in iron was 11.9 per cent., and the loss of insoluble matter was 35.4 per cent.

Numerous experiments with this and similar material satisfied us that it would not be profitable to attempt its concentration. It should be briquetted at once without further treatment, or mixed with 'heads' and briquetted.

Material through an 8-mesh and over a 15-mesh screen was tried on the inclined-magnet machine, with the following results:

	Iron.	Insoluble.
Raw ore through 8 over 15 mesh, 24 per cent	35.40	46.34
6 amperes, 100 volts, heads, 45.5 per cent	50.20	24.34
Middlings 19.0 per cent	43.00	34.95
Tails 55.5 per cent	15.40	75.35

By repassing the middlings, the yield of 'heads' could be increased perhaps to 50 per cent., so that there would be 50 per cent. of heads, instead of 35.40 per cent. But it would not be advisable to use ore of this degree of coarseness, as the mechanical separation of the ore into ferruginous portion plus matrix is more perfect in material through a 15 or 20-mesh screen than in coarser stuff. Crushing the ore merely separates it into two portions, the one carrying iron, the other carrying silica, and the object of the separation is to divide the one from the other.

The following results from concentrating low grade soft red ore by the Wetherill process are taken from the writer's note-books.

	Iron.	Insoluble.
Original ore	34.90	47.12
Gave.		
52 per cent. of heads with	49.20	25.84
20 per cent. of middlings with	39.20	41.00
28 per cent. of tails with	14.00	78.14
Original ore	36.80	45.56
46 per cent. of heads with	52.90	21.24
15 per cent. of middlings with	37.45	43.62
39 per cent. of tails with	17.20	74.68

	Iron.	Insoluble.
Original ore	39.20	40.16
Gave.		
51.6 per cent. of heads with	52.50	22.60
11.4 per cent. of middlings with	32.05	51.89
37.0 per cent. of tails with	16.10	74.76

Another trial of this ore under somewhat different conditions resulted as follows:

	Iron.	Insoluble.
Original ore	39.20	40.16
Gave.		
56.4 per cent. of heads with	53.80	19.02
43.6 per cent. of tails with	24.70	62.20

And a third trial, varying the treatment:

	Iron.	Insoluble.
Original ore	39.20	40.16
Gave.		
52.4 per cent. of heads with	55.40	17.10
6.9 per cent. of middlings with	38.85	41.35
40.7 per cent. of tails with	16.70	74.10

These last results having been already quoted.

	Iron.	Insoluble,
Original ore	34.82	47.60
Gave.		
42 per cent. of heads with	55.60	17.00
18 per cent. of middlings with	37.95	43.17
40 per cent of tails with	13.50	79.88

	Iron.	Insoluble,
Original ore	42.00	36.42
Gave.		
59 per cent. of heads with	51.00	25.20
23.7 per cent. of middlings with	45.70	31.76
17.3 per cent. of tails with	12.90	79.80
Original ore	37.30	42.90
Gave.		
47 per cent. of heads with	53.25	19.05
24 per cent. middlings with	30.26	51.94
29 per cent. tails with	13.70	78.70
Original ore	37.36	42.73
Gave.		
46 per cent. of heads with	50.50	22.12
15 per cent. of middlings with	36.80	42.73

39 per cent. of tails with............15.80 74.20

A great many more analysis could be given, all bearing on this question, as the writer has devoted much time to the study of the matter. But these will suffice to show what was done, and to indicate the lines along which future investigations will doubtless be conducted. So far as concerns the low grade soft red ore of the Birmingham district it may be said that it far exceeds in quantity the richer ores, and it can be mined more chaply than these. The vast deposit of low-grade ore carrying from 33 per cent. to 40 per cent. of iron can be utilized. Now they are practically worthles, and the exhaustion of the richer ores is proceeding very rapidly. There will come a time, and that soon, when the soft red ore as now used will become so scarce as to force the iron companies to discontinue its use, or pay more for it. The careful experiments that were made demonstrated beyond any question that an ore of 35 per cent. of iron could be concentrated to 52 per cent., and that 2 tons of raw ore would yield 1 ton of such concentrates. This means that ore now worthless can be made into concentrates richer than any soft red ore now used in the Birmingham district, with the possible exception of the Irondale seam. There is not in the entire State a more inviting field for cultivation by the far-seeing iron-master.

The enormous expense incurred by Mr. Edison in concentrating the low-grade magnetites of Sussex Co. New Jersey, would not be required here. It is true that he takes an ore of about 17 per cent. of iron and concentrates it to about 63 per cent., and it is also true that his concentrates are Bessemer ore, and worth four or five times as much as the Alabama product would be. But the market for the Alabama concentrates would be at the very door of the works, and the cost of production would be far below the cost in New Jersey.

In urging this matter upon the attention of the progressive iron makers in Alabama, it is hoped that steps will be taken to put to profitable use what is now useless, and yet is capable of being made of the highest use. We can never avail ourselves of the resources that nature has so bountifully supplied unless we overcome the obstacles that nature herself has placed in our path. The utilization of the low-grade soft ores if not now a necessity of the situation will speedily become so, for the other ore is disappearing; there is not enough cheap brown ore to take its place, and to replace it with limy ore means an increase of the cost account.

But the low-grade soft red ores are not the only ores that lend themselves readily to concentration. There are very large deposits of 'hard' red ore (limy ore) that can not be used because of the low percentage of iron and the high percentage of siliceous matter.

In view of the results obtained with the Wetherill process one is forced to the conclusion that concentration based on previous artificial magnetization cannot be recommended. It is true that the final heads from magnetized ore carry more iron than the final heads from the Wetherill process, but on the average this difference is not above 5 or 6 per cent. and can not counterbalance the difference in the cost of the two schemes.

Furthermore, the waste of iron in the tails from magnetized ore is very much greater than from the Wetherill machines. Unless all of the ore is thoroughly magnetized this loss will be constant, and unavoidable. The cost of thorough and uniform magnetization would be very great, even if possible at all. The writer may be pardoned for having taken an encouraging view of concentration based on magnetization in 1895, because it seemed then to be the only solution of the problem. To concentrate three tons of ore into one would have paid then as it will pay now. It is probable, from additional study of the subject, that in the magnetization process there would have been required three tons of raw ore for one ton of concentrates carrying 55 per cent. of iron, but by using the Wetherill process two tons of raw ore will make one ton of 53 per cent. concentrates. To mine and treat one ton of ore for two per cent. of iron does not present many attractive features.

The Wetherill process is carried on at so much less expense throughout that if it gives approximately the same results, this feature alone would commend it. The sole advantage that the magnetizing process possesses over the other is in the higher percentage of iron in the final heads, and this advantage disappears entirely when we consider the cost at which it is gained.

These two processes have been described because they are the only processes that seem to merit attention, and of these the magnetizing process must now be excluded. If it is asked why either one is to be considered we reply because the supply of cheap soft red ore carrying from 45 to 48 per cent. of iron is being rapidly depleted, and in a few years will be practically exhausted. This may not be a welcome truth to some, and others will deny it, but it remains, in spite of surprise and denial. So far as concerns the soft red ore the time is not distant when a much higher price will be paid for it than now maintains. The great bulk of the ore on the Red Mountain, near Birmingham, which uninitiated visitors regard with wondering eye, is too poor in iron to be used in the furnaces. If used at all it will have to be improved by concentration, or the furnace practice will be confined to hard (limy) ore and brown ore.

We may keep the great out-crops of ore for a sort of show-place, as they are to some extent now, and continue to publish photographs showing 15, 20, and 25 feet of ore as evidence of the prodigality of nature. But there is not a single place on Red Mountain, from Irondale to Raymond, where even 12 feet of ore is mined, and the huge seams taken as a whole are worthless. It is all very well to take visitors to some great cut in the seam, and ask them what they think of *that* for ore. What they will think depends entirely upon how much they know about the ore. If they do not know much their astonishment will be all that the most accomplished 'boomer' could wish, but if they know the ore they will be apt to ask how it is proposed to utilize such low-grade stuff.

This low-grade material, which exists in very large masses, can be utilized by concentration, but until this is done it is commercially of no importance.

Concentration of the 'Hard' (Limy) Red Ore.

The following experiments were made with the Wetherill process on the ordinary 'hard' (limy) ores of the Birmingham District.

Concentration of Hard (Limy) Ore.

Two experiments on the ordinary limy ore are first given.

	Iron.	Lime.	Insoluble.
Original ore..............	37.60	15.00	16.20
gave			
55 per cent. heads with.....	48.70	9.76	10.26
15 per cent. middlings with	29.00	21.40	18.20
30 per cent. tails "	18.20	25.12	27.00

With an ore not so good but still passable:

	Iron.	Lime.	Insoluble.
Original ore	34.50	17.10	18.04
gave			

64 per cent. of heads with	45.40	11.45	12.25
7 " " middlings "	25.80	24.02	17.95
29 " " tails "	13.55	27.10	30.34

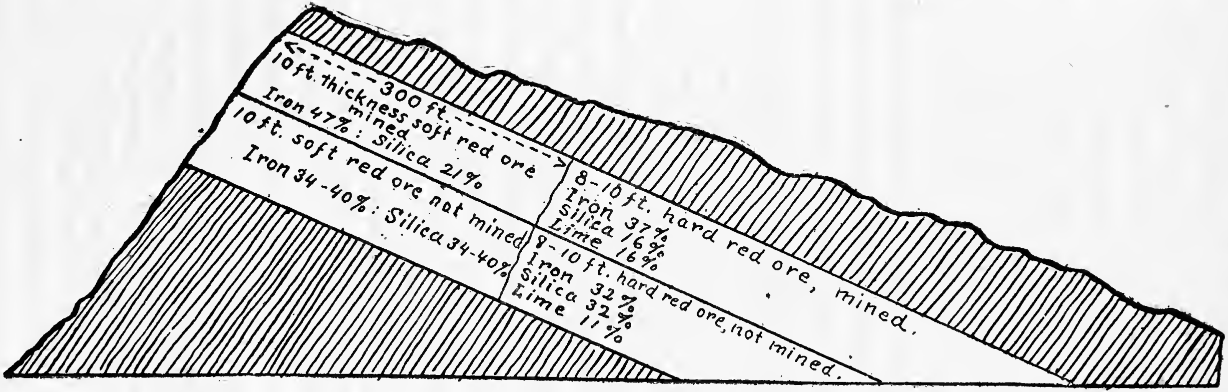
To bring the iron up from 37.6 per cent. to 48.70 per cent., and at the same time preserve the self-fluxing nature of the ore is very encouraging. The second results are still better.

The low-grade limy ore was then tried with the following results:

	Iron.	Lime.	Insoluble.
Original ore	31.80	10.79	33.10
Gave.			
44 per cent. of heads with	43.15	8.80	19.66
6 " middlings with	29.45	12.40	32.90
50 " tails "	22.80	12.52	43.82
Original ore	32.80	9.90	33.70
Gave.			
58 per cent. of heads with	44.50	9.00	17.30
10 " middlings with	35.90	13.20	23.28
32 " tails "	21.60	8.80	42.70

Other experiments on similar limy ore showed similar results. In its original condition this low-grade limy ore is not self-fluxing, i. e., it does not carry enough lime to flux the siliceous matter, and by concentration it does not become so. But it is greatly improved. In the one case the ratio in the raw ore between the lime and the siliceous matter is 1 : 3, but in the heads it was reduced to 1 : 2.2. In the other case the ratio fell from 1 : 3.4 in the original ore to 1 : 1.9 in the heads. The original ore is worthless, the concentrates, while not self-fluxing, are still very good semi-hard ore. The relation of the low-grade 'hard' ore to the 'hard' ore mined is approximately the same as that of the low-grade soft ore to the soft ore mined. Take for instance, the big seam on Red Mountain. In places it is 22 feet thick, but will average about 20 feet. Where the lime has been leached out the whole of the seam is soft ore, but only the upper 10 feet is mined, the lower 10 feet being too low in iron and too high in silica to allow of its profitable use in the furnace. As the seam goes under cover the lime increases and the ore becomes 'hard,' or limy, and when the lime and the silica are in equal proportions the ore is said to be self-fluxing, as has been fully explained in the chapter on ores. The 8 or 10 feet of the 'hard' ore next to the roof of the seam is the better portion, just as this part of the leached, or soft ore is the best. The 8 or 10 feet of the 'hard' ore next to the floor of the seam is too low in iron and lime, and too high in silica to be used. It must be concentrated, just as the corresponding part of the seam towards the outcrop must be concentrated.

The following sketch will explain the relative positions of the usable soft and hard ores, and the unusable.



Vertical Section to explain relative position of soft and hard Ore.

In this sketch the distance along the dip to which the 'soft,' or lime-free ore goes is taken at 300 feet. This is not always the case. Sometimes the 'hard' or lime-ore, begins much nearer the crop, and at places the soft ore extends further than 300 feet. But no matter whether the distance is more or less than 300 feet eventually the lime-ore replaces the other and extends from wall to wall. The sketch shows that about one-half of the soft is mined and used, the remainder being unfit for use. It also shows that about one-half of the 'hard' ore is mined and used, the remainder being unfit for use. It is the lower half in each case that must be concentrated.

It is not proposed, at present, to attempt the concentration of the upper half, either of the soft, or of hard ore, inasmuch as the prices at which they are delivered render the competition even of better ore very severe. But taking the best case in which one-half of the big seam can be mined, as the sketch shows, the other half is practically worthless as it is. This is the big seam at its best, and there is not much of the minable portion of it left. But in many places, as between Red Gap and Lone Pine Gap, on Red Mountain, near Birmingham, the entire thickness is of low-grade, none of it is fit to use, and the 20 feet would be available for concentration.

Reasoning from analogy we can expect the entire seam under cover, and when it becomes limy to be also of low-grade. The question of concentrating the low-grade limy ore, is, therefore, of no small moment. Allowing for the sake of the argument that the furnace practice in the Birmingham district will be based more and more on the use of limy ore, and that there will be less and less 'soft' ore used, where is the limy ore to come from? The estimates as to the amount of limy ore available will have to be greatly reduced, and when larger and larger demands are made upon it, as will certainly be the case if the use of soft ore is lessened or discontinued entirely, it is doubtful if they can be met, except at an increased cost. Regarded from any standpoint, whether that of soft ore, or of hard ore, concentration becomes a very live question, and one to which no prudent manager can refuse to give earnest heed.

The self-fluxing limy ores of the Clinton formation are highly esteemed, and justly so, for while not rich in iron they carry the lime necessary for fluxing their own silica. This is a great advantage, and any plan that promises to increase the available supply of these ores certainly merits the most careful consideration.

Another suggestion that has been made in respect of improving the quality of the limy ores is to calcine them and send the hot ore to the furnace. Taking an ordinary limy ore, *i.e.* With iron 37%, silica 16%, lime carbonate 28%, if the carbonic acid were entirely removed the analysis would show iron 42%, silica 18%, lime 17.9%. One hundred tons would weigh 87.7 tons, and in respect of weight to be handled there would be a positive advantage. Of the raw ore there would be required 2.7 tons per ton of iron, of the calcined ore 2.38 tons, a saving of 716 lbs., of ore per ton of iron. In other words, a 150 ton furnace running on all hard ore requires 405 tons and would require 357 tons of calcined ore. It it was charged with as much calcined ore as raw ore the output would be 170 tons instead of 150 tons, a gain of 13%.

Some experiments were tried here, but were not conducted long enough to warrant one in giving an opinion as to the results. There is no difficulty in removing the carbonic acid in a gas-fired Davis—Colby kiln, as we found that the ore from the shutes contained only a few tenths of a per cent. of carbonic acid, whereas it carried nerly 17% as charged into the kiln.

The ore would, of course, still be self-fluxing, and the question would be whether the removal of the carbonic acid outside of the furnace, with the consequent transformation of the carbonate of lime into caustic lime, would benefit the ore more than it would cost.

Without entering upon any lengthy discussion, as the matter has not yet passed the experimental stage, we may regard the question briefly, from a physical and a chemical standpoint.

Physically the ore would become more porous as the expulsion of the carbonic acid would, to a great extent, destroy its compactness. It would lose in weight, but this would be more than counter-balanced by the gain in the per centage of iron. Its increased porosity would allow easier penetration for the reducing gases of the furnace. Against this may be placed its increased friability, and the consequent production of a greater quantity of the fine material in the furnace. Chemically, we should have to consider the effect upon the combustible gases of the introduction of caustic lime instead of carbonate of lime.

The carbonic acid has to be removed and the question narrows down to a single consideration, viz: Is there any advantage in removing it outside of the furnace? The heat within the furnace removes it quite as effectively as the heat of a kiln, but then we would have to weigh the effect of large volumes of hot carbonic acid on the coke, with solution of carbon, &c. Cokes differ markedly in this respect, and each one has to be examined in and for itself. If the calcined ore is charged direct it would carry a considerable amount of heat into the upper part of the furnace and it would be more difficult to maintain a cool top. This, however, need hardly be considered, as the additional temperature, due to charging hot material, would be derived, not from reactions within the furnace, but from extraneous sources. A cool top under ordinary conditions means that the heat within the furnace is used in melting the stock, and is not escaping in the gases. But if a hot top is due to extraneous heat, such, for instance, as hot material charged, there would be no injurious effect upon the zone of fusion. It might be advantageous to have a hot top if the heat was not derived from the reactions within the furnace, as the gases to be consumed under the boilers and in the stoves would arrive at the burners at a higher temperature. Aside from such considerations, however, it seems advisable to use the calcined ore direct. Where it is stocked, or allowed to remain even for twenty-four hours in the air, it rapidly takes up water and becomes pasty. When the slacking of the caustic lime is completed the material appears dry but in reality contains not only water of hydration but carbonic acid also. When the water of hydration is expelled the lime becomes pulverulent and dusty, blows about in every breeze and is troublesome to both bottom and top fillers. It can be dampened with water from a hose-pipe, of course, but in that case the mass becomes pasty, and the stockhouse uncomfortable. If the ore is not used direct, (the kiln being in immediate proximity to the furnace), the advantages to be obtained from calcining begin to disappear at once, and continue to become less and less the longer the interval between calcination and charging.

CONCENTRATION OF BROWN ORES.

Some experiments on concentrating brown ores were made with the Wetherill process, but we did not proceed far enough to obtain any very positive results. We found that an ore carrying, on dry basis, 45% of iron, and 18% of silica could be improved so that about 55% of it carried 52% of iron. In the paper by Messrs. Wilkens and Nitze, already quoted, are given results from the trial of some Virginia brown ores. Thus a brown ore from Iron Gate, Alleghany county, gave the following results:

	Iron.	Silica.
Original ore	43.08	31.29
Gave		
Concentrates, 63.4% with	51.04	11.24
Tails 36.6% with	31.74	.....

Washer tailings from Barren Springs, Va.

	Iron.	Silica.
Original ore	32.03	29.93
Gave		
Concentrates, 30% with	53.14	7.43
Tails 70% with	22.98	39.58

It may be that some such process will be found to be applicable to low-grade brown ores, especially to washer-tailings and kiln screenings, but for the most part calcination will be used on brown ores for improving their quality.

There are doubtless many brown ores whose initial content of iron is so low as to forbid the expense of calcining, and some magnetic process may eventually be applied to them. But for brown ores that carry from 40 to 45% of iron, dry, calcining is to be preferred.

Calcining is not commonly practiced in Alabama. Some of the charcoal furnace calcine their brown ore, but by far the largest users of the brown ore, the Woodstock furnaces at Anniston, and the furnaces at Sheffield and Birmingham do not use calcined ore.

When calcining is practiced one of two methods are used, the old fashioned open air pile fired with charcoal breeze ; or the new fashioned gas-fired kiln. The former method needs no description. When properly managed it gives fair results, but can not be depended on to give uniformly calcined ore. Even with careful attention, which it seldom gets, a part of the ore will not be calcined at all, a part will be properly calcined, and a part will be 'louped'.

Attention is being drawn more and more to calcining in gas-fired kilns, and of the various kinds the Davis-Colby is preferred. In this kiln the current of heated gas and flame is drawn across the ore as it descends between the outer walls of the combustion chamber and a central space connected with the stack. The kiln is built of any convenient size, from 100 to 150 tons capacity, and is fired with producer gas.

Allowing 7 per cent. of hygrocopic water, removable at 212 deg. F, and 7 per cent. of combined water, removable only at red heat, a kiln holding 125-140 tons of raw ore will deliver from 107 to 120 tons of thoroughly and uniformly calcined ore per 24 hours, with a consumption of 2½ to 3 tons of coal. To calcine one ton of raw ore (2240 lbs.) requires about 52 lbs, of coal.

The advantages of the gas-fired kiln are economy of labor, and uniformity of product. These advantages maintain under all conditions, except where the price of coal is prohibitory, and even there the wood-fired or charcoal-fired producer may be used.

The use of all brown ore in coke furnaces may be rendered necessary by contracts specifying that the iron shall be made from brown ore, or by proximity to deposits known to be very considerable. A determination on the part of furnace owners to make a special high grade charcoal iron would also entail the exclusive use of brown ore.

A kiln to treat 140 tons of raw ore per day, with producer and all necessary fittings, will cost about $7,000, and will yield ordinarily about 120 tons of calcined ore. This amount would contain from 60 to 65 tons of iron, and would be equivalent to 20 per cent. of the ore burden for two 150 ton furnaces.

The freight on a ton of raw ore from the washer to the furnace may be taken at 25 cts. in the Birmingham district, and if the ore averages 47 per cent. of iron we would have 1052.8 lbs. of iron costing for freight 25 cts.

The freight on a ton of calcined ore would also be 25 cents, but it would contain 54 per cent. of iron, or in the ton 1209.6 lbs. of iron. So far, therefore, as concerns the transportation charges we would get 1209.6 lbs. of iron in the calcined ore at the same price paid for 1052.8 lbs. in the raw ore. Each ton of calcined ore delivered at the furnace would contain 156.8 lbs. of iron more than a ton of raw ore. If it requires 4 men in the stockhouse, as bottom-fillers, to handle 140 tons of raw ore per day, containing 65.8 tons of iron, 3 men could handle the 121.7 tons of calcined ore required for the same amount of metal. So far as concerns the handling of the ore in the stockhouse there would be a saving of one man at each furnace by substituting calcined ore for raw ore.

The economy becomes even more striking if we consider the kiln as situated at the furnace, so that the bottom-fillers could draw the ore from the shutes. At one well managed plant this has been the practice for several years. The trams come in from the washer and discharge into the kiln. The bottom-fillers draw from the shutes into the buggies, and the hot ore goes at once to the furnace. At this establishment it has been shown that there is great advantage in the use of calcined ore, irrespective of the easy way of handling it in use, and it fortunately happens that it is able to compare, for a term of years, the practice on raw ore, pile-calcined, and kiln-calcined ore.

It is not going too far to say that it would be profitable to erect kilns at the furnaces, even when the ore has to be hauled at a freight cost of 25 cts. per ton, or even more.

Excessive freight charges on ore would, of course, militate against this proposition, but until they rise beyond 40 cts. per ton calcining would be advantageous.

The erection of kilns at the mines, except under unusual conditions, can not be recommended, for the reason that the life of a brown ore deposit is uncertain.

But at the furnace, and especially where coke is made on the spot and it is possible to calcine with waste gases from the ovens, this objection is removed. The furnace operator would be able to buy ore from the smaller mines which can not incur the expense of building kilns, the entire process would be under one management, and the utilization of gases now going to waste would, of itself, show a profit.

It is a truth of general application that it pays to calcine brown ore, for it has been shown to be beneficial wherever it has been carefully and faithfully carried out.

CHAPTER X.

BASIC STEEL AND BASIC IRON.

The manufacture of basic open-hearth steel in Alabama began on the 8th of March 1888 at North Birmingham. It was the first attempt at steel making in the State,and this furnace was among the first basic open furnaces built in the United States, if not the first.

The enterprising character of the men composing the Henderson Steel and Manufacturing Company in undertaking at this early date to enter upon the production of basic steel when there was but one other establishment in the country is deserving of the highest praise.

There was very little known about basic steel then, for the development of the industry has been rendered possible during the last 10 years. The Henderson Steel and Manufacturing company may, therefore claim, to have been the pioneers in an industry which has grown to very large proportions elsewhere in this country and which now promises to be of increasing importance here.

While the operations at North Birmingham did not attain the commercial success so well deserved by the faith and progressiveness of the promoters, technically the process even then was successful. In its essential construction and operation the furnace did not differ from those now used, for although what was known as the Henderson process was employed yet there was no real difference between it and the more recent modifications of the basic open-hearth.

To the kindness of Mr. H. F. Wilson, the secretary of the company, the writer is indebted for some data concerning this furnace. It was of 13 tons capacity, and made 200 heats before it was closed down. The maximum out put in any one day of 24 hours was 25 tons, and about 1600 tons of steel were made. The steel was sold, as ingots, to the Bessemer Rolling Mill Company, Bessemer, Ala., for about $22.00 a ton and they made most excellent boiler plate of it. Crellin and Nalls, Birmingham, manufactured boilers of it, and some of their work may now be seen in the grain mill of Mr. B. B. Comer, Birmingham.

The pig iron used was mottled and white of local production. Mr. E. E. Robinson was melter. The following table gives the composition of the heats and the analyses of the steel from heat No. 93 to 105, inclusive

BASIC OPEN-HEARTH STEEL.—Henderson Steel & Manufacturing Company.

TABLE XLIV.

Run of Furnace October 5th to October 10th, 1890, At North Birmingham, E. E. Robinson, Melter.

Ht. No.	White & Mottled Pig.	Pit Scrap.	Com'n Scrap.	F. Spar.	F. Mg'nese	Stone.	Ore.	Ingots	Scrap.	Analysis.		
										C. C.	Phos.	Mg'nese
93	13,000	2,272	6,218	150	150	2,500	200	21,754	1,984	.12	.019	.35
94	13,042	1,984	6,673	150	150	2,500	300	19,401	2,070	.12	.025	.40
95	14,070	2,070	7,042	150	150	2,500	200	20.037	1,546	.09	.023	.36
96	14,017	1,542	6,490	150	150	2,500	150	20,950	2,004	.07	.03	.27
97	14,030	1,772	7,450	150	150	2,500	500	21,474	1,800	.07	.034	.28
98	13,880	2,004	6,726	150	150	2,500	400	19,985	2,256	.06	.029	.30
99	14,012	2,000	8,746	150	150	2,500	500	21,535	1,340	.10	.026	.33
100	14,104	2,256	6,332	150	150	2,500	500	18,618	2,066	.08	.08	.46
101	13,516	1,340	7,210	150	150	2,500	300	20.119	2,153	.06	.04	.34
102	14,136	2,066	6,702	150	150	2,500	400	19,698	1,218	.07	.03	.29
103	14,108	2,153	6,942	150	150	2,500	400	19,979	1,744	.05	.02	.31
104	13,988	1,218	7,518	150	150	2,500	300	19,006	2,004	.08	.05	.33
105	14,040	1,744	7,160	150	150	2,500	500	21,404	2,560	.06	.036	.30
	179,943	21.421	91,209	1950	1950	32.500	4650	263,960	24,745	. . .	....	....

Product, 263,960 lbs—117.83 tons ingots. Loss, 31,480 lbs—10.9 per cent.

Additional information in regard to the early history of steel-making in Alabama is contained in a pamphlet entitled "'Basic Steel. Report of committee on its successful and economical manufacture by the Henderson Steel and Manufacturing Company, North Birmingham, Ala., August 27th, 1890.''

This committee was composed of A. B. Johnston, president Birmingham Chamber of Commerce; W. H. Hassinger, manager Alabama Rolling Mill, Gate City; G. L. Leutscher, chemist Tennessee Coal, Iron and Railway Co.; P. Leeds, superintendent machinery Louisville and Nashville Railway Company; and H. R. Johnston.

Mr. Gogin was at that time manager of the steel company.

This committee reported that on August 19th, 1890, there was charged into the furnace—

	Pounds.
White Pig Iron from DeBardeleben furnaces Bessemer, Ala.	15,000
Pit scrap	5,525
Miscellaneous scrap	4,514
Brown ore, 55 per ct. iron	742
Spiegel	200
Ferro-manganese	200
Total metal	26,181

The quantity of fluorspar and limestone was not given.

The yield of metal was—	Pounds.
24 steel ingots	22,250
Pit scrap	1,510

The yield then was 85 per ct. of ingots and 6 per ct. pit scrap, and the loss of metal about 9 per ct.

The committee further reported that basic billets and slabs could be made for $22.00 a ton.

The analyses quoted were as follows:

WHITE PIG IRON.

Silicon	0.43	per ct.
Sulphur	0.149	"
Phosphorus	0.68	"
Manganese	0.10	"

BROWN ORE.

Metallic iron	56.12	per ct.
Phosphorus	0.34	"
Insoluble residue	4.99	"

LIMESTONE.

Carbonate of Lime	95.71	per ct.
Alumina and Oxide of Iron	1.04	"
Silica	1.33	"

STEEL.

Silicon	Trace.	
Sulphur	0.06	per ct.
Phosphorus	0.018	"
Manganese	0.29	"
Carbon	0.08	"

The writer made an analysis, in 1890, of a sample of the first heat of basic open-hearth steel March 8th, 1888. which had been drawn out, under a hammer and found its composition as follows:

Analysis of the first heat of basic open-hearth steel made in Alabama, at North Birmingham, March 8, 1888:

Silicon	0.023	per ct.
Sulphur	0.014	"
Phosphorus	0.038	"
Manganese	0.144	"
Combined Carbon	0.484	"
Graphitic Carbon	0.095	"

The report of the committee also stated that the physical tests of the steel they examined were as follows—plate ⅜ x 1.

	4-in. sect. Lbs.	8-in. sect. Lbs.
Ultimate tensile strength per sq. in. .	48,110	48,460
Elastic limit per sq. inch	32,030	32,275
Reduction of area	54.7 per ct.	57.4 per ct.
Elongation	32.0 ‘‘	28.0 per ct.

A sprue of the first group of ingots was forged into a bar 1 inch square, and was bent when cold, with a sledge until perfectly folded. Not the slightest flaw could be detected at the fold.

Excellent razors and knives were also made of this steel, and some of them are still in use in Birmingham. It is, therefore, to be concluded that the first basic open hearth furnace in Alabama, and one of the first in the United States, beginning operations in March, 1888, made excellent steel of native materials. The process was handicapped with white pig iron high in sulphur and of irregular composition, as also by lack of experience on the part of the operators, and many other obstacles besetting a new enterprise, but the promoters had the courage of conviction, and went as far as their means would permit. They are entitled to and should receive the highest commendations for what they did, for they laid the foundations of the steel industry in this State. The times were not ripe for the commercial success of the enterprise then, and it was not until the middle of 1897 that they seemed to hold out promise of fruition.

The Jefferson Steel Company succeeded the Henderson Company, and operated the North Birmingham furnace in 1892 and 1893, making, perhaps, 1600 tons of steel, under the management of Ernst Prochaska.

The operations were suspended during the summer of 1893. Here the matter rested as to Birmingham until 1897, for the crude experiments carried on under the Hawkins process at North Birmingham in 1895 can not fairly be included in a historical sketch of the rise of the steel industry here.

The amount of basic open hearth steel made at Birmingham, all of native materials, except as to spiegel, ferro-manganese and fluorspar, up to July 22nd, 1897, would not exceed 3500 tons, if indeed it is above 3000 tons.

Basic Open-hearth Steel at Fort Payne.

Steel was next made at Fort Payne, but in spite of repeated inquiries no definite information could be secured.

BIRMINGHAM ROLLING MILL COMPANY.

In 1897 the Birmingham Rolling Mill Company, which had been in successful operation for a number of years, and which of late had been buying steel billets in Pennsylvania and rolling them into shape here, took up the matter. The citizens of Birmingham subscribed to the undertaking to the amount of $40,000 and the first basic open hearth furnace went in July 22nd, 1897, being followed by the second on October 25th. Both furnaces were designed and built by S. R. Smythe & Co., Pittsburg, Pa., with a capacity of 35 tons each to the charge. The iron used was the basic iron made at the Alice furnace, within 200 yards of the mill. The quality of the metal has been and is now of an excellent quality, as the following analyses of the first 245 heats will show, in respect of chemical composition.

The chemical composition of the metal is given in the following tables :

Analyses of the first 245 heats of basic open-hearth steel made by the Birmingham Rolling Mill Company, Birmingham, Alabama, from July 22nd to December 31st, inclusive, 1897.

SULPHUR.

	Heats.	%
0.015 to 0.020	31=	12.7
0.020 " 0.025	69=	28.1
0.025 " 0.030	81=	33.1
0.030 " 0.035	33=	13.5
0.035 " 0.040	17=	7.0
0.040 " 0.045	8=	3.2
0.045 " 0.050	2=	0.8
0.050 " 0.055	1=	0.4
0.055 " 0 060	1=	0.4
0.060 " 0.065	2=	0.8
	245	
Average sulphur		0.028%

PHOSPHORUS.

	Heats.	%
0.001 to 0.005	100=	40.8
0.005 " 0.010	49=	20.0
0.010 " 0.015	15=	6.1
0.015 " 0.020	16=	6.5
0.020 " 0.025	18=	7.3
0.025 " 0.030	13=	5.3
0.030 " 0.035	8=	3.3
0.035 " 0.040	5=	2 0
0.040 " 0.045	6=	2.4
0.045 " 0.050	3=	1.2
0.050 " 0.055	1=	0.4
0.055 " 0.060	4=	1.6

0.060 " 0.065	2=	0.8
0.065 " 0.070	1=	0.4
0 090 " 0.095	1=	0.4
0.095 " 0.100	1=	0.4
0.100 " 0.150	1=	0.4
0.150 " 0.200	1=	0.4
	245	

Average phosphorus......... 0.012%
Average manganese, 0.45.
" carbon.... 0.18.
" silicon....0.008.

It will be seen that in 181 heats out of 245, or 73.9 per cent., the sulphur reached a maximum of 0.030 per cent., while in 64 heats, or 26.1 per cent., it was above 0.030 per cent. In only 14 heats out of 245, or 5.6 per cent., was it above 0.040 per cent.

In a list of sulphur estimations in basic open hearth steel, given by H. H. Campbell (Manufacture and Properties of Structural Steel, 1896, pp. 321 and 322), the number of heats examined was 973. Of these, 255 heats, or 26.2 per cent., showed a maximum sulphur of 0.030 per cent., while 618, or 63.5 per cent., gave sulphur above 0.030 per cent.

The conditions as to sulphur are then seen to be in the case of the Birmingham steel almost the reverse of those maintaining in the basic steel quoted by Mr. Campbell. In the Birmingham steel 73.9 per cent. of the heats showed a maximum sulphur of 0.030 per cent., while in the steels quoted by Mr. Campbell, and presumably of northern make, there were 63.5 per cent. *above* 0.030 per cent. in sulphur.

In the Birmingham steel there were 26.1 per cent. of the heats with sulphur above 0.030 per cent., as against

63.5 per cent. in the other steels.

Furthermore, in Mr. Campbell's steels there were 143 heats out of 973, or 14.7 per cent., in which the sulphur was above 0.040 per cent. as against 14 heats out of 245, or 5.6 per cent., of Birmingham steel, and in Mr. Campbell's steels there were 87 heats out of 973, or 8.9 per cent., in which the sulphur was above 0.050 per cent., as against 4 out of 245, or 1.6 per cent., in the Birmingham steel.

It is, however, in respect of phosphorus that the chief obstacles were encountered and successfully overcome. The sulphur may be considered an element whose maximum in the steel may be more easily controlled than that of phosphorus, especially when the pig iron used is low in sulphur. If the maximum sulphur in the pig iron is 0.050 per cent. the removal of 50 per cent. would cause the steel to carry from this source, 0.025 per cent. But with phosphorus at 0.75 per cent. in the pig iron 86.6 per cent. must be removed to bring the steel down to 0.10 per cent. the maximum allowable under most circumstances, while 93.3 per cent. must be removed to bring it to 0.05 per cent.

Basic open hearth steel has been made in Birmingham of pig iron, pit scrap and ore, in which the phosphorus was below 0.050 per cent. and in some cases below 0.010 per cent. The phosphorus estimations given in the preceding lists are of steel made with various mixtures of pig iron and scrap and ore, and there is practically no difference between them. An examination of the list shows that 149 heats out of 245, or 60.8 per cent. gave a maximum phosphorus of 0.010 per cent. while 180 heats out of 245, or 73.4 per cent. gave a maximum phosphorus of 0.020 per cent. Putting the phosphorus limit in the very highest grade of basic open-hearth steel at 0.030 per cent. we find that 86 per cent.

of the heats showed a maximum of this amount, and in 40.8 per cent. of the heats the maximum phosphorus was 0.005 per cent.

In the results given by Mr. Campbell (*ut supra*) we find that in 157 heats out of 973, or 16.1 per cent the maximum phosphorus was 0.010 per cent. as against 60.8 per cent in the Birmingham steel with a maximum of 0.010 per cent. In the northern steels there were 770 heats out of 973, or 79.1 per cent. in which the maximum phosphorus was 0.020 per cent. as against 73.4 per cent. in the Birmingham steel with a maximum of 0.020 per cent. The percentage of heats in the northern steels with maximum phosphorus 0.020 per cent. is somewhat higher than in the Birmingham steel. In the northern metal there were no heats in which the phosphorous was below 0.005 per cent.while, as before stated of the Birmingham steel 40.8 per cent. of the heats had maximum phosphorous 0.005 per cent.

Of the northern steels there were 898 heats out of 973, or 92.3 per cent. with maximum phosphorus 0.030 per cent. as against 86 per cent in the Birmingham steel. But when one considers the number of the heats of northsteel in which the phosphorus is above 0.030 percent it is found that they are 75 out of 973, or 7.7 per cent. while the corresponding percentage in the Birmingham steel is 13.7, nearly twice as many.

Taking everything into consideration, however, with due regard to the newness of the conditions surrounding the production of steel in Birmingham, and the fact that the results here given are from many different mixtures in the furnace we conclude that in chemical composition the steel compares very favorably with standard makes of northern steel, and that the severest specifications could be successfully met.

The following table gives the results of the examination of some basic open hearth steel plates made by the Birmingham Rolling mill, for elastic limit, tensile strength, elongation and reduction. All the chemical analyses, as well as the physical tests were made by Mr. David Hancock and the writer in the Phillips Testing Laboratory, Birmingham.

TABLE XLV.

Giving Physical Tests of Basic Open Hearth Steel Plates made by the Birmingham Rolling Company, 1897—1898.

Specimen of Plate. Size.	Elas. Limit Lbs. Per sq. Inch.	Ten. Str. Lbs. Per sq. Inch	Elongation in 8 Inch per Cent.	Reduct of area Per Cent.
5-16 inch.	35.360	65,600	25.7	49.6
5-16 inch.	34,720	62,440	27.2	52.6
5-16 inch.	35,200	63,720	27.5	51.5
5-16 inch.	33,300	58,290	26.0	49.6
5-8 inch.	33,930	57.900	25.0	53.0
5-8 inch.	28 900	53,680	32.5	51.0
5-8 inch.	31,040	52,510	27.0	52.8
5-8 inch.	32,360	53,390	31.7	56.5
7-16 inch.	31,400	50,520	32.0	64.0
7-16 inch.	32,360	50,650	30.7	61.6
7-16 inch.	29,960	51.130	30.0	60.8
7-16 inch.	32,790	53,960	27.2	57.4
7-16 inch.	32.760	53,360	26.5	55.7
7-16 inch.	32,260	53,420	30.5	58.0
1-4 inch.	39,560	58,420	27.8	53.1
1-4 inch.	41,450	57,260	25.0	54.9
1-4 inch.	43,040	64,380	25.0	55.1
1-4 inch.	43,470	63,310	25.0	50.6
1-4 inch.	44,280	58,480	26.7	55.8
1-4 inch.	44,850	57,490	26.0	54.9
1-4 inch.	43,590	56,680	26.0	54.9
1¾round.	32,680	50,520	32.5	63.5
1¾round.	37.560	58,940	30.0	53.9

The plates tested were 16 inches long over all, 8 inches long and 2 inches wide between fillets, with a fillet radius of 1½ inches. They were pulled on a 200,000 Riehle Testing Machine, with automatic extensometer and electric registration. the elongation being afterwards checked by measurements. Numerous other tests might be given but is is thought that these will be sufficient to show the quality of the material made from the basic iron of the Birmingham district. Up to the 1st. of May 1898, 500 heats had been made and the two furnaces are now in active operations. The material is made into boiler and tank plates, fire-box sheets, rounds. flats and squares, and is sold under specifications as to chemical composition and physical tests.

It is certainly excellent work even for an old established steel works to make basic open-hearth steel of such quality that in 245 heats practically 74 per cent. contained a maximum amount of sulphur of 0.030 per cent. and 86 per cent. a maximum of 0.030 per cent. of phosphorus. These results have been reached in Birmingham by the first open-hearth furnaces on regular run, and have been extended over nearly six months.

Can they be continued indefinitely? Are these results typical of what may reasonably be expected in the future? Were there any favorable conditions surrounding these 245 heats from July 22d to December 31st, that would not maintain in any number? These are vital questions, and upon the answers to them depend the future of the manufacture of basic steel in Alabama, as, indeed, in the entire South, for if this steel cannot be made in Alabama, it cannot be made anywhere south of the Potomac river.

In the Birmingham district, as, indeed, everywhere else, there are two aspects of the steel industry—technical and commercial. While the metal produced may be of the best quality so far as concerns chemical and physical tests, and while assurance may be given that the raw materials, of which the pig iron is made, exist in very large quantities, yet, after all, the main question is, whether the steel can secure and hold a profitable market.

Technically the basic open-hearth steel made at Birmingham is of a superior quality. The pig iron, which is the chief constituent, can be made here at a less cost than anywhere in the United States. These are facts beyond dispute. But they are not the only considerations which affect the establishment and development of the steel industry in Alabama. It is comparatively easy to convince even the most skeptical that excellent steel can be, has been, and is today, made here in quantities that fully warrant the assertion that the matter has long since passed the experimental stage. What is to be done with the metal after it is made? Can steelmakers in Alabama enter the steel market and obtain for their product the footing now enjoyed by Alabama pig iron, for instance? These are questions which only the lapse of time can fully answer. An industry may be established technically, and that within a comparatively short time, while its establishment commercially may be protracted through a number of years. This is is a matter which in some of its aspects is disconnected from the quality of the metal, and depends not only upon the management, but also and particularly upon the especial kind of competition which the metal has to meet.

In rectangular shapes, in rounds, in tank and boiler plate, in sheets, in structural material and agricultural steel, the competition varies according to circumstances, and a fully equipped plant must be able to enter the market offering the best inducements for each class of goods.

These are matters, however, which may be left to take care of themselves. Once established, the two facts that excellent steel is made here, and that the chief materials of its production are obtained in the district, and the growth of the industry follows in accordance with the usual laws of industrial development.

With the exception of the magnesite for the lining of the furnaces and fluorspar, there is not a single material which cannot be furnished either in the Birmingham district or within easy reach of it.

Manganese ore for ferro-manganese and spiegel, iron ore for basic pig, ferro-silicon and "fix," limestone for flux, can all be obtained here as cheaply as at any point in the United States. With large works there might be some difficulty in securing wrought and steel scrap to supplement the scrap produced at the plant itself, but excellent steel has been made here without the use of outside scrap. It is not necessary to use the pig and scrap process, for the pig and ore process has been used with very satisfactory results. Speaking from a full knowledge of the subject and with due regard to the emergencies that may arise, it is asserted that there is not a single thing required in the manufacture of steel that cannot be produced here with the exception of magnesite and fluorspar.

This statement may cause some surprise, for while it is known that basic iron, which is the chief raw material for the steel-maker, is made here, yet it is not known that ore for ferro-manganese, ferro-silicon, spiegel and "fix" can be obtained in Alabama. It has been supposed that the resources of the State were limited to the pig iron and the limestone, but this is not true. There is no special ore needed for ferro-silicon, and it can be made of Red Mt. ores quite as readily as from the ore now used elsewhere. Ten years ago, without any special effort to make high-silicon iron, it was made here with 7 per cent. of silicon, and this amount can be increased to 10 per cent. if a sufficient demand should arise. As to ferro-manganese and spiegel, manganese ores of 44 to 48 per cent. of manganese can be delivered in Birmingham for $8 a ton, while the deposits of magnetic ore not yet utilized can be drawn upon for material carrying 60 per cent. of iron to be used in the pig and ore process. But failing this, brown ore has already been used with good results.

As to basic iron, the industry has been established here two and a-half years. The iron has been shipped to the following steel makers:

Aliquippa Steel Co	Pittsburg, Pa.
American Steel F. Co	St. Louis, Mo.
Apollo I. & S. Co	Pittsburg, Pa.
A. & P. Roberts Co	Pencoyd, Pa.
Birmingham Rolling Mill Co	Birmingham, Ala.
Builders' Iron Foundry	Boston, Mass.
Burgess S. & I. Co	Portsmouth, Ohio.
Carnegie Steel Co. Ltd	Pittsburg, Pa.
Cleveland Rolling Mill Co	Cleveland, Ohio.
DeFour & Bruzzo	Italy.
DeKalb Company	Fort Payne, Ala.
Elmira I. & S. R. M. Co	Elmira, N.Y.
Granite City Steel Co	E. St. Louis, Mo.
Illinois Steel Co	Chicago, Ill.
Jefferson Steel & Mfg. Co	Birmingham, Ala.
Jones & Laughlins, Ltd	Pittsburg, Pa.
Kellogg Weldless Tube Co	Findlay, Ohio.
Kirkpatrick & Co	Pittsburg, Pa.
Midland Steel Co	Muncie, Ind.
Mt. Vernon Car Mfg. Co	Mt. Vernon, Ill.
Nashua I. & S. Co	Nashua, New Hampshire.
Naylor & Co	Pittsburg, Pa.
Otis Steel Co. Ltd	Cleveland, Ohio.
Pacific R. M. Co	San Francisco, Cal.
Park Bros	Pittsburg, Pa.

Passaic Rolling Mill	Patterson, N. J.
St. Charles Car Co	St. Charles, Mo.
Shickle, Harrison & Howard	St. Louis, Mo.
Societe H. F. F. de Ferne	Italy.
Spang S. & I. Co	Pittsburg, Pa.
Watson, Jas. & Co., Agents	Glasgow, Scotland.

The quality of the basic iron made in the Birmingham district is best shown in an article prepared by the writer for The Mineral Industry, Vol. V., The Scientific Publishing Co., N. Y., 1896. With some corrections and additions it is given here, with the understanding that if anything the quality of the iron therein described has improved during 1897. At any rate there has been no detorioration.

Basic iron of this quality can be furnished here regularly and in any desired quantity.

THE MANUFACTURE OF BASIC IRON IN ALABAMA.

From the Mineral Industry, Vol. V., 1896.

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The production of basic pig iron for the open-hearth steel furnace has become an important industry in the United States. It has had a rapid growth in Northern and Central iron and steel districts, and is recognized as a competitor of the Bessemer and acid open-hearth processes. The competition will probably become, in the immediate future, still more formidable. The discovery in Minnesota of enormous deposits of non-Bessemer iron ore, which can be cheaply mined and transported, must lead to the establishment of basic pig and steel plants in the Northwest, because the exhaustion of the more accessible Bessemer ores of the Lake regions steadily and rapidly proceeds by the increased demands made upon them. Indeed, it is an open question if we have not seen the high-water mark of the output of Bessemer and other acid steels.

So long as an abundant supply of Bessemer ore was assured at fair prices the attention of the steel-makers was, in a measure, restricted to ores which would yield pig iron containing not more than 0.10 per cent. of phosphorus. The extraordinary development of the demand for steel rails, bridge and structural steel of great strength and ductility, and above all the growing disuse of wrought iron, have combined to stimulate the production of Bessemer steel. But it has now been conclusively proved that this old favorite can no longer hold the field it once occupied.

It is no longer a *sine qua non* for the making of good steel that ore of less than 0.05 parts of phosphorus per 50 parts of iron shall be used, and consequently it is toward the more phosphoritic ores that attention is being directed. This is well, for assuredly, it would not be wise to wait until the price of Bessemer steel, due to the increasing scarcity of Bessemer ores, should bring us into an awkward situation. Hence, more interest is manifested in the manufacture and use of basic steel than ever before, and by far the greater tonnage of steel works built during the last three years consists of basic open-hearth.

Some may argue that the investments in the non-Bessemer Lake ores are compelling capitalists to provide an outlet for their product. There may be a modicum of truth in this, but the non-Bessemer ores could not be sold to steel-makers at any price if it were not perfectly feasible to utilize them, not merely for mixing with other ores, but of and for themselves.

Two classes of ore represent the extremes of chemical composition in respect to their applicability to steel-making—the high-grade Bessemer ores with phosphorus below 0.05 per cent., and the highly phosphoritic ores with phosphorus not below 1 per cent. The first find their adaptation in the acid Bessemer and the acid open-hearth processes, the latter for the most part in the basic Bessemer or Thomas process. Between them lie fully three-fourths of the iron ore deposits of the world—ores which yield pig iron carrying from 0.10 per cent. to 1.0 per cent. of phosphorus. In this country the Thomas process, based on the use of pig iron containing from 2 to 3 per cent. of phosphorus, has had a very limited application. The Pottstown Iron Company, Pottstown, Pa., was, until this year, when the Troy Steel and Iron Company began operations, the only establishment that attempted its manufacture on a large scale. The quality of the steel made was excellent, and there was a fair market for the slag as a phosphatic fertilizer, but the use of this process has not been extended, and practically all the steel made in the United States, over 6,000,000 tons annually, has been made from pig iron of less than 0.10 per cent., or not more than 1.0 per cent. of phosphorus. Unfortunately the exact statististics cannot be secured, since the production of acid open-hearth and basic open-hearth steel are not given separately, but it is well known that a very large proportion of the increase in steel production is to be credited to basic metal.

The following table, taken from the reports of Jas. M. Swank, Manager of the American Iron and Steel Association, shows the production of Bessemer steel and open hearth steels ingots in the United States from 1877 to the close of 1896.

TABLE XLVI.

Production of Bessemer Steel and Open Hearth Steel Ingots in the United States, Tons of 2240 lbs.

YEARS.	Bessemer Steel Ingots.	Open-hearth Steel Ingots.
1877	500,524	22,349
1878	653,773	32,255
1879	829,439	50,259
1880	1,074,262	100.851
1881	1,374,247	131,202
1882	1,514,687	143,341
1883	1,477,345	119,356
1884	1,375,531	117,515
1885	1,519,430	133,376
1886	2,269,190	218,973
1887	2,936,033	322,069
1888	2,511,161	314,318
1889	2,930,204	374,543
1890	3,688,871	513,232
1891	3,247,417	579,753
1892	4,168,435	669,889
1893	3,215,686	737,890
1894	3,571,313	784,936
1895	4,909,128	1,137,182
1896	3,919,906	1,298,700
1897	....	1,608,671

In these figures are included the production of direct castings.

One can not fail to be impressed with the remarkable increase in the production of open-hearth steel during the last few years, and allthough by no means all of this steel is basic open-hearth, yet the increase is very largely due to the extension of this process.

The development of this process has been the special feature of the steel trade during the last seven years.

The purpose of the present paper is to direct attention to the manufacture of pig iron suitable for the basic open-hearth steel process from materials not hitherto considered as very promising, viz; the ores, fluxes and fuels of Alabama.

The manufacture of ordinary grades of foundry, mill and pipe iron in this state is established on a firm foundation, but it was not until 1895, that it was proved that pig iron suitable for steel making could be made here regularly and on any desired scale. It has been thought best to restrict these remarks to the Birmingham district in Alabama, because it is here that the production of basic iron has attained its largest proportions, and that a great number of analysis of stock and product have been made for a year or more. While it is true that furnaces elsewhere in the South especially in Virginia, have made basic iron, and can do so successfully it is believed that the results will not differ essentially, except as to cost, from those on record here. The analysis of the tables of production and cost accounts covering 75,000 tons of basic iron in the Birmingham district will represent the industry as favorably as can be expected any where in the South.

It is assumed that the vital difference between any two districts in the South would be in respect of cost, and not of quality. The quality of the iron made would depend to a great extent upon the specification of the contract, for it is obvious that if these are severe the risk of increased percentages of costs not suitable for shipment, as also the cost production, would become greater.

Generally speaking, Southern iron men at present and Southern steel men in the future must work with ores that put from 0.30% to 0.80% of phosphorus in the iron. The ores are much too high in phosphorus for Bessemer metal and much too low in phosphorus for Thomas metal.

The southern iron trade has been marvellously developed during the past ten or fifteen years, and the costs of production have been forced to a point not anticipated by the keenest observers, but it has been built up on material not intended for steel works, but for foundries, mills, and pipe works.

It is to the same iron that we must look if we are to make steel. There must be less silicon and less sulphur in the iron, elements within easy control of an experienced furnaceman, but otherwise it will be the same iron as is made every day. It will be, and it must be made from local materials, and in the same furnaces and by the same men as the present iron. It will differ in composition only, and the difference will not very great, after all. Under specifications likely to continue, the maximum silicon must be 1 per cent. the maximum sulphur 0.050 per cent. with phosphorus about 0.75 per cent. although this latter element may, at times, not exceed 0.60 per cent. For the most part, however, the phosphorus will vary from 0.75 per cent. to 0.85 per cent. The amount of phosphorus allowable in basic stock is to some extent controlled by the exigencies of the trade, and is subject to greater variation than either silicon or sulphur. In many cases it may reach 1.0 per cent. and considerable shipments have been made with this as a maximum, while on the other hand larger shipments have been made with a maximum of 0.75 per cent.

If concentrates or other rich ores were used in the blast furnaces, the phosphorus in the pig would be lowered, not because the phosphorus is removed from the ore, but because the amount of ore required per ton of iron is lessened. For instance, if it requires 2.30 tons of ore per ton of iron, and the ore contains 0.32 per cent. of phosphorus, we would expect to find in the iron, from the ore alone, 0.73 per cent. of phosphorus. But if the amount of ore per ton of iron were reduced to 2 tons, the phosphorus remaining the same, there would be 0.64 per cent in the iron.

It is well known that Alabama ores, so far as explored, can not be used in the production of Bessemer iron. Isolated bodies of brown ore (limonite,) and perhaps some of the magnetites, may be suitable for this purpose, but no one who has had experience with such ores here would think of founding upon them an industry of this kind, for they are unreliable in composition. The brown ores are generally richer in iron than the hematites, and are almost always lower in silica. In the production of basic iron they are of great importance, as will hereinafter appear. Alabama is devoid of Bessemer ore in large quantities, so far as is now known, and it is also not to be considered as a source of ore suitable for Thomas pig, unless certain deposits of high phosphorus hematites, red and brown, not fully explored, should be found to be workable. Some of the fossiliferous ores of the Clinton formation contain from 1.5 per cent to 5. per cent of phosphorus, and would be suitable for the production of Thomas pig, if concentrated. They carry from 35 to 40 per cent of iron, and about the same amount of silica. By the use of the Wetherill process they can be concentrated to 50 per cent of iron, and even above.

Such ores as can be obtained here for years to come, so far as is positively known, can be made into steel only by the basic open-hearth. Even the duplex process, with its more or less successful conjoining of the Bessemer and the open-hearth, must be excluded in the light of the experience of the last twelve months. There is no need to desiliconize the pig iron after it has come from the furnace, or even to desulphurize it. These operations can be conducted in the blast furnace itself with a certainty and a regularity that renders any further experiments with desiliconizing and desulphurizing processes wholly unnecessary. In the interval between the production of the first basic iron, on regular orders, in 1888, and the fall of 1895, when large orders were taken under stringent specifications, there was more or less doubt, even among the best informed and most progressive iron men, as to the possibility of producing first-class basic iron from local materials. There was always the reservation of the use of some desiliconizing and desulphurizing process to be applied to the iron after it had left the furnace. It is true that some basic iron was made here in the spring of 1888 for use in the so called Henderson basic open-hearth furnace at North Birmingham; and again in the winter of 1892, and the spring of 1893, for the Jefferson Steel Company, successor to the Henderson, but the orders were not large, and the iron was made almost exclusively from brown ore.

When it became possible to secure large orders it was recognized that the iron could not be made frombrown ore, because an adequate supply was not obtainable, and even if it had been, the cost of all-brown ore iron would have wiped out the profit. There may be places in the South, or even in Alabama, where brown ore can be secured in such quantity and of such quality and price as to warrant its exclusive use for basic iron, but Birmingham is not one of them. If pig iron suitable for conversion into steel can not be made in the Birmingham district of local red hematite in admixture with brown ore, the commercial manufacture of steel from Birmingham iron can not be accomplished, either here or elsewhere.

The true significance of the production of the 75,000 tons of basic iron made here during the first year lies not in the fact that it was made at a cost that allowed it to be sent to distant markets, but in the fact that it was made of ores that can be and are produced here every day in the year, and that can be laid down in the stockhouses for 60 cents, and $1.00 per ton. The production of these 75,000 tons of basic iron is, therefore, one of the noteworthy occurrences in the development of the iron and steel industry of the United States.

Perhaps the commonest criticism of Alabama iron was that it carried too much silicon rather than too little. With the silvery irons showing over 5 per cent. of this element, and the foundry grades, at times, ranging from 2.50 per cent. to 3.25 per cent., the tendency was toward high-grade softeners, with sulphur from 0.030 per cent. to 0.050 per cent. When the furnaces were working cold, and mill and mottled irons were made, the difficulty was to keep the sulphur down. When the silicon fell to less than 1.50 per cent. the sulphur increased, and when the silicon was below 1 per cent. the sulphur was generally above 0.10 per cent.

This was the situation in August, 1895, when it was asked if large orders for basic iron could be taken under the following specifications: Maximum silicon, 1.0 per cent; maximum sulphur, 0.050 per cent; maximum phosphorus, 1 per cent. in a few cases, 0.85 per cent. in some, and 0.75 per cent. in most cases.

After careful consideration the orders were taken, and during the last thirteen months (September, 1895, to September, 1896, inclusive), every cast has been analysed for silicon, sulphur and phosphorus; very large shipments have been made, and not a single carload has been rejected. Considering the nature of the ores used, the irregularity of the stock, and the inevitable mishaps attendant on the prosecution of a new business, the success attained was certainly remarkable. Excluding the relatively small percentage of costs that showed either too much silicon or too much sulphur, the average silicon, sulphur and phosphorus in 1188 casts was as follows: Silicon, 0.51 per cent; sulphur, 0.032 per cent; and phosphorus, 0.72 per cent. Of manganese the metal carried about 0.50 per cent., graphitic carbon 2.75 to 3 per cent, and combined carbon 0.60 to 0.80 per cent.

Ore.

The ore used was of three kinds, no single one being used exclusively, and for the most part the three together, viz: hard or limy ore, soft or lime-free ore—these two being hematites,—and brown ore, or limonite.

Hard, or Limy Ore.

This is the red fossiliferous hematite of the Clinton formation, occurs in large quantities, and is mined at distances varying from 3 to 12 miles from Birmingham. It is the soft ore under cover, and is taken from the same general workings.

It carries in its best estate—

	%
Moisture	0.50
Metallic iron	37.00
Silica	13.44
Lime	16.20
Alumina	3.18
Phosphorus	0.37
Sulphur	0.07
Carbonic acid	12.24

In places it carries 5 per cent. more of lime than is here given, with less iron. For the most part it carries enough lime to flux its own silica, although occasionally there is a deficiency of lime. If it were always self-fluxing it would be of greater value, but even when the silica is in excess of the lime there is required much less extra flux, in the shape of limestone or dolomite, than when soft ore or brown ore is used.

It is necessary to keep a close watch over the hard ore, even from the same mine, on account of the lime-silica ratio and the decrease of the iron with the increase of the lime, or the silica.

Some hard ores carry from 3 per cent. to 6 per cent. more lime than silica and alumina, and in some the reverse is true, and it is necessary to know the composition in order to proportion the amount of extra flux required. Some furnaces in the district not, however, making a specialty of basic iron, use no extra flux at all, the lime of the hard ore being sufficient to flux not only the acid constituents of the ore burden but those of the coke also. In such cases, of course, the lime in the ore is in considerable excess of the silica in the ore.

The desiliconizing and desulphurizing action maintained in the blast furnace depends upon the basicity of the slag, and this, in turn, conditions the fusibility of the slag. The action of the basic slag in the furnace upon the iron that trickles down through it may be compared to certain desiliconizing and desulphurizing processes for the treatment of pig iron on its way from the blast furnace to the steel furnace. Instead of pouring molten pig iron, whether taken direct from the furnace, or remelted, through a bath of basic material, and removing the silicon and sulphur in this manner, the process is carried on in the blast furnace itself, and there is no longer a necessity for an intermediate process, whether desiliconizing or desulphurizing. We do not speak of the improvement in the iron due to the substitution of cast-iron moulds for sand moulds, but only of essential changes in the body of the iron due to the elimination of certain impurities. It is in respect of the basicity of the slag that the intelligent use of hard ore becomes so important. The better grades of this ore are excellent in one respect, they contain the flux in a state of perfect admixture with the material to be fluxed. No artificial mixture of lime and oxide of iron, with such impurities as are always present, could be any better than, if indeed so good as, the ore which nature has prepared. It is doubtful, if in the entire range of ores, there is one better adapted naturally for the manufacture of basic iron than the better grades of the limy ore of the Clinton formation.

The Soft, or Lime-free Ore.

An average analysis of this ore, as used for basic iron, is as follows:

	%
Moisture	7.00
Metallic iron	47.24
Silica	17.20
Lime	1.12
Alumina	3.35
Phosphorus	0.30
Sulphur	0.06

By far the greater part of the coke iron made in Alabama has been produced from ore mixtures carrying large proportions of soft ore. There was a time, 10 to 12 years ago, when but little limy ore was used, its value not having been recognized, and once when it was struck, in sinking a slope on the soft ore the mine operrators were disposed to abandon the property, thinking that the ore had given out.

The cheapness of the soft ore, 10 to 20 cents a ton less than the limy ore, and the fact of its carrying from 10 to 15 per cent. more iron, caused its general employment. It is quarried rather than mined, as nearly all of the workings are in open cut by the bench system. At some places regular mining operations are conducted underground, the soft ore, as indeed is always the case with the limy ore, being won by drift, slope, pillar, and room. But the quantity of soft ore obtained under cover is trifling compared with what is in effect quarried in the open air. The seams vary in thickness from 4 to 20 feet, the thinner seams being worked only when the iron is above 50 per cent. The present practice is to remove the overburden of soil, slate, sandstone and thin seams of ore, that is, from 10 feet to 30 feet. and to mine such ore as is suitable. The Big, or Ishkooda seam is about 20 feet thick, and the upper 10 feet carries about 47 per cent. of iron. Below this 10 feet mark the seam loses in iron at the rate of about one-half per cent. per foot, and the silica increases rapidly, although there is no regular rule governing all localities. But it has not been found advisable to mine more than the upper 10 feet. Under cover the soft ore gradually changes into the hard, or limy ore, and when the plane of atmospheric decomposition is passed, which is at distances along the dip varying from a few feet to 300 feet from the outcrop the entire seam is limy. The soft ore may, therefore, be regarded as the upper part of the hard ore from which the lime has been leached out.

From the very complete records at disposal it must be said that the best results in the production of basic iron have been attained by the use of the trinity of ores—hard, soft and brown, no attempt has been made to produce it from hard ore exclusively, on a regular commercial scale, or from hard and brown, or from soft and brown. There are results from the use of hard, soft and brown, and from hard ore and soft ore, with no brown. There is but little good in discussing the adaptability of brown ore alone from this purpose, as it is already known to be suitable, as also that the cost of production would be considerably higher, even if brown ore could be obtained in sufficient quantities.

The best practice will, therefore, be to continue the use of the three ores already tried, while striving to increase the proportion of limy ore.

The low cost of basic iron in the Birmingham district is certainly a strong argument for its production here. So long as ore suitable for producing this kind of iron can be laid down in the stockhouse for 1½ to 2½ cents per unit of iron, the manufacture of basic iron mav be commercially profitable. Whether the manufacture of basic steel will follow upon the manufacture of basic iron is another question.

BROWN ORE, OR LIMONITE.

An average analysis of the brown ore used in the production of basic iron is as follows:

	Per cent.
Hygroscopic water	7.00
Combined water	6.00
Metallic iron	48.54
Silica	11.22
Lime	0.84
Alumina	3.61
Phosphorus	0.38
Surphur	0.09

If carefully mined and washed the brown ore is of fairly uniform composition. No calcined brown ore has been used in the production of basic iron. Some good basic iron was made in 1892–93 from brown ore exclusively, but of late it has been used to the extent of about 20 per cent. only.

Good basic iron has been and can be made without using brown ore, but if it be omitted there is an increased risk of an excess of both silicon and sulphur. For instance, it was found that the best results were obtained by using an ore burden containing 20 per cent. of brown ore, irrespective of the percentages of hard and soft ore, which may vary within wide limits. So far as concerns the ore burdens the records cover a considerable range, from 36.10 per cent hard, 42.0 per cent. soft, and 21.3 per cent. brown, to 64 per cent. hard, 36 per cent. soft, and no brown. Of 30,222 tons of iron speccially examined with reference to the ore burdens on which it was made, the brown ore showed the following percentages, viz: 0; 8.9; 10.6; 14.5; 19.1; 20.0; 20.1; 20.3; 21.1; and 21.3. When running exclusively on hard and soft ore the average silicon was 0.68 per cent., the average sulphur 0.043 per cent., and the average phosphorus 0.70 per cent. With an ore burden of 52.3 per cent. hard, 27.5 per cent. soft, and 20.3 per cent. brown ths average silicon was 0.47 per cent., the average sulphur 0.033 per cent., the phosphorus remaining the same.

Important as are these differences between the silicon and the sulphur, they become even more so when it is stated that the chances of exceeding the 1 per cent. of silicon with an ore burden containing no brown ore are nearly four times greater than when 20 per cent of brown ore is used, and the chances of exceeding 0.050 per cent.

sulphur are more than twice as great. Furthermore, the range of both silicon and sulphur is wider when brown ore is omitted than when 20 per cent. of it is used. Lastly, the average consumption of coke per ton of iron with no brown ore was 1.53 tons, and with 20 per cent. of brown ore it was 1.19 tons.

The saving of flux with increase of hard ore is a partial offset to the advantages arising from the admixture of brown ore, but after deducting this the balance is decidedly in favor of the use of brown ore.

THE FLUXES.

The basic iron of 1892–93 was made with limestone as flux, but during the last 12 months dolomite has been exclusively employed in the production of the best quality of basic iron, The experience of the last year was not favorable to the use of limestone. The basic iron fell off in quality, and varied widely in composition, when limestone was used. It carried 4 per cent. of silica and 53 per cent of lime, with 0.40 per cent of oxide of iron and 0.60 per cent. of alumina, on the average, but varied widely in composition.

The dolomite that was used had the following average composition :

	Per cent.		
Silica	1.50		
Oxide of iron	0.60		
Alumina,	0.40		
Carbonate of line	54.00	Lime	30.31
Carbonate of magnesia	43.00	Magnesia	20.71

The value of magnesia as a desiliconizer and desulphurizer in the blast furnace is still somewhat in dispute, but the experience with dolomite here has proved, beyond question, that it can be used with great advantage. Dolomite has to a large extent supplanted limestone in the Birmingham district within the last year as a flux on ordinary grades of iron, and is exclusively used on basic iron. The amount of dolomite used, per ton of iron, varies, of course, with the amount of hard limy ore used. For basic iron the variation was from 0.12 ton with 81.2 per cent. limy ore and 18.8 per cent. soft ore to 1.08 tons with 36.2 per cent. limy ore, 53.2 per cent. soft, and 10.6 per cent. brown ore. In pounds, per ton of iron, the variation, then, was from 260.8 to 2419.2, certainly a wide range, and one that shows the fluxing power of the limy ore to great advantage.

When 268.8 lbs. were used the consumption of other ingredients, per ton of iron, was 2.64 tons of ore and 1.55 tons of coke, and the make of iron, under these conditions was 520 tons. When 2419.2 lbs. were used the consumption of other materials, per ton of iron, was 2.25 tons of ore, and 1.32 tons of coke, the make of iron being 2068 tons.

In making 7424 tons of basic iron the consumption in tons per ton of iron was :

Ore	2.10
Dolomite	0.92
Coke	1.23

The ore burden being composed, in per cent. as follows :

Limy ore	36.1
Soft ore	42.6
Brown ore	21.3

And the total burden

Limy ore	17.8
Soft ore	21.0

Brown ore	10.5
Dolomite	22.0
Coke	28.7

This matter will be discussed more fully under the heading 'Furnace Burdens.'

FUEL.

All of the basic iron is coke iron, the coke used being the ordinary 48 hour ''bee-hive,'' made from washed slack-coal. The average analysis is as follows:

	Coke. Per Cent.		Ash of Coke. Per Cent.
Moisture	0.75	Silica	45.10
Volatile matter	0.75	Oxide of iron	12.32
Fixed Carbon	89.00	Alumina	31.60
Ash	9.50	Lime	1.50
	100.00	Magnesia	trace.
Sulphur	1.00	Sulphur	0.10
		Phosphorus	0.02

The ultimate strength of the coke is about 2000 lbs. for a 1-inch cube, and the compressive strain about 500 lbs. The apparent specific gravity is 0.89, the true specific gravity 1.80, the percentage of cells by volume is about 45, and the volume of the cells in 100 parts by weight is about 47. In structure the coke is generally fine grained and close, and breaks into lumps rather than fingers. It is a small celled coke with strong walls, and carries a good burden, 1 lb. carrying as much as 2.54 lbs. The consumption of coke, in tons per ton of iron, varies from 1.56 when using 64.6 per cent. limy ore, 35.4 percent. soft, and no brown to 1.05 when using 60 per cent. limy ore, 20 per cent. soft, and 20 per cent.

brown, the respective returns being based on 1221 and 2934 tons of iron.

It is much better to state the matter in this way than to give the average over a long period during which the burden is changing constantly.

When no brown ore is used the consumption of coke is high. For instance with 64% limy ore and 36% soft, the make was 3521 tons, and the consumption of coke, per ton of iron, was 1.52 tons. With 81.2 per cent. limy ore, and 18.8 per cent. soft, the make was 520 tons, and the consumption of coke 1.55 tons.

With 64.6 per cent. limy ore, 26.5 per cent. soft, and 8.9 per cent. brown the make was 1140 tons, and the consumption of coke 1.24 tons. Lastly, with 36.1 per cent. limy ore, 42.6 per cent. soft, and 21.3 per cent. brown, the make was 7424 tons, and the consumption of coke 1.23 tons. Per pound of iron, then, the consumption of coke varies, according to the burden, from 1.36 lbs. down to 1.18 lbs.

Many other instances could be given but these are sufficient for the present purpose.

Coke of the kind described above can be secured here in large and regular shipments. During the last few years great improvements have been made in the Birmingham district in the manufacture of coke, especially in utilizing slack-coal and the best coke now made here will compare favorably with the best coke made any where else in the United States, as has been abundantly substantiated not only by chemical and physical tests, but also and particularly by furnace records. As regards basic iron there are records of the production of more than 22,000 tons showing the average consumption of coke, per ton of iron, as 1.26 tons. Considering the physical and chemical irregularities of the ore, points which have always to be borne in mind when discussing the blast furnace practice in the Birmingham district it is a good result to obtain a pound of iron with 1.18 lbs. of coke.

FURNACE BURDENS.

Let us now examine some what closely the furnace burdens, and their effect upon the quality of the iron, It is, of course, understood that these are only one of the elements entering into the subject. The physical and chemical condition of the stock, the amount, pressure and heat of the blast, the rate of driving, etc., all influence the quality of the iron. But as this paper deals chiefly with the raw materials used here in making basic iron, and designed to show when success has been reached in using local supplies of ore, stone and coke, we may be excused from enlarging upon the furnace practice. Suffice it to say that the furnace producing the basic iron under consideration has the following proportions.

Cubic area	11,865 ft.
Height	80 ft.
Diameter at bosh	17½ ft.
Diameter at crucible	11 ft.
Stock line	14½ ft.
Bosh angle	81½ deg.

Three blowing engines, having each 36 revolutions per minute ; eight 6-in. tuyeres ; pressure of the blast 11 lbs ; temperature 1400 deg. F. ; amount of blast per minute, 25,000 cubic feet. This furnace has produced 164 tons of basic iron in 24 hours, or 31 lbs. of iron per cubic foot of area, the average production being somewhat less than this.

The following tables give the results of the examination of the conditions attending the production of 30,222 tons of basic iron made during the year ending Septem- 9th, 1896. More than twice as much was made, but the examples selected are in no wise exceptional, being chosen for the sole purpose of exhibiting certain types of furnace burdens. Every cast during the year was analysed for silicon, sulphur and phosphorus, and many also for manganese and the two carbons. For the first time in the history of iron-making in Alabama, a critical examination of every cast of iron was insisted upon and faithfully carried out.

The total number of days represented in the tables is 195; of charges, 14,309, and the tons of iron, 30,222.

Ore Burdens of Hard (Limy) Ore, and Soft Ore, no Brown Ore being used.

TABLE XLVII.

TONS OF 2240 LBS.

Reference No.	No. of Charges.	Percentages.						Tons of Iron made.	Consumption.				Silicon.				Sulphur.				Phosphorus.				1 lb. coke carries lbs. burden.
		Of Ore Burden.		Of Total Burden					Tons per Ton of Iron.				Cast No.				Cast No.				Cast No.				
		Hard	Soft	Hard	Soft	Dolomite	Coke		Ore	Dolomite	Coke	Total	1	2	3	4	1	2	3	4	1	2	3	4	
1	1,848	64.0	36.0	33.1	18.6	14.5	33.8	3,521	2.34	0.66	1.52	4.52	.58	.68	65	69	044	.038	.035	.044	.73	.73	.74	.74	1.97
2	659	64.6	35.4	33.3	18.1	15.0	33.6	1,221	2.38	0.69	1.56	4.63	.54	.81	.86	.65	043	.035	.037	.046	.69	.69	.70	.69	1.85
3	569	61.5	38.5	33.1	20.7	12.4	33.8	1,122	2.30	0.54	1.48	4.34	.49	.54	.48	.46	.050	.042	.041	.049	67	.67	.67	.68	1.96
4	279	81.2	18.8	49.2	11.1	5.3	34.4	520	2.64	0.12	1.55	4.31	.86	.74	.95	.94	.056	.046	.045	.042	.69	.71	.72	.71	1.91

TABLE XLVIII.

Ore Burdens of Limy (Hard) Ore, Soft, and Brown Ore.

Tons of 2240 lbs.

Reference No.	No of charges	PERCENTAGES.								Tons of iron made.	CONSUMPTION.				SILICON.				SULPHUR.				PHOSPHORUS.				1 ℔ coke carries lbs. of burden
		Of ore burdens.			Of total burden.						Tons per ton of iron.				Cast No.				Cast No.				Cast No				
		Hard.	Soft.	Brown.	Hard.	Soft.	Brown.	Dolom.	Coke.		Ore.	Dolom.	Coke.	Total.	1	2	3	4	1	2	3	4	1	2	3	4	
5	570	64.6	26.5	8.9	35.3	14.4	4.8	16.0	29.5	1140	2.31	0.68	1.24	4.23	.60	.63	.60	.52	.023	.026	.031	.034	.76	.76	.76	.76	1.85
6	1099	36.2	53.2	10.6	17.8	26.2	5.2	22.0	28.8	2068	2.25	1.08	1.32	4.65	.48	.49	49	.52	.029	.028	.028	.029	.72	.73	.72	.73	2.42
7	704	61.5	24.0	14.5	33.1	13.0	7.7	12.4	33 8	1383	2.36	0.54	1.48	4.38	.48	.51	.43	.43	.031	.029	.031	.033	.68	.69	.68	.68	1.97
8	497	61.8	19.1	19.1	35.5	11.0	11.0	15.0	27 5	1106	2.33	0.53	1.11	3.97	.36	.38	.36	.37	.041	.037	.036	.033	.71	.69	.69	.69	2.09
9	1244	60.0	20.0	20.0	35.3	11.7	11.7	11.7	29.6	2934	2.09	0.42	1.05	3.56	.48	55	.49	.54	.039	.043	.039	.032	.72	.75	.75	.74	2.40
10	1306	59.8	20.1	20.1	35.0	11.7	11.7	11.5	30.1	2733	2.20	0.44	1.15	3.79	47	.49	.59	.59	.035	.034	.029	028	.72	.72	.74	.73	2.33
11	1571	59.4	20.3	20.3	32.9	11.2	11.2	10.4	34.3	3269	2.30	0.43	1.41	4.14	.60	.50	.62	.63	.039	.039	.031	.035	.67	.67	.68	.68	1.9[illegible]
12	386	36.7	42.2	21.1	17.9	20.5	10.2	23.1	28.3	781	2.13	1.00	1.22	4.35	.43	.41	.44	.55	031	.037	.021	.021	.70	.68	.71	.71	2.54
13	3677	36.1	42.6	21.3	17.8	21.0	10.5	22.0	28 7	7424	2.10	0.92	1.23	4.25	.35	.44	.35	.39	.028	.033	.032	.030	.71	.71	.70	.72	2.47

These tables fairly represent the conditions, as to ore, dolomite and coke, that were maintained during the production of more than 75,000 tons of basic iron in the Birmingham district. What may be legitimately inferred from these results? In the first place and principally that basic iron of excellent quality has been made here of native materials and in large quantities. Secondly, that the choice of these materials and the proportions in which they are used are of great importance in controlling the nature of the product.

What constitutes good basic iron? So much depends on local requirements, and the purpose for which the iron is to be used, *i. e.*, whether in admixture with other iron, or by itself, that no reply applicable to all cases can be made. As a rule, however, maximum limits can be assigned to silicon, sulphur and phosphorus, which should not be exceeded under ordinary circumstances. It is not customary to include in the specifications the percentages of manganese, graphitic carbon, or combined carbon, but to limit the demands to silicon, sulphur and phosphorus. Probably there are but few if any basic open-hearth steel makers who would purchase stock carrying more than 1 per cent. of silicon, or more than 0.050 per cent. of sulphur, although they might concede a little as to silicon if the iron was to be used in connection with other stock low in silicon. The limit for silicon has to be set somewhere, and at 1 per cent. it is certainly low enough, and works no hardship to the producer. If it can be brought still lower so much the better

If the producer of the iron were also the maker of the steel he could not afford to use pig iron of more than 1 per cent. silicon, unless he enjoyed exceptional opportunities for acquiring wrought iron and steel scrap. By stacking the iron above 1 per cent. in silicon, he could use it in mixture with his very low silicon iron, of which he would probably make a great deal more than of the other. Putting the maximum silicon at 1 per cent., there are a greater or a lesser number of casts, depending largely upon the condition of the furnace and the skill of the furnace-man, that will exceed this figure. These casts can not be shipped under the contract, but could be used on the spot. An iron with even 1.10 per cent. of silicon can not be shipped under a contract limiting the silicon to 1.0 per cent., but if used at home could be mixed with iron carrying 0.40 per cent., or 0.60 per cent., for steel making.

It is greatly to the advantage of the pig iron producer to keep well within the limits of the specifications, so as to allow for unavoidable irregularities in the working of the furnace. His purpose should be to keep the silicon below 0.75 per cent. This is good practice if he is selling his product on analysis, and especially so if he is making steel himself, as the lower the silicon is kept the better can he use the iron that exceeds the limit.

The silicon is not so apt to cause trouble as the sulphur. Fewer casts show a tendency toward increase of silicon than toward increase of sulphur, and under nearly all circumstances the silicon is more easily controlled than the sulphur. When the silicon falls the sulphur is apt to rise, but this tendency does not become serious until the silicon is below 0.30 per cent.

The burden that shows the greatest tendency toward increase of silicon is No. 4, which carries the largest proportion of limy ore, and no brown ore. This burden also gave the highest sulphur. The average silicon on this burden was 0.87 per cent., and the average sulphur 0.047 per cent. The charges on this burden were composed of 9300 pounds of limy ore, 2100 pounds of soft ore, 1000 pounds of dolomite, and 6500 pounds of coke.

Taking the analysis as given, we find that there were in each charge the following amounts of lime and magnesia: In the limy ore, 1506.6 pounds of lime; in the soft ore, 23.52 pounds; in the coke, 6.50 pounds; in the dolomite, 303.1 pounds of lime and 207.1 pounds of magnesia; a total of 2046.82 pounds of flux, of which 1839.72 pounds, or 89.9 per cent., was lime. Calculating the silica in the same manner, we find it to be in the limy ore, 1249.92 pounds; in the soft ore, 361.20 pounds; in the coke, 293.15 pounds, and in the dolomite 15 pounds; a total of 1919.27 pounds. Taking 1 part of magnesia as equal in fluxing power to 1.19 parts of lime, we may say that the 207.1 pounds of magnesia in the dolomite are equivalent to 246.44 pounds of lime, so that the lime-flux would be 2086.16 pounds. The silica to be fluxed is 1919.27 pounds, so that there is an excess of 166.89 pounds of lime per charge above the ratio silica : lime=1 :1.

During the period under examination there were 279 charges, with a production of 520 tons of iron, or 1.86 tons per charge. The excess of lime is practically 167 pounds per charge, so that the 520 tons of iron were exposed to the desiliconizing and desulphurizing action not only of the cinder but also of 46,593 pounds of lime not required for fluxing the silica. Each ton of iron was 'washed' with 89 pounds of lime. In spite of this, however, the tendency of the iron was decidedly toward an increase of both silicon and sulphur, and the burden was changed.

So much for No. 4. Let us now examine the results from a burden of exactly opposite tendency, the iron being of particularly good quality. We will select No. 12. The charges under this burden were composed as follows:

	Pounds.
Limy ore	3,500
Soft ore	4,000
Brown ore	2,000
Dolomite	4,500
Coke	5,500

The ore burden and the total burden were, as per centages:

	Ore burden.	Total burden.
Limy ore	36.7	17.9
Soft ore	42.2	20.5
Brown ore	21.1	10.2
Dolomite	....	23.1
Coke	....	28.3

The number of charges was 386, and the iron made was 781 tons, or 2.02 tons per charge.

	Lime per charge, lbs.	Silica per charge, lbs.
From limy ore	567.0	470.40
" soft ore	44.8	688.00
" brown ore	16.8	224.40
" dolomite	1,472.5	67.50
" coke	5.5	248.05
	2,106.6	1,698.35

We have then 2,408.3 pounds of lime in excess of that required for slagging the silica under the ratio silica :lime=1 :1. In other words, the 781 tons of iron were subjected to a bath of 543,603 pounds of lime, and every ton of iron was "washed" with 694 pounds of lime. The result was that the highest silicon found was 0.63 per cent. and the lowest 0.27 per cent., the average being 0.46 per cent. Contrast these results with those from

No. 4, in which the silicon went to 0.94 per cent., the lowest being 0.74 per cent., and the average 0.87 per cent. The lowest silicon in No. 4 is higher than the highest in No. 12, while the average silicon in No. 4 is nearly twice as much as the average in No. 12. The difference in the sulphur is also remarkable. In No. 4 the highest average sulphur was 0.056 per cent., the lowest 0.042 per cent., and the general average 0.047. In No. 12 the highest average sulphur was 0.037 per cent., the lowest 0.021 per cent., and the general average 0.028 per cent. Here also the highest average sulphur in No. 12 is lower than the lowest in No. 4, and the general average in No. 4 is 1.7 times as much as in No. 12.

Basic iron carrying a maximum silicon of 0.63 per cent. and a highest average sulphur of 0.037 per cent. is certainly very good stock for the basic open-hearth steel furnace.

But even in No. 12 the sulphur at times exceeded the limit of 0.050 per cent., 5 per cent. of the casts being above this, with the highest sulphur 0.063 per cent., the lowest 0.012 per cent., and the average 0.027 per cent. The expression highest average sulphur has been used. It means not the highest sulphur found, but the highest found by adding the sulphurs of each cast and dividing the sum by the total number of casts. For instance, in No. 12 the table shows the highest sulphur to have been 0.037 per cent., but this itself is an average of all the No. 2 casts of that series. As a matter of fact, 5 per cent. of the casts under No. 12 carried over 0.050 per cent. of the sulphur, but even then the results were a great deal better than with No. 4.

There are records covering the production of 11,379 tons of basic iron in which the maximum silicon was 0.98 per cent., and the average 0.48 per cent., not a single cast being up to the limit and only a very few anywhere near it. Of the 264 casts examined during this period only 15, or 5.7 per cent. ran over 0.050 per cent. sulphur, and then the maximum was 0.065 per cent. and the average 0.031 per cent.

Two more illustrations will be given, one in which no brown ore was used, corresponding in this respect to No. 4, and the other with brown ore, corresponding similarly to No. 12.

No. 1 burden:

	Ore burden. Per cent.	Total burden. Per cent.
Limy ore	64.00	33.1
Soft ore	36.00	18.6
Dolomite	.....	14.5
Coke	.....	33.8

Total burden in pounds:

Limy ore	6,400
Soft ore	3,600
Dolomite	2,800
Coke	6,500

Number of charges, 1,848. Iron made, 3,521 tons.

	Lime of burden, lbs.	Silica of burden, lbs.
From limy ore	1,036.80	859.16
" soft ore	40.32	619.20
" dolomite	1,538.35	42.00
" coke	6.50	293.15
	2,621.97	1,813.51

In addition to the lime required for fluxing the silica every ton of iron made was washed with 425 lbs. of lime. The iron showed much less tendency toward high silicon and high sulphur than No. 4, but a much greater tendency in this direction than No. 12.

Finally, let us consider No. 6:

	Ore burden, Per cent.	Total burden, Per cent.
Limy ore	36.2	17.8
Soft ore	53.2	26.2
Brown ore	10.6	5.2
Dolomite	....	22.0
Coke	....	28.8

Total burden in pounds:

Limy ore	3,400
Soft ore	5,000
Brown ore	1,000
Dolomite	4,200
Coke	5,500

Number of charges, 1,099. Iron made, 2,068 tons.

	Lime of burden, lbs.	Silica of burden, lbs.
From limy ore	550.80	456.96
" soft ore	56.00	860.00
" brown ore	8.40	112.20
" dolomite	2,307.90	63.00
" coke	5.50	248.05
	2,928.60	1,740.21

Every ton of iron was washed with 627 lbs. of lime. The iron was of excellent quality, the average silicon being 0.59 %, and the average sulphur 0.028%. Not a single cast exceeded the limit in silicon, and only 7.1 % exceeded it in sulphur, the highest sulphur being 0.65 %.

To sum up these four cases we may say: Total iron made, 6,890 tons from 3,612 charges. When the excess of lime was 89 lbs. per ton of iron the silicon and sulphur both showed strong tendencies toward the maximum allowed. When the excess of lime was 425 lbs., no brown ore being used, this tendenty was markedly diminished. In Nos. 1 and 4 no brown ore was used, the iron made was 4,041 tons, the excess of lime per ton of iron in No. 1 being 425 lbs. and in No. 4, 89 lbs. The quality of the iron from No. 4, with the small excess of lime, was much inferior to that from No. 1 with the large excess of lime. In neither case was it as good as that from No. 6 and No. 12, both of which carried brown ore. Furthermore, in examining other cases, which need not be quoted, we find that when the excess of lime, with a brown ore burden, is no more than 425 lbs. per ton of iron, the quality of the iron is better than when this excess is used with burdens containing no brown ore. In other words, brown ore is of a decided advantage irrespective, to a certain extent, of the excess of lime. The smaller excess of lime, with burdens composed of limy and soft ore, yielded worse iron than the larger excess because the desiliconizing and desulphurizing actions within the furnace were not sufficiently powerful, or while powerful enough, perhaps, within the sphere of their active influence were not distributed over the entire mass of the iron. A slight excess of lime is not sufficient, there must be a large excess, for when it rises to 400 lbs. per ton of iron the results are much better than when it is about 100 lbs. per ton of iron.

In the production of basic iron it is not sufficient that the cinder be merely basic; it must be basic enough to exert a powerful desiliconizing and desulphurizing action, or the results will not be satisfactory. This is true irrespective of whether the action within the furnace is such as to hinder the reduction of silica, or to cause an oxidation of silicon already reduced from the siliceous materials of the burden. It is possible that the former is the cause most in operation, for the highly reducing action of the gases in the lower part of the furnace tends strongly toward preventing any considerable oxidation of substances already deprived of their oxygen.

It is possible that a very basic charge prevents the reduction of silica, while at the same time it either prevents the absorption of sulphur by the iron, or removes the sulphur already absorbed. In the Saniter desulphurizing process the sulphur already combined with the iron is removed in a bath of calcium chloride. It is slagged off as sulphide of calcium. In the blast furnace making basic iron the same result is accomplished in a different manner with the attainment of practically the same result.

Basic iron has been made with less than 0.20 per cent. of silicon, and less than 0.020 per cent. of sulphur, the excess of lime per ton of iron being close to 700 lbs. We have had to depend upon the lime and the magnesia as desulphurizers, as the ores seldom carry more than 0.30 per cent. of manganese. If the manganese ores proper, or manganiferous iron ores could be obtained at a reasonable cost the basicity of the burden might be diminished, provided such a change did not tend to increase the silicon. But the purpose was to use the ordinary materials of the district, such as are mined and used every day, and manganese ore is not among them. Whether it would pay to buy manganese ore at 18–20 cents per unit f. o. b. mines in Georgia is an open question, and does not now concern us much.

It will be noticed that the magnesia has been calculated as lime, the magnesia of the dolomite being stated in terms of this base. It is more convenient to adopt this method for purposes of calculation, and when the fluxing ratio between the two is given no confusion can take place. The ratio adopted is, as already stated 1 magnesia = 1.19 lime. But irrespective of this ratio it has been found here that the exclusive use of limestone as a flux in making basic iron is not advisable. The composition of the iron is neither so regular nor so good. This is true of limestone alone, and also of a mixture of limestone and dolomite. The available supply of dolomite is very large, and no fears need be entertained that it will not be sufficient for many years.

It will also be noticed that no account has been taken of the alumina in the ores, flux and fuel. It cannot be stated positively what part alumina plays at such high temperatures, and in the presence of large excess of lime and magnesia. At some temperatures it appear to require silica for its removal, and the custom is to add siliceous soft ores to aluminous soft ores in the burden, when using ore containing 5 per cent. to 7 per cent. of alumina for the ordinary grades of iron. Under such circumstances alumina is a base, and requires an acid flux, but it by no means follows that it is always a base. The exact role of alumina in the blast furnace is a disputed question, and it may be that it is a base or an acid according to circumstances. Just what these are, how brought about, and how controlled is beyond the province of this paper. If it be taken as an acid the foregoing calculations as to the excess of base in the burdens would have to be modified considerably, the extent of such modifications depending upon the saturation point of the alumina with respect to lime, magnesia, and magnesia and lime.

If we take the ratio of silica to alumina, under the usual cinder made, as 1:1 (as a matter of fact it seems to be 1:0.87) the excess of lime-magnesia also calculated as lime—in No. 4, of 89 lbs. per ton of iron would entirely disappear, and in place of it we would have 336 lbs. of silica and alumina per ton of iron. No. 4 burden would then be acid, and it may be that the unsatisfactory results from it are to be attributed to this. Taking the other hard—soft burden, No. 1, instead of 627 lbs. of excess of base per ton of iron we would have 336 lbs., and in No.12, instead of 694 lbs. we would have 425 lbs. of excess of base per ton of iron.

These changes in the calculations do not alter the fact that a very basic burden is required for uniformly good basic iron. In fact, they strengthen this conclusion, for if the silica and alumina taken together may be regarded as the total acidity of the burden it is found, as before, that as we approach more and more closely to a neutral burden that quality of the iron begins to deteriorate, and is at its worst when the line is passed and the burden becomes acid. On the other hand, as we approach the maximum basicity, consistent with fluidity of cinder and regular working of the furnace, the quality of the iron improves, and is at its best when the excess of base, per ton of iron, is between 400 and 600 lbs.

This is one of the most important things in connection with basic iron practice, for it determines the efficiency of the desiliconizing and desulphurizing action that is to accomplished. The iron must be subjected to a basic bath, and the blast furnace is even better than a bath, for every particle of iron must trickle through the basic cinder, and be exposed on all sides to its powerful action, whether this be deterrent, as perhaps is the case with the silicon, or positive as is the case with the sulphur. No exterior process for desiliconizing or desulphurizing can be more effectual than the process within the furnace itself, provided the proper conditions are maintained. But it is not enough that the saturation point of the acid element of the burden be reached; this indeed is necessary, but unless there at the same time an excess of material which (*a*) can prevent the combination of silicon and sulphur with iron, or (*b*) remove them after they have entered the iron there can not be made a regular and good quality of basic iron.

The saturation of the acids and excess of base must go hand in hand. Whether the excess of base prevents the iron from absorbing silicon and sulphur, or whether, after they are once absorbed, it removes them, is of no special moment. Perhaps both these actions go on within the furnace, a deterrent action and a removing action, the one in the cooler and the other in the hotter zones. If a furnace on basic iron is working cold we might expect to find a decrease of silicon, and an increase of sulphur, and the main point in basic practice is to keep the furnace hot enough to lower the sulphur and cold enough to lower the silicon. This is largely a question of burdening and blowing.

THE CONSUMPTION OF COKE.

The consumption of coke is always the most interesting, as, perhaps, it is the most important, question in the manufacture of iron. It is by far the most costly raw material, and on this account economies in its use soon become evident. With coke at $1.75 per ton, each 100 pounds saved represents a saving of 8.75 cents. If a furnace has been working on 2,500 pounds of coke per ton of iron, and can diminish this by 100 pounds, the saving on 150 tons of iron per day is $13.12, which would pay the wages of the superintendent, the master mechanic and the chemist, or pay 6 per cent. interest on the cost of building 250 coke ovens.

In the production of basic iron the consumption of coke has varied from 2441.6 pounds to 3427 pounds per ton (2,240 pounds) of iron, the average being 2,979 pounds, or 1.33 tons of 2,240 pounds. The tons used in all these statements are of 2,240 pounds, so that it is easy to pass from one to the other.

Taking the cost of the coke as $1.96 per ton the variation in the cost per ton of iron is from $2.13 to $2.99, or 86 cents, the average cost being $2.60. The lowest coke consumption was on the following burden:

	Ore burden. Per cent.	Total burden. Per cent.
Hard ore	60.2	35.1
Soft ore	19.9	11.7
Brown ore	19.9	11.7
Dolomite	....	11.9
Coke	....	29.6

There were 2,033 charges, and 4,553 tons of iron were made, or 2.24 tons per charge. The consumption of coke per ton of iron was 1.09 tons, or 2,441.6 pounds. There were examined 126 casts, of which 94, or 74.6 per cent. gave silicon below 1 per cent., and 89, or 70.6 per cent. gave sulphur below 0.050 per cent. The average composition of the iron, below these limits, was silicon, 0.47 per cent.; sulphur, 0.030 per cent.; phosphrus 0.73 per cent.

The analysis of the stock was as follows:

	Limy Ore.	Soft Ore.	Brown Ore.
Iron	36.71	46.54	48.81
Silica	12.59	19.19	11.00
Alumina	3.15	3.00	3.25
Lime	17.14	1.00	0.60
Phosphorus	0.35	0.30	0.40
Sulphur	0.07	0.06	0.09

	Dolomite.	Ash of Coke.
Silica	1.95	45.10
Lime	29.10	1.30
Magnesia	19.20	trace
Oxide of iron	0.40	12.32
Alumina	0.60	31.60
Sulphur	0.03	0.16

The coke contained 11.32 per cent. of ash, and 0.91 per cent. of sulphur.

The consumption and cost of raw materials per ton of iron was:

	Tons.	Dollars.
Ore	2.19	1,765
Dolomite	0.45	0,336
Coke	1.09	2,429
	3.73	4,530

The burden was not the same throughout this period, but the average charge was as follows, in pounds:

Limy ore	6,532
Soft ore	2,276
Brown ore	2,276
Dolomite	2,234
Coke	5,500
	18,818

Taking the analysis, as quoted, and considering the silica and alumina as the acid elements, we would have of acid and basic constituents the following:

	Acid, lbs.	Basic, lbs.
From the limy ore	1,028.13	1,119.58
" " soft ore	505.04	22.76
" " brown ore	324,33	13.65

	Acid.	Basic.
“ “ dolomite......	56.96	1,160.34
“ “ coke..........	425.68	9.34
	2,340.14	2,325.67

By the method of calculation adopted this would be very nearly a neutral burden. We cannot but think that the good quality of iron was due in great measure to the brown ore, for when this was omitted and the ore burden composed of limy ore and soft ore, the charge being basic, there was a noticeable falling off in grade.

Let us now consider a case in which the consumption of coke was 1.53 tons, or 3,427 pounds per ton of iron. The burdens were as follows:

	Ore burden. Per cent.	Total burden. Per cent.
Limy ore........	61.2	31.5
Soft ore.........	34.3	17.6
Brown ore........	4.5	2.4
Dolomite........	....	15.1
Coke............	....	33.4

The burden was not the same during this period, but the average charge was in pounds:

Limy ore........................	6,245
Soft “	3,314
Brown “	512
Dolomite........................	2,900
Coke...........................	6,500
	19,471

The number of charges was 2,381, and the iron made 4,500 tons, or 1.89 tons per charge. The consumption and cost of materials per ton of iron were:

	Tons.	Dollars.
Ore	2.37	1,643
Dolomite	0.70	0,219
Coke	1.53	2,864
	4.60	4,726

There was very little difference in the composition of the materials during this period and the one just considered, and they may be taken as practically the same. In this latter case we have them, as the constituents of the burden:

	Acid Pounds.	Basic Pounds.
From the limy ore	982.96	1,070.39
" " soft "	735.37	33.14
" "Brown"	72.96	3.07
" " Dolomite	73.95	1,506.26
" " Coke	498.55	97.50
	2,333.79	2,710.36

There was an excess of base of 376.57 pounds per charge, so that each ton of iron was 'washed' with 197.12 pounds of lime-base. There were examined during this perriod 120 casts of iron, of which 90, or 75 per cent., gave silicon below 1 per cent.; and sulphur below 0.050 per cent., the average of these 90 being as follows: silicon, 0.64 per cent.; sulphur, 0.031 per cent.; phosphorus, 0.71 per cent.

So far as concerns the quality of the iron there is not much to choose between the results from 1.09 tons and 1.53 tons of coke per ton of iron.

But the lower yield of the best iron obtained from the latter burden, viz., 9.1 per cent., makes it less desirable, even if the difference of cost of 19 cents per ton of iron were not considered.

As it is, however, the burden carrying much less brown ore and requiring much more coke is handicapped with a difference of 19 cents per ton of iron, and a 9.1 per cent. less yield of the best iron. In considering the matter further it was found that even with an excess of lime-base in the burden the yield of the best iron was 9 per cent. less when the burden was slightly acid but carried over 19 per cent. of brown ore.

If now we examine the table relating to the use of limy and soft ores it will be seen that with hard-soft burdens only 17.5 per cent. of the iron was made with a coke consumption as low as 1.48 tons per ton of iron, the average being 1.52 tons. With burdens in which brown ore formed a notable proportion only 6 per cent. of the iron was made with a coke consumption as high as 1.48 tons per ton of iron, the average being 1.24.

As a rule, brown ore burdens will require 600 pounds less of coke per ton of iron than burdens carrying no brown ore.

In the production of ordinary grades of iron the best burden is the burden that will yield at the least cost the greatest amount of the most saleable iron. In the production of basic iron the same principle maintains but in a much greater degree, for this iron is sold on analysis, and every cast not up to the specifications must find another maket.

The production of basic iron in Alabama is a settled industry, and will grow with the demand for basic open-hearth steel. It is made exclusively of native materials, which exist in large quantities. The cost of these materials, per ton of iron, should not exceed $5.00, and may be brought to $4.50. Putting the operating expenses at $2.00 per ton, certainly a fair estimate, the total expense should not exceed $7.00.

The production of basic iron in the United States in

1896 and 1897, according to Mr. J. M. Swank, was as follows in tons of 2,240 pounds:

	1896.	1897.
Pennsylvania	219,863	350,068
Virginia Alabama	73.604	97,562
New England New York, New Jersey,	22,692	79,141
Ohio Wisconsin	20,244	29,720
	336,403	556,491

Virginia and Alabama are grouped together, but certainly the production of Alabama alone would not fall much short of 50,000 tons; and about 40,000 tons for 1897.

The returns for 1897 under New York and New Jersey include also New England. Virginia and Alabama include Maryland. Ohio and Wisconsin include Illinois and Missouri.

CHAPTER XI.

FURNACES, ROLLING MILLS, &c.

Coke Furnaces in Alabama.

(From the Directory of the Iron and Steel Works in the United States, Amer. Iron and Steel Assoc.. Phila., 1898. Jas. M. Swank, Manager.)*

Clifton Furnaces, Clifton Iron Company, Ironaton, Talladega county; two stacks; No. 1, 55x13, changing to 70x16, built in 1884, blown in April 16, 1885; No. 2, 60x14, built in 1889–90, and blown in during 1891; built to use charcoal for fuel, but changed to coke in 1895; six Cowper stoves; fuel, Alabama coke; ore, local brown hematite; product, foundry pig iron; total annual capacity, 72,000 gross tons. Brand, "Clifton." T. G. Bush, President, Anniston; Augustus Lowell, Vice-President, Boston, Mass.; C. L. Pierson, Treasurer, Boston, Mass.; Paul Roberts, Secretary and Assistant Treasurer, Ironaton. Selling agents, Matthew Addy and Co., Cincinnati; C. L. Pierson & Co., Boston and New York.

Fort Payne Furnace, DeKalb Furnace Company, Fort Payne, DeKalb county. One stack, 65x14, built in 1889–90 and blown in September 3, 1890; three Siemens–Cowper–Cochrane stoves; fuel, coke; ores, red and brown hematite, product, forge and foundry pig iron; annual capacity, 27,000 gross tons. (Formerly operated by the Fort Payne Furnace Company). A. L. Tayles, President; E. Dudley Freeman, Treasurer. Idle and for sale.

Gadsden-Alabama Furnace, Gadsden, Etowah county; one stack, 75x16, built in 1887–88, and first blown in October 14, 1888; three Whitwell stoves; fuel, coke; ores, local red and brown hematite; product, foundry and basic pig iron; annual capacity, 35,000 gross tons. Brand, "Etowah." Owned by Thomas T. Hillman, George L. Morris and Mrs. Aileen Ligon, of Birmingham. Idle, and for sale or lease.

Hattie Ensley Furnace, Colbert Iron Company, lessee, Sheffield, Colbert county; one stack, 75x17, built in 1887 and blown in December 31st, 1887; three Whitwell stoves; fuel, coke; ore, local brown hematite; product, foundry pig iron, annual capacity 48,000 gross tons. Brand, "Lady Ensley." A. A. Berger, President: Wade Allen, Vice-President; J. V. Allen, Secretary and Treasurer; A. J. McGarry, Manager. Selling agents, Rogers, Brown & Co., Cinti., N. Y., &c.

Mary Pratt Furnace, W. T. Underwood, Birmingham, Jefferson county. One stack, 65x14, built in 1882, and first put in blast in April, 1883; rebuilt in 1889; three Whitwell stoves; fuel, coke; ores, local brown and red fossiliferous; annual capacity 30,000 gross tons. Brand, "Mary Pratt." Idle for several years.

Philadelphia Furnace, Florence Cotton and Iron Company, Florence, Lauderdale county. Main office, 330 Walnut St., Philadelphia. One stack, 75x17, commenced by the W. B. Wood Furnace Company in 1887, and completed by the present company in 1890–1; three Whitwell stoves, each 70x20; fuel, coke; ore, brown hematite from Lawrence county, Tenn.; product, foundry pig iron; annual capacity 45,000 gross tons. Brand, "Philadelphia." Robert Dornan, Vice-President; James Pollock and William H. Arrott, committee for bondholders; E. Cooper Shapley, attorney, Girard Building, Phila. For sale. Idle since 1893.

Pioneer Furnaces; Pioneer Mining and Manufacturing Company, Thomas, Jefferson county; two stacks, each 75x16.5; No. 1 built in 1886–88, and blown in May 15, 1888; No. 2 built in 1889–90, and blown in February 22nd, 1890; eight Siemens-Cowper-Cochrane stoves; fuel, Alabama coke; ores, red and brown hematite from the company's mines near the furnaces; product, foundry pig iron; total annual capacity 95,000 gross tons. Brand, "Pioneer." Edwin Thomas, President, and Samuel Thomas, Vice-President, Catasaqua, Penna.; George H. Myers, Secretary and Treasurer, Bethlehem, Penna. Selling agents, Matthew Addy and Co., Cincinnati; W. R. Thomas, 50 Wall St., N. Y., Dallett & Co., 201 Walnut Place, Phila.

Sheffield Furnaces, Sheffield Coal, Iron and Steel Company, Sheffield, Colbert County. Three stacks, each 75x18, built in 1887-88; No. 1 blown in during Sept., 1888, and No. 2 blown in during Oct., 1889; No. 3 not yet blown in; Nos. 1 and 2 rebuilt in 1891; nine Whitwell-Cowper stoves; fuel, Alabama and Virginia coke; ores, Alabama and Tennessee brown hematite; product, foundry pig iron; total annual capacity. 150,000 gross tons. Brand, "Sheffield." A. W. Willis President, E. W. Cole, Vice-President, T. D. Radcliffe, Secretary, Sheffield; S. B. McTyer, Treasurer, J. J. Gray, Jr., Superintendent, Sheffield. Selling agents, Rogers, Brown and Co., N. Y., Miller, Wagoner, Feiser & Co., Columbus, Ohio.; Hickman, Williams & Co., Louisville, Ky.

Sloss Furnace, Sloss Iron and Steel Company, Birmingham, Jefferson County. Four stacks: No. 1, 82.25x18, built in 1881-82, put in blast April 12th, 1882, and rebuilt in 1895; No. 2, 68x18, built in 1882: No. 3, 73x16.5, built in 1887-88, and blown in during Oct., 1888; No. 4, 73x16.5, built in 1887-89, and blown in during Feb., 1889; five Whitwell, eight Gordon-Whitwell-Cowper, and three two-pass 18x70 stoves; fuel, coke; ores, red fossiliferous, hard and soft, and brown hematite; ores and coal mined on the company's property within ten to fifteen miles of furnaces; product, foundry and mill pig iron; totol annual capacity, 200,000 gross tons, Brand, "Sloss." Sol Haas, President; E. W. Rucker, Vice-President; J. W. McQueen, Secretary, A. H. McCormick, Treasurer. Selling agents, D. L. Cobb, Louisville and Chicago: Rogers, Brown and Warner, Phila.; Hugh W. Adams and Co., 15 Beekman St., N. Y.

Spathite Furnace, The Spathite Iron Company, Florence, Lauderdale County. One stack, 75x14, completed in December, 1888, and blown in during in during Oct., 1889; rebuilt in 1893; three improved Pollock stoves; fuel, coke; ores, spathite and brown hematite from Iron City, Tenn.; product, spathite pig iron; annual capacity, 30,000 gross tons. Brand, "Spathite." (Formerly called North Alabama Furnace.) J. Overton Ewin, Receiver; J. H. Short, Superintendent. Selling agents, Rogers, Brown & Co., Cincinnati. Sold Nov. 25th, 1895, to Louisville Banking Company. Louisville, Kentucky. Idle and for sale.

Spathite Furnace, No. 1, Spathite Iron Company, Nashville, Tenn. Furnace at Birmingham. One stack, 65x15½; commenced building February 9, 1890; blown in August 23, 1890; remodeled in 1897; three Massicks and Crooke stoves; fuel, Alabama coke; ores, spathite and brown; product, spathite pig iron; annual capacity, 40,000 gross ton. (Formerly called Clara Furnace), Thomas Sharp, President (died 1898); William M. Duncan, Vice-President; John P. Helms, Secretary and Treasurer.

Talladega Furnace, Talladega Furnace Company, Talladega, Talladega County. One stack, 72x18, built in 1889, and blown in October 5th, 1889; three Ford and Moncur stoves, each 62x26; fuel, Alabama and West Virginia coke; ore, local brown hematite; product, Bessemer, foundry and forge pig iron; annual capacity, 40,000 gross tons. Brand, "Talladega." Rudolph Gutmann, President; William P. Parrish, Secretary. Idle for several years.

Tennessee Coal, Iron and Railroad Company, Birmingham, Jefferson County. Thirteen stacks in Jefferson County. Five stacks at Bessemer: Nos. 1 and 2, each 75x17, built in 1886-87; No. 1 put in blast in 1888, and No. 2 in 1889; seven Whitwell stoves; Nos. 3 and 4, each 75x17, built in 1889-90; eight Whitwell stoves; No. 5, or Little Belle, 60x12, built in 1889-90, three Whitwell stoves.

Oxmoor Furnaces, at Oxmoor, (formerly called Eureka Furnaces) two stacks: No. 1 75x17, completed in July 1877, and rebuilt and blown in during Dec. 1885; No. 2, 75x17, first blown in in March, 1876, and rebuilt and blown in during Aug., 1886; seven Whitwell stoves. Fuel, Pratt and Blue Creek coke, made in Company's ovens; ores, local brown hematite and red fossiliferous from the company's mines; product, foundry, mill and basic open-hearth pig iron; total annual capacity, 126,000 gross tons. Brand, "DeBardeleben."

Alice Furnaces, at Birmingham, two stacks: No 1, 75x15, built in 1879–80, and put in blast November 23d, 1880; raised to present height in 1890; three Gordon-Whitwell-Cowper stoves; No. 2, 75x18, built in 1883, and put in blast July 24th, 1883; three Whitwell stoves; brand, "Alice," product, basic and foundry pig; annual capacity, 113,000 tons.

Ensley Furnaces, at Ensley. Four stacks, each 80x20, built in 1887, 1888, and 1889; No. 1 blown in

March 19. 1889; No. 2, December 1st, 1888; No. 3, June 5th, 1888, and No. 4 April 9th, 1888; four Gordon-Whitwell-Cowper stoves to each furnace. Brand, "Ensley." Fuel, Pratt coke made in the company's ovens; ores, red and brown hematite from the company's mines product, foundry, and forge pig iron; annual capacity of Alice Furnaces 113,000 gross tons; of Ensley furnaces, 292,000 tons. Total annual capacity of the thirteen stacks, 823,000 tons. N. Baxter, Jr., President; James Bowron, 1st Vice-President and Treasurer; A. M. Shook, 2d Vice-President; George B. McCormack, General Manager; T. F. Fletcher, Jr., Secretary and Assistant Treasurer; H. D. Cooper, Auditor; Erskine Ramsay, Chief Engineer; John Dowling, Superintendent of Bessemer Division · A. E. Barton, Superintendent of Ensley Division. Selling agents, Rogers, Brown & Co., Cincinnati, and branch houses; Matthew Addy & Co., Cincinnati and St. Louis.

Trussville Furnace, Trussville, Jefferson County. One stack, 65x18, built in 1887–89, and blown in in April, 1889, three Whitwell stoves; fuel, Alabama coke; ore, local red hematite; product, foundry pig iron; annual capacity, 30,000 gross tons. Brand, "Trussville." Owned by Messrs. Hogsett, Ewing and Thompson, Uniontown, Pa.

Williamson Furnace, Williamson Iron Compay, Birmingham, Jefferson county. One stack, 65x13.66, built in 1886, and first blown in in October, 1886; three Massicks and Crooke stoves; fuel, coke made at Coalburg; ores, red fossil and brown hematite; product, foundry and mill pig iron; annual capacity 18,000 gross tons. Brand, "Williamson." C. P. Williamson, President and General Manager; H. D. Williamson, Vice-President; J. B. Simpson, Secretary and Treasurer. Idle since 1892.

Woodstock Furnaces, The Woodstock Iron Works, Anniston, Calhoun county. Two stacks, each 75x16, built in 1887–89, and one blown in October 10th, 1889; seven Whitwell stoves; fuel, Alabama coke; ore, local brown hematite; product, foundry pig iron; annual capacity of No. 4, 60,000 gross tons. Brand "Woodstock." John D. Probst, President, and George Glover, Secretary, New York; H. Atkinson, Vice-President and Treasurer, and A. H. Quinn, Assistant Treasurer, Anniston.

Woodward Iron Company, Woodward, Jefferson county. Two stacks, each 75x17, one built in 1882–83, and put in blast in August, 1883, and the other built in 1886; eight Whitwell stoves; fuel, coke made from the company's coal; ore, red fossiliferous, mined within three miles of the furnace; specialty, foundry pig iron; total annual capacity, 100,000 gross tons. Brand, "Woodward." J. H. Woodward, President; Frank M. Eaton, Secretary; Silas Hine, Treasurer; J. H. McCune, General Superintendent.

Number of coke furnaces in Alabama, 37 completed stacks, and 1 stack partly erected.

Annual capacity of coke furnaces in Alabama, 1,965,000 gross tons.

Number of coke and bituminous furnaces in the United States, 247; annual capacity 15,114,700 gross tons.

Alabama has 15.0 per cent. of the total number of coke furnaces, 10.8 per cent. of the total annual capacity, and produces 16.0 per cent. of the total amount of coke iron.

Dividing the period 1876–1895 into 4 sub-periods of 5 years each we have the following comparisons:

1876–1880, coke furnaces built 4; production in 1876, 1,262 tons; in 1880, 35,232 tons; increase 33,970 tons, or 28 times.

1881–1885, coke furnaces built 6; production in 1881, 48,107 tons; in 1885, 133,808 tons; increase, 85,701 tons, or 2.78 times.

1886–1890, coke furnaces built 29; production in 1886, 180,133 tons; in 1890, 718,383 tons; increase 538,250 tons, or 3.99 times.

1891–1895, no coke furnaces built.

The greatest activity was displayed in the period 1886–1890, as of the 39 completed stacks in 1895, 29 or 74.5 per cent. were built during these years. It was not until 1888 that the production of coke iron passed the 200,000 ton mark, and not until 1889 did it rise above 500,000 tons, and assume respectable proportions. Until 1897 the year 1895 witnessed the largest production of coke iron ever recorded in the State, 835,851 tons, excelling the output of 1892 by 11 tons.

Of the 835,851 tons 387,793 tons, (46.4 per cent.) were made during the first half of the year, 18 furnaces being in blast June 30th, and 448,058 tons (53.6 per cent.) in the second half, 20 furnaces being in blast December 31st.

The 60,265 tons made in the second half of the year in excess of the output during the first half may be taken as representing the increase due to the upward tendency of prices which seemed to be genuine about that time.

The production of coke iron since 1876 is given in the following table:

TABLE XLIX.

Production of Coke Iron in Alabama.—Tons of 2240 pounds.

YEAR.	TONS.	YEAR.	TONS.	YEAR	TONS.	YEAR.	TONS.
1876	1,262	1882	51,093	1888	317,289	1894	556,314
1877	14,643	1883	102,750	1889	608,034	1895	835,851
1878	15,615	1884	116,264	1890	718,383	1896	892.383
1879	15,937	1885	133,808	1891	717,687	1897	932,918
1880	35,232	1886	180,133	1892	835.840		
1881	48.107	1887	176.374	1893	659.725		

Charcoal Furnaces in Alabama.

[From the Directory to the Iron and Steel Works in the United States, American Iron and Steel Association, Phila. Jas. M. Swank, Manager.]

Attalla Furnace, Buffalo Iron Company, Nashville, Tenn. Furnace at Attalla, Etowah county. One stack, 55x11, built in 1888–89, and blown in June 15th, 1889; iron stoves; ores, red and brown hematite from Etowah and Cherokee counties; product, car-wheel pig iron; annual capacity, 18,000 gross tons. Brand, "Attalla." Robt. Ewing, President; J. A. Cooper, Secretary and Treasurer. Idle since 1892.

Bibb Furnace, Alabama Iron and Steel Company, Brierfield, Bibb county. One stack, 55x12, built in 1864 to use charcoal; rebuilt in 1881, and remodeled in 1886 to use coke; returned to the use of charcoal in 1890; re-built in 1892; warm blast; ore, brown hematite, mined in the vicinity; product, car-wheel pig iron; annual capacity, 14,500 gross tons. Brand, "Bibb." T. J. Peter, President. Selling agents, C. R. Baird & Co., Phil., De Camp & Yule, St. Louis; Forster, Hawes & Co., Chicago. Idle since 1894.

Clifton Furnace, Clifton Iron Company, Ironaton, Talladega county. One stack, No. 2, 60x14; built in

1889–90, and blown in in 1891; hot blast; ore, local brown hematite; product, car wheel and malleable pig iron; annual capacity, 22,000 gross tons. Brand, "Clifton." (See Coke Furnaces).

Jenifer Furnace, Jenifer Furnace Company, Jenifer, Talladega county. Central office, Anniston. One stack, 56x11, built in 1892, and blown in December 5th, 1892, taking the place of the old stone stack built in 1863; two Hugh Kennedy stoves, each 45x16; ore, local brown hematite; product, car-wheel pig iron; annual capacity 12,000 gross tons. Brand, "Jenifer." (One stack, built in 1863, abandoned and dismantled in 1872.) John H. Noble, President, and John E. Ware, Secretary and Treasurer, Anniston. Selling agents, Rogers, Brown & Co., Cincinnati, and St. Louis; C. R. Baird & Co., Phila.

Rock Run Furnace, Rock Run Iron and Mining Company, Rock Run, Cherokee county. One stack, 54.5x11.5, built in 1873–4, enlarged in 1881 and 1892, and rebuilt in 1894; warm blast; ore, local brown hematite; product, car-wheel pig iron; annual capacity, 15,000 gross tons. Brand, "Rock Run." J. H. Bass, President, J. I. White, Secretary, and F. S. Lightfoot, Treasurer, Fort Wayne, Indiana; J. M. Garvin, Superintendent, Rock Run.

Round Mountain Furnace (formerly called Round Mountain Iron Works), the Round Fountain Furnace Company, lessee, Chattanooga, Tenn. Furnace at Round Mountain, Cherokee county. One stack, 45x9.5, built in 1853, rebuilt in 1874 and remodeled in 1888; cold blast; ore, red fossilliferous; specialty, cold blast charcoal pig iron for chilled rolls and car-wheels; annual capacity, 6,500 gross tons. Brand, "Round Mountain." L. S. Colyar, President; Jo. C. Guild, Vice-President; E. Shackelford, Secretary; E. B. Pennington, Superintendent. Selling agents, Rogers, Brown & Co., Cincinnati, and branch houses; J. E. Cartright, St. Louis. Owned by the Elliott Pig Iron Company, Gadsden.

Shelby Furnaces, Shelby Iron Company, Shelby, Shelby county. Two stacks, Nos. 1 and 2, each 60x14, built in 1863 and 1873; No. 1 rebuilt in 1889; warm blast; ore, brown hematite obtained on the furnace property; product, car-wheel pig iron; total annual capacity, 40,000 grosstons. Brand, "Shelby." T. G. Bush, President, Anniston; B. Y. Frost, Secretary, and W. S. Gurnee, Treasurer, 80 Broadway, N. Y.; E. T. Witherby, Assistant Treasurer, Shelby. Selling agents, Matthew Addy & Co., Cincinnati; C. L. Pierson & Co., Boston and New York.

Number of charcoal furnaces in Alabama, 8 completed stacks, and 1 stack partly erected, annual capacity, 12,800 gross tons. Number of charcoal furnaces in the United States, 79; annual capacity, 957,400 gross tons. Dividing the period 1876–1895, as under coke furnaces, into four sub-periods of five years each, we have the following comparisons:

1876–1880—Charcoal furnaces built, 1; output in 1876, 20,818 tons; in 1880, 33,693 tons; increase, 21,875 or 1.62 times.

1881–1885—Charcoal furnaces built, 2; output in 1881, 39,483 tons; in 1885, 69,261 tons; increase, 29,778 tons, or 1.65 times.

1886–1890—Charcoal furnaces built, 4; output in 1886, 73,312 tons, in 1890, 98,528 tons, increase, 25,216 tons, or 1.34 times.

1891–1895—Charcoal furnaces built, 2; output in 1891, 77,985 tons; in 1895, 18,816 tons, decrease 59,169 tons, or a little more than three-fourths.

Of the twelve completed charcoal stacks in 1895, 4, or 33 per cent. were built in the period 1886–1890, two in

1873, one in 1874, and the others as above. In charcoal, as in coke furnaces, the greatest activity was displayed during the period of 1886–1890, although the activity in coke furnaces was much more pronounced. Alabama has 72.5 per cent. of the total number of charcoal furnaces, 15.3 per cent. of the total annual capacity, and made in 1895 8.3 per cent. of the total production of charcoal iron.

The charcoal iron industry has been declining for several years. It reached its maximum in 1889, with 98,595 tons. At that time Alabama was producing 17.1 per cent. of the total, and was second in point of production.

The statistics of production are given in the following table:

TABLE L.

Product of Charcoal Iron in Alabama. Tons of 2,240 Pounds.

Year.	Tons.	Year.	Tons.	Year.	Tons.	Year.	Tons.
1872	11.171	1878	21.422	1884	53.078	1890	98 528
1873	19.895	1879	28.563	1885	69.261	1891	77.985
1874	29.342	1880	33.763	1886	73.312	1892	79.456
1875	22.418	1881	49.483	1887	85.020	1893	67.163
1876	20.818	1882	49.590	1888	84.041	1894	36.078
1877	22 180	1883	51.237	1889	98.595	1895	18.816

1896, 29.787.
1897, 14.913.

TABLE LI.

Hot Blast Stoves in Alabama—1896–98.

Cowper.		Ford and Moneur.		Gordon-Whitwell-Cowper.		Hugh Kennedy.		Massicks and Crooke.		Pollock.		Siemens-Cowper-Cochrane.		Whitwell		Whitwell-Cowper.		Total.
No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent	No.	Per Cent.	No.	Per Cent.	
6	4.4	3	2.2	31	22.8	2	1.5	6	4.4	3	2.2	11	8.1	65	47.8	9	6.6	136

Rolling Mills, Steel Works, Etc., in Alabama.

(From the Directory of the Iron and Steel Works in the United States. American Iron and Steel Assoc., Phil., 1898, Jas. M. Swank, Manager).

Alabama Iron and Steel Company (formerly Brierfield Rolling Mill), Brierfield, Bibb county. Built in 1863, rebuilt in 1882-3, and put in operation in August, 1883; 10 double and 4 single puddling furnaces, 5 heating furnaces, 3 18-inch trains of rolls and 72 cut nail machines; product, merchant bar iron and nails; annual capacity, 12,000 gross tons. E. J. Peter, Secretary.

Alabama Rolling Mill Company, Birmingham, Jefferson county. Works at Gate City, Jefferson county. Built in 1887-88 and put in operation in February, 1888; 23 single puddling furnaces, 2 gas heating furnaces, and 3 trains of rolls (18-inch muck and 8 and 16-inch bar); products, bars, bands, hoops, light T rails, &c.; annual capacity, 24,000 gross tons. W. J. Behan, President; W. H. Hassinger, Vice-President and General Manager; D. M. Forker, Secretary and Treasurer.

Alabama Steel Works (formerly Fort Payne Rolling Mill), The DeKalb Company, lessee, Fort Payne, DeKalb county. Built in 1889–90; two 15-gross ton basic open-hearth steel furnaces; first steel made in July, 1893; 4 gas heating furnaces, 5 cut-nail machines (idle), and 2 trains of rolls (one 2-high 32-inch reversing and one 22-inch nail plate); product, ingots, blooms, billets and slabs; annual capacity, 10,000 gross tons of ingots, Fuel used, producer gas. J. A. Wilder, President; J. K. Lanning, Vice-President and Treasurer.

Anniston Rolling Mills, Anniston Iron and Steel Company, lessee, Anniston, Calhoun county. Built in 1890–91; 12 single puddling furnaces, 2 large heating furnaces and 2 trains of rolls (3-high, 20-inch muck and 3-high 12-inch finishing). J. K. Dimmick, President; H. B. Cooper, Vice-President and General Manager; John S. Mooring, Secretary and Treasurer. Owned by the Anniston Rolling Mills Company.

Bessemer (The) Rolling Mills, Bessemer, Jefferson county. Built in 1887–88; 24 single puddling furnaces, 6 heating furnaces, 5 trains of rolls (one 20-inch muck, one 8-inch guide, and 16 inch car, one 22-inch sheet, and one 26-inch plate), and three Siemens gas producers; product, bar, guide, plate and sheet iron; annual capacity, 27,000 gross tons. Owned by Morris Adler, of Birmingham, and others. Idle since the spring of 1891, and for sale.

Birmingham Rolling Mills, Birmingham Rolling Mill Company, Birmingham, Jefferson county. Built in 1880, and first put into operation in July, 1880; enlarged in 1887 and 1895; 11 double and 24 single puddling furnaces, one scrap furnace, seven gas, four box annealing, two pair and four sheet heating and annealing furnaces, and nine trains of rolls, (two 8-inch guide, one 16-inch bar, two 18-inch forge, two 24-inch sheet, one 26-inch plate, and one 24-inch finishing); product, iron and steel bars, plates, sheets, angles, round-edge tire, small T rail, fish plates, &c.; annual capacity, 70,000 gross tons. Fuel used, producer gas and coal. Two 30-ton basic open hearth steel furnaces were built in 1897, and the first heat made July 22, 1897.
James G. Caldwell, President; Thomas Ward, General Manager; J. D. Dwyer, Superintendent; J. H. Mohns, Salesman.

Jefferson Steel Company, Birmingham, Jefferson county. Built in 1889–90; one 15-gross ton basic open-hearth steel furnace; first steel made April 14, 1890; product, ingots; annual capacity, 8,100 gross tons. Brand, "Jefferson." (This furnace takes the place of one experimental Henderson open-hearth steel furnace built in 1887–88, and first steel made February 27, 1888. Formerly operated by the Henderson Steel Manufacturing Company.) Eugene F. Enslen, Secretary, Treasurer and General Manager.

Sheffield Rolling Mill, Sheffield, Colbert county. Built in 1897–98, utilizing machinery from the abandoned Midway Iron Works and Roanoke Rolling Mill, Roanoke, Virginia; 12 double puddling furnaces, 5 heating furnaces, and 4 trains of rolls (one 3-high 18-inch muck and billet, one 3-high 16-inch bar, and two 10-inch guide); product, bar, angle, rod and band iron, small size T rails, D links and cotton ties, railroad and boat spikes; annual capacity, 20,000 gross tons. Fuel, bituminous coal.

Shelby Rolling Mill Company (formerly Central Iron Works), Helena, Shelby county. Works started in March, 1873; enlarged by present company in 1889; 10 single puddling furnaces, three heating furnaces and four trains of rolls; product, merchant bar and band iron, and light T rolls; annual capacity, 7,200 gross tons. Company failed; works idle for several years. Address, Joseph F. Johnston, Birmingham.

Illinois Car and Equipment Company, Anniston, Calhoun county. Chicago office, 1480 Old Colony Building; New York office. 45 Broadway. Built in 1884 and enlarged in 1888–89, and 1893; one single and six double puddling furnaces, six heating furnaces, one scrap furnace, two trains of rolls (one 18-inch muck and bar, and one 10-inch merchant and guide), and five hammers (one 6,000 pound, two 4,000 pound, and two helve); product, car axles and merchant bar iron; annual capacity, 15,000 gross tons. David Cornfoot, President, London, England; H. A. Ware, Vice-President, New York; S. M. Dix, Secretary and Treasurer, J. M. Maris, General Manager, Chicago; O. M. Stinson, General Superintendent, Anniston.

Steel Works Projected.

The Tennessee Coal, Iron & Railroad Company, in connection with other capital, will erect a large basic open-hearth steel plant during 1897–98. Location, Ensley, Jefferson county.

Number of rolling mills and steel works in Alabama: Ten. Of these, three have basic open-hearth steel plants.

No steel was made in the State in 1894, 1895, or 1896. The total amount made from 1888 to the close of 1893 will not exceed 4,000 gross tons.

Annual capacity of rolling mills, 193,300 gross tons with one mill not reporting. Allowing 10,000 gross tons for this one, the total annual capacity is 123,300 gross tons.

Number of contemplated rolling mills and steel works in the United States, January 1, 1898, 504; annual capacity, double turn, 17,929,850 gross tons.

Forges and Bloomaries.

Anniston Bloomary, Cherokee Iron Company, Cedartown, Georgia. Works at Anniston, Calhoun county. Built in 1887; five forge fires and one hammer; steam power; product, blooms made from pig iron. Idle. Wm. C. Browning, President, and J. Hull Browning, Treasurer, 408 Broome steert, New York; J. R. Barber, Secretary and General Manager, Cedartown, Georgia. Now abandoned.

Pipe Works, Car Wheel Works and Miscellaneous.

Bridge Building Works.

Southern Bridge Company, Birmingham. Works at Avondale, Jefferson county. Capacity, 1,000 tons.

Alabama Bridge and Boiler Works, Birmingham. Railroad and highway bridges. Annual capacity, 1,500 tons.

Gas and Water Pipe Works.

Anniston Pipe Works, Anniston Pipe and Foundry Company, Anniston, Calhoun county. Size from 3 to 30 inches. Daily melting capacity, 350 tons.

Chattanooga Foundry and Pipe Works, Chattanooga, Tenn. Works at Bridgeport, Jackson county. Sizes, from 14 to 36 inches, inclusive. Daily melting capacity, 160 tons.

Howard-Harrison Iron Company, Bessemer, Jefferson county. Sizes, from 3 to 72 inches, inclusive. Daily melting capacity, 300 tons.

Soil and Plumbers' Pipe Works.

Alabama Pipe Company, Bessemer, Jefferson county. Sizes, from 2 to 10 inches, inclusive. Daily melting capacity, 30 tons.

Birmingham Soil Pipe Works, Birmingham Soil Pipe Company, Birmingham, Jefferson county. Sizes, from 2 to 8 inches. Daily melting capacity, 10 tons.

Hoffmann, Billings, and Weller Manufacturing Company, 96–100 Second St., Milwaukee, Wis. Works at Gadsden, Etowah county, Ala. Sizes from 2 to 12 inches. Daily melting capacity, 40 tons.

Hercules Foundry, E. L. Tyler & Co., lessees, Anniston, Calhoun county. Sizes, from 2 to 18 inches. Daily melting capacity, 50 tons.

Car Axle Works.

Peacock's Iron Works, George Peacock, Selma, Dallas county. Iron and steel mine car axles. Annual capacity, 15,000.

Illinois Car and Equipment Company, Anniston, Calhoun county. Office, 1480 Old Colony Building, Chigo; 66 Beaver street, N. Y. Car and locomotive axles. Daily capacity, 120.

Car Wheel Works.

Decatur Car Wheel and Manufacturing Company, Birmingham. Product, chilled, cast-iron wheels. Annual capacity 125,000.

Elliott (the) Car Company, Gadsden, Etowah county. Product, charcoal iron standard M. C. B. railroad wheels. Annual capacity, 48,000.

Hood Machine Company, Birmingham, Jefferson county. Product, 12, 14 and 16-inch mine car wheels. Annual capacity, about 14,000.

Peacock's Iron Works, George Peacock, Selma, Dallas county. Product, all kinds of small car wheels. Annual capacity, 35,000 self-oiling and 15,000 plate wheels.

Carbuilding Works.

Elliott (the) Car Company, Gadsden, Etowah county. Freight cars. Annual capacity, 3,600.

Peacock's Iron Works, George Peacock, Selma, Dallas county. Mine, logging and other small cars. Annual capacity, 5,000.

Union Iron Works Company, Selma, Dallas county. Logging, push, cane and other small cars. Annual capacity, 1,000 of each.

Illinois Car and Equipment Company, Anniston. Offices, 1480 Old Colony Building, Chicago; 66 Beaver street, N. Y. Annual capacity, 12,000 freight cars at each place.

Alabama Bridge and Boiler Works, Birmingham. Iron, steel and wooden tram cars and all styles of cars for blast furnace use. Annual capacity, from 500 to 1,000.

TABLE LII.

Production of Iron Ore, Coal, Coke and Pig Iron in Alabama.

Year.	Iron Ore. Tons of 2,240 lbs.	Coal. Tons of 2,000 lbs.	Coke. Tons of 2,000 lbs	Pig Iron Tons of 2,240 lbs.		
				Coke.	Charcoal	Total.
1870	11,350	13,200	....	....	....	....
1871	....	20,000	....	....	....	....
1872	22,000	30,000	....	....	11,171	11,171
1873	39,000	44,800	....	....	19,895	19,895
1874	58,000	50,400	....	....	29,342	29,342
1875	44,000	67,200	....	....	22,418	22,418
1876	44,000	112,000	....	1,262	20,818	22,080
1877	70.000	196,000	....	14,643	22,180	36,823
1878	75,000	224,000	....	15,615	21.422	37.037
1879	90,000	280.000	....	15.937	28,563	44,500
1880	171,139	380,000	60,781	35,282	33.693	68,925
1881	220,000	420,000	109,033	48,107	39.483	87,590
1882	250,000	896,000	152,940	51,093	49,590	100,683
1883	385,000	1,568,000	217.581	102.750	51,237	153,987
1884	420,000	2,240.000	244,009	116.264	53,078	169,342
1885	5 5,000	2,492,000	301,180	133,808	69,261	203,069
1886	650.000	1,800,000	375,054	180,133	73,312	253,445
1887	675,000	1,950.000	325,020	176,374	85.020	261,394
1888	1,000,000	2.900,000	508,511	317.289	84,041	401,330
1889	1,570.000	3,572.983	1,030,510	608,034	98,595	706.629
1890	1,897,815	4.090,409	1,072,942	748,383	98,528	816,911
1891	1,986,830	4,759,781	1,282,496	717.687	77,985	795,672
1892	2,312,071	5,529,312	1,501,571	835.840	79,456	915,296
1893	1,742,410	5,136,935	1,168,085	659,725	67,163	726,888
1894	1,493,086	4,397,178	923,817	556,314	36,078	592,392
1895	2,199,390	5,693,775	1.444.339	835.851	18,816	854,667
1896	2,041.793	5.745,617	1,689,703	892,383	29,787	922,170
1897	2.050.014	5.893.771	1.395.252	932.918	14.913	947.831

Freight tariff for pig iron, per ton, in carload lots of not less than 17½ tons of 2,268 pounds from the following points in Alabama, effective February 24th, 1898: Anniston, Attalla, Bessemer, Birmingham, Boyles, Brierfield, Columbiana, Ensley, Gadsden, Ironaton, Jenifer, North Birmingham, Oxmoor, Rock

Run, Round Mountain, Shelby, Talladega, Tecumseh, Thomas, Trussville, Woodward—

1896.	To		1898.
$ 1.30	Atlanta, Ga		$ 1.30
	Baltimore, Md., all rail		3.76
3.60	“ “ rail and water		3.10
	Boston, Mass., all rail		5.33
4.10	“ “ rail and water		3.60
4.40	Buffalo, N. Y		3.85
	*Chattanooga, Tenn		0.75
2.75	Cincinnati, Ohio		2.25
3.90	Cleveland, Ohio		3.30
3.85	Chicago, Ill		3.10
	Columbus, Ohio		2.90
	Denver, Col		9.19
3.95	Detroit, Mich		3.40
	Galveston, Texas		5.97
5.10	Hamilton, Canada		4.30
	Kansas City, Mo		4.40
2.50	Louisville, Ky		2.00
	Minneapolis, Minn		4.95
2.50	Mobile Ala., export		1.00
	Montreal, Canada		5.60
	*Nashville, Tenn		1.00
2.50	New Orleans, La., export		1.60
	Newport News, Va		2.25
3.75	New York, N. Y.,	all rail	5.13
		rail and water	3.25
	Norfolk, Va		2.35
	Omaha, Neb.		4.50
4.75	Philadelphia, Pa., all rail		4.02
	“ “ rail and water		3.25

*From Birmingham.

	Pensacola, Fla., export		1.00

4.40	Pittsburg, Pa	3.70
14.47	Portland, Oregon	12.84
	San Francisco, Cal	12.84
2.90	Savannah, Ga	2.90
3.25	St. Louis, Mo	2.75
5,10	Toronto, Canada	4.30
	Youngstown, Ohio	3.30

From the Sheffield District the all-rail differential is 40 cents under the Birmingham rate.

The distances from Birmingham to these points is about as follows:

From Birmingham to	Distance in Miles.
Atlanta	167
Baltimore	1,050
Boston	1,450
Buffalo	950
Chattanooga	143
Cincinnati	504
Cleveland	767
Chicago	650
Columbus	630
Denver	1,400
Detroit	766
Galveston	800
Hamilton	975
Kansas City	850
Louisville	394
Minneapolis	1,050
Mobile	276
Montreal	1,600
Nashville	209
New Orleans	417
Newport News	800
New York	1,225

Norfolk	775
Omaha	1,000
Pensacola	260
Philadelphia	1,150
Pittsburg	817
Portland	3,675
San Francisco	3,000
Savannah	448
St. Louis	528
Toronto	996
Youngstown	875

The pig iron produced in Alabama goes into almost every State of the Union, and into many foreign countries. The transportation rates, therefore, are most important to the stability of the industry. Taking the figures given in the preceding statements as to the rates and the distances, it will be found that the highest rate per ton-mile from the Birmingham district is to Atlanta, a distance of 167 miles, to which point the rate is $1.30, or 7.78 mills per ton-mile. The lowest rate is to Louisville, a distance of 394 miles, to which point the rate is $2.00, or 1.97 mills per ton-mile.

As it might be of some interest to know what the rates per ton-mile are for pig iron, the following table has been constructed, based on the above rates and distances, and all rail freights.

TABLE LIII.

Giving the freight rates per ton-mile on pig iron from the Birmingham district to points as below, in mills.

Atlanta	7.78
Baltimore	3.58
Boston	3.68
Buffalo	4.05

Chattanooga	5.24
Cincinnati	2.24
Cleveland	4.30
Columbus	4.60
Denver	6.56
Detroit	4.44
Galveston	7.46
Hamilton	4.51
Kansas City	5.18
Louisville	1.97
Minneapolis	4.71
Mobile	3.62
Montreal	3.50
Nashville	4.78
New Orleans	3.83
Newport News	2.94
New York	4.19
Norfolk	3.03
Omaha	4.50
Pensacola	3.85
Philadelphia	3.50
Pittsburg	4.53
Portland	3.49
San Francisco	4.28
Savannah	6.47
St. Louis	5.21
Toronto	4.32
Youngstown	3.77

Freight tariff for coal and coke in effect in the Spring of 1898, from Birmingham to

Atlanta, Ga	$1.05
Augusta, Ga	1.80
Charleston, S. C	2.05
Columbia, S. C	2.20

Columbus, Miss	1.05	
Dallas, Texas	4.75	steam coal, $4.95 coke.
El Paso, Texas	6.44	
Greenville, Miss	1.15	
Houston, Texas	2.90	coal, $3.55 coke.
Macon, Ga	1.50	
Meridian, Miss	1.15	
Mobile, Ala	1.50	
Montgomery, Ala	1.10	
New Orleans, La	1.40	steam coal, $1.60 coke.
Pensacola, Fla		
Savannah, Ga	1.80	
Selma,	1.00	
Shreveport, La	2.15	
Vicksburg, Miss	1.55	

Bunker rate to	Mobile	$1.10
" " "	New Orleans	1.40
" " "	Pensacola	1.10

The same rates hold for export.

These rates are per ton for carload of not less than 23 tons of 2,000 pounds.

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