SPIEGELEISEN MANUFACTURING.

BY HUGH HARTMANN, CIVIL ENGINEER.

In two previous letters, which the late Prof. J. W. Foster, of Chicago, brought very kindly before the A. A. for the A. of S., during its sessions at Dubuque, Iowa, last summer, and which Prof. E. T. Cox, of Indianapolis, incorporated with his last Geological Report on Indiana, I spoke already of the great facilities which this State offers to the iron producers, stating that those elements, which are required for the producing of a pig iron, adapted for the Bessemer process of steel making, are marvelously combined in her natural resources as well as her other particularities.

Supported by some experience which I had in Germany, I reviewed to a limited extent the materials used there and the modus operandi upon which those iron works are conducted which produce the Spiegeleisen. (Specular, glittering iron, or Spiegeleisen—as it is called now throughout the technical world—is the raw material for the Bessemer process).

Comparing the same with the facts already obtained in Indiana, it is true to say, that she is only in her infancy as to the development of technical enterprise (mining and smelting), but there can be no doubt as to her future magnitude. That she will be a great iron producing State, and the future seat of American Steel making, I shall try to prove this in considering

Firstly, The qualities which a pig iron must bear to be fit for the Bessemer process.

Secondly, The difierent ways upon which the blast furnaces of different countries are worked to produce an iron of the required properties.

Having thus laid out not only the preliminary, but the fundamental part of the theme in question, I shall

Thirdly, Take a survey of those questions in regard to Indiana herselt.

1. OF THE QUALITIES OF SPIEGELEISEN.

The qualities of a pig iron adapted for the Bessemer process must be, briefly stated, the following:

1. Freedom from sulphur and phosphorus.

2. Presence of manganese.

Sulphur and phosphorus, noxious as they are in any kind of iron destined for the refinery process, are the greatest enemies of the Bessemer process.

The true spiegeleisen has a silver color and a high metalic lustre; broken into pieces, it shows large and bright, mirror like facets. All the analyses made of spiegeleisen demonstrate the presence of a certain amount of manganese, while it is also found, that the more or less glittering appearance, or the formation of large facets, depends more upon the per centage of combined carbon, than manganese. It is found, furthermore, that the state of crystallization is the same either with a large or small amount of compounded manganese. The formation of large facets is facilitated or increased, when the iron (after the tapping from the furnace) is covered with slag, because the cooling of the iron is retarded. It is therefore necessary, to accummulate in the hearth of the furnace, before the tapping, a large quantity of slag, sufficient to cover the pigs in the moulds to a thickness of several inches. Should the iron be poor in carbon, the pigs will show after this operation far better facets than without it. On the other hand, when the iron is rich in carbon (when containing about 5 per cent. carbon), this covering with slag is useless. It is also of some influence for the producing of large facets, to have the iron running very lively from the furnace into the moulds. If there is much manganese in the iron, and the iron itself very hot, a vivid oxydation on the surface of the pigs takes place.

Iron, in the constitution of which a portion of the always present silica is replaced by manganese, will rather part with the latter than the former. Iron, on the point of passing from the liquid to a solid state, will retain the manganese and expel the silica, which appears in the form of fine needles on the surface of the pigs.

Spiegleisen of different casts, appearing entirely uniform, can be ot a very different chemical constitution in reference to the manganese. The buying and selling of spiegeleisen is based at present upon its standard of manganese; each cast should therefore be analysed.

The following analyses represents the chemical constitution of iron from two establishments in Rhenish Prussia, well famed for their products:

	HAMM*	HOCHDAHL*
Carbon - -	4.129	5.04
Silica - -	0.458	0.41
Copper - -	0.291	0.16
Manganese - -	8.706	7.57
Iron - - -	85.929	86.74
Sulphur - -	....	0.08
Phosphorus - -	....	....
	99.513	100.00

From Dr. H. Wedding's (Professor of the Royal Polytechnical Academy of Berlin) additional explanations to

*See Chapter II.

Perry's Handbook on Iron, I glean also the following partial analyses of German and other spiegeleisen:

	MANGANESE.	CARBON.
Analyzed by Tooky -	11.12 ℔ cent.	4.77
Analyzed by Fresenius	10.707 ℔ cent.	4.323

These and many other analyses of well known chemists seem to prove, that the chemical constitution of the spiegeleisen is not only Fe. 4 C, as taught and believed up to this time, but that the chemical formula of its composition must be:

(Fe. mn) 4 C.

II. OF THE PRODUCING OF SPIEGELEISEN IN FOREIGN COUNTRIES.

The countries which at present produce the bulk of spiegeleisen—Russia, Sweden and Germany—are, strange to say, worked upon the most different iron ores, while they, notwithstanding, come to the very same result.

A.—RUSSIA.

The country around the coast of the Baltic Sea contains very rich mineral deposits of magnetic ores and around the many lakes and scattered over the whole country, such as brown hematites.

I give here, and in the following chapters, some analyses made under the supervision of Prof. C. F. Rammelsberg, Prof. of the Berlin Royal Polyt. Academy.

BROWN IRON ORE FROM NISCHNEI–NOVGOROD.

	I.	II.
Oxide of iron - -	30.57	32.75
Oxide of manganese - -	1.55	1.00
Water - - - -	13.87	13.00
Phosphoric acid - -	2.93	3.50
Silica - - - - -	......	......
Sand - - - -	50.28	47.50
Precipitated silica - -	1.08	2.50
	100.28	100.25

In No. I. the 2.93 per cent. of Phosphoric acid are equal to 1.28 phosphorus.

In No. II. the 3.50 per cent. of Phosphoric acid are equal to 1.53 phosphorus.

For fuel, charcoal is used, and at Nischnei Tagilsk they produce a spiegeleisen which is known everywhere for its excellent qualities. The iron ores (which contain, as the analysis shows, only a small amount of manganese) are mixed with an iron—containing Brownit—bearing 40 per cent. of manganese and 10 per cent. of iron. The yielding mottled iron contains in the average 1.2 per cent. of manganese.

At Watkinskii they melt this iron in a cupola furnace and adding some 12.15 per cent. of oxide of manganese (Manganit or Pyrolusit) a spiegeleisen results, which contains from 5 per cent. to 6 per cent. of manganese, and which is especially suitable for the manufacture of steel.

B.—SWEDEN.

The Scandinavian peninsula is very rich in excellent iron ores, occurring in three different classes.

The first class, containing from 6 to 10 per cent. of manganese and represented by the manganiferous magnetic iron ores of all the primitive rock formations, as Granite, Gneiss, etc., is very pure. Quartz very seldom occurs, while there is oftentimes some calcareous gangue mass present, enough not to require an admixture of flux to the ores in the blast furnace. Phosphorus is very seldom, while sulphur, even in the very best ores (of Dannemora) appears.

The second class comprises series of red hematites, both in a compact or a soft form, in veins forming gangues in quartzite. This class, therefore, is accompanied by some silica.

The third class is represented by those brown ores of the very latest formation, occurring at the bottom of lakes or marshes.

The district of Wermeland, the principal geological formation of which is the Gneiss, bears magnetites in the neighborhood of Presberg, Taberg, etc., and red hematite in the vicinity of Philipstadt and Carlstadt.

Delarne and Westmorland are well known for their manganiferous magnetic ores of the crystalized slates in the Gneiss. The mining regions of Bispberg, near Sater and Schisshyttan, Ramshyttan in Dalesarlien are the note-worthiest. In the following are shown some analyses of ores:

MAGNETIC ORES.

Peroxyde of iron	69.74	75.87	70.23	70.41	71.85	70.71
Sesquioxyd of iron	30.00	24.13	29.65	29.40	28.00	28.78
	99.74	100.00	99.88	99.80	99.85	99.49

BROWN IRON ORE.

Oxyd of iron	62.56
Oxyd of manganese	2.60
Magnesia	5.80
Silica	20.40
Phosphoric acid	0.68
Water, etc	7.50
	99.54

GRANULAR IRON ORE.

Iron	43.53
Manganese	3.45
Lime	1.80
Magnesia	0.08
Alumina	3.41
Silica	39.84
Phosphoric acid	0.18
Sulphuric acid	trace
Water	7.70
	99.99

For fuel, either charcoal alone, or a mixture of hard charcoal and coke, (equal parts,) is used. Generally, the blast furnaces are blown with hot blast and about 30 per cent. of lime are added to the mixture of ores for flux.

The general features of the greater part of the Swedish furnaces are the following: The cavity has the form of an elongated ellipse, whose small diameter is about 7½ feet across, at a height of 14 feet above the bottom of the hearth; hence, at this part, the interior space constitutes a belly corresponding with the upper part of the boshes. In other respects, the details of the construction resemble those of England, Belgium, Rhenish Prussia, and others. Such furnaces are related to yield (by only 30 feet height) 47 per cent of iron.

Fig. 1.

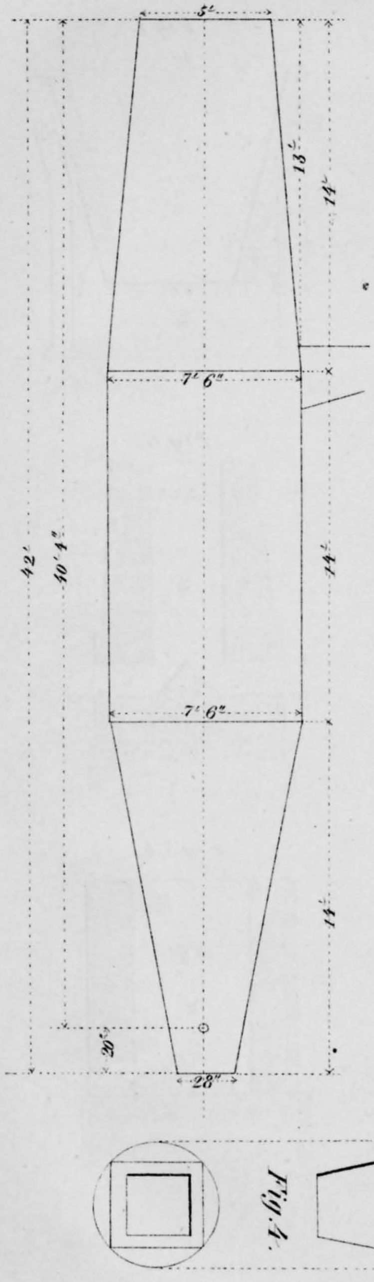
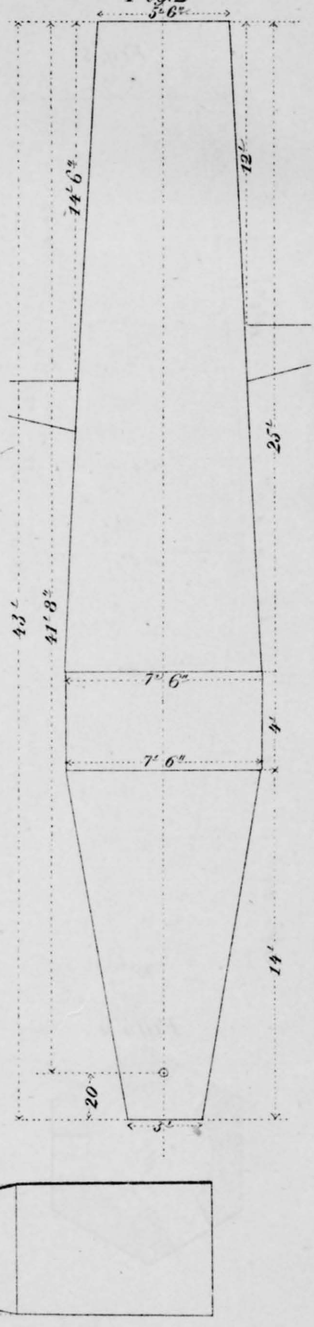


Fig. 2



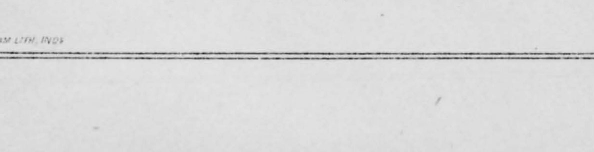


Fig. 4.

BRADEN & BURFORD, STEAM LITH. INDP.

Fig. 3.

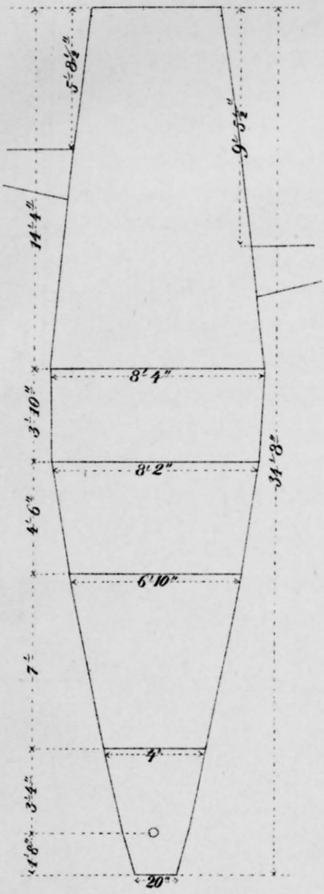


Fig 7.

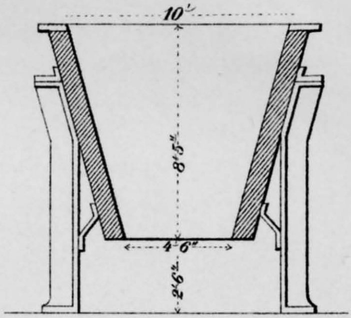


Fig. 6.

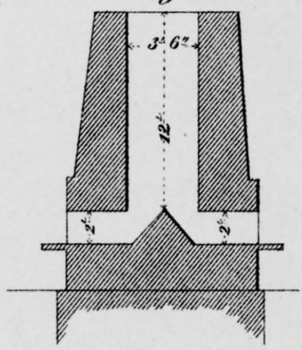


Fig. 5 a.

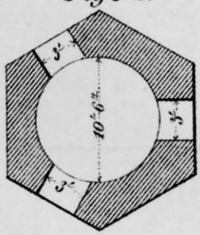
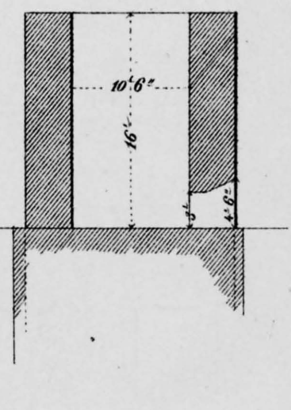


Fig. 5. b.



BRADEN & BURFORD, STEAM LITH, INDP

At Hammarby the blast furnace has the dimensions shown in Fig. I, Tab. I. She is blown with three tuyeres 22.7''' (1.89 inches) diameter; the noses of the two tuyeres, on opposite sides having each a diameter of 19.9''' and the nose of the tuyere in the posterior wall of 18.5'''. The gases are used for the heating of the blast air and for the calcining of the ores. They (the gases) are taken from the furnace at a point about 13' below the tap.

The usual charges are composed each of,

Fuel—32.7 cubic feet charcoal=316.4 lbs.*

Ores—iron glance (containing quartz), with 44 per cent. iron=340.0 lbs.; red hematite, with 50 per cent. iron =238.0 lbs.; magnetic iron ore, with 56 per cent. iron =42.0 lbs.

Flux—lime (dolomitic), nearly 24.9 per cent. of the ores =153.0 lbs.

The number of charges given in 24 hours is about 48 or 50. The yielding of the mixture (ores and flux) is from 38 to 40 per cent. of pig iron, partly gray, partly mottled. The blast is heated to 200° C, (392° F,) and has a pressure of 20.4–23.1'''.

The blast furnace at Forssjoe is of the dimensions as shown in Fig. 2, Tab. I. The furnace is blown with two tuyeres of 28.3''' diameter, the noses having a area each of 3.6 square inches. The gases for heating the blast air are taken about 12' below the tap, those for the calcination of the ores, 14½' below.

Each charge is composed of,

Fuel—charcoal, 43.2 cubic feet=401 lbs.

Ores—manganiferous magnetits (containing quartz), =723 lbs.

Flux—lime (16.43 per cent of the ore)=119 lbs.

*1 Swedish ton=6.3 cubic feet Swedish.

2.2046 lbs. English (avoirdupois)=2.3511 Swedish.

The blast air is heated to 170° C. (312° F.) and has a pressure of 16.3 to 17.7‴. The yielding from the mixture is 44.4 per cent. of mottled pig iron.

The blast furnaces at Hasselfors are represented in Fig. III, Tab. I. The upper part of the shaft is conical. Below the largest diameter, the hearth commences by means of an arched part, which is circular as far as to the vicinity of the tuyeres, and elliptical from there to the bottom. The greatest diameter of the ellipse (2′10″ reaches from the posterior wall to the tymp, while the smaller one (2′5½″) extends from side to side. The tuyere of the posterior wall has a diameter=21.9, those of the sides respectively 25.6 and 27.2 inches. The diameters of the noses are respectively, 1.91–2.31–2.31 inches.

The gases for the roasting of the ores are taken 9′5½″, those for the hot air stoves 5′8½″ below the tap.

Each charge is composed of,

Fuel—charcoal, 43.2 cubic feet=394.4 lbs.

Ores—iron glance (with 45.8 per cent. metallic iron,) =272.0 lbs; magnetic ores (49.7 per cent. metallic iron) =663.0 lbs; rich manganiferous calcareous gangue containing brown hematite=153.0 lbs.

Flux—lime=17.0 lbs.

The number of charges given in twenty-four hours is about thirty; the yielding is about 45.5 per cent. of a white, silvery iron, the pigs showing gray spots toward the centre. The temperature of the blast air is 200° C. (392° F.), the pressure is about 14.3‴.

It is found that the iron yielded from the manganiferous ores is not only of an excellent behavior in the Bessemer furnace, but also very much qualified for the producing of a first-class steel. The ores containing some quartz are found to be also very suitable for the Bessemer process as long as they are mixed with other good natured ores.

It is furthermore a fundamental rule that all the different ores are carefully calcined. An accuracy in this regard may enable the iron master to make proper use even of an ore of medium or bad quality. For, nevertheless it is a fact now that a small percentage of sulphur (about 0.15 per cent.) can be abstracted or rejected from the iron, in Bessemer's process of refinery, this depends upon the fact that the crude metal must be in every other respect of the most suitable properties. It is a singular but stated fact that in using an iron, resulting from a period of derangements in the blast furnace, the amount of sulphur very often seems to be increased in the refinery process of Bessemer. The coincidence with other different methods of refining, is very eminent. The German forge, which is generally worked upon a gray pig, is very well adapted for the utilizing of a sulphurous iron. The other methods, the Wallon, Lancashire, and French or Catalan method, refining white iron, require an iron nearly entirely free of sulphur, for the producing of a good, malleable iron. It is therefore absolutely necessary to diminish the sulphur in the crude metal as far as possible, to be suitable for the Bessemer process. And for this reason the ores have to be carefully roasted.* The furnace has always to be kept in a good working condition, the slag must bear a superamount of lime, and the heat of the blast has to be kept at a very high degree. The materials must have a regular, not too rapid, slope in the boshes, and the deoxydizing as well as the reducing process of the ores has to take place in the proper zones of the furnace. The color of the slag is the surest test of the behavior of the furnace, as it indicates the quality of the product; a yellowish, green tinted slag, slightly covered with a brown translucent coat, smelling from sulphuret of calcium, when sprinkled with water, (the excess of lime having absorbed and carried off the sulphur), will always be found to be the unmistakable sign of a good working condition of the furnace.

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*In the following chapter I shall say more about the roasting of the ores.

As to the impurity of posphórous and other obnoxious substances, there seem to exist no certain reports of the Swedish iron works, probably, because there are so many good natured ores, free from such impediments, that the former can be very easily avoided.

For the better understanding, I add two analyses of slags from the furnaces at Edskin:

	I. Containing oxygen.			II. Containing oxygen.		
Silica	47.30	24 50	......	46.37	24.08	?
Alumina	1.66		0.78	4.30		2.01
Lime	24.34		6.95	38.64		11.04
Magnesia	22.86		9.19	7.40		2.96
Potash	0.62		0.10	0 30		0.05
Soda	0.09		0.02	0.14		0.04
Protoxyd of iron	0.99		0.22	0.95		0.21
Protoxyd of manganese	1.40		0.32	1.86		0.42
Copper	1.40		......	trace		......
Phosphorus	trace		......	......		......
Sulphur	0.07		......	0.03		......
	99.73	24.50	17.53	99.99	24.08	16.73

It remains to say that the above mentioned iron works export their common product to the Bessemer establishments in England and Northern Germany. The iron works of Dalekarlien, which produce a spiegeleisen from a mixture of Knebelit and manganiferous iron garnet, containing in the average about 42 per cent. of metallic iron and 13 per cent. of manganese, export also their iron to Germany. It is rumored that the slag of the furnaces of this district contains sometimes 4 per cent. of sulphur and as much as 16 per cent. of manganese, the spiegeleisen itself bearing variably from 9 to 13 per cent. manganese and about 4 to 5 per cent. of carbon, silica, etc. Invariably it is also experienced there, that, as soon as the manganese exceeds a certain standard, the carbon diminishes proportionaly. Should the iron contain as much as 30 per cent. of manganese, the carbon is found to be reduced to 0.40 and even to 0.25 per cent.

The cost of the production of a ton of iron is very different, according to the different localities. In the average a calculation can be made in the following manner—percentage for amortization and the interests of stock excepted—for the production of 1 cwt. are afforded:

2.1 cwt. ores at 13.2cts. per cwt.	26.4c.
15 cubic feet charcoal at 2.4c. per cubic foot.	36.0c.
Wages	6.0c.
Repair	2.4c.
Wear and tear	6.0c.
	77.8c.

Or, per one ton English (of 2,000 lbs): $18,36, while the market price (at the establishment) is about $24.8–25.0, giving therefore to the interested persons a net profit of from six to seven dollars per one ton.

C.—GERMANY.

The production of spiegeleisen in this country is larger than in any other, but the same is confined to only two, comparatively small districts: the northern part of Rhenish Prussia and the south-western part of Westphalia, also a province of the Kingdom of Prussia.

THE ORES

used for the manufacture of spiegeleisen are found in gangues which are interjected in the Devonian formation of the eastern borders of the Rhine and the Hartz Mountains. They are to be classified

1. As sparry iron ores, or carbonate of iron and manganese ($Fe. O. CO_2 + Mn O. CO_2$). These ores are often impregnated with quartz, copper pyrites, sulphates of iron, lead and zinc. It is therefore absolutely necessary, that a

very careful roasting of the ores takes place in order to reduce the sulphates, which the ore, as presented by nature, may contain.

2. As red or brown hematite.

Both varieties of ore contain, the former more, the latter less, manganese. Besides these two principal classes some argillaceous carbonate of iron, or clay iron stone is used as an auxiliary in some establishments.

The following tables give an average of the chemical constitution of several of the best known mines:

SPARRY IRON ORE.

	1	2	3	4	5	6
Protoxyd of iron.....................44.9	44.9	47.96		50.72	47.20	....
Carbonate of iron..............................	......	......	74.47	......	......	82.63
Protoxyde of manganese............10.3	10.3	9.50	......	7.64	8.34	......
Carbonate of manganese..................	......	......	17.08	......	......	15.45
Magnesia..	1.0	3.12	......	1.48	3.75	......
Carbonate of magnesia......................	......	......	5.75		......	......
Lime...	1.0	......	......	0.40	0.63	......
Carbonate of lime..............................	......	......	1.34	......	......	......
Carbonic acid..................................	37.0	39.19	1.08	38.90	38.85	......
Silica or gangue mass.......................	4 2	......	......	0.48	0.95	......
Water...	......	......	......	......	......	1.91
	98.4	99.77	99.72	99.62	99.72	99.99

No's 1, 2, 3, are from mines at Stahlberg, near Musen, in Westphalia.

No. 4 are from mines at Kesselgrube, near Siegen.

No. 5 are from mines at Kirschenbaum near Siegen.

No. 6 are from mines at Brische, near Siegen.

RED HEMATITE.

Iron	38.72	38.73
Manganese	0.81	1.64
Oxygen	16.90	16.59
Silica	29.15	21.41
Alumina	8.40	11.09
Lime	0.16	2.02
Magnesia	0.14	1.41
Water	4.89	7.33
Phosphoric acid	0.01	0.64
Sulphuric acid	0.13	....
	99.31	100.86

These analyses are taken as a fair average from several others of a group of mines near Wetzlar on the Lahn, a tributary of the Rhine. They give the best picture of all the ores of the surrounding mining districts. These ores are extensively consumed by all the works on the Lower Rhine.

BROWN HEMATITE.

Iron	39.33	25.00
Manganese	2.00	4.59
Oxygen	17.80	12.65
Lime	0.52	0.46
Magnesia	trace	....
Alumina	12.50	7.23
Silica	16.18	33.01
Water: chemic. combined	2.40	2.40
Water: hygroscopic	8.99	14.44
Phosphoric acid	0.09	0.17
Sulphuric acid	0.27	0.03
	100.18	99.98

The ores are in the vicinity of Linz on the Rhine; they are also extensively used.

According to some news which I received lately from Dusseldorf, there is, since a short time, also used in combination with the ores mentioned, to a limited extent, an ore imported from Spain, sparry ore as well as brown iron ore, the analyses of which are in an average the following:

	BROWN IRON ORE.	SPARRY ORE.
Protoxyd of iron - -	......	53.17
Sesquioxyd of iron - -	70.10	......
Sesquioxyd of manganese -	3.65	3.70
Lime - - - -	0.32	2.30
Magnesia - - - -	0.23	3.80
Alumina - - - -	6.33	......
Silica - - - -	13.66	7.60
Water and carbonic acid -	5.71	29.71
	100.00	100.28

THE ROASTING OR CALCINING OF THE ORES,

is executed mostly in kilns of which there are about five different kinds. One group or class has a grate, upon which a fire is sustained for warming the kiln, and which is afterwards taken away, while the four other classes have no such grate, and differ in the following way:

The first class has a cylindrical shaft with a smaller, rectangular hearth below (Fig. 4 Tab. I), a horizontal bottom and two openings for the extracting of the roasted ore.

The second class (Fig. 5) has a shaft bearing the same dimensions from the top to the bottom, and three apertures on the horizontal bottom

The third class (Fig. 6) has a cylindrical shaft and a conical bottom, the top of the cone laying in the centre-line of the kiln, with two apertures.

The fourth class (Fig. 7) represents a truncated cone, supported by pillars, the greatest diameter of the cone forming the top.

The manner of conducting the process of roasting is the same in all cases. For fuel small coke is always used, of about one-half to three-fourth inches diameter. The proper charge of ore is spread evenly over the coke to a depth of six to eight inches and the fire is pushed moderately, while the roasted ore is progressively withdrawn below.

As to the chemical action taking effect in roasting, I may remark the following:

Sparry ore is natural carbonate of iron and is, in its purest state, a compound of $Fe\ O,\ CO_2$. But in the sparry ore mostly always a part of the iron is replaced by manganese, and this in certain proportions. Likewise are lime and magnesia proportional substitutes. According to Rammelsberg the ore of Musen, (near Siegen), is $Mn\ O,\ CO_2,+4\ FeO,\ CO_2$, or is composed of

Peroxyd of iron - -	49.01=37.85 metallic iron.
Peroxyd of manganese	12.45
Carbonic acid - - -	38.46
	99.92

Sparry ore, as a crude mine, is very indifferent to reduction, but roasted and submitted for a certain period to a process of decantation and decomposition—by means of the influence of the atmosphere and humidity—it can be very easily reduced, giving in the furnace the very best material for the Spiegeleisen. The sparry ore oftentimes turns over by natural decomposition into brown hematite, which, nevertheless always contains some carbonate of iron, and much hygroscopic water.

By means of the chemical process: the roasting, decomposing and decanting:

1st. The peroxyd changes into sesquioxyd.

$Mn\ O,\ CO_2+4\ Fe\ O,\ C\ O_2—Fe_2\ O_3$, 56.21=81.89, containing 59.78 iron. $Mn\ O$, 12.49=18.11, because the $Fe\ O,\ CO_2$ changes to $Fe_2\ O_3$=68.34 and in 100 parts of $Fe_2\ O_3$ are 69.34 Fe.

2d. The phosphoric acid, always combined with lime or iron, is insoluble in water, but even slightly acidulated waters dissolve it.

It is for this reason that the sulphuric acid, formed by the decomposition of the sulphates acts as a solvent upon the phosphates.

If the phosphorus of the ores is combined with the oxydized iron itself, it will be ejected to a small amount from the molten iron instead of a corresponding part of silica, which will join the iron.

If the phosphorus is not combined with the iron, but with other compounds, such as lime, magnesia, or alumina, it will go for the greatest part into the slag, as soon as the same bears an superamount of bases. But, if the slag is acid, the silica absorbs all the bases and the phosphorus will always join the iron.

3d. The bisulphuret of iron changes into sulphate of iron ($Fe\,S_2$ into $Fe\,O, SO_3$ in taking up two parts of O,) which is very soluble in water. It is to be remembered, that the sulphur never can be ejected from the ores by means of the roasting process alone; decaying and decanting have to do the rest. It is therefore entirely incorrect to bring such ores into the blast-furnace as soon as they come from the roast-kiln; three or four months at least, they should be subjected to the two latter processes named. For, if there is not a large superamount of lime in the charge of the furnace, or in the slag, the sulphur will always join the iron. In offering sulphur to a large amount of lime it forms sulphuret of calicum, Ca S, which is chemically combined as follows:

1 part S, 44
1 part Ca, 56

100

In forming the calculation for the construction of the slag it must, therefore, always be remembered that 100 parts of sulphur afford:

127.13 calcium.
178.15 lime.
316.60 carbonate of lime.

The formation of large quantities of this Ca S often takes place in furnaces using coke for fuel. It appears as a fine white powder, covering the tunnel-head and the tymp of the furnace. Naturally can its amount in a slag be of the most different quantities, but slag, containing much of it, is heavy and crumbles under the influence of the atmosphere to a coarse powder.

In conducting the calcination, care has to be taken not to expose the ores to a too great heat. For over-roasted ores, which have a vitrified appearance, resist very much the reduction, because the lime or other bases can not operate on the same. Such over roasted ores should always be charged to the furnace only in small quantities, mixed with others.

Having explained somewhat the chemical action of the roasting process, it remains to say something about its economy.

At Charlottenhutte, near Siegen, where a kiln of the second class is in operation, the diameter of which is 7′, and another one of 11 feet diameter, each about 15′ high, they roast—

In the smaller kiln: 6 wagons of 40 cwt.=24,000 lbs. per 24 hours, with an expenditure of 10 cubic feet fuel. The wages paid are 18c per wagon.

In the larger one: 10 wagons of 40 cwt.=40,000 lbs., with 17.8 cubic feet fuel in the same time; same wages

At Rolandshutte, a kiln of class 4 is in operation, 9′ high, roasting daily 40,000 lbs. of ore by means of 10.14 cubic feet of fuel, and 12-13.2 cts. wages per 4,000 lbs. roasted ore. Time the same as above.

At Storch & Schoneberg, near Gosbach, a kiln of class 1., 14½′ high, 6′ wide, is in operation roasting 28-32,000 lbs.

ore in 24 hours, with an expenditure of 16-17.8 cubic feet fuel, and 12-14.4 cts. per 4,000 ℔s., for wages.

At Hainer Hutte they use a kiln only 5′ wide but 15′ high, of class 2, roasting 20,000 ℔s. in 24 hours, using 13 cubic feet of fuel.

These examples show, that the production increases with the width of the kiln, and that the consumption of fuel increases with the decreasing production.

I can not omit mentioning another kiln of late construction, which is found to be working always in a very economical manner. It is constructed with two grates, one above the other. Its height varies from 18 to 20 feet, the diameter from 9½ to 10 feet. The usual charges are 8.4 cubic feet fuel and 4,500 ℔s. ore, alternately spread above the upper grate. A fire is maintained in the lower grate and the withdrawing of the roasted ore takes place once in 24 hours by means of pulling out the upper grate-bars. The production of this kiln amounts to 45,000-50,000 ℔s. per 24 hours.

It remains to remember that besides the expelling of the carbonic acid, water, etc, the roasting affords the very best means for the separation of the quartz. The roasted pieces are broken down to the size of nuts, and while the ore itself bears a dark, reddish brown color, the quartz is of a pure white appearance, so as to be easily recognized.

It is stated by experience that:

The magnetic ores lose	3–5 per cent.
Iron-glance and hematite, red	3–5 per cent.
Hematite, brown	10.5–14.7 per cent.
Sparry ore	28–35 per cent.
Argillaceous ore	18–30 per cent.

of their weight in roasting, but also that all compact ores, after some time, take up 2 per cent. hygroscopic water, and all soft ores 6 per cent. hygroscopic water.

Furthermore: that fuel, (coke cinders) of a size not less than ⅓ and not more than ¾ diameter, answers the best, and that

One part of coke cinders (by weight) is sufficient for 20–30 parts of ore.

One part of charcoal (by weight) is sufficient for 10 parts of ore.

One part of crude coal (by weight) is sufficient for 5–8 parts of ore.

I shall pass now to describe a few of the iron-establishments best known for the Spiegeleisen which they produce. To enumerate all would exceed the limits of this paper, for there are over fifty, all of good fame. I shall divide them in two groups.

FURNACES USING CHARCOAL OR CHARCOAL AND COKE, MIXED, FOR FUEL.

As an example of this group I name the Laher Iron Works, near Siegen, in Westphalia. The blast-furnaces of this establishment belong to the Cohn-Musner Iron Co., and use either pure charcoal or pure coke, seldom a mixture of both, for fuel. If charcoal is used, the charges are composed of

30 cubic feet charcoal of hard wood,
1,035 lbs. roadside ores,
180 lbs. lime (17.5 per cent. of the ore.)

If coke alone is used, they are composed of

42 cubic feet coke.
21.97 lbs. roadside ore,
602 lbs. lime (27.4 per cent. of the ore.)

If a mixture of coke and charcoal is used the charges consist of

10½ cubic feet coke,
20 cubic feet of charcoal,
1,233 lbs. roasted ore,
360 lbs. lime, (29.2 per cent.)

The number of charges given in 24 hours is, in the average, forty.

The principal dimensions of the blast furnaces are the following:

DESCRIPTION.	Dimensions Feet.
Height, total	4.24
Height of the hearth	4.3
Height of the boshes	9.6
Height of the cone	28.5
Height of the chimney	6.0
Width of the bottom of the hearth	4.3
Width of the upper end of the hearth	4.3
Width across the boshes	11.3
Width of the mouth	5.3
Height of the center of the tuyeres above the bottom.	2.1

The temperature of the blast air is, in the average, 570° F., but this is regarded as not sufficient. The latest news received from that place states that the company is engaged in the building of two more hot air ovens after the best and latest plans, thus giving four heating furnaces to each stack.

Each furnace is blown with three tuyeres. The diameter of the nose pipes varies according to the nature of the fuel used, also the pressure; the former changing from 16.6 to 21‴, the latter from 16 to 22.‴

The waste gases of the furnaces are used for heating the steam boilers and the hot air ovens. They are taken near the top of the furnace, which is closed with a cover and opened for each charging.

To produce a good spiegeleisen great care is taken to conduct the furnace in snch a manner that the charges slope down very regular and slowly, in order to expose the manganiferous ores as long as possible to a rigorous deoxydizing and reducing process. For only in such a manner can it be successfully entertained that the highest possible amount of manganese be reduced and combined with the iron.

For the same reason the temperature and the pressure of the blast have to be kept at a high degree. The smelting zone particularly—that is the point at which the carbonized iron is brought to a liquid state, has to be kept as near as possible to the tuyeres (or, in other words, as low as possible in the hearth), for when the room of this zone expands too much, the heat never can be great or concentrated enough to produce the process wanted—the joining of manganese and iron. Should it nevertheless happen that this zone goes too high (as it is often the case in those furnaces of Westphalia, which are worked upon a very porous coke), proper remedies have to be applied, such as diminishing the pressure, charging of soft ore, moistening of the same, etc.

As to the cost of producing spiegeleisen at Laher, the following data are given:

During a period of six days (by coke and charcoal mixed) were

CONSUMED.	AT A COST OF.	PRODUCED.
190 tons of roasted ores	$745 00	28,333 lbs. per day,
55½ tons limestone	41 75	or 85 tons in
6,150 cubic feet charcoal	339 25	6 days.
48½ tons coke	174 75	
For breaking of 55½ tons limestone	7 00	
For transportation of slag	13 75	
For wages	55 00	
For general cost, wear and tear	28 00	
	$1,404 50	

Each ton costs, therefore, $\frac{1404.50}{85}$=$16.53. From this statement it follows also that

1. The yielding of the pure mine was....44.73 per cent. of metallic iron
2. The yielding of the mixture (ore and lime)....34.60 per cent. of metallic iron
3. Per ton of iron were consumed—coke....1,140 lbs.
4. Per ton of iron were consumed—charcoal.... 651 lbs.
5. Per ton of iron were consumed—ore....4,235 lbs.
6. To 100 lbs. ore were consumed—lime.... 29.2 lbs.

In using pure charcoal, the price of one ton increases to about $18.50; in using pure coke, the price of one ton diminishes to about $15.

FURNACES USING COKE FOR FUEL.

All the establishments of a later existence now use simply coke for fuel. The iron works at Sayn, Charlottenhutte, Hamm, Oberhausen, Duisberg, Hochdahl, etc., are based entirely upon the employment of this material. By all evidence it is a fact now—certainly after much trouble and many fruitless trials, as I stated at another place—that coke is preferable to charcoal or a mixture of charcoal and coke, because the heat can be far more increased in the former than in the latter case, and we know that "great heat" is one of the requirements for the production of a good spiegeleisen. Of course, the coke has to be of a first-class quality, free from a noticeable amount of ashes and sulphur. Past experience has proved that, in using coke, more manganese joins the iron, as if the same ore was worked by means of charcoal. Ores very rich in manganese are better treated in the furnace with coke than with soft charcoal.

The rules for conducting coke blast furnaces are, in general, the same as for charcoal—I refer, therefore, to those mentioned above.

Mostly all the furnaces of this group are blown with three tuyeres, some with five and seven (one in the posterior wall and a set of two or three at opposite sides), the nose pipes having from two to three inches diameter, with a pressure of the blast air of from two to two and a half and three pounds per square inch, and a temperature of 350 to 400° C. (6750° F.). The furnaces have a capacity so as to produce 60,000 to 80,000 pounds per 24 hours; the dimensions are mostly the following:

DESCRIPTION.	DIMENSIONS. Feet.
Height, total	56 to 58
Heighth of the hearth	6 to 7½
Height of the boshes	10 to 12
Height of the cone	38 to 40
Height of the chimney	8 to 9
Width of the hearth, upper part	3½ to 4½
Width of hearth, lower part	3 to 3½
Width across the boshes	13 to 15½
Width of the mouth	9 to 9½
Height of the center of the tuyeres above the bottom	2½ to 3
Square contents of the mouth—sq. ft	63.6 to 70.8
Square contents of the boshes—sq. ft	133 to 189

The charges of the furnaces at Hochdahl, Duisburg, Hamm and Oberhausen, are, in the average, composed as follows :

Coke—1,680 lbs.; ore—2,800–3,500 lbs.; lime—1,200–1,400 lbs. (35 to 40 per cent.).

Others charge their furnaces in the following manner :

Coke—2,400 lbs.; ore—3,000–4,500 lbs.; lime—1,570 lbs. (35–40 per cent.).

In the average all the furnaces use per 1,000 lbs iron :

Coke—1,250–1,900 lbs.,
Ore—2,500–2,600 lbs.,
Lime—850–900 lbs.

The above mentioned analysis of iron from Hochdahl and Hamm give a good idea of the excellent quality of the iron produced in all these furnaces.

Consequently, one finds now-a-days Bessemer furnaces everywhere and the fabrication of cannons, rails, tires, implements of every description has already reached a point where a "halt" is impossible.

It is from this state of affairs, not only in Germany, but also in Sweden, and Russia, that I derive my judgment.

D.—INDIANA.

The Bessemer-steel manufacturers of our country thus far could not very well do without the peculiar kind of English iron, which resembles very much the Spiegeleisen. But I do not say too much in stating, that the time is not very distant when, throwing overboard such an auxiliary, Indiana will be the State, where not only the crude metal for the Bessemer steel will be produced, but where also the steel manufacturing process itself will open a new era to her health and wealth.

The block coal of Indiana is unsurpassed by any other tuel. Profs. Cox and Foster are the developers of the extensive beds of this marvelous coal, and their geological reports are so well known that I can not do better than refer to the same. Blast furnaces, rolling mills and also steel works have tested the new fuel thoroughly and severely, with results leading to the conclusion, that there is no better fuel whatever. The blast furnaces at Brazil, Knightsville, Shoals, Harmony and Terre Haute, produce by means of this block coal an iron of superior quality, proving therefore, the adaptability of the block coal for smelting purposes.

There are also iron ores in different counties of the south-western part of the State, well adapted for admixture. It remains only to bring good natured ores to the coal. Every where in the manufacturing centres of England, Belgium, France or Germany, it is always found to be more economical to conduct the iron ores to the coal, than the latter to the former. Experience of decades has proved this to be a fundamental law for every establishment, which pretends to be a well conducted one.

And the facilities in this regard are excellent for Indiana. To the north as well as to the southwest she is connected by means of rail with countries bearing a superamount of splendid ores, well adapted for the fabrication of Bessemer crude pig iron. These countries are: the Lake Superior iron region in the north—the Iron Mountain region of Missouri.

To commence with the northern region, I give below a series of analyses, which will give the best testimony of my assertion of their being suitable for Bessemer crude metal, for in comparing these analyses with those mentioned above under Sweden and Germany, one must come to the conclusion that the ores bear exactly the properties which are wanted for the production of Spiegeleisen.

There are five varieties of ores in the Lake Superior region:

1. The most valuable is the specular hematite, a very pure anhydrous sesquioxyd, occurring either granular or massive. It yields from 60–70 per cent. of metallic iron.

2. A soft hematite, very much resembling the brown hematite (limonite) of Pennsylvania and Connecticut, and generally associated with specular ore, from which it is supposed to be formed by decomposition and disintegration. It is very easily reduced in the furnace, yields about 50–55 per cent. of metallic iron and is of a very porous structure.

3. Magnetic ore, from which very likely the specular ore originated, by some metamorphic action. In some of the mines it is of a dark, bluish, black color, highly penetrated with crystals. It is very heavy, and, when free of quartz, resembling almost black oxyd of iron. It yields from 70–72 per cent.

4. Flag or slate ore, a silicious hematite, containing less metallic iron and of a very indifferent character in the furnace.

5. Silicious iron ore containing a variable amount of manganese and deposited always in the vicinity of the flag ore. This ore is of the greatest value as an admixture, for the smaller percentage of metallic iron is favorably replaced by the valuable manganese.

All manufacturers of iron understand the great advantage of having such a variety of ores. In England, the foremost importer of iron into the United States, can not do well without drawing upon Sweden and Russia for the best qualities of ores. The magnetic ores of Lake Superior have been sufficiently tested to prove that they produce the best quality of iron, and it is known that from a mixture of the magnetic with the different hematites of this district alone, can be produced every grade of iron that can possibly be required. The ores, without any notable percentage of sulphur, phosphorus or other obnoxious foreign substances, are embodied in mines, the gangue-matter of which are silicates of iron, alumina, lime and quartz.

Analyses of ores from the Marquette district are contained in the following table:

Iron, metallic, -	64.0	58.0	67.0	66.0	58.0
Oxygen, - -	27.0	24.0	26.0	28.0	24.5
Alumina, - -	2.0	2.0	1.5	2.5	3.5
Lime, - -	0.2	0.8	1.0	1.7	2.5
Gangue matter, -	6.5	15.0	4.5	1.5	11.0
	99.7	99.8	100.0	99.7	99.5

Such ores need no careful calcination, because nature itself has performed the process of decomposition.

Some later discoveries prove that there is also in Spurr Mountain district a deposit of manganiferous ores. Specimens collected for analysis from many parts of the outcrops of this new bed and from loose masses, have the following constituents:

Metallic iron	67.32
Oxygen	25.70
Oxyd of Manganese	1.01
Silica	3.06
Lime	0.12
Water	0.57
Alumina	2.12
	99.90

And it is already found that the percentage of manganese increases with the depth, and there are reasons to believe that this manganiferous ore will be found abundantly throughout the whole district. The ores of the Iron Mountain mine contain also this highly prized metal. Some of this ore has already been shipped and most successfully tested and used in the manufacture of Bessemer crude metal.

Other ores have been tested and found to possess a peculiar quality as compared with others, being equally prolific in the yield of metallic iron. It is the presence of large quantities of carbonate of lime in the body of the ore that gives it its particular character. It is this that at once recommends it to iron producers, for this ore is eminently fitted for mixing with other and especially silicious ores. The ore is said to contain from 45 to 50 per cent. of iron and 15 to 20 per cent. of lime. That this is an eminently important service to the metallurgy, and that such an ore must take a place in the very first rank even among the other rich Lake Superior minerals, will be admitted by every one who looks at the question in a practical light. It will produce economy in smelting, in supplying a lime flux in its most favorable conditions, and in allowing the use of a cheaper kind of ore (Indiana ore) in mixture with it, without introducing any deleterious substances to injure the quality of the iron produced. The blast furnaces of the Lake Superior iron district, numbering to about fifteen, produce an iron excellent in quality. They are, up to this time, using charcoal for fuel, except the Marquette furnace, which runs on bituminous coal from Pennsylvania.

The expenses per one (1) ton of iron are about:

$13 50	for fuel.
6 75	for ore and flux.
6 75	for labor, etc.
$27 00	

It is but fifteen years ago since the first shipments of the ore took place. Since that time mines have developed into an inexhaustible source of wealth, proving the superiority and excellency of the ores. From 1,500 tons of ore in 1855 the shipment increased to over one million of tons in 1872. The largest portion of the ores go to Cleveland, whence they are reshipped to the coal fields of the Mahoning and Shenango valleys by rail. The average cost of mining and delivering ore on the cars, at the mines, is estimated at $2.00 per ton. The cost of transportation to Cleveland via Marquette was last year $4.25. At these rates the ore is put upon the docks at Cleveland at a cost of $6.25, where it is sold at $8.00 and upwards.

About one hundred furnaces in Ohio and Pennsylvania use Lake Superior ore and this number is rapidly multiplying because the iron masters find that it is more economical to use a rich, pure ore from a distant location, than a cheap but impure one of the neighborhood of the furnaces.

From such facts it proves sufficiently, that the fame of the Lake Superior ore is a well supported one. But in comparing the same with the state of affairs in Indiana, we may say, that every point of the block coal field is far more favorably situated than any of those iron establishments throughou Pennsylvania or Ohio. Favorable points in Clay county coal fields are about 180 miles from Chicago.

Taking the same cost for mining..........................	$2 00
Transportation from the mines to Escanaba (62½ miles at 1⅓c per ton a mile)............................	83
Transportation from Escanaba to Chicago per 1 ton...	1 00
Transportation from Chicago to Clay county, Ind......	2 40
	*$6 23

*This estimate is, comparatively correct, but the freight and ores may now be had for something less. From Terre Haute to Chicago the distance is 183 miles. From Indianapolis to Chicago it is 194 miles; and from Indianapolis to Michigan City where Lake Superior ores may be had as cheap as at Chicago, the distance is 154 miles by rail.—E. T. C.

This would be a price for which the ores can be put on market at the locality named, enabling the Indiana iron-master to produce not only a good iron, but also an iron as much cheaper as the freight from Cleveland to the furnaces in Ohio or Pennsylvania.

Having spoken thus far only of the manufacturing of iron with Lake Superior ores and block coal, it remains also to mention the distribution of ores in Indiana.

Of the ores of Parke County, says Prof. Cox in his Geological Report, the banded and kidney ores are abundant throughout the county, and they are estimated to yield about 30–33 per cent. of metallic iron. Very good natured clay iron ores are also found at different creeks of this and other counties, which Prof. Cox classifies in the following manner:

1. The impure carbonate of iron, including clay iron stones, in flattened spheroidal masses and in bands, more or less continuous, associated with argillaceous shales.

2. Brown sesquioxides or limonites.

3. Silicious oxides.

The ores indicate sufficient richness to justify smelting, whenever facilities can be had for cheap and ready transportation. Especially do they show that the country has the desirable ore for admixture with those of Lake Superior and Missouri.

Close to the block coal fields we have, thirdly, the well known Iron Mountain ores of Missouri. These ores, forming veins in the crystalized slates, contain in the average:

Peroxide of iron	40.97 per cent.
Sesquioxide of iron	46.60 per cent.
Silica	7.28 per cent.
Alumina	5.45 per cent.
	100.39

There is also the red hematite from Pilot Knob, the constituents of which are:

Sesquioxide of iron	84.85
Silica	10.41
Alumina	5.64
	100.90

It would be of no use to give here a more precise description of the ores of Missouri, for every one interested in the matter knows that large deposits of specular and brown hematite exist, and are mined upon, in the vicinity of the Maramec river, in Phelps and Crawford counties.

The Pilot Knob bears large quantities of silicious specular ore, while the magnetic ores are found in Shephard's mountain.

According to Prof. Foster a ton of these ores can be delivered at Terre Haute, 15 miles only distant from the seams of the block coal field, at a cost of $2.20.

In the blast furnaces, rolling mills, etc., block coal has had a thorough and severe test, as I said before, and I may add here, that it is highly preferable to coke. Coke, as stated above, is considered now the best reducing agent in the fabrication of Spiegeleisen, but the producing of coke involves a great economical loss. The volatile matter of the coal is to its greater portion wasted, and while on the one hand the coal loses in coking about 30–35 per cent of its weight, the expenses are multiplied on the other.

Practical working at Carondelet has shown that the quality of the iron made by the use of block coal, is very superior to any produced in the United States for Bessemer steel making.

Trials made in the large furnaces of the Vulcan Iron Works at St. Louis, where the charges of the furnace were composed of 2,000 lbs. of block coal and Iron Mountain ores, the temperature of the blast ranging from 750° to 800° F., resulted in a foundry pig. No. I.

It is believed that blast furnaces of a far greater cubical capacity than those used now, will prove especially valuable.

Finally, I may say that, according to Prot. Foster, the Staab coal of Spencer county, Indiana, on account of its extreme hardness and its absolute freedom from deleterious substances, will, no doubt, prove peculiarly valuable as a fuel for furnaces of great dimensions.

These facts, compared with those related to above, under Russia, Sweden and Germany, there can be no doubt that the pig iron made of Lake Superior, Indiana and Iron Mountain ore, with Indiana block coal, will be not only able to compete with English, used now as an admixture by the Bessemer steel manufacturers, but that it will be even of a far better quality. Those interested in the matter may earn great profits, and the proposed plans to erect Bessemer works in Brazil, or Indianapolis, must be con sidered as enterprises, based upon the most sound ground.