Fig. II
Cut through the Length

Cut through the Sides

Scale of Fig. II 1" : 3"
MANUFACTURE OF
Spiegeleisen, Specular or Glittering Iron.

BY HUGH HARTMANN.


In this short but very comprehensive description of the "simple process," Prof. Foster says that the 10 or 15 per cent of Spiegeleisen which is allowed to flow into the mass of decarbonized iron in the "Convertor," is, up to the present time, mostly manufactured in Germany, and brought from there to this country.

Having been employed in that country during a series of years with an Iron Works Company, especially producing
the above mentioned kind of iron, I shall try to give to the readers of Prof. Foster's letters an explanation of the manner in which the manufacturing of the Spiegeleisen is, at the present time, produced.

The Spiegeleisen, specular or glittering iron, a pig metal which breaks into more or less large mirror-like facets, was formerly produced by charcoal, out of manganiferous iron ores, its singular peculiarity being due to the presence of 10 to 12 per cent. of manganese, on which the Bessemer process depends for its success. The hot-blast furnaces were of small outlines, but always in splendid working condition. The stacks of the well-known Meisener Stahlberg Iron Works, and others in that vicinity, were built as follows:

Total height of furnace....................35 ft.  
Height of tuyeres above bottom........ 1 ft. 3 in.  
Height of hearth..........................5 ft.  
Height of boshes..........................9 ft. 5 in.  
Diameter of tunnel head..................3 ft.  
Diameter of boshes.......................9 ft.  
Diameter of upper part of hearth...... 2 ft. 8 in.  
Diameter of lower part of hearth...... 1 ft. 11 in.  

They were conducted with hot blast air of from about 300° to 480° F., the air forced into the furnace through two tuyeres of 2½ to 2¾ inches diameter, under a pressure of 1½ to 1¾ pounds per square inch. The average consumption of charcoal, per one hundred pounds pig metal, was about one hundred and eighteen to one hundred and twenty pounds; the average daily production during the year, nine thousand pounds, or four and a half tons. In the practical working of the furnace the spathic ores yielded about thirty-eight to forty per cent. of iron.

But, on account of the devastation of the forests and of the scarcity of hard wood suitable for conversion into good charcoal, this fuel, soon after the year 1859, proved insufficient for the large production of spiegeleisen wanted; therefore, they were compelled to make great efforts in replacing the charcoal by coke made from well prepared
bituminous coal, as a reducing agent, there not being in the iron manufacturing region a coal sufficiently free from sulphur and other deleterious materials to allow its use in a crude state. The spiegeleisen made with charcoal was a very valuable metal, due to the purity of the ores, entirely free from sulphur and phosphorus, and we all know that no metallurgic skill has thus far been able to expel these deleterious ingredients from any ores or coke, or prevent them from passing into the pig iron.

In Rhenish Prussia are some great and well conducted iron manufacturing establishments, (in the vicinity of Dusseldorf and Durisburg,) where, during the year 1860, the first trials were made of producing spiegeleisen with coke as the fuel. These first trials being a total failure, it is certainly a noteworthy fact that, nevertheless, the zeal of the iron-masters did not relax. On the contrary, the first, though a failure, was followed by a series of trials, and it is impossible to say how great and high a praise this persistence merits; but it required the skill of highly experienced men to solve the problem of this entirely new branch of work, while, at the present day, the fabrication of specular iron is common work to many well trained iron-masters. Having at last been successful, there are at the present time some eight or ten large blast furnaces, each producing daily some thirty tons of this valuable and peculiar pig metal.

In giving a detailed description of one of these establishments, I shall first speak of the iron ores, of which four different kinds are used.

First: Red Hematite, a very pure ore from the beds existing on the borders of the "Lahn," a larger tributary of the Rhine, in the province of Nassau. Of this ore there are two varieties; a harder and compact mineral associated with a calcareous gaugue, and a softer and pulverulent hematite. Both varieties are entirely free from sulphur and phosphorous, containing from three to four cent. of manganese, a small per centage of alumnia, water and silica. The presence of carbonate of lime in the body of the compact ore gives it a particular character and renders it eminently
fitted for mixing with other siliceous ores, there being in the ore fifty per cent. of iron and from ten to fifteen per cent. of carbonate of lime. This ore is highly esteemed for the reason that there is great economy in smelting, owing to the presence of a lime flux in its most favorable conditions. The soft pulverulent ore is richer, yielding fifty-five to fifty-eight per cent. of metallic iron in the practical working of the furnace. Both kinds are easily reduced.

Second: The products from decomposition of the specular ore—the German "Brauneistenstein"—of similar favorable constitution and equally free from obnoxious admixtures. It contains some water chemically combined (2 Fe₂O₃, 3.40) is porous in structure, yields about fifty to fifty-four per cent of iron and is more easily reduced than any other ore.

Third: Excellent spathic iron ore from the vicinity of Musen (Stahlberg), in which a certain proportional part of the iron—from eight to fourteen per cent.—is replaced by manganese.

More or less, all the spathic ores (FeO, CO₂) contain a trace of sulphur, and afford therefore, and for expelling the carbonic acid gas, and the subsequent process of dispersion and decomposition of the formed sulphuric acid constitutes by means of the influence of the atmospheric moisture. The calcination takes place in kilns, for the outlines of which see Fig. 1, page 451. In these roasting furnaces, by distributing it in alternate layers with waste coal, the ore is rendered porous and easily broken into small pieces, whereby it is more readily acted upon in the smelting furnace. The chemical constitution of the ore in the crude state is, viz.:

\[
\begin{align*}
MnO, CO₂ \rightarrow 4FeO, CO₂ \quad \{ & \text{Oxide of iron,} & \quad - & \quad 49.01 \\
& \text{Oxide of manganese,} & \quad - & \quad 12.43 \\
& \text{Carbonic acid,} & \quad - & \quad 38.56
\end{align*}
\]

The above oxide of iron equals 37.85 per cent. of metallic iron. The above ore is changed by the calcining process into sesquioxide of iron, - - 81.89 = to 56.78 metallic iron.

Sesquioxide of manganese, - 18.11.
Fourth: An aluminous ore, used for admixture with the above named ores to make a slag of a good natured character; it contains some 20 per cent. of iron.

A glance at a map of the county will show that these deposits of ores, being only from 80 to 100 miles distant are as easily accessible by navigation as by rail; the cost of transportation by railroad estimated at four and two-tenths cents per ton per mile, these ores are delivered at the furnace, by rail, at five to six dollars per ton.

To convey the ores from Nassau to the iron manufacturing centre involves a navigation of seventy-five miles at a cost of $1.20 per ton, in addition to dockage and transfer from the docks on the Rhine, making the entire cost of the ore (including the purchase money) $3.40 cents per ton.

THE FLUXING AGENT.

The flux is a very pure carbonate of lime, obtained in the vicinity of the iron works, from the borders of a small creek, the Dussell, the constituents of which are:

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonate of lime,</td>
<td>98.00</td>
</tr>
<tr>
<td>Silica</td>
<td>1.50</td>
</tr>
<tr>
<td>Hygroseopic water</td>
<td>.50</td>
</tr>
</tbody>
</table>

OF THE FUEL.

As a reducing agent coke is used (as above mentioned), the bituminous coals being purified prior to their application to the blast furnace. The coals are from the vicinity of the iron works and the ores are brought thither, for it is always cheaper to bring the iron ores into union with the coals, than the coal into union with the ores. They contain a good deal of slate and from 5. to 1. per cent. of sulphur, and to eliminate these noxious adherents they are subjected to a very careful process of grinding (to the size of a hazel-nut,) and separating by means of water, there being a difference between the specific gravity of pure coal on the one hand, and the slate and sulphur on the other, viz.:
Specific gravity of the coal, 1.21 to 1.51
Specific gravity of the slate, 2.64 to 2.67
Specific gravity of the sulphur, 1.96 to 2.05

Having been subjected to this process the coals are coked in closed furnaces (Frangois' system, fig. 2, p. 455), the charge of each furnace consisting of 120 sheppel a' 1.7-9 cubic feet a' 92-100 lbs. (1 sheffel = 1.5-6 bushels) covering the bottom of the furnace to a height of 18-20 inches. The coking process lasts 36 hours, and furnishes from 57 to 60 per cent. of coke, by weight, of a porous, cellular character, sufficiently firm to hold up the burden of the furnace and containing 8 to 10 per cent. of ashes of a reddish white or gray color. The volatile carbonic matter of the coals, after having been used to heat the partitions and floors of the coking furnaces, are sufficient to heat the steam boilers.

OF THE STEAM ENGINES:

Which produce the blast air. There are two eighty horse-power horizontal engines, manufactured by the magnificent Seraing Iron Works Company, Belgium, of the most elaborate character, maintaining four blast furnaces; and one vertical one hundred horse power engine for a fifth furnace, and for reserve.

To regulate the movement of the blast-air, it passes next to a reservoir two hundred feet long, and six feet in diameter, and equal to five thousand six hundred and fifty-four cubic feet.

The principal dimensions of the horizontal engines are as follows:

Diameter of steam cylinder .................... 3 ft. 3 in.
Diameter of blast-air cylinder ..................... 7 ft. 6 in.
Length of steam cylinder ......................... 6 ft. 0 in.

Producing, therefore, during each revolution of the fly-wheel, one thousand and sixty cubic feet, or by eighteen or nineteen revolutions per minute, eighteen thousand cubic feet, and with a loss by leakage, of twelve per cent., sixteen thousand eight hundred cubic feet.
The vertical engine has the same diameter of the steam cylinder as the foregoing, three feet, three inches.
Length of cylinder ........................................ 7 ft. 9 in.
Diameter of blast-air cylinder .............................. 8 ft. 0 in.

By thirteen revolutions per minute, there will be eighteen thousand cubic feet of blast air, less ten per cent. for leakage.

Before being forced into the furnace, the blast-air is heated by means of the gases escaping from the mouth of the furnace and collected there by means of an apparatus described in another place. Two heating apparatus of the shape like figure 3, page 460, are sufficient to heat the blast-air of each furnace.

Fifth: The outlines of the Blast Furnaces (figure 4, page 465) are as follows, there being two groups of stacks constituted after the shape of No. 1, and No. 2:

<table>
<thead>
<tr>
<th></th>
<th>No. 1</th>
<th>No. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FT.</td>
<td>IN.</td>
</tr>
<tr>
<td>Height of furnace</td>
<td>54</td>
<td>0</td>
</tr>
<tr>
<td>Diameter of tunnel head</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Diameter of boshes</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Diameter of hearth, (upper end)</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Diameter of hearth, (lower end)</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Height of hearth</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Height of boshes</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Height of center of tuyeres above the bottom</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Inclination of the boshes, fifty degrees.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Square contents of the mouth.</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>Square contents of the boshes</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>Cubic contents of the whole furnace</td>
<td>6396</td>
<td></td>
</tr>
</tbody>
</table>

The bottom and lower part of the hearth, as high as three feet above the tuyeres, are built with “Puddingstone,” a coarse grained siliceous sandstone from Marchin, near Huy, Belgium, in the province of “des Andennes,” a very excel-
lent and durable material, and the upper hearth, boshes and tunnel of the furnace with bricks formed out of the excellent fire clay from Andennes, Belgium.

The business of iron-producing is managed in the following manner. It must be previously borne in mind, and anxiously considered—this having been the problem which caused so much trouble and meditation to the iron-masters—that the spiegelzeisen is chemically composed of four parts of iron and one of carbon (Fe. 4, C.), and that the combination is only formed during the period of the smelting process, which follows immediately after the deoxidation of the iron ores.

To fulfill the conditions under which this combination of iron and carbonic matter can take place it is absolutely necessary that the mixture of ores and flux be of the most fusible nature, so as to allow of the accumulation of the charge—in proportion to a fixed amount of coke—to such a degree, that the smelting and the separation of the iron from the slag occurs at a point as near as possible to the tuyeres. It is safe to say that this separation, when resulting at a higher place in the hearth would give too great an opportunity for the carbonic acid gas (Co. 2) to carry off some of the carbonic matter from the iron, changing itself into C. O. and reducing, at the same time, the constitution of the Spiegelzeisen (Fe. 4, C.) to a lower grade of carbonization. The temperature at which the specular iron melts is the same as that at which its constitution is formed and is calculated to = 3582° Fahr.

It was therefore found necessary that the charges should be composed as follows:

30 per cent. red hematite.
38 per cent. spathic ore.
20 per cent. decomposed brown ore.
12 per cent. aluminous ore.

Yielding 40 to 50 per cent. metallic iron in the practical working of the blast furnace and to create the needed fusible slag there was added from 32 to 40 per cent of lime.

Each charge consisting of
1860 lbs. coke (according to six small wagons of three hundred and ten lbs. each.)
2800 to 3200 lbs. mixed ore.
800 to 960 lbs. carbonate of lime.

The furnace affording thirty-five to forty charges every twenty-four hours, and yielding an average of 60,000 pounds or thirty tons per day.

For a ton (2,000 lbs.) of pig metal, were consumed.
Iron ores, 4,000 lbs. = 50 per cent.
Lime, 1280 lbs. = 32 per cent. fluxing agent, yielding 37 to 87 per cent.
Coke, 2480 lbs.

The ashes of the coke are always found to represent in their chemical constitution the proportion of the

Oxygen of the acids, 2:
Oxygen of the bases 1:

Even together with a part of 3:1, while the oxygen of the constituents of the always is of slag the proportion O. of B. 1: But it would be of the slightest influence to give the ashes a proportional admixture of flux (lime) because they will melt only at the nearest point to the tuyeres, or the focus where the whole process of smelting takes place, which if brought into calculation to join the ashes will always enter the slag formed by the other earthen materials accompanying the iron.

Nevertheless, it is absolutely necessary to accumulate so much of the lime in the slag, that the same will be of a caustic character, dismembering under the influence of the atmospheric moisture.

Slags resulting from many different kinds of chemical constitution (of different ores) will always admit more carbonate of lime than it seems to be possible considering their chemical constitution.

The blast air, with a temperature of from 630° to 660° Fahr. averaging above the melting point of lead, is forced into the furnace under a pressure of 2 2/3 to 3 lbs. per square inch at the engine, and of 2.2 to 2.6 at the tuyeres.

Out of the five tuyeres two are on opposite sides and one at the rear of the furnace, each one declined a few degrees from the center of the hearth so as to force the blast-air into
a kind of whirlwind (fig. 5, page 465) which is considered the best way of distributing the compressed air through the smelting and combustible mass.

The diameter of the mouth of the nose-pipes varies from 2 to 3½ inches, according to the working condition of the furnace; each increase or diminution is made with one sixteenth of an inch. The nose-pipes are constructed in a manner so as to close the tuyers preventing the escaping or rebounding of the blast-air. (fig. 6, page 465.)

Owing to the high temperature in the hearth, the tuyers, and even the mass of stone forming the hearth, would not endure for any length of time, but being provided with a circulation of water (fig. 7, page 470) they last two or three years and over.

The signs of a good working condition of the blast furnace are, to an experienced eye, the following: The slag is nearly stony, showing a superamount of lime, only the edge being somewhat glassy, the color of the interior stony part is a light green or greenish yellow, covered on the outside with a thin brown coat; the slag flows steadily and easily over the sandstone, even to a considerable distance, proving thereby not only its own fluidity and warmth but also the existence of the desired and necessary heat in the hearth of the furnace.

The furnace is tapped every eight hours and the fore part of the hearth, as far as the tuyeres, is cleaned once during the time. The tuyeres are always clear and bright and very seldom need a mechanical cleaning, the flame escaping from the tunnel head of the furnace is without any smoke, not very hot and of a light reddish-blue color, (a hot, red flame indicating a change in the working of the furnace.) If the mouth of the furnace is closed by means of an apparatus to prevent the gases from escaping, so as to use them for heating the blast-air, they never show a temperature greater than between 140° and 176° Fahr.

The metallic iron runs into large channels formed in sand, which are covered as soon as possible with a layer of dry sand to retard its cooling, thereby producing facets of a
larger and brighter form, sometimes as large as the palm of the hand. The cold pig-metal is very brittle and sonorous; the surface of the casts are concave, the fracture representing the silvery facets, and its mean specific gravity of 1.500.

Having thus far described, to a limited extent, the materials which are used in producing the spiegeleisen, and the manner in which the smelting process is conducted, there still remains a great deal more to say; but space will not permit a review of the many points embraced in this subject. The study of periodical phenomena, the study of the physical conditions of the materials and of the action of other different physical agents, is a subject worthy the attention of iron-masters.

(Signed,) HUGH HARTMAN.

DESCRIPTION OF FIGURE 1, PAGE 451.

The kilns of the shape like figure 1, require for roasting process 100 lbs. of waste coal to each 1000 to 1500 lbs. of spathic ore, 100 lbs. of waste coal to each 500 to 600 lbs. of aluminous ore, and are sufficient to produce 7½ to 10 tons every 24 hours (about one-sixth to one-fourth of the contents of the kiln) of roasted ore. The loss, by calculation, of the spathic ore is equal to 21 to 25 per cent., of the aluminous ore is equal to 18 to 30 per cent. of moisture and other volatile matter. The spathic ore, as well as the aluminous ore, will attract some atmospheric moisture after being roasted, viz., the spathic ore from 2 to 2½ per cent., the aluminous ore from 4 to 5 per cent. The average cost of roasting the two ores is about 35 cents per ton.

FIGURE 2, PAGE 455.

The coking furnaces are three feet four inches wide by four feet nine inches high in the centre, and twenty-four feet long. There are generally from thirty to thirty-six furnaces connected in a "battery," the gases of which are conducted by means of the channel A to four steam boilers of twenty-five feet in length and seven and a half feet in diameter, each one with two boilers of two and a half feet diameter. The
coke is cooled by means of water, of which about three gallons is required to each bushel of coke. The cost of the coking process is something over three cents per 100 lbs.

**FIGURE 3, PAGE 460.**

There are fifty-two pipes in each apparatus of the shape like Figure 3, (representing a cut through the center line of a pipe), which are divided by means of a partition into two parts, so as to enable the blast-air to ascend and descend in each pipe. The latter are each of a length of from 10 to 12 feet; the surface exposed to the fire is 2429 square feet, and the cubic contents of the 52 pipes 460 cubic feet.

**FIGURE 4, PAGE 465.**

The tuyeres are made of copper and cooled with water, which enters at A so as to bring the coldest water to a point as near as possible to the greatest heat; the warm water runs off at B. The plates D, supporting the tuyeres, are also cooled with water, which is poured in from time to time before it is entirely evaporated. The tuyeres are mostly of the dimensions shown in the figure. The noise pipes of cast iron are fixed by means of a key, C, and bear on their extreme end a rounded ring which, when brought forward as far as possible, entirely closes the tuyeres.

**FIGURE 7, PAGE 470.**

The water comes from a higher point so as to be under a certain pressure, and enters the first reservoir, which is made of cast iron and covered for the purpose of supporting also a part of the brick work of the furnace. This reservoir A (of larger dimensions than the lower ones) and the following B and C, surround the furnace entirely. They are made in four parts, to give opportunity to move them easily in cases of necessity.

The water runs from A to B and C like the water of a cascade, and from the last point K to a large reservoir, from which a pump takes the supply to the steam boilers. The reservoirs B, C, and D are of wrought iron, and E of stone or cast iron.
SPIEGELEISEN MANUFACTURING.

A few general remarks on the forming of the slag.

In commencing this second chapter I begin with a few general remarks on the great influence of chemistry in the metallurgy of iron.

No study can have a greater material significance than the one which gives a knowledge of the causes of accidents in the process of iron producing, and a knowledge of the means and natural laws which enables the iron master so to modify the working conditions of his blast furnace, that all the deficiencies and defects, which always will appear at times, can not deprive him of a certain success.

The history of scientific iron producing is particularly worthy of attention; up to 1856 the directors placed at the head of iron manufacturing establishments in Germany and elsewhere, must be what people termed "practical men," and, according to such a principle, success would solely depend upon the practical skill and dexterity of men. But when new and greater demands were trying their knowledge and experience at a time when the want of iron increased by the development of railroads and every other kind of engineering work, and had reached dimensions previously unknown, it soon appeared that their experience, so highly prized, had lost its power over such new, and until then, unknown fields.

The years following after 1856 represent, therefore, a transition state of theory and practice, and while on the one hand too much reliance was placed upon the practical skill as the only attribute necessary, on the other, the theoretical skill was not more than in a state of development, and thus a very big struggle resulted in introducing science into the field of iron manufacturing.

At present, almost daily we read in the journals not only of experiments made, but of experience had under the guiding star of scientific skill, of chemistry; a science almost unknown in such practical application some fifteen or twenty
years ago, and it is entirely safe to say that in our days the knowledge, the scientific knowledge of this art is the only ground upon which even practice can grow. I do not go too far in saying that knowledge of chemistry is the bottom of the modern system of iron producing.

The more one studies the course of development of the different manufacturing branches, and especially that of the iron which is called spiegeleisen, the more he will be impressed with the truth of this assertion. The success now before us is marvelous, and only scientific working was able to produce such unexpected results.

As mentioned in my previous letter, the mixture of the different ores and fluxes, or in other words, the chemical constitution of the slag resulting from the different earthen and silicious admixtures of the different ores and flux, form the ground upon which the whole process is founded.

The principal rule in forming the slag is to supply it with more bases than the chemical constitution requires. It is necessary to know beforehand what mineral element the slag requires, and it will appear at first sight a very simple matter to have this question determined, but in looking over the several analyses made of ore from the same mine we do not find such a uniformity of the constituents of the ores which is desirable to render them reliable once and for ever as exact statements. Extended analyses of the ores, even of different places of the same mine, are needed; for those made of one place can not be made a rule for another. Hence it is necessary that well managed iron works always should keep at hand a large stock of ores, classified regularly according to their chemical constitution; and furthermore, that a well trained chemist be incessantly at work furnishing the analysis of each new ore.

I know there are, even in this country, many iron-masters who will laugh at such a conscientiousness, but I know by experience that, whatever any one may think about this assertion, it most assuredly can not be denied that all powers of the iron-masters in Germany, Belgium, and England are now concentrated in the laboratory, and this not
without success. The magnificent sparkling iron which they produce is my proof.

THE CONSTITUTION OF THE SLAG CHEMICALLY EXPLAINED.

It is not necessary to tell here the reasons why the different kinds of fuel (charcoal or coke) require each another rule for forming the chemical constitution of the slag. It is sufficient to say, because every iron-master knows this, that a blast furnace supplied with charcoal as a reducing agent requires a slag of the formula—

Oxygen of the acids : Oxygen of the bases, \(= \frac{2}{1}\); while the slag of a furnace supplied with coke must be of the proportion—

Oxygen of acids : Oxygen of the bases, \(= \frac{1}{1}\).

In the practical working the slag, which results, very seldom reaches this chemically calculated point accurately, but comes as near as possible to it, and I may say it is of the greatest importance that the management of the working conditions of the furnace permits extended variations, because without such possibility, each management itself would be merely a chimera.

In every case where only lime can be used for introduction as a base to the silica, the strictly chemical, above mentioned, constitution (1.1) of the slag is without any question the best point in view, and I may mark this constitution by means of the formula: \(\text{CaO}_3 : \text{SiO}_3\). But as stated before, the more other earthen bases are in the one itself, the more they serve the purpose of forming a well-natured, fusible slag, i. e., a compound with the silica. Particularly these earthen bases allow a deviation from the formula, by using coke for fuel, extending within the limits—

From \(\text{R}_2 \text{Si}_3\) to \(\text{R}_3 \text{Si}_3\), even to \(\text{R}_5 \text{Si}_5\).

Or otherwise expressed,

From Oxygen of the bases : Oxygen of the acids, \(= \frac{1\frac{1}{2}}{1}\) or \(1 : \frac{2}{3} - \frac{1}{3}\).

G. R.—30
THE QUANTITY OF THE SLAG COMPARED WITH THE AMOUNT OF IRON.

Of the greatest influence in producing glittering iron is furthermore the quantity of the slag (by weight) compared with the quantity of iron; and it is proved by experience that the relation between these two materials being 1 : 1 is the best.

For when it would be more like,

1st. \[ \frac{Fe}{1} : \frac{Slag}{2} \], the working affairs of the furnace in general would be good enough, but a too large mass of slag always injures the iron by diminishing its quality in impregnating the same with too much silica. We know a certain amount of silica is of the greatest influence in the Bessemer process, but too much is also an evil, and it rests with the experience of the iron producer to determine this required amount of silica. At the same time a too large quantity of slag will afford too much carbonic matter for its own smelting, which would be worse than every other accident in the Spiegeleisen producing, because the forming of the constitution \[ \frac{Fe}{4} C \] requires a great amount of superfluous carbon.

2d. \[ \frac{Fe}{1} : \frac{Slag}{3} \] would be an unfavorable relation because there is not enough of the slag to cover the iron and protect it against combustion and decarbonization. The higher the pressure of the blast-air, the larger the quantity of slag required and I mentioned before that the usual pressure is from two and a half to three pounds per square inch.

It is therefore entirely erroneous, as some of the iron masters used to do, in working with a very hot blast-air to economize with the lime flux, because in every such case the quality of the iron will be deteriorated.

Of the greatest influence in forming the slag is also the Manganese.

One part of the Mn. O. forms with different other siliceous compounds a very fusible slag; another part of the oxidated manganese will lose its oxygen and join the iron, but of this part only another smaller portion remains. During a certain period of the cooling of the iron one can
observe the withdrawing of a more or less thin, scaly and blistery layer on the surface of the iron which is found to be composed of Mn. O, Si. O3 together with a small portion of Fe O, Al2 O3, and other bases. The compounding of the manganese and silica with oxygen, viz.: Mn. O. and Si. O3, takes place only at a time when the atmosphere adds to the molten iron, so that the latter is enabled to join with the oxygen, for there is, without any question, in the molten iron only Mn. and Si. This peculiarity of the manganese to join the silica in the iron, forming Mn Si, which is of less specific gravity than the iron, gives the highly esteemed value to the manganiferous pig metal.

The next circumstance which has to be considered in this connection is the relation of

THE ALUMINOUS ORES

to the slag. The alumina acts as a base in regard to the silica whenever the latter is preponderating, and therefore an admixture of aluminous ore is as much an importance in producing the slag as the carbonate of lime.

Having so far explained the general points which the iron master should take into consideration when forming the calculations, I shall now proceed to point out especially the manner in which such a calculation is to be made:

The figures in the following tables are only supposed ones, for iron masters know that bringing entirely correct statements before the public would be an indiscretion, nevertheless they represent strictly the mode of operating.

Say the analysis of several ores are the following:
<table>
<thead>
<tr>
<th></th>
<th>I Spathic Ore roasted</th>
<th>II Red Hematite</th>
<th>III Brown Decomposit'n</th>
<th>IV Alumina Ores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxide of Iron</td>
<td>60.10</td>
<td>71.89</td>
<td>71.30</td>
<td>38.40</td>
</tr>
<tr>
<td>Silica</td>
<td>18.27</td>
<td>13.99</td>
<td>15.85</td>
<td>37.40</td>
</tr>
<tr>
<td>Lime</td>
<td>8.64</td>
<td>2.17</td>
<td>Trace</td>
<td>9.12</td>
</tr>
<tr>
<td>Magnesia</td>
<td>2.04</td>
<td>1.25</td>
<td>2.05</td>
<td>2.10</td>
</tr>
<tr>
<td>Alumina</td>
<td>0.50</td>
<td>1.37</td>
<td>1.20</td>
<td>7.28</td>
</tr>
<tr>
<td>Ox. Manganese</td>
<td>7.00</td>
<td>8.13</td>
<td></td>
<td>1.38</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.35</td>
<td></td>
<td></td>
<td>0.14</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.35</td>
<td>1.38</td>
<td>10.10</td>
<td>4.60</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
<td></td>
<td>100.00</td>
</tr>
<tr>
<td></td>
<td>100.25</td>
<td>100.21</td>
<td>100.64</td>
<td></td>
</tr>
</tbody>
</table>

As shown in the previous letter from these different ores are taken:

- Of No. 1 - - - - 38 per cent.
- Of No. 2 - - - - 30 per cent.
- Of No. 3 - - - - 20 per cent.
- Of No. 4 - - - - 12 per cent.

For mixture, and therefore the figures of Table I have to be calculated in accordance with this ratio. The product will be in hundred parts of mixed ore:
TABRE NO. II.

<table>
<thead>
<tr>
<th></th>
<th>No. I.</th>
<th>No. II.</th>
<th>No. III.</th>
<th>No. IV.</th>
<th>In 100 lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxide of Iron</td>
<td>25.12</td>
<td>21.57</td>
<td>14.26</td>
<td>4.37</td>
<td>65.32</td>
</tr>
<tr>
<td>Silica</td>
<td>6.94</td>
<td>3.92</td>
<td>3.17</td>
<td>4.48</td>
<td>18.51</td>
</tr>
<tr>
<td>Lime</td>
<td>2.14</td>
<td>.65</td>
<td>1.09</td>
<td>.37</td>
<td>3.88</td>
</tr>
<tr>
<td>Magnesia</td>
<td>.77</td>
<td>.37</td>
<td>.41</td>
<td>.37</td>
<td>1.92</td>
</tr>
<tr>
<td>Alumina</td>
<td>.19</td>
<td>.41</td>
<td>.24</td>
<td>.96</td>
<td>1.89</td>
</tr>
<tr>
<td>Oxide of Manganese</td>
<td>2.66</td>
<td>2.43</td>
<td>.16</td>
<td>.16</td>
<td>5.25</td>
</tr>
<tr>
<td>Sulphur</td>
<td>.13</td>
<td></td>
<td>.02</td>
<td></td>
<td>.15</td>
</tr>
<tr>
<td>Phosphorus</td>
<td></td>
<td>.03</td>
<td>.06</td>
<td>.06</td>
<td>.09</td>
</tr>
<tr>
<td>Water</td>
<td>.13</td>
<td>.42</td>
<td>2.02</td>
<td>.88</td>
<td>3.05</td>
</tr>
<tr>
<td>Total</td>
<td>36.08</td>
<td>29.47</td>
<td>20.13</td>
<td>11.99</td>
<td>99.97</td>
</tr>
</tbody>
</table>

Henceforth these:

Oxide of Iron, 65.32 contains 41.76 per cent. metallic iron.
Silica, 18.51 contains oxygen, 9.80
Lime, 3.88 contains oxygen, 1.17
Magnesia, 1.92 contains oxygen, .76
Alumina, 1.80 contains oxygen, .84
Oxide of Manganese, 5.25 contains oxygen, 1.18
Sulphur, .16 contains oxygen, ....
Phosphorus, .09 contains oxygen, ....
Water, 3.05 contains oxygen, ....

99.97 35.9 9.80

The formula of the Singulo Silicate requires that the oxygen of the bases should be 9.80, but being only 3.95 there is a deficit of 5.85, which is contained in 20.48 Ca O, or in 36.57 Ca O, C O2; the lime used as a flux contains 98 per cent. Ca O, C O2; therefore, 98 : 100 : : 36.57 : 37.32 per cent. of carbonate of lime for a fluxing agent.

To show the correctness of this calculation, the lime has to be added to the mixture of ores.

In 100 parts of the Ca O, CO2 are—
98.00 Ca O, C O2, therefore in 37 parts 36.57
1.50 Si O3.............................. .55
.50 water............................. .02
Omitting the C O2, which will be withdrawn in the furnace, the slag will contain the following constituents:

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Quantity</th>
<th>Calculation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxide of Iron</td>
<td>65.32 x</td>
<td>= 65.32 = 47.68 = 33.00 Fe</td>
<td></td>
</tr>
<tr>
<td>Silica</td>
<td>18.51 x .55</td>
<td>19.06 = 13.91 with O=.737</td>
<td></td>
</tr>
<tr>
<td>Lime</td>
<td>3.88 x 20.48</td>
<td>24.36 = 17.78 = 5.07</td>
<td></td>
</tr>
<tr>
<td>Magnesia</td>
<td>1.92 x 1.83</td>
<td>1.92 = 1.40 = .56</td>
<td></td>
</tr>
<tr>
<td>Alumina</td>
<td>1.80 x 1.83</td>
<td>1.80 = 1.34 = .62</td>
<td></td>
</tr>
<tr>
<td>Oxide of Manganese</td>
<td>5.25 x 3.23</td>
<td>5.25 = 3.33 = .86</td>
<td></td>
</tr>
<tr>
<td>Sulphur</td>
<td>.15 x .18</td>
<td>.15 = .11</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>.09 x .18</td>
<td>.09</td>
<td></td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>3.05 x .18</td>
<td>3.05 = 2.35</td>
<td></td>
</tr>
</tbody>
</table>

| Total                        | 99.97     | 38.20       | 137.30  | 100.14  | 7.11  | 7.37 |

We see, therefore, that the constitution of the slag will bear the proportion Oxygen of the Bases 7.11 : Oxygen of the Acids 7.37.

In regard to the quantity of the slag, the slag forming materials are represented by:

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica</td>
<td>13.91</td>
</tr>
<tr>
<td>Lime</td>
<td>17.78</td>
</tr>
<tr>
<td>Magnesia</td>
<td>1.40</td>
</tr>
<tr>
<td>Alumina</td>
<td>1.34</td>
</tr>
</tbody>
</table>

and the proportion of the slag to the iron is 34.43 to 33.06, being nearly equal.

These data explain fully the way in which the iron master forms his idea of the materials which he intends to bring into his blast furnace; nevertheless it is safe to say that in the working of the furnace many revolutions will appear which may seriously disturb this mode of operation, and therefore it is certain that theory without practice is worth no more than practice without theory; but this, I repeat, is the only true means of finding out, in the shortest time, the real causes of disturbance and irregularity.

Making use of the foregoing explanation in regard to the spiegeleisen, there is the first rule in composing the ores to-
a good slag. Each slag will be of the most fusible nature, which is composed of more than one earthen base with silica, because such compounds act as fluxes on each other. And experience has proved that ores of a refractory character are more easily worked when mixed with other ores than when mixed with lime alone.

There are still three general remarks to be added:

1st. That neither the slag be too infusible.
2d. Not fusible enough.
3d. Not to accumulate too much ore in fulfilling the first condition in the spiegeleisen manufacture mentioned before.

To commence with the latter remark, there will not be heat enough in the furnace to produce Fe. 4 C., and, extended to a larger scale, even not heat enough to reduce the ores. The signs of a coming disaster, like this, are indicated by a slag which bears a glassy appearance throughout the whole mess, changing, by and by, to a dark-brown porous mass. This crude slag is at first very fusible, cools very quick, and after a few hours flows very slowly and thickly over the damstone, the tuyeres become darker, and the flame at the tunnel-head is very red and hot. The best remedy in such a case is less blast-air, a few charges of coke only, and smaller charges of ore.

If the mixture of flux and ore be too fusible, then the ores will melt before they are entirely reduced, the slag can not protect the iron from combustion in the vicinity of the tuyeres, and it will, therefore, be reduced to FeO, which renders a dark black slag. The tuyeres will be clear but not clean, requiring frequent mechanical cleaning; the forming of a mass of unreduced ores and slag takes place in the centre of the furnace, which one can not see on account of the bridle tuyeres, but which can be easily observed by means of an iron bar thrust into the furnace through the openings in the tuyeres. The first indications of such a crude working state of a furnace are found in a quicker, irregular going down of the charges at the mouth of the furnace, and only less blast air but of higher pressure, forcing the charges to go down slower, is a remedy in this case,
until there is found opportunity to change the mixture of ores of flux.

The constitution of the mixture, where it is not fusible enough, produces a black slag indicating that the same involves the iron in the vicinity of the tuyeres, hindering its reduction; the heat decreases in the furnace. The best remedy for this state of affairs is more blast air with the same width of the nose pipes, less ore and flux.

I may now bring this letter to an end, but cannot omit to say that the first development of the Spiegeleisen manufacturing, by means of coke, was attended by many difficulties, which at times seemed almost insurmountable. The first trials were met with many and great difficulties, calling forth the highest skill of the engineers, and at the same time with many expressions of doubt; and when at last it was definitely known that the science of metallurgy had overcome the greatest obstacles, there still remained in the minds of iron-masters an aversion to the new metal. The iron had to be introduced into the market and its merits made known, and iron-masters, reluctant to experiment with a material of such different quality from that they had been accustomed to use, must be induced to try the new metal. The first thing was to test its value, and bring it to the favorable notice of the iron-masters, experiments were made and proved that its freedom from sulphur and phosphorus, on the one hand, and the presence of manganese on the other, produced a metal unequalled in value by any known to commerce, except the small quantity produced by means of charcoal. Quantities of the new iron were soon introduced into the rolling-mills and other works, and the unanimous verdict of all who tried it was to the effect that it was preferable to the best iron previously known, and the only kind which would enable Bessemer steel manufacturers to bring into execution his (Bessemer’s) manner of manipulating. Ever since that time the demand has exceeded the supply.