

ELECTRIC FURNACE REDUCTION OF IRON ORE.

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In order that one can understand thoroughly the problems arising in the reduction of iron ore by carbon in an electrically heated furnace, he should first of all have a clear idea of how this reduction proceeds in an ordinary non-electrical blast furnace.

The iron ore contains iron oxide, with silica and clay as usual impurities, and more or less moisture; its phosphorous content may be low or high, but its sulphur content must be low, not over 0.5%. If the ore carries over 1% of sulphur it is given a preliminary roasting. In the furnace perhaps 99% of the iron oxide is reduced to metallic iron, 10 to 20% of the silica is reduced by carbon to silicon, which combines with the iron, all of the phosphorous is reduced into pig iron, and a varying proportion of sulphur, this proportion being smaller the more basic the slag is made with lime and the higher the running temperature.

Flux is added to make fusible slag by combining with the unreduced silica and the clay in the ore. Limestone, unburnt, is the usual flux, but magnesian limestone, carrying $MgCO_3$, is quite commonly used, the magnesia increasing the fusibility of the slag if not in greater proportion to the lime than the proportions $CaO.MgO$. The amount of flux added is variable; it depends on how basic the slag must be made. If the fuel is coke, and, therefore, considerable sulphur comes into the furnace, the slag formed must be nearly half lime and magnesia, to make low sulphur pig iron; if the fuel is charcoal, carrying almost no sulphur, and the ores carry none, the slag may be only one-third lime and magnesia and two-thirds silica and alumina, and make best quality pig iron. Such slag costs less for flux, and is more fusible than the basic lime slags.

Fuel is needed to provide heat and reducing effect. The heating effect is almost entirely produced by the combustion of the larger part of the fixed carbon (non-volatile carbon) of the fuel to carbon monoxide (CO) before the tuyeres. This combustion fills two functions: it provides the high temperature necessary to melt down the iron and slag, and it provides large quantities of reducing gas, practically identical in composition with producer gas (30 to 35% CO, 1 to 2% H_2 , rest N_2), which performs in the upper part of the furnace the larger part of the reduction.

The amount of fuel used in a blast furnace is determined by the amount which must be burned at the tuyeres to produce the necessary smelting temperature, and not by the amount necessary to perform the reduction of the metallic oxides. The amount necessary for performing the reductions taking place in the furnace is only one-third to one-half of the amount necessary to be burned to provide the smelting heat. That this statement is true of the ordinary blast furnace may be seen from the fact that if the smelting zone is increased in temperature by heating the blast, the amount of carbon used in the furnace per unit of pig iron made is at once decreased. Or, if the heat available in the smelting zone is increased by drying the blast, and thus removing the strong cooling influence which the decomposition of the moisture of the blast exerts, economy of fuel at once results. In fact, any means of getting high smelting temperature without combustion of carbon before the tuyeres decreases at once the quantity of fuel necessary to use in the furnace, since the quantity used is determined by the heat requirements in the smelting zone, and not by the requirements for reduction, which are only a fraction to the former. The ash of the fuel is largely silica, with some alumina and lime, if coke, or alkalis, if it is charcoal. This requires flux to slag it, an amount which may be considerable when using

poor coke high in ash. Regard for this item of cost should be had in purchasing or valuing the fuel.

The pig iron produced contains carbon between 2.5 and 4.5%, silicon in varying quantity 1 to 4%, according to the temperature and rate of running of the furnace, practically all the phosphorus of the charge, and one-tenth to one-fourth of the sulphur. Its melting point is about $1,200^\circ C.$, and it runs from the furnace ordinarily at $1,500^\circ C.$ to $1,600^\circ C.$, carrying out as sensible heat 250 to 300 calories.

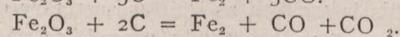
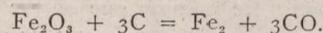
The slag may be basic or acid, as before explained, and these varieties will average in per cents.:-

	Basic Slag. High Sulphur Charge.	Acid Slag. Low Sulphur Charge.
SiO ₂	35	55
Al ₂ O ₃	10	10
CaO	40	25
MgO	10	5

These slags melt at about $1,350^\circ C.$ and $1,200^\circ C.$ respectively, and ordinarily run away from the furnace at $1,600^\circ C.$ carrying out as sensible heat 500 calories.

The reduction of silica and phosphorus oxide in the furnace is accomplished by solid carbon in the smelting zone. A small part (10 to 20%) of the iron oxide in the furnace is also similarly reduced by fixed carbon; the rest is reduced in the upper half of the furnace by the excess of carbon monoxide gas. So much of the latter gas, however, is produced before the tuyeres in generating the temperature necessary in the smelting zone, that only a fraction of it is converted into carbon dioxide, CO_2 , in reducing the iron oxides of the charge. This is the chief reason for the excess of unused carbon monoxide in the gases of the blast furnace, an amount whose potential calorific value often represents one-half of the calorific power of the fuel put into the furnace. It is true that all the carbon monoxide in the gases could not be utilised, no matter how small its amount, but that is a limit set by the principle of chemical equilibrium or mass action, which ordinarily is not approached because of the excessive amount of carbon monoxide produced in the lower part of the furnace in the effort to get the requisite smelting heat and temperature. The proportions of carbon ordinarily consumed at the tuyeres are 9 atoms (108 parts) of carbon for each molecule of iron oxide (160 parts) reduced by the carbon monoxide gas. The chemical equation is: $Fe_2O_3 + 9 CO = 2 Fe + 3 CO_2 + 6 CO$. This equation shows us that only one-third of the carbon monoxide produced before the tuyeres in generating the smelting temperature is utilised in reduction, while two-thirds escapes unused.

Passing to the electric principle of smelting, we have here to deal with the case of all necessary heat supplied by electrical energy, no blast blown in, and, therefore, all the solid carbon utilised for reduction (always excepting the small amount which dissolves in the pig iron) in calculating the amount of carbon necessary to thus reduce the iron oxide, we meet at the outset with this difficulty. What proportion of the carbon will form CO_2 , and what proportion CO? We know that when reduction takes place at a very high temperature, CO is almost the only product; but as this passes more or less slowly through the cooler portions of unreduced charge, CO_2 is formed in increasing amounts, until at a low red heat, given sufficient time, about half the CO may be converted into CO_2 . The formulae corresponding to these two extremes are:



Comparing these with the ordinary blast-furnace reaction, which requires 9 C put into the furnace for the reduction of Fe_2 , we see that 3 C, or one-third as much carbon, is the greatest amount necessary in the electric furnace reduction and $\frac{1}{2}C$, or between one-third and one-fifth as much, is the smallest amount necessary. As will be further shown, the uncertainty as to how much CO_2 can be formed in the electric furnace reduction is perhaps the chief difficulty in running the electric furnace.

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