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PROCESS OF SMELTING TITANIFEROUS ORE

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This invention relates to a process of smelting iron ores with particular reference to iron ores which contain fairly large percentages of titanium, such as the titaniferous magnetite ores.

Many attempts have been made to smelt iron ores containing titanium in conventional iron blast furnaces by the usual process of reduction. These attempts have heretofore failed, because the titanium contributes to increased viscosity of the slag and also to some extent enters the iron. According to some theories, highly infusible titanium nitride crusts are formed which interfere with the normal settling of the furnace.

Other attempts have been made to smelt the iron and to increase the fluidity of the slag by using alkali metal fluxes. While these attempts were in the right direction, they did not become commercial, I believe, for the reason that it is difficult to hold an alkali metal flux in a furnace at high temperatures. Nevertheless, such fluxes benefit both the iron and the slag by promoting a clean separation of the titanium into the slag.

According to the present invention, I follow the prior art to a limited extent in that I use an alkali metal flux and carbon in the preliminary reduction. I depart from the prior art, however, in that I very soon replace a substantial part of the alkali metal flux, which may be sodium carbonate, by a non-volatile flux, which may be lime or limestone. Another departure is that for the carbon I use a coking coal, which enables me to produce almost complete reduction by the first smelting operation which produces a dispersion of metallic iron and sodium titanate in a mechanically strong porous form of carbon, which is coke. The physical state of this product is vital to the success of my process, because without mechanical strength, it would be crushed in the furnace, and without porosity it would be impossible to force oxidizing gases through it at a rate sufficient to make the process fast enough for commercial success. A third difference from the prior art is that my process is a dry one throughout; I employ no liquids to separate the slag from the iron. The speed of my process is thereby much increased, and the amount of apparatus necessary is much diminished. I do not require the high blast furnace but only a conventional coke oven and a low melting furnace of the cupola type.

My process of treating a titaniferous iron ore is as follows: I grind the ore to a coarse state of subdivision, preferably the particle will range between U. S. Standard #2 and #8 mesh. The particle size is not absolutely critical, but I have found the above screen sizes to be practical and

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convenient. I mix the subdivided ore with finely divided coking coal, although the mesh size of the coal is also not critical. To this mixture I add soda ash (preferably anhydrous). A typical blend may be as follows:

	Pounds
Ground ore	100
Ground coal, preferably of the coking type	50–100
Soda ash (56% Na_2O)	5–10

While I have shown sodium carbonate as the source of alkali metal, I may use sodium sulphate, sodium chloride, sodium hydroxide, or the corresponding potassium compounds.

After thoroughly blending, I place this charge in any suitable type of coking oven preheated to about 1900° F. I continue the heating at about 2000° F. until all volatile material such as coal gas and gas formed from the reduction of the iron is removed. This usually takes about 9 hours for the normal volume of charge, but the time is regulated by the volume of charge. The coking procedure takes place more rapidly than if a solid charge of coal is used on account of the greater thermal conductivity of the ore. When the charge is first placed in the furnace, a very heavy flow of gas is evolved which consists of tars and low temperature volatile coal gas. As the temperature in the retort rises, much carbon monoxide is produced by the reaction between hydrocarbon gases and the iron ore. It is probable that some of the carbon of the coal enters into the reduction of the ore, although I believe that under the conditions described, the major part of the reduction is accomplished by the volatile gases. I have found that under these conditions the particles of iron ore are reduced to metallic iron almost completely. My results show that above 95% reduction is accomplished and possibly over 99% may be accomplished, and the sodium carbonate enters largely into combination with the titanium, thus fixing it from that point on. The resultant product is a fairly strong coke containing fine particles of metallic iron and fine particles of slag which may be considered as metallic titanates. There may be other slag-forming materials in the ore such as silica in which case there would also be present metallic silicates. I have called this product metallized coke, and I prefer it to run from 20% to 27% of fixed carbon, i. e. just enough to support the furnace charge and to furnish heat for melting it in the next step. It analyzes also from 34% to 37% Fe with proportions of titanium silicates,

calcium sodium silicates, and, if V-bearing ores have been worked, a substantial proportion of V_2O_5.

I remove the metallized coke from the coke retort. It is preferred to cool this coke in an enclosed chamber to prevent oxidation at the high temperature at which it is removed. I now complete the production of metallic iron by a second step which I consider as a process of melting and coalescing the finely divided iron particles. This may be done in several types of furnace, such as cupola, a regular blast furnace, or a reverberatory type of furnace. Since the ordinary iron blast furnace process involves the reduction of the ore as well as the melting of the reduced iron, my metallized coke, which also requires melting of the iron but not its reduction, does not need the excessive size and costly construction of the regular iron blast furnace. It is probable that an electric furnace would involve too much cost for commercial production of pig iron, but it would perform the operation very satisfactorily.

The reverberatory type may also be used, but I prefer the cupola type of furnace. In such a furnace I introduce the metallized coke with additional, from 5% to 20% by weight, calcium carbonate or magnesium carbonate or both of the corresponding oxides, depending on the desired composition of the resulting slag and also on the slag-forming impurities in the original ore. Such additions must be predetermined by a knowledge of the impurities originally present and the melting point of the slags which can be made from time to time. The operations of the cupola is very similar to the ordinary foundry cupola in which operation iron or pig iron is mixed with coke and the metal melted with a blast or air blown through the charge. The molten metal settles to the bottom of the furnace and is drawn off at periodic intervals according to standard practice. The molten slag collects on the top of the iron and is drawn off through a separate tap hole. I find that such a slag may carry from 40 to 55% of titanium dioxide, depending on the titanium content of the original ore and the amount of addition agent required to produce a slag of proper melting point. I find also that the pig iron is of very high quality and in the ores with which I have worked, may carry from .25 to .6% vanadium. Since the sulphur and phosphorus content of western U. S. titaniferous iron ore is very low, I find that the pig produced from these ores requires less purification for refining to steel than does the pig from the usual iron ores. The production of pure titanium dioxide and from the titaniferous slag which I produce by my process is very much simpler and cheaper than from the ordinary source of titanium which is ilmenite ore. This process will allow, I believe, the commercial use of the large quantities of titaniferous iron ores known to exist in this country and which are now practically useless.

I claim as my invention:

1. The process of smelting titaniferous iron ore which comprises subdividing the ore, mixing therewith finely-divided coking coal and a minor proportion of a solid, non-siliceous alkali-metal compound giving a fusible slag, then reducing the ore and coking the coal to form an iron sodium titanate dispersion in a mechanically strong form of carbon, adding a substantial proportion of a flux consisting essentially of an alkaline-earth-metal compound, then separating the iron from the coke by burning out the latter thereby reaching a temperature above the melting point of the iron, and then separating the molten iron from the generated slag.

2. The process of smelting titaniferous magnetite ore which comprises grinding the ore, mixing therewith a major proportion of finely divided coking coal and a minor but sufficient proportion of a solid non-siliceous sodium salt capable of giving a fusible slag, then reducing the ore and simultaneously coking the coal, adding a substantial portion of a flux consisting essentially of an alkaline earth metal compound containing chemically bound oxygen, then separating the iron from the coke by burning out the latter to reach a temperature above the melting point of the iron and of the titaniferous slag, and then separating the iron from the slag.

3. The process of smelting titaniferous magnetite ore which comprises reducing the size of the ore particles to about 2 mesh to 8 mesh, mixing therewith a major proportion of finely-divided coking coal and about 3% to 10% of sodium carbonate, calculated on the anhydrous basis, subjecting the mixture to reduction under coking conditions for about 5 to 20 hours, adding a substantial portion of a flux consisting essentially of an alkaline earth metal compound containing chemically bound oxygen, and then burning out the carbon at a temperature above the melting point of the ferrous metallic component and above the melting point of the so-generated titaniferous slag, and then separating the molten iron from the molten slag.

4. The process of smelting titaniferous iron ore which comprises reducing the particle size of the ore to from 2 to 8 mesh, mixing therewith, per 100 parts of ore, from 50 to 110 lbs. of finely-divided coking coal and from 3% to 10% of the weight of the mixture of a solid non-siliceous sodium salt capable of forming sodium titanate under smelting conditions, coking the coal in the mixture under conditions to form a dispersion of reduced iron and sodium titanate in a mechanically strong form of porous carbon, adding at least enough of a flux consisting essentially of an alkaline earth metal compound containing chemically bound oxygen to compensate for the loss of alkali metal by volatilization, then burning the carbon out of said dispersion at a temperature above the melting point of iron and above the melting point of titaniferous slag to generate a mass of molten iron in a molten mass of slag, and thereupon separating the slag from the iron.

5. The process of smelting a titaniferous iron ore which comprises mixing the subdivided ore with a nearly equal weight of coking coal in finely divided condition and a minor proportion of a solid, non-siliceous alkali-metal compound giving a fusible slag, subjecting the mixture to a coking operation at a temperature of about 2000° F., thereby producing a dispersion of iron and sodium titanate in a mechanically strong form of carbon, then adding a flux consisting essentially of an alkaline-earth compound containing chemically bound oxygen, heating the so-formed charge with access to oxygen to burn the carbon to a temperature at which the slag and the iron will freely separate and then separating them.

6. The process of smelting titaniferous iron ore which comprises mixing the subdivided ore with coking coal and soda ash in the approximate proportions:

	Pounds
Ground ore	100
Ground coking coal	50 to 110
Soda ash (anhydrous basis)	5 to 10

heating the charge so-formed to about 2000° F. for from 5 to 20 hours under reducing conditions, then heating the so-formed coked mass with access of air and with the addition of 5% to 20% of its weight of a fixed flux consisting essentially of an alkaline-earth compound containing chemically bound oxygen, to a temperature high enough to permit clean separation of the slag from the iron and then separating these two.

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