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METHOD OF REDUCING ORE

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Fig. 1.

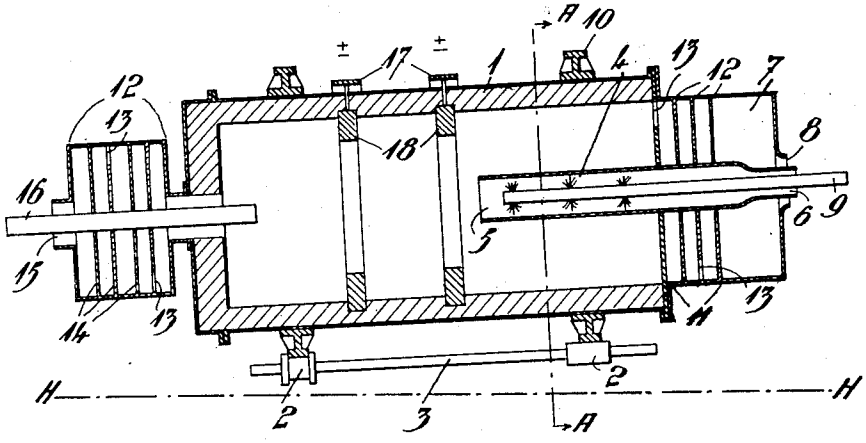
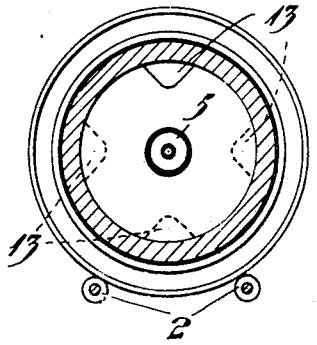


Fig. 2.



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METHOD OF REDUCING ORE

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In the reduction of ore, for instance iron ore, without fusing it is of great importance that the ore used should be as far as possible, pure and free from gangue. If the ore contains gangue a metal containing gangue is obtained which afterwards is very difficult to concentrate to the required degree of purity. Since, most kinds of ore contain gangue in a finely disseminated form, it is generally necessary to crush the ore finely and to concentrate it before the reduction. The fine crushing also gives the advantage in the reduction that the reduction time can be limited to a minimum as compared with that necessary for ore in lumps.

The reduction of finely crushed ore (concentrate) in certain cases and particularly with iron ore causes great difficulty on account of the tendency of the concentrate to sinter during the reduction and to adhere to the walls of the furnace or to form blocks in the furnace. This disadvantage can, however, be avoided in those processes in which the reducing agent consists of coal dust, which when it is mixed with the ore in sufficient quantity can prevent this sintering. In this way the reduction process can without difficulty be carried out continuously in a rotating furnace, which type of furnace is most suitable for the reduction of fine ore on account of the continuous agitation which produces a uniform reduction.

With processes carried out on these lines, however, other drawbacks arise in certain cases. A part of the ash content of the coal material is always found in the product obtained and unless coal with a small ash content is used, there is a danger that the metal will contain too much impurity. Also the sulphur of the coal material is chiefly taken up by the reduced metal so that with this method of reduction the sulphur content of the coal material has to be considered.

If the reduction is carried out with gas instead of solid coal, which gas can be produced, for example by combustion of coal in a generator, coal-ash has no bearing on the quality of the metal. Sulphur also does not enter into the problem. In this case, however, the above mentioned difficulties relative to sintering in carrying out a continuous process in the rotating furnace, arise, with the concomitant danger of having to interrupt the operation on account of the tendency of the concentrate, in the absence of the coal dust particles, to sinter during the reduction.

The present invention solves the problem in the following manner. The furnace is charged with a mixture of ore and coal containing material in an analogous manner to that used in processes where the coal is used directly as reducing agent but at the same time another reducing agent with a more rapid reducing action, for example a reducing gas is supplied. It has been found that in this way the process can be so carried out that the reduction is effected mainly by means of the more rapidly acting reducing agent, and only to a small extent by means of the coal mixed with the ore which thus chiefly remains in the furnace without being burnt and can be used for the process again. In this manner one avoids the drawbacks and obtains the advantages of the direct coal reduction process, as well as the above mentioned known gas reduction process.

In order that the more rapidly acting reducing agent may be employed in the manner intended by the invention without a large amount of coal being used at the same time it is desirable to use a coal material which is relatively difficult to burn, for example coke, graphite electrode carbon, petroleum carbon, silicon carbide, or a similar carbon containing material which is relatively difficult to burn. Furthermore the size of grain has an important effect; the more finely powdered is the carbon containing material, the greater is the consumption. The crushing should therefore not be carried further than is necessary to loosen the charge and prevent sintering.

As a reducing agent, for example ordinary coal generator gas can be used which however, must as far as possible be free from carbon dioxide. A high content of carbon monoxide is of course desirable, and an hydrogen content is also of advantage. So called water gas which consists principally of a mixture of carbon monoxide and hydrogen is therefore of advantage for the process. Coke oven gas is also suitable.

The reducing gas may in certain cases advantageously be partly or wholly replaced by known gaseous reducing agents for example liquid organic substances, for example oils and similar substances which evaporate on heating, a decomposition into simpler compounds with simultaneous formation of carbon dust generally taking place. This carbon dust is also effective in the reaction and it has been found that a very easily oxidizable carbon material, for example finely divided wood char-coal, lamp black from furnace gases etc., may also be used as the reducing agents with or without simultaneously supplying gas, by introducing same through suitable openings. The reducing agent must then be so finely divided that for the most part it remains here suspended

like a dust-cloud by the revolving movement of the charge inside the furnace during the rotation of the furnace, and in so far as it is not burnt in the furnace, escapes with the reaction gas.

The reduction agent whether it is gaseous or solid should preferably be made to pass through the furnace in a direction opposite to that of the charge. It is, therefore, preferably introduced at the discharge end of the furnace and the reaction gas is removed at the charging end.

The process can be carried out in rotary furnaces of known constructions. The supply of heat necessary is dependent to a great extent on the reducing agent used. In the reduction of iron ore, for example with carbon monoxide, it is not necessary to supply heat for the reduction itself, while reduction with solid carbon requires a considerable supply of heat. The method of supplying heat which is best in most cases, is by means of electric current which is passed through resistance elements or resistance material provided in the furnace or in its walls. The known method of making the charge itself serve as the resistance for the electric current which is carried between contacts or electrodes provided in a suitable manner in the furnace through the charge, is especially advantageous. In this case it is important that the charge should contain carbon or such carbon containing material that suitable current conditions are obtained. The ore concentrate is generally a relatively poor conductor of electricity, while the metal obtained by reduction has too great a conductivity. The presence of carbon or carbon containing material makes the conductivity more constant and makes it possible by varying the quantity and quality of the said material to regulate the resistance as desired between wide limits. The reaction gas passing out has usually considerable fuel value which, where this is possible, may be used for the process. An advantageous method for this purpose is that previously proposed by the inventors for burning the gas in a central chamber provided in the furnace through the walls of which the heat is transmitted to the charge lying in the furnace outside the walls. Through the rotation of the furnace a satisfactory uniform heating of the charge can be obtained in this manner. The ore may be charged, together with the carbon or carbon containing material, into the outer space or anteroom which is anterior to the combustion chamber; or, alternatively the ore, separate from the said material, can first be fed into the combustion chamber and there mixed with carbon containing material. It has been found of advantage to combine the electric heating with the combustion of the reaction gas, that is the gas obtained in the reaction. The heating of the charge to the reaction temperature is then advantageously effected by burning the gas in a centrally disposed furnace space or pipe at the charging end of the furnace after which the charge in order to receive the heat which is necessary to maintain the desired temperature, must pass a zone in which electric current is led through it.

Using a reducing gas containing carbon monoxide, it is possible to utilize, for improving the process, the dissociation of carbon monoxide into carbon dioxide and carbon, whereby the carbon will act as a reducing agent. This chemical reaction requiring special temperature conditions the reducing gas, before being burnt, is brought into contact with the ore under such temperature conditions. The range of temperature, here in question, is determined by the course of said dissociation, which takes place between about 445° and 1000°, at the lower term almost all carbon monoxide being dissociated into carbon dioxide and carbon so that a suitable range near that lower term may be chosen.

In order to render the invention clear a constructional example of a furnace for carrying out the reduction process is illustrated diagrammatically by way of example in the accompanying drawing.

Fig. 1 shows the furnace in longitudinal section.

Fig. 2 is a cross section A—A of Fig 1.

1 indicates the rotating furnace itself which is carried in a known manner by rotatable rollers 2 connected in pairs by means of an axle 3, and if necessary also constructed that they can serve to set the furnace in rotation. 4 is a tube or tubular combustion chamber disposed centrally in the interior of the furnace, which communicates with the interior of the furnace space through the aperture 5, and at the charging end of the furnace is provided with an opening 6 for the introduction of the ore and the solid carbonaceous matter (for instance, coal) and the material intended for binding the sulphur (for instance CaO), in through this way, if necessary, as also for leading away gas obtained by the process which before leaving the furnace is partly or wholly burnt by means of air admitted through the tube 9. The combustion chamber is surrounded at its outer end by a chamber 7 which is intended to serve as a pre-heating and drying chamber for the charge, preferably the carbon containing material which is used, which is fed into this chamber through the opening 8. The charge before reaching the furnace chamber proper passes a lock arrangement 11, which in the form shown in the drawing preferably consists of a number of separating walls 12, each of which is provided at its periphery with a cut-out part 13, distributed in relation to each other so that when the furnace rotates one of them is at the bottom in the material supplied, which in this way prevents gas from passing out of the interior of the furnace. A similar lock arrangement 14 is also provided at the discharging end of the furnace and is provided with an outlet opening 15 so that the treated material may leave the furnace without gas passing out through the opening. At the discharging end of the furnace there is provided a centrally disposed tube 16 through which suitable reducing gas or a liquid reducing agent is led into the furnace chamber. The supply of heat required in excess of that generated by the combustion of the reduction gas in the chamber 4 is supplied to the furnace by means of electric current which is supplied in the usual manner through slip rings 17 to the contact rings or electrodes 18, between which the current passes through charge and heats it. The line H—H indicates the horizontal plane. The geometrical axis of the furnace is therefore higher at the charge end, so that during the rotation of the furnace the material will pass automatically through the furnace.

Having thus described our invention we declare that what we claim is:

1. A process for reducing finely divided iron ore without involving fusion, comprising feeding a mixture of ore and solid carbonaceous material into a rotating heat zone, in which the charge is continuously stirred by the rotating action of the furnace, adding a reducing agent practically free from sulphur and ash and having a more

effective reducing action on the ore than the first mentioned solid carbonaceous material mixed with the ore, and supplying heat to reduce said mixture, the first mentioned reducing material being passed through the heat without taking any substantial part in the reducing process and acting substantially as a filling material to prevent sintering of the ore during the process, the size of grains and the physical strength thereof being such as to answer said purpose.

2. A process for reducing finely divided iron ore without involving fusion, comprising feeding a mixture of ore and solid carbonaceous material into a rotating heat zone, in which the charge is continuously stirred by the rotating action of the furnace, adding a reducing agent practically free from sulphur and ash and having a more effective reducing action on the ore than the first mentioned solid carbonaceous material mixed with the ore, and supplying heat to reduce said mixture, the first mentioned reducing material being passed through the heat without taking any substantial part in the reducing process and acting substantially as a filling material to prevent sintering of the ore during the process, the size of grains and the physical strength thereof being such as to answer said purpose, in which process at least a part of the more rapidly acting reducing agent is in the liquid phase.

3. A process for reducing finely divided iron ore without involving fusion, comprising feeding a mixture of ore and solid carbonaceous material into a rotating heat zone, in which the charge is continuously stirred by the rotating action of the furnace, adding a reducing agent practically free from sulphur and ash and having a more effective reducing action on the ore than the first mentioned solid carbonaceous material mixed with the ore, and supplying heat to reduce said mixture, the first mentioned reducing material being passed through the heat without taking any substantial part in the reducing process and acting substantially as a filling material to prevent sintering of the ore during the process, the size of grains and the physical strength thereof being such as to answer said purpose, in which process at least a part of the more rapidly acting reducing agent is in a gaseous phase.

4. A process for reducing finely divided iron ore without involving fushion, comprising feeding a mixture of ore and solid carbonaceous material into a rotating heat zone, in which the charge is continuously stirred by the rotating action of the furnace, adding a gaseous reducing agent practically free from sulphur and ash and having a more effective reducing action on the ore than the first mentioned solid carbonaceous material mixed with the ore, and supplying heat to reduce said mixture, the first mentioned reducing material being passed through the heat without taking any substantial part in the reducing process and acting substantially as a filling material to prevent sintering of the ore during the process, the size of grains and the physical strength thereof being such as to answer said purpose, in which process the gaseous reducing agent having a more effective reducing action is introduced at the discharging end of the furnace, and the reaction gas is led away at the charging end thereof.

5. A process for reducing finely divided iron ore without involving fusion, comprising feeding a mixture of ore and solid carbonaceous material into a rotating heat zone, in which the charge is continuously stirred by the rotating action of the furnace, adding a reducing agent practically free from sulphur and ash and having a more effective reducing action on the ore than the first mentioned solid carbonaceous material mixed with the ore, and supplying heat to reduce said mixture, the first mentioned reducing material being passed through the heat without taking any substantial part in the reducing process and acting substantially as a filling material to prevent sintering of the ore during the process, the size of grains and the physical strength thereof being such as to answer said purpose, in which process the heat necessary for carrying out the process is created at least partly by means of electric current which, for this purpose, is led through electrical resistance material provided in the furnace in a suitable manner.

6. A process for reducing finely divided iron ore without involving fusion, comprising feeding a mixture of ore and solid carbonaceous material into a rotating heat zone, in which the charge is continuously stirred by the rotating action of the furnace, adding a reducing agent practically free from sulphur and ash and having a more effective reducing action on the ore than the first mentioned solid carbonaceous material mixed with the ore, and supplying heat to reduce said mixture, the first mentioned reducing material being passed through the heat without taking any substantial part in the reducing process and acting substantially as a filling material to prevent sintering of the ore during the process, the size of grains and the physical strength thereof being such as to answer said purpose in which process at least a part of the heat for the process is obtained from an electric current, said current being caused to pass through the charge which in this way is itself employed as heating resistance.

7. A process for reducing finely divided iron ore without involving fusion, comprising feeding a mixture of ore and solid carbonaceous material into a rotating heat zone, in which the charge is continuously stirred by the rotating action of the furnace, adding a reducing agent practically free from sulphur and ash and having a more effective reducing action on the ore than the first mentioned solid carbonaceous material mixed with the ore, and supplying heat to reduce said mixture, the first mentioned reducing material being passed through the heat without taking any substantial part in the reducing process and acting substantially as a filling material to prevent sintering of the ore during the process, the size of grains and the physical strength thereof being such as to answer said purpose in which process at least a part of the supply of heat required for carrying out the process is effected by combustion of the gases previously obtained in the reduction.

8. A process for reducing finely divided iron ore without involving fusion, comprising feeding a mixture of ore and solid carbonaceous material into a rotating heat zone, in which the charge is continuously stirred by the rotating action of the furnace, adding a reducing agent practically free from sulphur and ash and having a more effective reducing action on the ore than the first mentioned solid carbonaceous material mixed with the ore, and supplying heat to reduce said mixture, the first mentioned reducing material being passed through the heat without taking any substantial part in the reducing process and acting substantially as a filling material to

prevent sintering of the ore during the process, the size of grains and the physical strength thereof being such as to answer said purpose in which process at least a part of the heat for the process is obtained by the combustion of the gases obtained in the reaction, said combustion being effected in a segregated combustion zone rotating with the main combustion zone, through the boundaries of which the heat is transmitted to the charge.

9. A process for reducing finely divided iron ore without involving fusion, comprising feeding a mixture of ore and solid carbonaceous material into a rotating heat zone, in which the charge is continuously stirred by the rotating action of the furnace, adding a reducing agent practically free from sulphur and ash and having a more effective reducing action on the ore than the first mentioned solid carbonaceous material mixed with the ore, and supplying heat to reduce said mixture, the first mentioned reducing material being passed through the heat without taking any substantial part in the reducing process and acting substantially as a filling material to prevent sintering of the ore during the process, the size of grains and the physical strength thereof being such as to answer said purpose, in which process the charge is first heated by combustion of the gases obtained in the reaction, and is then passed through an electrically heated zone in the furnace.

10. A process for reducing finely divided iron ore without involving fusion, comprising feeding a mixture of ore and solid carbonaceous material into a rotating heat zone, in which the charge is continuously stirred by the rotating action of the furnace, adding a reducing agent practically free from sulphur and ash and having a more effective reducing action on the ore than the first mentioned solid carbonaceous material mixed with the ore, and supplying heat to reduce said mixture, the first mentioned reducing material being passed through the heat without taking any substantial part in the reducing process and acting substantially as a filling material to prevent sintering of the ore during the process, the size of grains and the physical strength thereof being such as to answer said purpose, in which process using a reducing gas containing carbon monoxide the gas before being burnt is brought into contact with the ore under such high temperature conditions as favor the dissociation of the carbon monoxide into carbon, and carbon dioxide, which carbon is employed as a reducing agent.

11. A process for reducing finely divided iron ore without involving fusion, comprising feeding a mixture of ore and solid carbonaceous material into a rotating heat zone in which the charge is continuously stirred by the rotating action of the furnace, adding a solid reducing agent practically free from sulphur and ash and having a more efficient reducing action on the ore than the first mentioned solid carbonaceous material mixed with the ore, and supplying heat to reduce said mixture, the first mentioned reducing material being passed through the heat without taking any substantial part in the reducing process and acting substantially as a filling material to prevent sintering of the ore during the process, the size of grains and the physical strength being such as to answer said purpose.

12. A process for reducing finely divided iron ore without involving fusion, comprising feeding a mixture of ore and solid carbonaceous material into a rotating heat zone in which the charge is continuously stirred by the rotating action of the furnace, adding a solid reducing agent practically free from sulphur and ash and having a more efficient reducing action on the ore than the first mentioned solid carbonaceous material mixed with the ore, and supplying heat generated by electric current to reduce said mixture, the first mentioned reducing material being passed through the heat without taking any substantial part in the reducing process and acting substantially as a filling material to prevent sintering of the ore during the process, the size of grains and the physical strength being such as to answer said purpose.

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