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APPARATUS FOR BENEFICIATING NONMAGNETIC ORES TO RENDER THEM MAGNETIC

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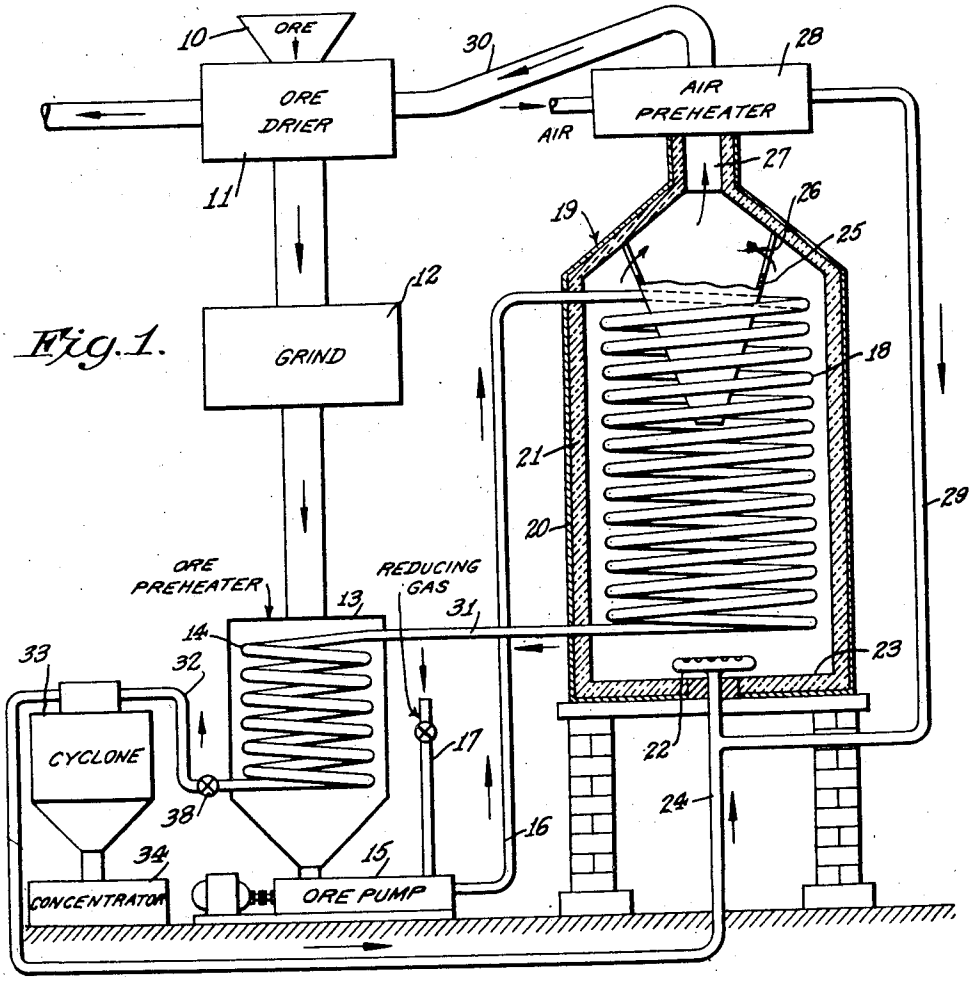


Fig. 1.

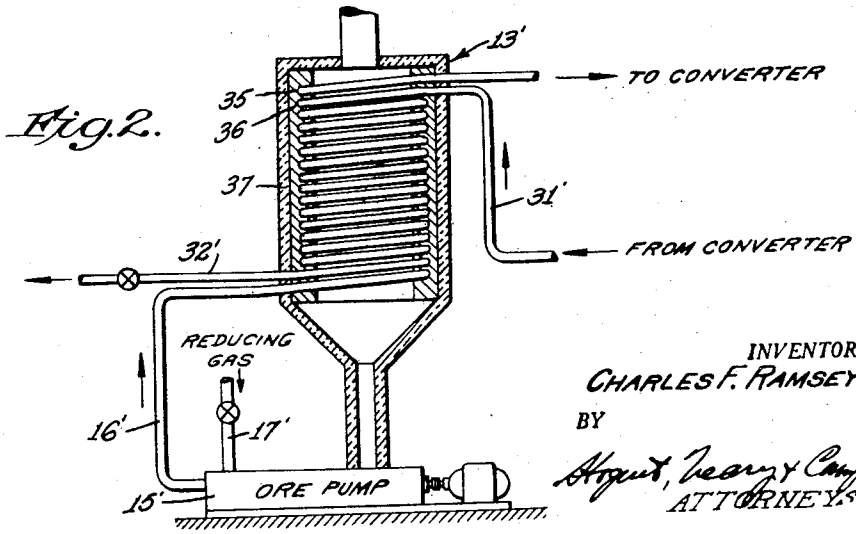


Fig. 2.

INVENTOR:
CHARLES F. RAMSEYER
BY
Arguet, Geary & Campbell
ATTORNEYS

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APPARATUS FOR BENEFICIATING NON-MAGNETIC ORES TO RENDER THEM MAGNETIC

Charles F. Ramseyer, Old Greenwich, Conn., assignor to H. A. Brassert & Company, New York, N. Y., a corporation of Illinois

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1 Claim. (Cl. 209—8)

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This invention relates to the continuous beneficiation of metallic oxides and has particular reference to apparatus for rendering magnetic the normally non-magnetic iron ores, such as the hematites, limonites, carbonates and mixtures thereof, in order that they may be concentrated magnetically for further processing, such as reduction to iron.

As is well known, non-magnetic iron ores abound throughout the world, but the expense of concentrating them by washing, jigging, tabling, flotation, or the like, renders the cost of the finished product prohibitive, but if these ores could be simply and inexpensively converted to material that is sufficiently magnetic to permit of relatively inexpensive magnetic concentration, such heretofore relatively useless ores would become commercially useful.

The present invention provides simple apparatus for inexpensively beneficiating such low grade non-magnetic ores so that substantially all of the gangue therein may be readily removed by magnetic concentration according to any one of several known processes, whereby the low grade ore is inexpensively converted into a high grade magnetic concentrate for reduction to iron by any of the several known processes.

In accordance with the invention, the non-magnetic ore as mined, such as the siliceous hematite of the Lake Superior district, commonly known as taconite, for example, is first ground to an average fineness greater than fifty mesh, and is then pumped with an admixture of an excess of reducing gas under pressure, such as water gas, cleaned producer gas, or other hydrogen- or carbon monoxide-containing gas, through an elongated tube, preferably in coil form, that is externally heated to such temperature that at least partial conversion from Fe_2O_3 to Fe_3O_4 takes place without the formation of FeO, which means at temperatures below 1100° F. The preferred temperature range is lower, from 750° to 850° F. and may be carried out successfully at temperatures as low as 500° to 600° F., depending upon the physical nature of the ore, its fineness, the reducing gas employed, the pressure in the tube, which, in addition to the velocity of the material through the tube, govern the length thereof. The actual time of conversion under these conditions is normally very short, a matter of a few minutes and, under the most favorable conditions of fineness and high hydrogen gas content, a matter of seconds. The conversion is also aided by the exothermic nature of the conversion, the attrition between the particles and their envelopment in

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the reducing gas under the conditions provided within the tube, i. e., suspension of the particles in the gas so that the entire mass is rendered fluent or "fluidized" and actually flows through the tube like a fluid. Inasmuch as the tube is externally heated the conversion takes place without contamination by combustion gases.

After the ore is thus converted into magnetic material to a degree such that at least about 25% of each particle is magnetic, which is sufficient to cause the particle to respond to a magnetic field, the converted ore is separated from the gangue by a conventional magnetic process, preferably the wet magnetic process in view of the higher degree of concentration obtainable thereby. The heat for externally heating the tube is preferably provided by the excess reducing gas not expended in the conversion, which is recovered and may be burned in the converter or furnace containing the tube. The fluidized raw ore and incoming cold gas mixture may be preheated by heat exchange with the hot converted gas-ore mixture, and the flue gases from the furnace may be employed to preheat the combustion-sustaining air supplied to the converter furnace burners, and the like.

It will be seen that the invention provides a very simple and efficient way of continuously beneficiating large quantities of naturally non-magnetic ores at the mine site, and makes available a valuable magnetic concentrate from ores that were heretofore regarded as of low value because of expense of concentration or cost of transportation to concentration points, or both.

For a more complete understanding of the invention, reference may be had to the accompanying drawings, in which:

Figure 1 illustrates, partially schematically, a preferred form of apparatus for conducting the beneficiation of non-magnetic ores according to the invention; and

Fig. 2 illustrates a modification in which the hot converted ore from the converter is passed in heat-exchanging relation with the raw ore being pumped to the converter.

Referring to Fig. 1, the raw ore such as the aforementioned taconite as mined is supplied to hopper 10 and is preferably dried in drier 11, preferably by the waste heat of the converter combustion gases, as will be described, and is then ground at 12. The drier will heat the ore to between 150° F. and 250° F. and this heat will ordinarily be retained during the grinding operation. In order to be pumpable and also to facilitate the conversion and subsequent con-

centration, the material should be ground to a fineness such that not materially more than half is as coarse as 50 mesh and the balance finer. In the case of taconite and other siliceous hematites it is frequently necessary to grind them to 150 mesh in order to free the siliceous gangue, and in doing so at least half of the material is reduced to a fineness of 200 mesh.

The slightly heated finely-divided material is gravity fed to an ore preheater 13 in which the ore is preheated up to about 350° F., more or less, preferably by waste heat from the converted ore pumped through the coil 14 within the preheater 13 and over which the ore flows by gravity in heat exchanging relation.

The warmed raw ore is gravity fed from preheater 13 to ore pump 15 of the type that is provided with a motor-driven screw for advancing the material through and beyond the pump through tube 16, after the material is mixed with a gas supplied under pressure by pipe 17. Such pumps for pumping finely-divided solids are well-known in several arts, particularly those employed in the cement industry, and one form of such pump is marketed under the name "Fuller-Kinyon." In adapting this form of pump to the present invention, the warmed raw ore is pumped through pipe 16 at the average velocity of about thirty feet per second, and the gas that is admixed therewith is a reducing gas supplied through pipe 17 at a pressure of about one hundred pounds per square inch gauge or more. At this gas pressure and under the conditions of agitation and mechanical pressure produced by pump 15, the particles of raw ore are suspended in the gas and the entire ore mass is rendered fluent or "fluidized" so that it flows like a fluid through pipe 16.

The reducing gas that is employed may be any suitable available gas containing substantial amounts of hydrogen or carbon monoxide, or both. An example of an inexpensive gas that is suitable for the purpose is uncarburetted water gas, usually comprising about 50% of hydrogen and 40% of carbon monoxide by volume. Cleaned producer gas, although not as rich in reducing agents may also be used, or any other convenient reducing gas high in hydrogen or carbon monoxide, or both, but preferably low in hydrocarbons since they are inert and some of them may decompose at the temperatures of operation of the process.

The fluent mixture of ore and reducing gas flowing through pipe 16 is introduced into the upper end of the spiral tube 18 of the converter 19 for downward spiral flow therethrough. The capacity of ore pump 15 is preferably such that a steady stream of the material flows at an average velocity of around thirty feet per second through a four inch diameter pipe 16, which is extended to the coil 18, also of four inch diameter tubing and preferably of a spiral diameter of ten to twenty feet and a length of eight hundred to two thousand feet, depending upon the several aforementioned variables.

The spiral 18 of converter 19 is enclosed in a suitable steel housing 20 lined with fire brick 21 or other refractory material. The spiral 18 is heated externally by one or more burners 22 positioned above the floor 23 of the converter and preferably supplied with gas as a fuel by pipe 24 from a source to be described. The upper portion of the converter contains a reflecting cone 25 for radiating the heat in the hot gases laterally and downwardly toward the spiral 18

before the gases flow out the slots 26 through the stack 27 into the air preheater 28 which is used to preheat the combustion supporting air supplied to the burner 22 by pipe 29. The residual heat in the flue gases after they leave the air preheater 28 may be employed to dry the raw ore prior to grinding at 12, and to that end they are supplied by pipe 30 to drier 11, as shown.

Converter spiral 18 preferably leads by tube 31 to the coil 14 of ore preheater 13 for heat exchange between the hot ore in the coil 14 and the finely-divided raw ore feeding thereover by gravity. The cooled ore is then delivered by pipe 32 to cyclone 33 where the converted ore is separated from the mixture of spent and excess reagent gas which is preferably supplied to pipe 24 for combustion at burner 22, so that the thermal content, both sensible and latent, of the combustible components of the off-gas is recovered and used. The converted ore, having been rendered magnetic by the conversion, is separated from the gangue in the magnetic concentrator 34, which is preferably of the wet type in which the ore and gangue are conveyed through water and the magnetic ore separated from the gangue by electromagnets, as is shown, for example, in copending abandoned application Serial No. 485,195, filed April 30, 1943, by H. A. Brassert. The concentrate may be sintered or briquetted to a size permitting its use in a blast furnace or it may be directly reduced to iron in finely-divided form in accordance with known processes.

In the modification shown in Fig. 2, the heat of the converted ore after it leaves the converter 19 is transferred to the ore as it leaves the ore pump 15' instead of before it enters the ore pump as in Fig. 1. To this end, the ore preheater 13' contains two spiral coils 35 and 36, either concentric or of the same diameter, each made of separate tubing and the turns of each spiral in contact with the corresponding turns of the other. Preferably the two coils 35 and 36 are integrally encased in cast iron for better heat exchange and the whole may take the form of a hollow cylinder or large diameter tube fitting within the insulating jacket 37 of ore preheater 13' with its center being filled with the raw ore so that remaining heat may be transferred thereto. The lower end of one of the coils, 35, is connected to discharge pipe 16' of ore pump 15' and its upper end to the converter spiral 18, while the upper end of the other coil, 36, is connected by pipe 31' to the lower end of the converter spiral 18 and its lower end is connected to pipe 32' leading to the cyclone separator. In this way the hot converted fluidized ore and spent gas mixture flows counter-currently to the raw ore and fresh reducing gas mixture and efficiently transfers heat thereto. Other methods of recovering the heat in the converted ore by heat exchange with the raw ore may be employed.

In operation of the apparatus described, the temperature at which the conversion or beneficiation of the ore and conditions under which that takes place are important. Unlike the reduction of iron oxides to iron, the conversion of Fe_2O_3 to Fe_3O_4 by hydrogen, for example, is slightly exothermic, and when the ore is finely-divided, such as 150 mesh hematite or limonite, the conversion at 750° to 800° F. is extremely rapid, taking place in a matter of seconds, partly due to the comparatively large surface area of the fine grains. Also as long as only a small amount of unreacted hydrogen is present under the conditions mentioned, the conversion will continue on

to virtually complete reduction to Fe_3O_4. With only carbon monoxide present as the reagent, a much longer time for conversion is necessary and a greater volume of the gas is required, and there is also liability of excessive deposition of carbon, according to the reaction

$$2CO \rightarrow C + CO_2$$

which is catalyzed by finely-divided iron oxide.

However, since only conversion to the magnetic state is desired, and then not materially greater than is necessary, i. e. not more than 25% of the particle need be magnetic to permit magnetic concentration, the aforementioned factors, utilized according to the invention, make the very rapid and inexpensive conversion of the plentiful low-grade non-magnetic ores a commercial possibility.

Only a low volume of gas, normally from twenty to thirty cubic feet at atmospheric pressure, is required to convey one cubic foot of pulverized material. Somewhat more than this is required to furnish the hydrogen component used in the conversion, but that additional volume only helps to fluidize the mass for pumping. Only about one-tenth of the gas required for the reduction of Fe_3O_4 to metallic iron is required to convert Fe_2O_3 to Fe_3O_4. With hydrogen in the gas, the temperature of conversion may be kept well below that at which undesirable non-magnetic FeO is formed as well as low enough so that but little of the carbon monoxide has time to break down to carbon dioxide and carbon due to the relatively brief time it is under pressure at the maximum temperature. Advantage is also taken of the exothermic nature of the reaction and the consequent rapidity thereof in the presence of hydrogen as one of the reagent components.

In order to avoid the use of too long a spiral 18 in the converter 19, or to increase the velocity therethrough and hence the output, the temperature to which the material in the spiral 18 is heated may be between 700° and 800° F. However, by increasing the pressure on the reducing gas to pipe 17 to upwards of one hundred pounds per square inch, the conversion may be effected at temperatures as low as 500° to 600° F. without increasing the size of the apparatus or reducing the velocity of throughput. The velocity may be regulated by adjusting the amount of gas fed to pump 15, whereby the degree of deoxidation may be regulated. The gas pressure in the spiral 18 may be regulated by means of a throttling valve at the discharge end, such as is shown at 38.

The temperature of the converted material discharged from converter spiral 18 accordingly is in the neighborhood of the conversion temperature, i. e., between about 500° and 900° F., and by transferring this heat to the raw ore in preheaters 13 or 13' considerable thermal economy is achieved. Likewise the surplus gas from the cyclone separator retains considerable sensible as well as its latent heat and this when added to the heat of the preheated air from 28, also provides an additional item of thermal economy, all conducive to inexpensive operation, rendering possible the commercial use of heretofore virtually useless low-grade non-magnetic iron ores.

Although certain preferred embodiments of the invention have been illustrated and described herein, it is to be understood that the invention is not limited thereby, but is susceptible of changes in form and detail within the scope of the appended claim.

I claim:

In apparatus for beneficiating non-magnetic ores to render them magnetic, the combination of an elongated tube, a pump connected to one end of said tube, means for supplying finely-divided ore to said pump for pumping through said tube, means for supplying a deoxidant gas to said tube for admixture with the ore therein to render the same fluent, means for heating said tube externally to cause the gas and the oxygen in the ore contained in said tube to react chemically to a degree rendering the ore magnetic, an ore preheater exchanger interposed between the other end of said tube and said means for supplying ore to said pump for preheating the latter with the residual heat in the treated ore, and means at said other end of the tube beyond said ore preheater for magnetically separating the magnetic particles from the gangue.

CHARLES F. RAMSEYER.

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