PROCESS OF PREHEATING ORES FOR REDUCTION IN SMELTING FURNACE

Filed Feb. 15, 1962

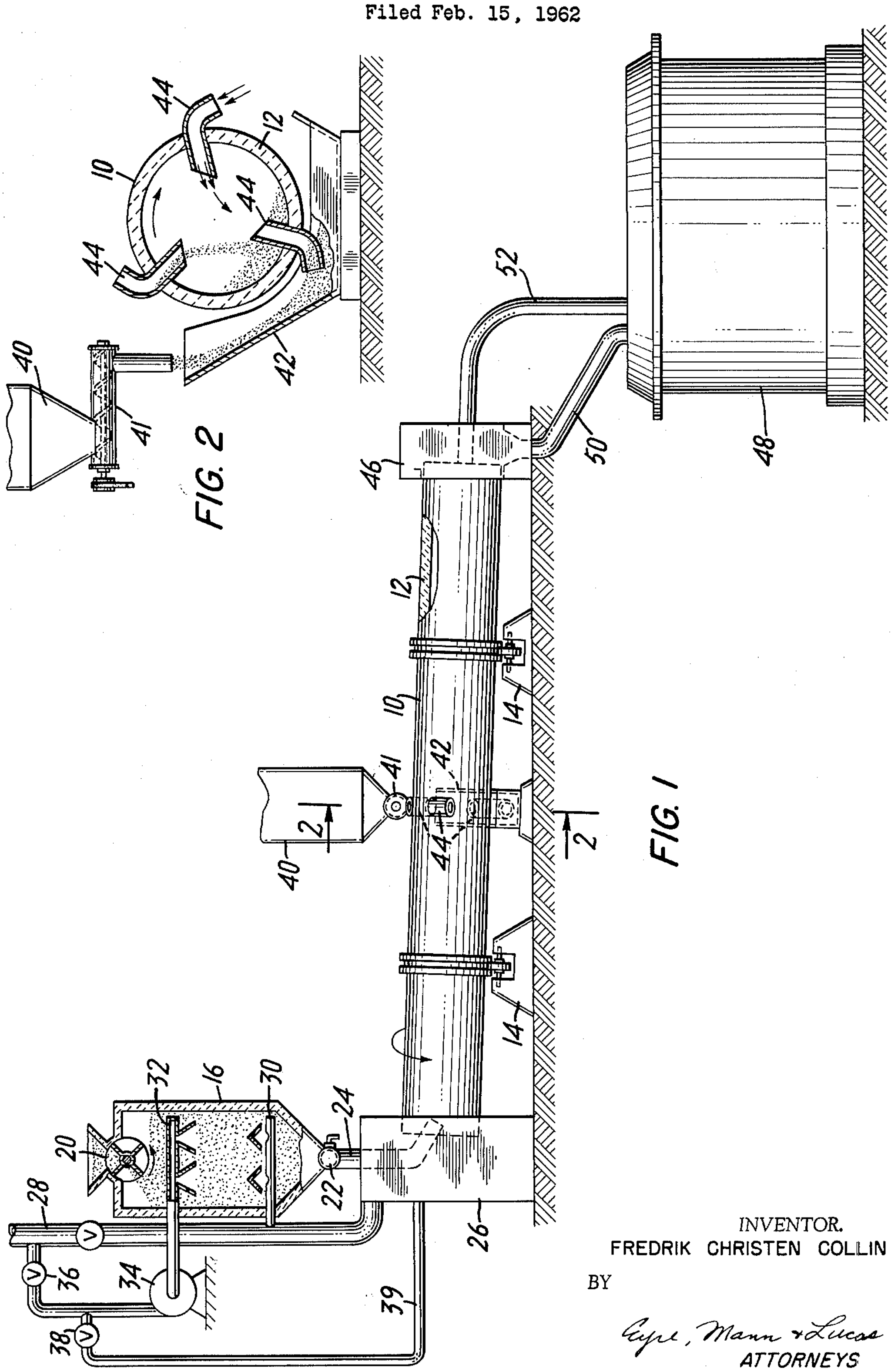

FIG. 1

FIG. 2

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United States Patent Office

3,224,871

Patented Dec. 21, 1965

3,224,871

PROCESS OF PREHEATING ORES FOR REDUCTION IN SMELTING FURNACE

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Filed Feb. 15, 1962, Ser. No. 173,450
Claims priority, application Norway, Feb. 24, 1961, 139,224
6 Claims. (Cl. 75—34)

Treatment of ores in a rotary kiln at temperatures of about 900 to 1100° C. prior to reduction in an electric smelting furnace is known and used in commerce. In the rotary kiln the charge is heated by combustion of gas rich in CO which is formed by reaction between oxygen in the charge and a carbonaceous reducing agent and additional heat is ordinarily supplied at the discharge end of the kiln. The charge which is preheated and at times prereduced in the rotary kiln is then fed into the electric furnace in which final reduction and smelting take place.

While the rotary kiln has many outstanding advantages for pretreating the charge, heat transfer between the hot combustion gas and charge is not particularly good and this is especially true at the relatively cool feed end of the kiln. The layer of charge which moves along the bottom of the kiln has little if any contact with the hot combustion gas and only the surface layer is fully exposed to the heat of the gas. As a result commercial rotary kilns which may for example pretreat up to 10 to 50 tons of charge per hour must be made very long and will average about 50 to 150 meters in length. The temperature of the off gas leaving the feed end of the kiln will ordinarily be in the neighborhood of about 200 to 500° C. and loss of heat in the off gas is a decided drawback to efficient operation. This heat loss is further increased when raw coal is fed directly through the wall of the rotary kiln into the high temperature zone as this causes an increase in the temperature of the gas leaving the kiln. Feeding coal into the high temperature zone of the rotary kiln is described in a copending application Serial No. 18,158, filed March 28, 1960 and now abandoned.

In accordance with the present invention, the heat content of the gas leaving the feed end of the rotary kiln is most effectively utilized by passing the gas in countercurrent flow through a bed of charge moving downwardly in a shaft. The hot gas in passing through the interstices in the bed of charge contacts a large surface area of the charge to provide a much greater transfer of heat than that obtained in the rotary kiln without sacrificing the advantages of pretreatment in the rotary kiln.

Best results are achieved by providing a plurality of relatively small preheating shafts which continuously feed parallel streams of charge into the rotary kiln. In general five to twenty shafts may be employed depending upon the size of the equipment at hand and fans are preferably used for sucking the hot gas through the bed of charge in the shaft. In some applications it is of advantage to limit the height of the column of charge in the shaft to about one meter.

As previously described the preheating shafts increase the heat efficiency of the rotary kiln operation and many other advantages may be achieved by the combined shaft and rotary kiln system of the present invention. For example when raw coal or other high volatile carbonaceous material is fed into the high temperature zone of the rotary kiln the off gases from the kiln may be at a temperature of about 500 to 900° C. or more. In such case the charge in the shafts may be heated to a temperature of about 500 to 800° C. before it is fed into the rotary kiln. Such a hot charge makes it possible to reduce the length of the rotary kiln which is of advantage in re-

ducing the cost of installation. The temperature of the off gas from the rotary kiln may be further increased to about 1200° C. by feeding all of the carbon required for reduction of the charge as coal into the high temperature zone of the rotary kiln. In such case the charge in the shafts may be heated to about 1000° C. This is of particular advantage in connection with the production of calcium carbide as in such case the limestone will be heated and precalcined in the shafts while the final calcination and coking of the raw coal will take place in the rotary kiln.

Many combinations are possible. A combination of preheating in the shafts and prereduction in the rotary kiln is especially advantageous for treating pellets or briquettes. Raw pellets of finely ground metal oxide, bituminous coal and a binding agent such as Portland cement must be heat treated to provide the necessary mechanical strength for prereduction in a rotary kiln. In accordance with the present invention the pellets are heated treated in the shafts at a temperature of about 600 to 900° C. At this temperature the coal is converted to coke and during this process a coke lattice is formed which reinforces the pellets to provide the mechanical strength required for treatment in the rotary kiln. In the rotary kiln the pellets are heated to about 900 to 1100° C. by combustion of gas in the space above the surface of the charge to provide rapid and effective reduction of the oxides without any appreciable loss of carbon due to reaction between the oxygen in the air or combustion gas in the kiln. In the case of raw pellets or briquettes it is especially advantageous to limit the height of the bed of charge in the shaft to about 1 meter because the raw pellets have such low mechanical strength that they tend to break under the pressure of a charge column of greater height.

In certain applications it is important to control the temperature and composition of the gas used in the shafts. In general this is done by controlling the amount of heat supplied at the discharge end of the kiln and by controlling the amount of air and coal fed into the high temperature zone of the kiln. Final control of the temperature and composition of the gas in the shaft is achieved by providing an air lock at the mouth of the shaft and by withdrawing the gas below the air lock by means of fans which may be employed for recycling the gas.

Further advantages and the details of the process of the present invention will be readily understood by reference to the accompanying drawings which illustrate one preferred form of apparatus for carrying out the present invention and in which

FIG. 1 shows a side view of the combined shaft and rotary kiln system of the present invention,

FIG. 2 is a section on line 2—2 of FIG. 1.

As illustrated in the drawings **10** is a rotary kiln with the usual refractory lining **12** and roller supports **14** upon which the kiln rotates. Shaft **16** with refractory lining **18** is provided with a conventional type air lock valve **20** for feeding charge into the shaft. Valve **22** controls the flow of charge from the discharge end of the shaft where the charge is fed into the kiln by pipe **24**. The off gas from the kiln is collected in box **26** and fed into the bottom end portion of the shaft by the pipe **28** and a conventional gas feeder **30** which distributes the gas to the charge in shaft **16**. The gas is collected at the top of the shaft by a conventional gas collector **32** and fan **34** overcomes the pressure drop in shaft **16** to suck the gas through the charge. Valves **36** and **38** control the flow of gas from the fan and the gas is either returned to the exhaust stack or recycled through pipe **39** to chamber **26** for adjusting the temperature and composition of the gas fed to the shaft.

While only a single shaft **16** is illustrated in the drawings it will be understood that ordinarily a plurality of shafts will be employed for feeding the charge in parallel flow into kiln **10**. For best results each shaft is equipped with its own individual fan and gas feeding and recycle pipes connected to chamber **26** as described for shaft **16**.

As shown in the drawing the rotary kiln may be equipped with one or more devices for feeding coal or other high volatile carbonaceous material into the kiln. One such device is illustrated in the drawings and as there shown the device comprises a hopper **40** with conveyor **41** which feeds coal into the open container **42**. A plurality of pipes **44** which extend into the interior of the furnace are bent at their outer end in the direction of rotation of the kiln to provide scoops which pick up the coal from container **42** and feed it onto the charge in the kiln which is at a temperature of 800° C. or more. The heat of the charge will quickly drive off the volatiles and convert the coal to coke. The volatile material is burned above the charge with a luminous heat radiating flame.

Air for burning the volatiles may be introduced through the same pipes used for introduction of the coal or additional air pipes (not shown) may supply air to the kiln near the discharge end in conventional manner or excess air may be supplied by a burner if such is employed for introducing heat into the discharge end of the kiln. If desired coke or other low volatile carbonaceous material may also be fed into the kiln by means of pipes **44**.

The material treated in the kiln is discharged through a conventional so-called "front wagon" **46** and it may be fed directly into an electric furnace **48** by the inclined chute or pipe **50**. In larger installation the kiln discharges into an intermediate hopper (not shown) and the discharged material is then transferred from the hopper to the electric furnace. In the structure shown in the drawings furnace gas rich in CO is supplied to the discharge end of the kiln by pipe **52** and the gas is burned in the kiln to supply heat at this end of the kiln. If desired a conventional gas burned (not shown) may be used for supplying heat at the discharge end of the kiln.

In a typical operation iron ore and the usual limestone flux are charged to the preheating shafts and all of the carbon required for reduction of the charge is fed into the kiln as coal by pipes **44**. Air fed into the kiln is so adjusted that the off gas of the kiln is at a temperature of about 1000° C. and contains about 3% oxygen. The iron ore and limestone flux are heated to a temperature of about 900° C. in the shafts and as a result FeS in the ore will be oxidized to Fe_2O_3 and the limestone flux calcined to lime. Under these conditions about 30% of the oxygen is removed from the ore in the rotary kiln. This illustrates the use of a divided charge in the system in which only the oxide ore and limestone flux are fed into the shaft and in which all of the carbon required for reduction of the charge is fed into the kiln as raw coal. In such case an oxidizing atmosphere is provided in the shafts by supplying gas containing from 1 to 5% oxygen and when the temperature of the charge in the shafts reaches approximately 900° C. or greater sulphur is eliminated from the ore and the limestone flux is calcined.

In another typical operation powdered iron ore 50 to 90% of which passed through a 200 mesh standard Taylor screen is pelletized with slightly more than the stoichiometric proportion of bituminous coal necessary for reduction and about 5% Portland cement as a binder. The raw wet pellets were hardened by storing for three days at atmospheric temperature whereby the point pressure strength of the pellets increased from 3 kgs. to 15 kgs. The mechanical strength of the hardened pellets of 15 kgs. is adequate for pretreatment in the shafts but insufficient for treatment in the rotary kiln. The pellets are fed into the shaft.

In this case gas supplied by the furnace to the discharge end of the rotary kiln contains 45% CO_2 and 55% CO. The gas is burned in the rotary kiln and the supply of air is so controlled that the off gas from the kiln is at a temperature of about 900° C. The off gas contains about 13% CO_2, 0.2% oxygen, 1.0% CO and the remainder N_2. The pellets in the shaft are heated to about 800° C. by the hot off gas whereby the point pressure strength of the pellets is increased from 15 kgs. to about 160 kgs. to provide the desired mechanical strength for treatment in the rotary kiln. The hardened pellets are transferred to the kiln where they are heated to a temperature of about 900° C. by combustion of the furnace gas and by combustion of CO generated by the prereduction reaction in the pellets. In the rotary kiln about 50% of the oxygen is removed from the pelletized ore. In the case of pelletized metal oxides the charge in the shaft is heated to a temperature of about 500 to 900° C. in order to provide the pellets with the necessary mechanical strength for treatment in the rotary kiln and for best results the oxygen content of the gas utilized in the shaft is below about 1.0% and the CO content is also below about 1.0%. Care is taken to limit the depth of the charge column in the shafts to about 1.0 meter because of the low mechanical strength of the pellets charged to the shafts.

Excellent results are achieved using the system of the present invention for the production of carbide. In such case limestone is charged to the shafts while the raw coal is fed separately into the middle portion of the kiln. The combustion in the kiln is so adjusted that the off gas is at a temperature of about 1100° C. and contains about 5% oxygen. The gas when fed to the shafts will heat the limestone to about 1000° C. and cause it to be calcined to CaO. The temperature of the lime and coke leaving the rotary kiln was about 1200° C. This example again illustrates the use of a divided charge and in this case the temperature of the charge in the shaft is raised to about 900 to 1200° C. to calcine the limestone. Excess oxygen is supplied to the rotary kiln in order to achieve the heat required for calcining the limestone in the shafts in an oxidizing atmosphere.

It will now be understood that the system of the present invention may be used for pretreatment of ores or other oxides or materials of the type which are customarily treated in a submerged arc smelting furnace. These include iron oxides, various oxides for producing ferro alloys such as ferromanganese or ferro silicon and also can be used in the production of calcium carbide.

What I claim is:

1. The method of treating ores in a rotary kiln having at least one shaft associated therewith for feeding charge into the kiln which comprises the steps of introducing charge into the shaft to establish a column of charge therein which is relatively short with respect to the length of the kiln, moving the charge in the column downwardly in the shaft, collecting hot off gas from the rotary kiln, introducing at least a portion of the hot off gas into the lower end portion of the shaft, passing the introduced off gas upwardly in the shaft in countercurrent flow through the interstices in the column of charge, withdrawing the introduced off gas from the upper portion of the shaft and feeding the charge heated by the introduced off gas into the rotary kiln.

2. The method specified in claim **1** which includes the step of recycling at least a portion of the gas withdrawn from the upper portion of the shaft by feeding such portion back into the bottom of the shaft.

3. The method specified in claim **1** which includes the step of providing a flow of oxidizing gas countercurrent to the bed of charge containing from about 1 to 5% oxygen at a temperature of not more than 900° C.

4. The method specified in claim **1** which includes the step of providing a flow of gas which contains not more than about 1% oxygen, and not more than about 1% CO, such gas being at a temperature of about 500 to 900° C.

5. The method specified in claim **1** which includes the step of introducing gas into the shaft at a temperature of about 900° C. to about 1200° C.

6. The method of treating ores in a rotary kiln having a plurality of stationary shafts associated therewith for feeding charge into the kiln, said method comprising the steps of introducing charge into the shafts to establish vertical columns of charge therein which are relatively short in comparison with the length of the kiln, moving the charge in each column downwardly, passing hot off gas from the rotary kiln upwardly through the interstices in each column countercurrent to the movement of the charge to heat the charge, withdrawing from each column the gas passed upwardly through the column, passing said withdrawn gas upwardly through the columns along with off gas from the rotary kiln and introducing charge so heated into the rotary kiln.

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