April 12, 1966 T. E. BAN 3,245,778

METHOD OF INDURATING IRON ORE CONCENTRATES

Filed April 6, 1962 2 Sheets-Sheet 1

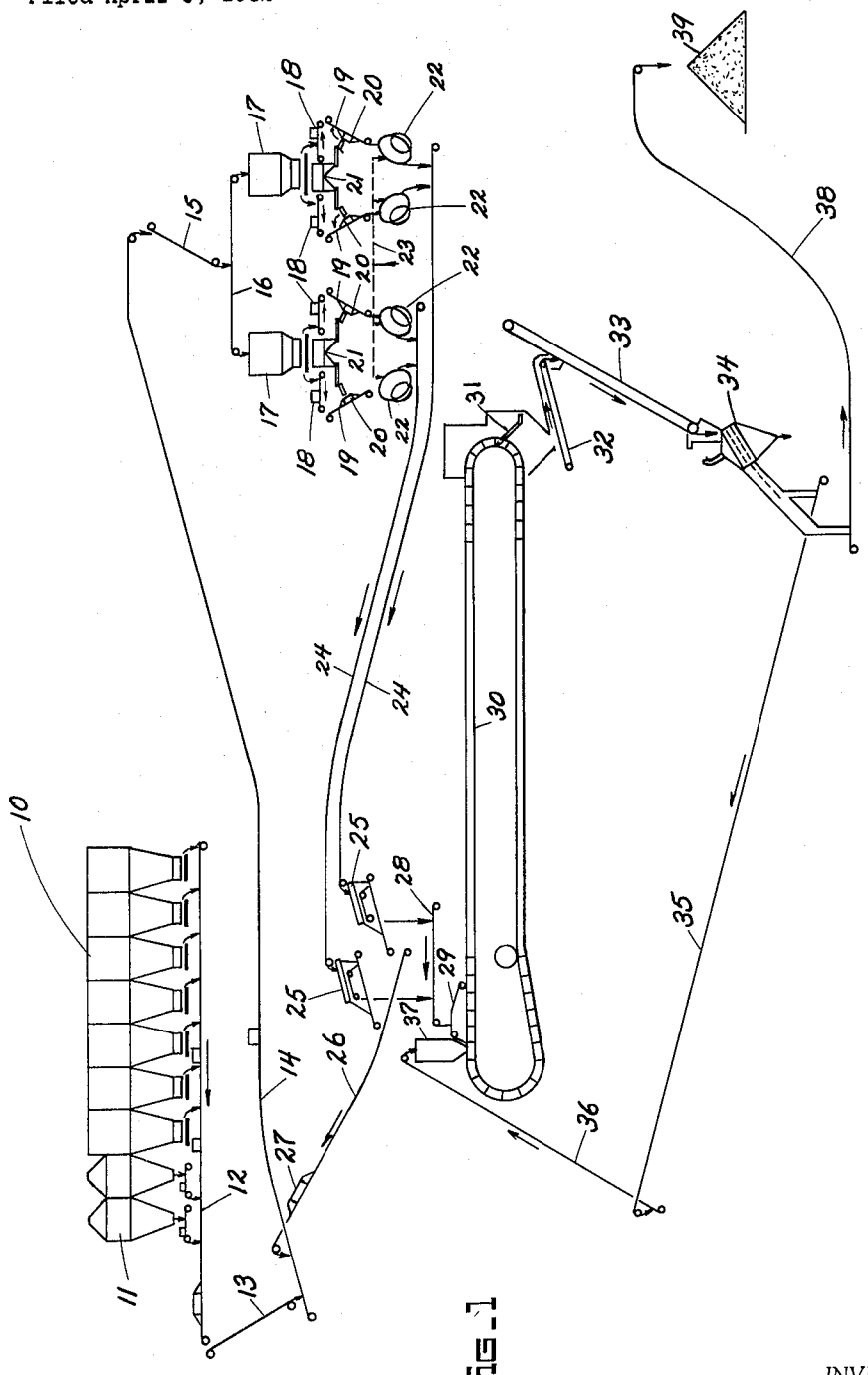



FIG. 1

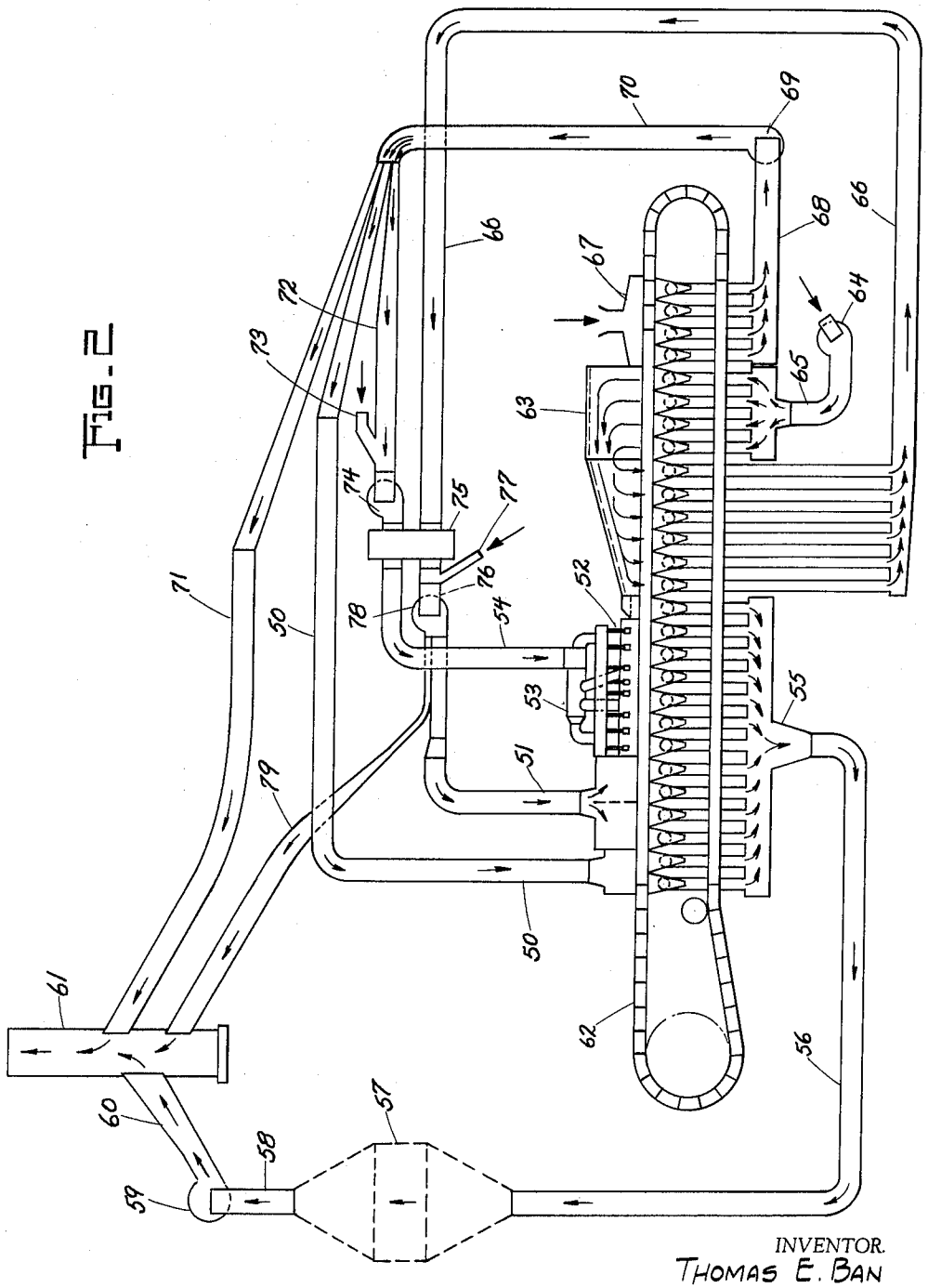
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Filed April 6, 1962 2 Sheets-Sheet 2

FIG. 2




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# METHOD OF INDURATING IRON ORE CONCENTRATES

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1 Claim. (Cl. 75—5)

The present invention relates to an improved method of heat-hardening green balls formed from the pulverulent products of low grade iron ore beneficiation processes.

As the amount of available high grade iron ores has gradually become depleted it has become quite evident that processes must be developed for beneficiating the lower grade ores. One of the most common low grade ores is exemplified by taconite, an extremely hard rock which can be reduced to usable form by a series of crushing and separating steps which form no part of this invention. For a proper understanding of the advantages of the invention a brief resume of the pelletizing of the beneficiated taconite ore now follows:

The beneficiated taconite end product is a fine powder containing between sixty and seventy percent of iron in the form of a magnetic oxide of iron, having the formula $Fe_3O_4$. This powder is unsuitable for direct charging into a blast furnace. However, this material can be efficiently fed to a blast furnace in the form of small rounded agglomerated and hardened particles from about one-quarter inch to about five-eighths inch in diameter. These particles which are the product of the present process will herein be identified by the conventional term "pellets."

A preferred method of pellet manufacture comprises moistening the beneficiated taconite fines and rolling them into balls in a large drum which is rotating on an axis somewhat inclined to the horizontal. The concentrate is charged into one end of the drum and rolls along the inner peripheral wall of the drum as it rotates. Nuclei form and increase in size as the growing particles progress towards the discharge end of the drum. By various expedients not necessary to discuss here the ball-forming procedure is controlled to yield balls within a pre-determined size range.

The beneficiated ore concentrate may contain a certain amount of moisture, preferably around ten percent, which increases the tacky or cohesive character of the powder to achieve improved balling properties. It may also contain a minor amount of some bonding material, as for example, bentonite. The balls, after formation, are subjected to rather vigorous handling. They must, therefore, be treated to increase their strength, hardness, and impact resistance, because in the progression from the balling apparatus to the blast furnace they are transferred from conveyors to bins, thence perhaps to storage yards, thence to other conveying means, thence to ore-carrying boats, thence to railroad cars, etc. It is accordingly necessary that the green balls be given an induration treatment to prevent them from being substantially completely broken up by handling before they reach the point of ultimate use.

This induration treatment has involved heating to an elevated temperature but preferably just below the range at which incipient fusion takes place. With beneficiated taconite a good operating upper limit is about 2500° F., with a preferred temperature of about 2370° F. If this temperature is materially exceeded incipient fusion and mutual adhesion occurs between the pellets, producing excessively fused lumps which are undesirable in subsequent reduction to metallic iron in the blast furnace.



Heating is supplied, for the most part externally. In one preferred system, which will appear more in detail hereinbelow, the pellets are disposed in a layer on an endless type of conveyor, consisting of a series of pallets, moving in end-to-end contact, and having a gas-permeable floor consisting of slightly spaced grate bars supported on the pallet frame. The layer may be from six inches to eighteen inches thick, and the conveyor is moved slowly through a series of zones comprising, in succession, a drying zone, a combustion zone, a soaking-recuperation zone, an updraft recuperation-cooling zone and a downdraft recuperation-cooling zone. Combustion can be accomplished by burning gas or fuel oil in a manner such that the hot combustion gases are directed toward the pellet bed. If desired, the beneficiated ore may be mixed with ground limestone prior to the balling operation so as to form fluxed pellets. The pellet bed, as it moves through the combustion zone, is subjected to a penetrating current of heated air which augments the effect of the fuel burners in raising the pellets to the desired temperature. Heated air withdrawn from the recuperation zones is preferably routed at least in large part to the drying, combustion, and soaking zones in a manner which is described hereinafter.

As noted above, the iron oxide constituent of taconite is originally substantially completely in the form of magnetite, namely $Fe_3O_4$. During the induration process, a major proportion is changed to ferric oxide, namely $Fe_2O_3$ which is a non-magnetic type. This reaction is exothermic, considerable heat is evolved, and a substantial saving is achieved in the quantity of fuel which must be added in the combustion zone.

An object of the present invention is to provide a process and system for the induration of iron ore concentrate pellets of materially improved quality.

A further object of the invention is to provide a process wherein substantial volumes of heated air, previously wasted, can now be diverted to useful purposes in the cycle.

A further object of the invention is to provide a pellet induration process involving the use of a gas-permeable horizontally-movable, pellet-supporting grate assembly arranged as a conveyor on which a bed of pellets can be advanced and indurated in a bed depth that is practicable and versatile in a system of this general type.

A further object of the invention is to provide a pellet indurating system using a horizontal endless grate on which induration can be satisfactorily accomplished with a substantial decrease in B.t.u. input per unit weight of treated pellets.

A further object of the invention is to provide a pellet indurating process of the nature described, which fosters a controlled amount of exothermic reaction, thereby liberating a considerable amount of heat while improving product quality and reducing the required amount of externally supplied fuel.

A further object of the invention is to provide a pellet indurating system which is characterized by a relatively greater degree of temperature control in the various stages than has been heretofore accomplished.

A further object of the invention is to provide a process involving the induration of beneficiated taconite pellets on an endless grate, gas permeable conveyor, and in which grate bars and supporting pallets can be maintained at a temperature below that previously developed, thereby reducing grate bar warpage and necessity for bar and pallet replacement, as well as greatly reducing maintenance costs in labor and materials.

A further object of the invention is the provision of a pellet indurating process in which the furnace room temperature mainly originating in the indurating furnace unit,

has been substantially reduced to a more bearable working temperature.

A further object of the invention is to provide a pellet indurating process of the type hereinabove defined in which the pellets being discharged from the grate conveyor are at a temperature low enough to obviate the necessity of cooling them further by water spray or otherwise, and in which the pellets so issuing consequently contain no material amount of moisture which would have added an undesired weight increment to the shipment of pellets from the pelletizing location to the blast furnace.

Other objects and advantages will be apparent from a study of the following description of the invention, in conjunction with the accompanying drawings, a description of which now follows:

In the annexed drawings:

FIGURE 1 is a diagrammatic, schematic layout of a method of indurating iron ore concentrates in accordance with the present invention.

FIGURE 2 is a diagrammatic illustration of the gas flow within a sintering machine in which the process of the present invention is carried out.

Referring specifically to FIGURE 1, a plurality of bins **10** are provided for the storage of the beneficiated taconite. If limestone is needed such as is the case in the manufacture of fluxed pellets, the bins **11** are provided for limestone storage. The bins **10** and **11** discharge their contents on the conveyor **12**. Conveyor **12** is operatively connected with conveyors **13**, **14**, **15** and **16** whereby the material from the bins **10** and **11** is transferred to the surge bins **17**. Material from the bins **17** is transferred by means of feeders **18** to conveyors **19** which are equipped with mixers **20**. If desired, bentonite is introduced on the conveyor **19** at this point from bins **21**. Material from the conveyor **19** is discharged to conventional balling apparatus **22** where it is formed into green balls.

If necessary, additional water may be added to the balling apparatus **22** through the conduit **23**. The green balls which are discharged from the balling apparatus **22** are transported by conveyors **24** to the ball screens **25** where they are sorted according to size. Undersize balls are returned to conveyor **14** on the conveyor **26** which also passes them through a shredder **27**. Those balls of the proper size are transferred by means of the conveyors **28** and **29** to a conventional traveling grate sintering machine of the Dwight-Lloyd type **30**. After traveling through the sintering machine **30**, the pellets are removed from the grates by means of the grizzly **31** and discharged on to conveyor **32** which in turn discharges on conveyor **33**. Conveyor **33** discharges into a double deck screen **34** which sorts the pellets according to size.

Sized pellets are discharged from the screen **34** on to conveyor **35**, which is associated with conveyor **36**. Conveyor **36** discharges into the bin **37**. The fired pellets contained in bin **37** are discharged on to the traveling grate machine **30** in order to form an insulating bed on the bottom and sides of the pellets within which the green balls are subsequently received. In this manner, the grates in machine **30** are provided with an insulating layer which protects them from exposure to excessively high temperatures with a consequent savings on maintenance costs and also reduces heat loss from the side walls of the machine. Finished pellets of the correct size range are transferred from screen **34** to conveyor **38** which transports the pellets to storage on the pile **39**.

Referring now to FIGURE 2, the arrangement of the gas flow within the sintering machine **62** is shown in detail. In the first section of the sintering machine **62** which is hereinafter referred to as the drying section, the green balls are subject to a down draft of recycle gas issuing from conduits **50** and **51** so that they are subjected to gradually increasing temperatures in three distinct stages. The temperature of the gas in the first stage is 400° F. to 550° F., in the second stage is 550° F. to 700° F., and in the third stage is 700° F. to 950° F. Temperature control in the three stages is accomplished by bleeding in outside air or by adding heat from auxiliary burners (not shown). Next the balls move to the combustion zone which is equipped with a plurality of burners **52** which may burn oil or gas. Combustion air for burners **52** is supplied from manifold **53** and conduit **54** at a temperature of about 1050° F. Four distinct temperature stages are maintained in the combustion zone. In the first stage the temperature is gradually increased from about 1000° F. to about 1800° F.; in the second stage from about 1800° F. to about 2000° F.; in the third stage from about 2000° F. to about 2200° F.; and, in the fourth stage from about 2200° F. to about 2500° F. All of the exhaust gas from the drying and combustion zones is collected in a common header **55** and transferred by means of conduit **56** to dust collector **57**. The dust-free gases are withdrawn from dust collector **57** through conduit **58** by the action of a blower **59** which discharges the gas through conduit **60** into a stack **61**.

Returning now to the sintering machine **62**, the pellets leave the combustion zone at a temperature of about 2400° F. whereupon they are transferred to a heat soaking-recuperation zone which is defined by windbox **63**. Windbox **63** is divided into two zones in the rear section of this zone outside air at the ambient temperature is forced by blower **64** through conduit **65** through the bed of pellets in up draft flow. The flow of this air after passing through the bed is then reversed by means of baffles (not shown) so that it passes in down draft manner through the pellet bed and the exhaust gases enter conduit **66** at a temperature of about 1250° F. to 1350° F.

Outside air is also drawn into the final windbox **67** which makes up the final cooling zone and it is pulled in downdraft fashion through the sinter bed into conduit **68** by blower **69** and it then passes into conduit **70** at a temperature of about 550° F. The gas in conduit **70** is split into three parts; (1) part flows through conduit **71** to stack **61**, (2) part flows through conduit **50** to furnish hot gas to the initial drying zone, and (3) part flows through conduit **72**.

The hot gas in conduit **72** is mixed with outside air which enters at **73** and the mixture is passed to blower **74** which transfers it to an indirect heat exchanger **75**. In heat exchanger **75** the gas exchanges heat with hot gas from conduit **66** and the heated gas is discharged into conduit **54** in order to furnish hot combustion gas at a temperature of about 1050° F. for the burners **52**. The relatively cooled gas leaves exchanger by way of conduit **75** where it is mixed with outside air entering at **77**. The mixture then enters blower **78**. A part of the exhaust is transferred to stack **61** by way of conduit **79**, while the remainder is transferred to conduit **51** in order to furnish gas at a temperature of about 600° F. to 950° F. to the drying zone.

In the present process for heat hardening green balls made from taconite concentrates or other ore concentrates, the machine system incorporates downdraft drying, downdraft firing, recuperative downdraft soaking, recuperative updraft cooling, and a final downdraft cooling. Green balls are sized at about one-quarter inch to about five-eighths inch in diameter. These are charged to the sintering machine in a 10 to 12 inch layer. Upon entering the drying chambers, the layer of green pellets is dried by using downdraft air that ranges in temperature from 400° F. to 950° F. section. In the firing section, the temperature is raised to about 2500° F.

As the charge emerges from the 2500° F. zone, it is subjected to a heated downdraft supplied from the updraft recuperative cooling section at a temperature of about 1100° F. and it serves to further oxidize, anneal and harden the pellets. The exhaust gases having a temperature of about 1200° F. to 1250° F. from this section are directed through an indirect heat exchanger where the gases are quenched and they are then pumped to the dry-

ing section where the heat is utilized for drying. A fan drawing air from the final downdraft cooling section fan and the atmosphere discharges through the indirect heat exchanger and supplies a 1100° F. heated air medium for combustion in the firing section thereby reducing fuel costs.

The updraft cooling section supplies a heated draft of about 1100° F. directly into the soaking section and it serves to minimize the amount of heat drawn into the pallet members. In order to economically cool the product to the specified temperature conditions, updraft cooling is followed by downdraft cooling. This provision takes advantage of the high temperature differences existing between the cooling medium and the upper heated layers of pellets. The 550° F. exhaust gases from this downdraft cooling zone are directed to one of the drying hoods and to the fan which supplies air through the indirect heat exchanger. The product of the pelletizing process discharges from the machine in an indurated state, and the draft arrangement enables efficient heat recuperation to be practiced.

The features that appear unique for pelletizing operations include the use of an indirect heat exchanger and the use of updraft cooling followed by downdraft cooling. A clean high temperature air draft of about 1100° F. is made available by the indirect heat exchanger, and this draft ordinarily cannot be supplied by a practical fan system coupled to a specific high temperature zone. Furthermore, the high temperature draft assures a maximum oxidizing condition for induration of the pellets.

The downdraft system of firing including the drying operation offers advantages for the pelletizing system since it enables the heated draft to be placed along the machine in many different locatons. Staged downdraft drying assures controlled moisture removal from the topmost layers which become immediately directed to the high temperatures of the combustion chambers. The first stage or low temperature stage of drying in conjunction with high draft velocities in the bed minimizes coalescence of removed moisture on the pellets near the bottom of the bed and prevents these pellets from congealing. Drying efficiency is attained with the remaining higher temperature stages. The use of this multiple stage firing section permits the temperature gradient through the pellet bed to be controlled during induration and co-ordinated with the exothermic oxidizing reactions of magnetite. Also, this avoids crystallization of magnetite that is usually caused by a rapid rate of temperature increase.



When it is desired, a fluxed variety of pellet product (such as by the addition of limestone) considerable flexibility for the firing operation is provided. Ordinarily flux additions minimize the requisite pellet temperature, yet require precise control for avoiding fusion of pellet masses. Flux additions to the pellets require higher heat inputs in the preheat stages and somewhat less heat inputs in the final firing stages as compared to normal pellet operations. For this reason a rather versatile system of firing is proposed to enable natural or fluxed pellets to be produced.

I claim:

In a method of indurating green balls comprising an iron ore concentrate and including the steps of drying, preheating, ignition and cooling, the improvement which comprises the steps of moving a bed of said balls having a depth of from 6" to 18" through a down-draft drying zone having a first stage maintained at a temperature of about 400° F. to 550° F., a second stage maintained at a temperature of about 550° F. to 700° F., and a third stage maintained at a temperature of about 700° F. to 950° F.; next moving said bed into a down-draft combustion zone containing a plurality of burners having a first stage maintained at a temperature of about 1000° F. to 1800° F., a second stage maintained at a temperature of about 1800° F. to 2000° F., a third stage maintained at a temperature of about 2200° F. to 2500° F., next moving said bed into a soaking recuperation zone where it is subjected to a down draft of gas maintained at a temperature of about 1100° F., next moving said bed into a cooling-recuperation zone wherein it is first subjected to an updraft of air at a temperature approximating the ambient temperature, and then finally to a down-draft of air at a temperature approximating the ambient temperature, and finally recovering indurated pellets from said bed.

**References Cited by the Examiner**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 2,750,272 | 6/1956 | Lellep | 75—5 |
| 2,750,274 | 6/1956 | Lellep | 75—5 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 600,026 | 6/1960 | Canada. |

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