Jan. 28, 1958 E. W. DAVIS 2,821,469

GRATE TYPE PELLETIZING METHOD AND APPARATUS

Filed Feb. 6, 1953 2 Sheets-Sheet 1

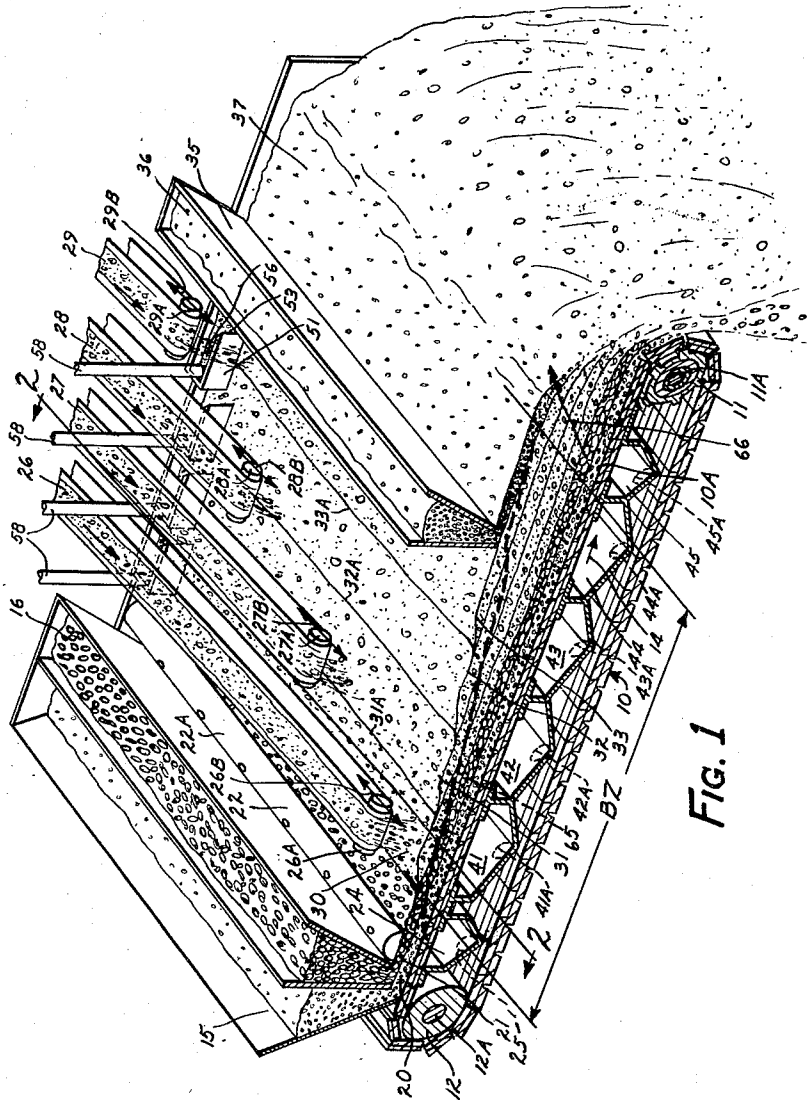


FIG. 1

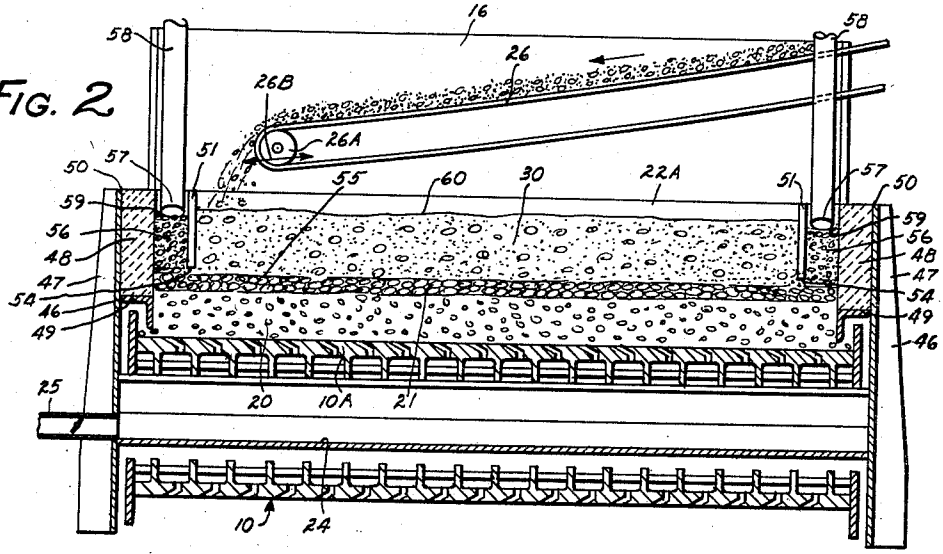
INVENTOR.
EDWARD W. DAVIS
BY Paul, Moore & Rugger
ATTORNEYS

Jan. 28, 1958 E. W. DAVIS 2,821,469

GRATE TYPE PELLETIZING METHOD AND APPARATUS

Filed Feb. 6, 1953 2 Sheets-Sheet 2

FIG. 2



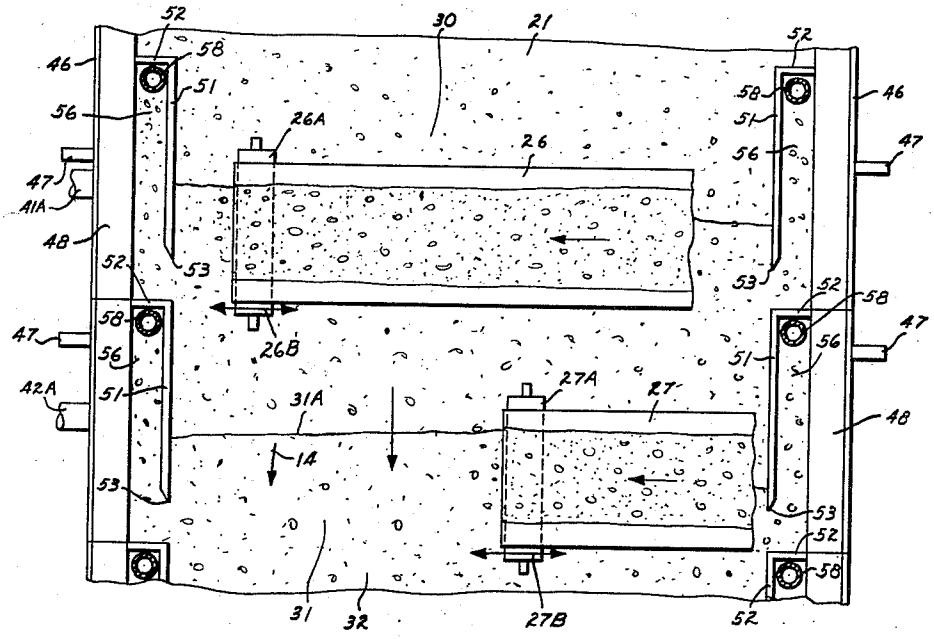


FIG. 3

INVENTOR.
EDWARD W. DAVIS
BY
Paul, Moore & Dugger
ATTORNEYS

United States Patent Office 2,821,469
Patented Jan. 28, 1958

2,821,469

GRATE TYPE PELLETIZING METHOD AND APPARATUS

Edward W. Davis, Minneapolis, Minn., assignor to Regents of the University of Minnesota, Minneapolis, Minn., a corporation of Minnesota

Application February 6, 1953, Serial No. 335,539

16 Claims. (Cl. 75—5)

This invention relates to an improved method and apparatus for pelletizing ores and other pulverulent materials, particularly iron ore. In the beneficiation of some ores it is necessary to reduce the ore, as it occurs in nature, to a fine powder so as to release the ore particles from the particles of silica and other gangue-like constituents of the ore to thereby permit beneficiation. After being so reduced the fine particles of ore are separated from the silica and gangue by processes well known in the art and the ore which is accordingly beneficiated is thereby caused to contain much higher percentage of iron than as found in nature. The division of the ore into fine particles, though necessary for the beneficiation or concentrating steps, may be a distinct disadvantage insofar as the use of the product is concerned, for the fine particles are not suitable for use in blast furnaces of usual construction. For blast furnace use the ore should be in relatively larger particles, thus ⅛ inch to 1 inch or even larger so as to be capable of packing loosely to allow the furnace blast to pass upwardly therethrough during the smelting operation.

It is possible by known procedures to produce balls of ore of sufficient wet strength to permit a limited amount of handling. Thus, the finely divided ore may be introduced with 8% to 12% of water into a revolving tube set at a slight gradiant. The particles of ore rolling upon themselves agglomerate into spherical masses ranging in size from ⅛ inch up to 1 inch or even larger. By suitable control of the moisture, speed of rotation of the mill and other factors, the production of spherical or nearly spherical balls or compacts may be accomplished at relatively low cost. These compacts, however, are not suitable for shipping or for use directly in the blast furnace because, though strong enough to stand some handling, they are relatively friable when they dry out. It is known that when such spherical compacts of ore particles are heated to a temperature just below the melting temperature of the ore, the particles will sinter together and form hard, very strong pellets capable of shipment, storage and handling and sufficiently strong for use in a blast furnace. To accomplish this, the temperature to which the balls are heated must be closely controlled. There are many suggestions in the patented and published arts concerning the production of sinter, but satisfactory commercial processes for the production of sintered spherical masses of iron ore at commercially acceptable costs using a chain grate stoker mechanism were not accomplished prior to the present invention.

I have discovered that if the moisture containing balls of ore are heated in a thick layer by heat passed upwardly through them, moisture driven out of the balls at a lower level may condense on and soften the balls at a higher level, with the result that flattening of the balls will occur, and even though the flattened balls may later on be sintered into hard masses, this flattening is a disadvantage. Even a small amount of flattening radically reduces the voids between the balls, through which gases must pass, and such flattening increases the resistance and decreases the gas flow rate. Thus, flattening spherical compacts by only 17% of their diameters reduces the percentage of voids almost 50%. The flattened pellets not only burn slowly but also cool slowly due to lack of gas flow. This is a disadvantage.

It is an object of the present invention to provide an up-draft stoker type pelletizing method and apparatus capable of producing strong uniformly heated treated spherical masses of iron ore suitable for handling and use in a blast furnace.

It is another object of the invention to provide an up-draft stoker type pelletizing method and apparatus capable of heat treating spherical agglomerates of iron ore, uniformly, under accurate control, economically and upon a vast tonnage basis.

It is another object of the invention to provide a method of burning balled ore-fuel compacts in successive relatively thin layers and under closely controlled conditions which may be varied as needed to effect control and to provide a method whereby the burning of the compacts can be effected at a lower overall fuel cost than heretofore possible and without undue flattening.

It is another object of the invention to provide an up-draft stoker type method and apparatus for the production of merchantable sintered spherical balls of iron ore of uniform treatment.

Other and further objects of the invention are those inherent in the apparatus herein illustrated, described and claimed.

The invention is illustrated with reference to the drawings in which corresponding numerals refer to the same parts and in which

Figure 1 is a perspective view showing in longitudinal section certain portions of an exemplary apparatus of the present invention;

Figure 2 is a transverse sectional view along the line and in the direction of arrows 2—2 of Figure 1;

Figure 3 is a plan view of one part of the side edge of the apparatus shown in Figures 1 and 2, the view in Figure 2 being taken along the line and in the direction of arrows 3—3 of Figure 2.

The method of the present invention will be illustrated with reference to the exemplary apparatus herein described and shown in the drawings. Referring to the drawings, the apparatus comprises an endless chain grate generally designated 10 which is arranged so as to travel horizontally or nearly so upon two rollers 11 and 12 supported, respectively, on the shafts 11A and 12A. The shaft 11A and roller 11 are driven by a power source, preferably of the variable speed type, so as to move the upper surface 10A of the chain grate in the direction of arrow 14. After traveling over the drive roll 11, the chain belt returns along the course of travel 10B and after passing over the idler roller 12 again resumes its travel along course 10A. The chain grate may be of suitable commercial construction. The area of the chain grate to a considerable extent determines the capacity of the installation and can be made as large as mechanical design factors permit. The speed of travel of the grate is to a considerable degree determined by the rate of burning upwardly through the bed or layer of unsintered balls and by the thickness of the burden on the grate. Thus, a grate having a width of 15 feet and a length of the burning zone (denoted by the dimension BZ) of 15 feet, may have an overall length of 25 feet. Such a machine having a 24 inch depth of burden, wherein the grate travels at a rate of, for example, 7½ inches per minute, has a capacity in the neighborhood of 1000 tons of finished sintered balls for each 24 hours of operation.

Along the upper course of travel 10A of the grate are arranged a number of instrumentalities as follows: Thus, just after the chain comes around the roller 12 and begins

to move along its course of straight travel **10**, it travels under the feed box **15** which is provided for depositing a hearth layer on the grate. The hearth layer preferably consists of already burned balls (which may be be cracked or broken balls) which are separated after the end of the process. These are relatively hard and resistant and are deposited in a smooth and uniform layer preferably ranging from 1 to 4 inches in thickness, for example 3 inches in thickness. I prefer to use burned balls or chips ranging in size from ⅛ to ⅜ inch and these form a protective layer for the grate which not only saves the grate surface but also serves as a layer of material which can be charged with heat to assist in ignition.

Adjacent the hopper **15** is another hopper **16** which contains compacts of spherical or nearly spherical configuration, preferably ranging from ⅛ to ⅜ inch in size, although larger or smaller sizes, such as 1 inch or larger, may be used. These compacts may be in the "green" condition, that is to say, unburned and containing moisture, or this layer may be formed of any sintering mixture. I prefer to use already burned and broken compacts for this layer. Such compacts (whether already burned or "green") are coated on this outer surface or mixed as in sintering with pulverized fuel. A binder such as bentonite may be used if necessary. Thus, pulverized coal containing 20 pounds per ton of bentonite as a binder forms a coating which can be coated onto the balls by tumbling or rolling. Enough pulverized or crushed fuel is provided to give a fuel content of 5% to 20% based upon the weight of the compact, thus 11% may be used. It may be stated that the crushed or pulverant fuel is of carbonaceous character, thus anthracite or bituminous coals, pulverized sub-bituminous coals, coke breeze, lignite or lignite char, all in crushed or pulverant form may be used. Where "green" pellets are used, some of the pulverized fuel (thus ½% to 2%) may be admixed with the pulverized concentrated ore prior to passing it into the balling mills, wherein the spherical agglomerates are built up to sufficient sizes for use. When thus accomplished, that portion of the fuel is substantially uniformly mixed throughout the entire volume of the spherical compacts. Then the remainder of the fuel, sufficient to bring the fuel content up to 5% to 20%, or even higher, is applied as a surface deposit upon or a mixture with the compacts. Where previously burned compacts are used, there will not, of course, be any fuel within the compacts and in such case the entire fuel content is added as a mixture of crushed or pulverized fuel with or without a binder (such as bentonite) is added in the requisite percentage amounts as aforesaid.

In any event, the mixture contained within the bin **16** and herein designated the ignition layer, contains several percent of fuel. Thus, while the main layers **30–33** may contain up to 1% to 2% fuel (for magnetite ores) the ignition layer **21** may have from 5% to 20% or even more fuel as a surface coating or as a mixture. The reason for the use of increased fuel in the ignition layer is to foster and encourage the production of a strong hot ignition layer. It has been discovered in accordance with this invention that uniformity of product and reduction of overall fuel costs is dependent to a considerable extent upon strong and uniform ignition. In order to insure strength and uniformity of ignition of the entire multiple layered mass which is ultimately deposited upon the grate as it travels, there is, in accordance with this invention, first deposited the ignition layer having a superabundance of fuel. The thickness of the ignition layer may be from ½ to 3 inches or more, but usually a layer of 1 inch is sufficient, particularly where an insulative grate layer of previously burned compacts is used. To anyone versed in the art, it is sufficient to state that a thin, high fuel, sintering layer **21** is placed on top of a comparatively thick hearth layer **20** which is protective in character.

As illustrated there is provided an igniter **22A** which may be either gas, oil or coal fired and in the exemplified form is positioned above the ignition layer **21**. If desired, however, the ignition may be accomplished by an under grate igniter, although the over-grate igniter is preferred. Beneath the ignition zone there is provided a wind box **24** having an outlet **25** to which suction is applied, when using the over-grate type of igniter. Thus, the windbox **24** may be provided with a negative pressure of approximately 1 to 4 inches of water, such as two inches of water. The suction box is provided with flanges at its upper edges which serve to support the under side of the moving grate sections throughout the area of the flanges. The suction thus applied pulls the products of combustion of the igniter **22A** downwardly, against and through the ignition layer **21** and into and through the protective and insulative layer **20**. In so doing the fuel content of the ignition layer is ignited and as the ignition layer **21** emerges from beneath the igniter **22A**, it has been brought to ignition temperature and is in a strongly glowing and ignited condition. The production of a good hot uniform ignition layer is enhanced by the insulative layer **20** which holds heat, and prevents undue radiation and conduction of heat downward from the under side of layer **21**.

As the grate then travels throughout the length of the burning zone BZ there are deposited upon it a plurality of layers of spherical or nearly spherical "green" compacts which are to be burned. This is an important feature of my invention.

I have discovered that if the layer of spherical compacts is too deep, the products of combustion passing upward cool down to such an extent that moisture condenses on the portions of the layer. This condensed moisture weakens the spherical or nearly spherical compacts to such an extent that their weight and the superimposed weight of other compacts above them may cause them to flatten. Even a small amount of flattening of the spherical or nearly spherical compacts radically reduces the voids between the compacts through which the gases pass, thereby increasing the resistance and decreasing the rate of gas flow. This radically reduces the burning rate and interferes with the process. Flattening spherical compacts by 17% reduces the percentage of voids between the ball by approximately 50%. The flattened compacts not only burn slowly but also cool slowly due to lack of gas flow. I have found that when the layer is too deep the spherical compacts, flattened as aforesaid, often discharge from the machine red hot while in other parts of the layer where flattening has not occurred the compacts will be discharged cool.

Whether or not moisture condenses out of the gases on the cold spherical compacts freshly added on top, or in the upper part of a thick layer, is a complex function of the temperature of the gases, the temperature of the surface of the compacts, and the rate of gas flow at any point. Thus, the rate of flow preferred is the result of blowing about 80 C. F. M. of air (calculated to normal temperature and pressure) upward through the grates of the machine for each square foot of grate area. At this blowing rate and where the compacts have a moisture content of 9½% and a diameter of ⅝ inch (which is normal practice in pelletizing magnetic taconite concentrate), 3-inch layers are a satisfactory thickness, the preferred range being 2 to 5 inches. With drier compacts and other conditions the same, thicker layers may be used, and with wetter compacts, layers of only 1 inch or 2 inches thick are preferred. With smaller compacts, thinner layers are required than with larger compacts. The thickness of the layer of new compacts placed on the surface of the charge is, therefore, varied directly with the size of the compacts, the temperature of the top gases and the velocity of these gases, and varies inversely with the moisture in the compacts. Of course, other requirements determine workable limits for all of these variables.

The importance of adding the compacts to the surface

of the charge in a plurality of layers of proper thickness cannot be over-emphasized. By this mode of operation it is possible to build up and burn beds of very great total thickness. Five foot thick beds have been built up without difficulty and even thicker beds are possible because the big drop in air pressure through the bed occurs at the comparatively narrow burning zone. The drop in pressure caused by blowing the required amount of air through a mass of cold pellets is not large. By adding successive thin layers of spherical or nearly spherical compacts, the total burden can thus be built up to great depths without undue flattening and only one ignition layer is used, thus reducing overall ignition cost and increasing process efficiency.

In the exemplary form of apparatus there are accordingly deposited four layers by feeder belts, herein designated shuttle belt feeders **26**, **27**, **28** and **29**. Obviously, a greater number of layers may be used. These belt feeders **26–29** are continuous belts and each travels over suitable drive and idler rollers of which the idler rollers **26A–29A** are illustrated. The shuttle belt feeders are supported upon a suitable framework (not illustrated) for movement of the delivery ends of the belts back and forth in straight lines across the width of the chain grate as denoted by the arrows **26B–29B**. The shuttle belt feeders have their delivery ends supported, respectively, at a uniform distance above the layer of compacts immediately underneath each belt. Thus, the belt **26** has a delivery end slightly lower than the belt **27** and it in turn is slightly lower than the belt **28** and so on. Since the shuttle feeder belts have their delivery ends moving back and forth in straight lines transversely in respect to the chain grate **10**, the compacts of ore which are uniformly fed onto each one of the shuttle belt feeders (by apparatus not illustrated) are carried by the shuttle feeder belts and deposited in line back and forth across the chain grate as the latter moves. It will be understood that the back and forth motion of the delivery ends of the shuttle belt feeders is relatively much more rapid than the rate of movement of the chain grate **10** and the pattern of deposition (which is actually a close zigzag pattern) has the effect of building up a layer of green spherical or nearly spherical compacts under each of the shuttle belts. Accordingly, under the shuttle belt **26** there is built up a first layer **30** of compacts and likewise under the shuttle belt **27** there is built up a second layer **31**, under the belt **28** there is built up a third layer **32** and under the belt **29** there is built up a fourth layer **33**. The thickness of these layers (which, as previously stated, may be from 1 inch to 5 inches or more) is dependent upon the rate of feed of compacts delivered by each of the shuttle belts as compared with the speed of the chain grate **10**.

Each of the belts **26–29** is provided with an adjustable feeder of standard design (not illustrated) by means of which the rate of feed of the spherical (or substantially spherical) compacts of ore may be adjusted. The feed of compacts onto each belt is thus separately adjustable so that the thickness of each layer delivered by the belt onto the next lower layer on the grate can be adjusted with precision. The desideratum of the adjustment is to have each successive layer thick enough so that the moisture bearing hot products of combustion of the lower layers will be cooled down (and the compacts of the upper layer thus heated), but the cooling down of the products of combustion should stop short of that temperature at which the moisture would condense out on the ball-like compacts in amounts sufficient to wet them and permit them to slump (i. e. flatten). It is best, from the operation standpoint, to not cool the gases much below the dew point. Now this regulation may be easily achieved simply by regulating the depth of layer deposited by each belt; the operator can observe the progress of the grate. If too much moisture is condensed out the feed to the belts need only be decreased, thus thinning the layers deposited. Or alternatively, the moisture in the compact balls may be reduced while holding the layer thickness constant.

Thus, in an exemplary form of method and apparatus the green and unburned spherical or nearly spherical balls of ore may be deposited in layers from two to six inches thick, thus, for example, in layers 3 to 4 inches thick. The balls range in size from ⅛ to ½ inch in diameter, but may be larger if desired. Thus, balls up to 1 to 1½ inches in diameter may be used but a limit of ¾ inch is preferred.

Beyond the point at which layer **33** is deposited there is (for best results) preferably provided another hopper **35** in which already burned compacts **36** which may be cracked and fragmented compacts similar to the hearth layer separated from previous runs are deposited in a layer **37**. This layer of material, which requires no burning, serves as an insulative layer which also prevents upward heat radiation and hence serves to retain the heat generated in layers **30–33**.

It may be stated in respect to the main layers **30–33** that they contain fuel in an amount sufficient to provide heat necessary for firing. The amount of fuel that is used depends to some extent upon the ore and varies from 1% to 3%, although more may be used with some ores. Ores which contain sulfur or contain a relatively higher percent of the lower oxides of iron, will require a lesser amount of fuel for producing pelletizing temperatures, than ores which do not naturally contain such materials which oxidize during firing and produce some of the heat. Ores which are magnetite in character are largely oxidized to hematite during the pelletizing operation and in so doing produce heat. Such ores accordingly require a lesser amount of added fuel for producing requisite pelletizing temperatures than hematite, which during pelletizing does not reach a state of higher oxidation and hence produces no heat. As as example in firing ore compacts made from beneficiated taconite ore, enough heat was produced so that an average coal content of 1.8% was sufficient.

I prefer to incorporate at least some of the fuel on the green compacts as a surface coating or as a mixture. There are several reasons for this. In a continuous run some control facility (for regulating temperature) is very desirable so as to allow heating up to but not beyond pelletizing temperatures. If all of the fuel is incorporated into admixture with the ore forming the compacts, regulation is much encumbered, since the compacts which are being burned at any one time may have been formed hours earlier. However, by putting only part of the powdered solid fuel (or none of it) into admixture with the ore, the balance of fuel (or all of it) can be rolled onto the compacts by tumbling and rolling in a balling drum or otherwise mixed immediately before the compacts are delivered by belts **26–29**. Hence, there will be very little time lag between the time the fuel percentage is determined and the time the compacts bearing the fuel are delivered for burning. Since the stream of powdered fuel delivered to the machine (tube mill) for coating the compacts can be varied readily, this method, which is a feature of this invention, affords very ready temperature control. I accordingly prefer to place some or all of the fuel on the compacts as a surface coating or as a mixture with them. Where the compacts are of larger sizes (i. e. ¾ inch and up) some of the fuel should (for best results) be incorporated with the ore forming the compacts.

As shown in Figure 1 there are provided beneath the grate a plurality of wind boxes **41**, **42**, **43**, **44** and **45** which extend from adjacent the flange of the suction box **24** throughout the upper course of travel **10A** of the grate to adjacent the delivery end of the grate at roller **11**. Each of the wind boxes is provided at its upper edge with inturned flanges which serve as transverse structural members forming supports for the chain links that make

up the chain grate, and each of the wind boxes is provided with a suitable aperture as at 41A–45A for the introduction of air under pressure. The air under pressure thus introduced into each of the wind boxes 41–45 is spread under uniform pressure across a transverse area of the grate extending for a prescribed length of the grate as determined by the distance between the inturned flanges of the wind boxes across the grate. In general, it may be stated that the pressure maintained in boxes 41 through 45 increases in the direction of travel of the grate. Thus, in an exemplary installation a pressure of 2 inches of water was maintained in wind box 41, a pressure of 3 inches of water in wind box 42, a pressure of 4 inches of water in wind box 43 and a pressure of 5 inches of water in wind boxes 44 and 45.

It may be stated further, in general, that the wind boxes are located beneath the layers as they are deposited, but slightly downstream in the direction of travel of the grate from each belt 26–29. The final wind box 45 is provided for maintaining pressure in the end zone so as to prevent, to some extent, passage of air supplied by the box 44 from movement endwise under the burning area and thence out through the burned compacts at the delivery end.

Referring to Figures 2 and 3 it is preferred in the present method and apparatus to provide an edge layer on each side of the grate of fuel coated already burned compacts against which (the side edge of) each of the layers 30 through 33 may be deposited. These already burned compacts are preferably mixed with fuel so that they will heat up and thus block flow of air through them as would otherwise occur if they were cold and not heated. Thus, adjacent the sides of the grate are provided side walls 46 supported by a suitable framework 47 and lined with a refractory layer of brick or other refractory material 48 supported upon the structure 49. The upper edge 50 of each side wall adjacent each edge of the chain grate is increased in height slightly ahead of the position where each of the layers 30 through 33 are deposited. Thus, in the preferred form the side wall steps up as the overall thickness of the burden on the grate is increased. Adjacent the side wall and preferably throughout the width of each of the shuttle belt feeders 26 through 29 there is also preferably provided an internal shield 51 which is close to the refractory wall by the shield 51—52. The shield 51—52 extends from the upper surface of the side wall 46 to a point 54 which is slightly above the level 55 of the preceding layer, whether it be the ignition layer 21, as shown in Figure 2, or one of the succeeding layers 30 through 33, as shown in Figure 1. The downstream end of the shield 51 terminates at a thin edge 53 and within the space 56 there is situated the delivery end 57 of the feed pipe 58 which is connected to an overhead bin not illustrated. Delivered down through the pipe 58 are small pieces or previously burned balls, which may be cracked or broken pieces of previously burned balls similar to the hearth layer, if desired, and these are delivered to a level 59, Figure 2, which is approximately equal to the level 60 to which the layer, as layer 30, is built up by the shuttle feed belt here illustrated as belt 26. It will be understood, therefore, that against the refractory wall 48 there is continuously deposited a wall of already burned balls and within this wall and against the plate 51 there is continuously being built up the layer, as layer 30, the ends of that layer in the transverse direction with respect to the grate being thus separated from the refractory wall 48 by the thickness of the protective and insulative filling of previously burned balls in the space 56. Two similar walls of already burned balls coated with fuel are deposited on each side of the chain grate at the transverse ends of the paths of movement of each of the shuttle feeder belts 26 through 29, and accordingly each of the layers 30 through 33 is protected at its transverse edges from scraping movement along the refractory wall 48. In this way the unburned balls at the edges of layers 30–33 are insulated from the cold refractory surface and are mechanically protected from abrasion. At the same time burning of fuel in the mixture on the balls in the spaces 56 insures that the air from the wind boxes will not be channeled through such spaces.

In operation the hearth layer 15 of already burned compacts is deposited from the hopper 15 and forms the hearth layer 20, upon which there is then deposited from the hopper 16 the ignition layer 21, which as previously described may be green compacts but is preferably composed of already burned compacts containing several percent more fuel than is contained in the compacts of layers 30 through 33 (such as 5% to 20% or more). Thus deposited, the ignition layer passes under (or over) an igniter, here illustrated as the overhead igniter 22A, and becomes ignited and reaches a glowing temperature throughout its entire width. There is then deposited in succession from the shuttle feed belts 26 through 29 a plurality of layers 30 through 33, preferably protected from the side walls of the grate by the refractory and insulative layer of previously burned balls and fuel, as 56—56, Figure 2. Burning is initiated at the bottom of layer 30 and as the grate proceeds, the zone of burning gradually passes up through layer 30 and reaches the surface of that layer at approximately the edge 31A of the layer 31. Then as the layer 31 is deposited, the burning proceeds upwardly through it and reaches the surface at approximately the edge 32A of the layer 32 which is being deposited on the lower layers. Burning continues to proceed upwardly through layer 32 and reaches the surface at about the edge 33A, whereupon the final layer 33 is deposited. The burning proceeds up through the layer 33 and reaches the surface at or approximately at the place where the protective and insulative layer 37 is deposited, and then burns to completion in the zone beyond the hopper 35 in the direction of grate travel. It may be stated parentheticallly that the air is forced upwardly from the wind boxes 41 through 45 and as the air passes upwardly through the gate it meets with relatively little resistance in those lowermost regions of the superimposed grate load that have already burned out and cooled off. Thus, the air that is being forced up through the load on the grate remains relatively cool (and unexpanded) until it approaches the burning zone at that particular place. The burning zone, as previously described, gradually slants up through the successive layers in the direction of grate travel. At the burning zone, the air which is being forced up through the grate burden, enters into combustion with the solid fuel of the balls and in so doing the gaseous products of combustion are, like the balls of ore, intensely heated. Accordingly, in the burning zone there is produced a very rapid and marked expansion of the combustion air and products of combustion, and it is in the burning zone that the movement of the gaseous constituents encounters greatest resistance to upward travel. Above the combustion zone the products of combustion in traveling upward give up their heat to the superimposed compacts which are green and even somewhat moist as the surface is reached. In so doing the superimposed unburned ore compacts cool off the products of combustion which are accordingly delivered to atmosphere at reduced temperatures. This cooling off should not proceed to the place at which moisture condenses out in appreciable amounts on the balls, or if it does the superimposed layer should not be thick. In this way undue flattening is avoided. I prefer to operate so that the thickness of the superimposed added layers is such that the moisture bearing products of combustion from lower layers is cooled down just short of a temperature at which the moisture begins to condense out on the balls of the uppermost part of the upper layer. In this way a maximum re-

covery of heat is achieved, but the moisture never condenses since it does not reach the dew point.

Accordingly, it will be understood that there is a zone of combustion gradually slanting up through the burden on the grate as denoted generally by the dotted line 65—65, at which the air rising from the pressure boxes 41 through 45 meets with a maximum resistance to upward travel, while below such line there is a relatively lower resistance. Accordingly, toward the delivery end of the chain grate there is a tendency for the air to move endwise of the grate and in a downstream direction as denoted by the arrow 66. The pressure box 45 and other pressure boxes which may be provided in the downstream zone, introduce air under pressure into the burden on the grate which therefore produces a pressure gradiant against which the air moving upwardly from the box 44 is held. Thus, the air delivered by the box 45 is effective for holding the air from box 44 in place from endwise movement out through the end edge of the grate burden. In this way a sufficient upward flow of air is maintained to insure completion of combustion of the unburned compacts on the grate.

The insulative layer deposited on the bottom of the grate and insulative-heating layer preferably deposited on the side edges and the insulative layer deposited on the top serve to retain in place the heat which would otherwise be dissipated to the side walls and radiated upwardly from the top layer on the grate. In addition, the side wall layers serve to minimize abrasion of the compacts, which would otherwise occur before they reach maturity and hardness.

The specific form of apparatus herein described with reference to which certain constants of operation, dimensional size, etc. have been given and the specific sizes of compacts, fuel percentages, wind pressures, etc. are all exemplary and are cited for the purpose of illustrating the invention, but not by way of limitation thereon.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that I do not limit myself to the specific embodiments herein.

What I claim is:

1. The method of burning substantially spherical ore compacts without undue flattening which comprises depositing fuel-containing ore compacts in a layer of substantially uniform thickness on the upper surface of a moving grate, igniting said layer along a transverse line across the grate as the layer is moved thereon, then depositing successively a plurality of further layers of fuel-containing compacts, blowing air upwardly through those portions of the grate upon which said successive plurality of layers are deposited for combustion of the fuel in said compacts, and then removing all of the compacts from said grate.

2. The method of burning substantially spherical compacts of ore which comprises coating compacts with solid powdered carbonaceous fuel, depositing said fuel-containing compacts in a substantially uniform ignition layer on the upper surface of a moving grate, igniting said ignition layer as the grate moves, depositing on the ignition layer on said grate successively, a plurality of further layers containing a less amount of fuel than that of the compacts of the ignition layer, blowing air upwardly through those portions of the grate upon which said successive plurality of layers are deposited, said air being blown at pressures that are increased in the direction of travel of the grate and continuing the blowing of air under pressure through the layers on said grate beyond the place where burning of the compacts has proceeded to the upper surface of the uppermost layer.

3. The method of burning compacts of ore containing solid fuel which comprises depositing upon a moving grate a layer of already burned compacts, said compacts having a surface coating of solid carbonaceous fuel, igniting said layer of fuel coated compacts as the grate with the compacts thereon moves along, then depositing in a plurality of successive layers unburned compacts of ore containing solid carbonaceous fuel, blowing air under pressure upwardly through those portions of the grate having the successively deposited layers thereon as the grate moves along and then removing all of the compacts from the grate.

4. The method of burning or compacts which comprises depositing fuel-containing compacts in a layer of substantially uniform thickness on the upper surface of a moving grate, igniting said layer along a transverse line across the grate as the layer is moved thereon, then depositing successively a plurality of further layers of fuel containing compacts, depositing a final layer of already burned compacts on the uppermost layer on the grate, blowing air upwardly through those portions of the grate upon which said successive plurality of layers of compacts are deposited for combustion of the fuel in said compacts, and then removing all of the compacts from said grate.

5. The method of burning compacts of ore containing solid fuel which comprises depositing upon a moving grate a layer of already burned compacts, said compacts having a surface coating of solid carbonaceous fuel, igniting said layer of fuel coated compacts as the grate with the compacts thereon moves along, then depositing in a plurality of successive layers unburned compacts of ore containing solid carbonaceous fuel and depositing a final layer of already burned compacts on the uppermost layer on said grate, blowing air under pressure upwardly through those portions of the grate having the successively deposited layers thereon as the grate moves along, said pressure being increased in the direction of grate travel and finally removing all of the compacts from the grate.

6. The method of burning compacts of iron ore containing solid fuel, said compacts containing from 1% to 3% of solid carbonaceous fuel, based upon the weight of the iron ore thereof, which comprises depositing upon a moving grate a layer of already burned compacts having a surface layer of solid carbonaceous fuel thereon, said solid carbonaceous fuel being in an amount ranging from 3% to 10%, based upon the weight of the burned compacts, igniting said layer of fuel coated already burned compacts as the grate with the compacts thereon moves along, then depositing in a plurality of successive layers said unburned compacts of ore containing solid carbonaceous fuel in an amount ranging from 1% to 3%, blowing air under pressure upwardly through those portions of the traveling grate having the successively deposited layers of unburned compacts thereon as the grate moves along, and then removing all of the compacts from the grate.

7. The method of burning compacts of iron ore containing a minor percentage of solid fuel therein which comprises depositing an ignition layer of fuel containing compacts uniformly upon the upper surface of a moving grate, igniting said ignition layer uniformly as it moves, at opposite edges of the grate depositing walls of already burned compacts and between said walls depositing successive layers of unburned compacts containing fuel, blowing air upwardly through the layers of compacts on the grate until the compacts have burned completely through and removing the burned compacts from the grate.

8. The method of claim 7 further characterized in that the unburned compacts deposited as walls at opposite edges of the grate are surface-coated with solid carbonaceous fuel.

9. The method of claim 7 further characterized in that the ignition layer of compacts which are already burned compacts are coated with solid carbonaceous fuel in an amount ranging from 5% to 20% of the weight of the compacts and the green compacts have a fuel content of 1% to 3% solid carbonaceous fuel.

10. The method of claim 7 further characterized in that a grate layer of burned compacts is first deposited upon the upper surface of the grate before there is deposited thereon the first fuel containing layer of compacts.

11. The method of claim 7 further characterized in that a final layer of burned compacts is deposited upon the uppermost layer of compacts on said grate.

12. In the pelletizing of ball-like moisture containing compacts of iron ore according to an updraft grate-type pelletizing process wherein the moisture of the compacts is evaporated and they are burned to sintering temperatures, the improvement which comprises depositing said compacts on a layer of fuel-containing ore compacts on said grate in a multiplicity of successive layers, igniting the fuel layer and forcing air under pressure upwardly through said superimposed layers to carry the heated products of combustion through the layers of compacts, said pressure increasing in the direction of travel of the grate whereby the moisture evaporated from compacts in lower layers does not materially condense upon and increase the moisture of the compacts of superimposed added layers.

13. The method of burning iron ore compacts which comprises forming compacts of finely divided ore and solid fuel, the proportion of solid fuel being substantially in excess of that required for maintaining sintering temperature of the compacts, depositing said compacts in a layer upon a traveling grate, igniting said layer, depositing upon said layer another layer of compacts containing substantially less powdered fuel incorporated therein than in said first layer, blowing air up through the layers on said grate until all the compacts have burned out.

14. The method of burning iron ore compacts which comprises forming compacts for a grate layer comprising finely divided iron ore and solid carbonaceous fuel, the amount of fuel ranging from 3% to 10% by weight as compared to the amount of ore, depositing said grate layer compacts upon the upper surface of a moving grate, igniting said grate layer, depositing upon said grate layer at least one further layer of compacts containing finely divided pulverized fuel in an amount substantially less on a percentage basis than the amount of finely divided solid fuel in said grate layer, blowing air upwardly through said layers of compacts on said grate until they have finally burned through, and removing the burned compacts from the grate.

15. In an apparatus for burning ore compacts which comprises a chain grate having side walls therealong, a plurality of rollers for supporting said chain grate for a course of travel in a generally horizontal plane, means for rotating the rollers for moving the gate, means for depositing layers of compacts on the grate, an igniter, and wind box means under said grate, the improvement which resides in means for depositing vertical wall layers of granular material longitudinally along the outer edges of the grate adjacent the inside of each of the side walls thereof, means for simultaneously depositing on the grate other granular material in the space between said wall layers as said wall layers are deposited.

16. The apparatus of claim 15 further characterized in that the grate is provided with a plurality of stations at each of which means is provided for depositing adjacent the inside of each of the side walls longitudinal wall layers of granular material and for simultaneously depositing at each station between said wall layers a layer of other granular material on the grate to a level substantially equal to the height of said wall layers.

References Cited in the file of this patent

UNITED STATES PATENTS

916,397	Dwight	Mar. 23, 1909
942,052	Bellinger	Dec. 7, 1909
951,199	Perkins et al.	Mar. 8, 1910
1,221,962	Bittmann	Apr. 10, 1917
1,598,176	Tharaldsen	Aug. 31, 1926
1,684,958	Hyde	Sept. 18, 1928
1,896,884	Cooper et al.	Feb. 7, 1933
2,052,329	Wendeborn	Aug. 25, 1936
2,143,905	Ahlmann	Jan. 17, 1939
2,411,873	Firth	Dec. 3, 1946
2,511,400	De Jahn	June 13, 1950
2,532,335	Royster	Dec. 5, 1950
2,608,481	Royster	Aug. 26, 1952

FOREIGN PATENTS

229,608	Great Britain	Feb. 26, 1925
379,057	Great Britain	Aug. 25, 1932
498,837	Great Britain	Jan. 19, 1939
510,786	Great Britain	Aug. 8, 1939
573,539	Great Britain	Nov. 26, 1945
645,444	Great Britain	Nov. 1, 1950