July 27, 1954 O. DIETTRICH 2,684,897

SMELTING OF ORE, PARTICULARLY IRON ORE

Filed Dec. 28, 1951 3 Sheets-Sheet 1

FIG. 1

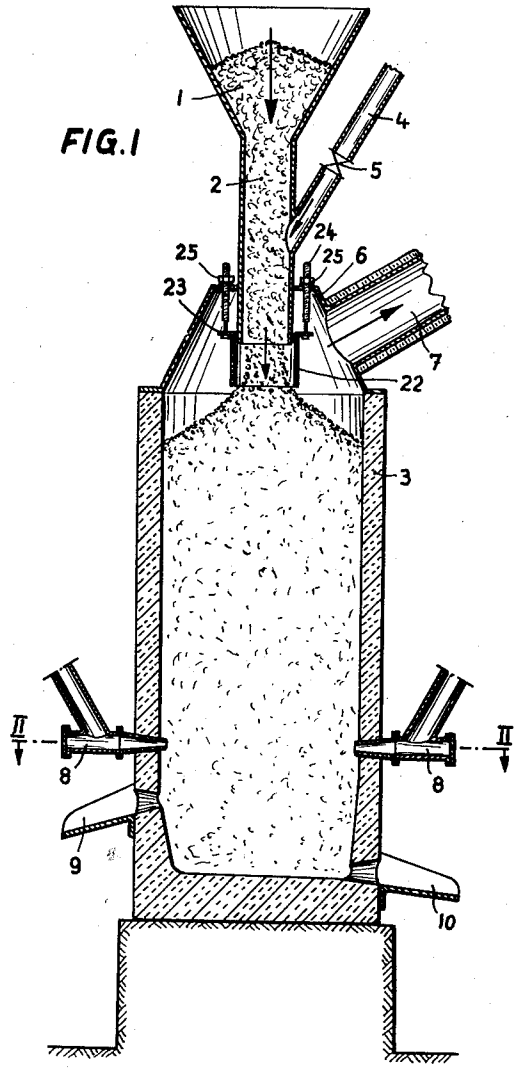
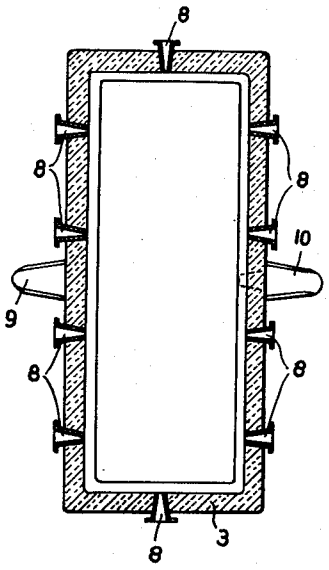


FIG. 2



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July 27, 1954 O. DIETTRICH 2,684,897

SMELTING OF ORE, PARTICULARLY IRON ORE

Filed Dec. 28, 1951 3 Sheets-Sheet 2

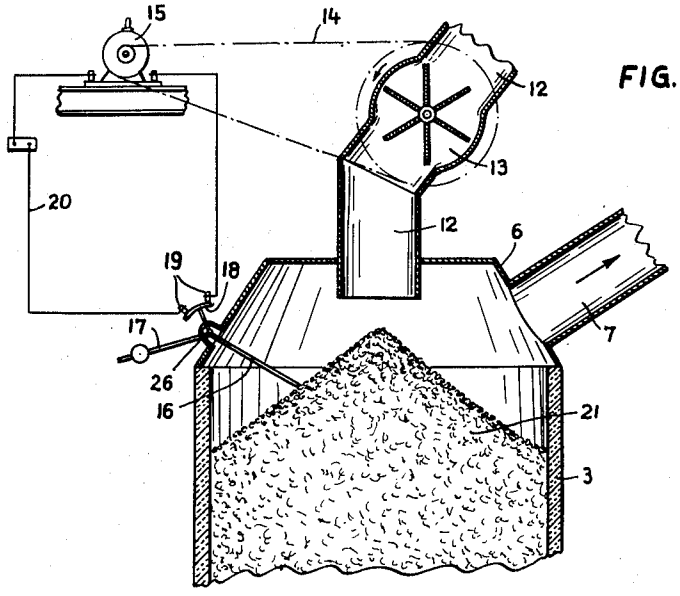


FIG.3

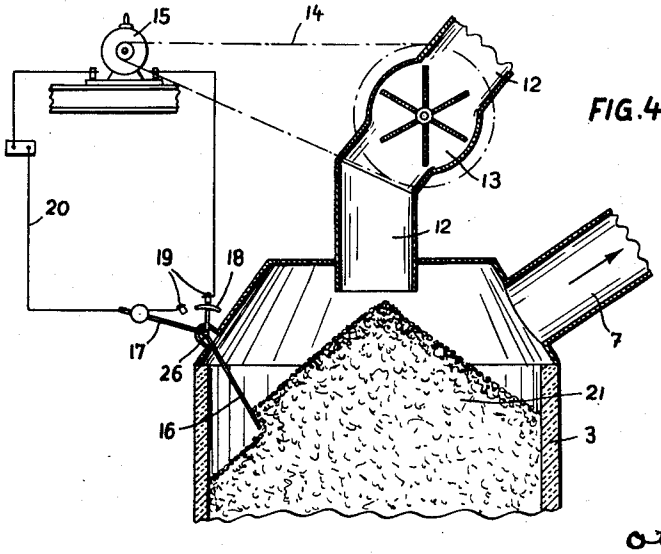


FIG.4

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July 27, 1954 O. DIETTRICH 2,684,897

SMELTING OF ORE, PARTICULARLY IRON ORE

Filed Dec. 28, 1951 3 Sheets-Sheet 3

FIG.5

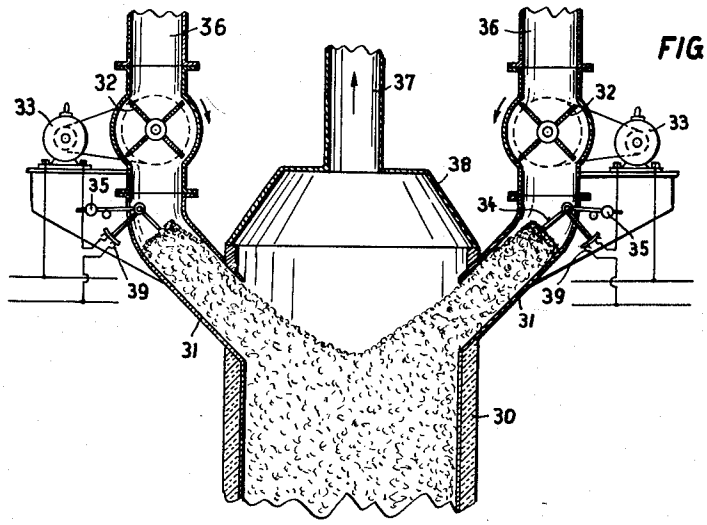
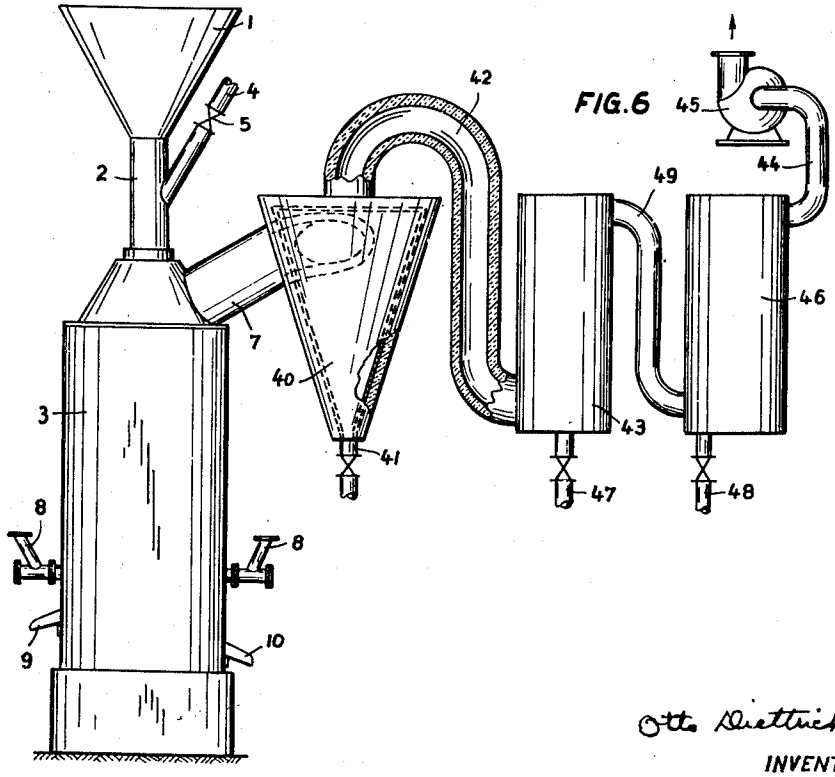


FIG.6



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UNITED STATES PATENT OFFICE

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SMELTING OF ORE, PARTICULARLY IRON ORE

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Application December 28, 1951, Serial No. 263,800

Claims priority, application France September 8, 1948

11 Claims. (Cl. 75—41)

1

This is a continuation-in-part of my copending applications Serial No. 67,250, filed December 24, 1948, now abandoned; Serial No. 111,351, filed August 19, 1949, now abandoned; and Serial No. 178,570, filed August 10, 1950, now abandoned.

My invention relates to the smelting of ores, particularly iron ores, in blast furnaces and has for its objects to improve the smelting process and equipment as regards economy of operation, to permit the use of low-grade coal heretofore unsuitable for blast-furnace smelting, and to combine the smelting of ore with the production of distillation products from volatile coal. These as well as more specific objects and advantages of the invention will be apparent from, or will be referred to, in the following.

According to my invention, the blast-furnace smelting of ore is carried out by first preparing mixed briquets of a fine-grained ore, a crude fine-grained volatile fuel such as volatile mineral coal, and a binder such as lime, clay, marl or pitch. These mixed briquets are charged into a shaft furnace as uniformly as feasible and substantially in accordance with the progress of the smelting and reduction performance so as to maintain a charge height between about 2 and 6 meters above the tuyère plane, the width of the charge as determined by the distance between oppositely located tuyères being at most about 3 meters. The hot gases evolving from the volatile fuel components of the charge column are subjected to fractional condensation to yield tars. The process therefore combines the ore reduction and smelting operation with a distillation of the raw volatile fuel.

This process has the advantages that the required blast furnace plant is considerably lower than the conventional high-shaft furnaces; that the fine-grained iron ore need not be pre-sintered; that raw coal can be used without pre-coking; and that a much larger variety of coal becomes available than heretofore suitable for blast furnace operations.

As apparent from the foregoing, the mixed ore-fuel briquets are not subjected to coking prior to being charged into the furnace, the required coherence being secured by the binding agent contained in the briquets. Due to the small height of the charge column in the furnace only moderate requirements are placed upon the strength of the briquets. It is therefore possible to use for briquetting a binding agent tending to become soft, for instance, pitch. The height of the charge column is preferably kept as small as possible, namely just high enough to secure

2

the proper carbonization and distillation of the fuel in the top zone and the reduction and smelting of the ore in the bottom zone of the charge.

According to another feature of the invention, the binding agent for the production of the briquets is wholly or partly derived from the smelting and carbonizing blast furnace operation itself. Accordingly, the gases evolving from the fuel in the upper zone of the blast furnace charge are subjected to fractional distillation while still hot from the furnace operation. The distillation is carried out in two stages to yield respective condensation products. The first condensation step results in the precipitation of a heavy or thick tar, i. e. a tar which is thickly fluid to solid at about 15° C., while the tar obtained by the second condensation step is thinly fluid. The thick tar resulting from the first condensation is used as a binding agent in the ore-coal briquets, so that the production of these briquets is largely independent of any supply of material other than ore and fuel.

When the binding agent consists only partly of the thick tar obtained in the above-mentioned manner, the remainder of the binding agent may consist, for instance, of marl or lime.

The blast furnace top gas may be liberated from dust prior to the condensation, for instance, in a separator chamber. This is especially of advantage when the amounts of dust contained in the top gas is very large.

The invention affords of a much larger choice than heretofore available relative to the kinds of fuel that may be used for blast furnace operations. For instance, a mineral coal may be used that is unsuitable for the production of metallurgical coke (blast furnace coke), such as gas coal, gas flame coal or the like highly volatile subbituminous or bituminous coals which are non-coking or badly coking.

Mainly suitable as a fuel are medium-volatile to high-volatile bituminous coals as exemplified by the 26% volatile coal mentioned in a later place. However, less coalified fuels such as high-volatile and weathering bituminous coal, soft coal, brown coal and lignite are also applicable, although the water contents of the raw coal should first be reduced by drying if brown coal or the like lignitic fuels are used. All these other fuels may either be used alone with the binding medium needed to secure proper briquetting, or they are used in mixture with a higher-grade coal, preferably a baking mineral coal. In the latter case, the amount of binding agent may be reduced because the coherence of the briquets is

then largely conferred by the baking ability of the mineral coal. When the mineral coal thus used tends to bake excessively, that is when the briquets, during the carbonization or the subsequent further heating in the furnace charge, tend to cake together, the mineral coal should be made leaner, i. e. the fuel components of the briquets should then be composed partly of a baking mineral coal and partly of a lean mineral coal.

When a marly-gangue iron ore is used, the marl contained in the ore acts as a binding medium so that a smaller amount of binding medium or none at all need be added to the mixture to be briquetted.

The grain size of the ore in the briquets must be kept rather small and should not exceed 10 millimeters. Especially advantageous is a grain size of up to 3 mm. The fuel component of the briquets must have a similarly small grain size, a grain size of up to 5 mm. being preferable. If the fuel is not by nature of the fine grain size required, it must be reduced prior to the briquetting.

For minimizing break and friction wear, the briquets should have rounded corners and edges as well as curved surfaces as obtained, for instance, by making them egg shaped.

The size of the briquets should preferably not exceed 300 cubic centimeters (ccm.). Best suited are briquets of only about 40 to 80 ccm. volume.

While substantially the entire fuel of the charge is incorporated in the briquets, it is not always necessary to completely briquet the ore to be smelted. That is, in certain cases some of the ore may be charged into the furnace in the shape of lumps. The size of the ore lumps should be about similar to that of the briquets. That is, the largest ore lumps should have a diameter corresponding to about the average diameter of the briquets while the diameter of the smallest ore lumps should be about 5 to 10 mm.

It is possible to use slaked lime as a binder in the briquets. In this case, the briquets are dried and hardended by means of CO_2-containing gases before they are charged into the shaft furnace. If clay or marl serve as binders, they must be reduced to a finely grained state before they are mixed with the minerals to be briquetted; and for fully utilizing their binding properties, they must be used in a moistened condition, for instance, with a moisture content of about 6 to 10%. For that reason, such briquets must be dried before charging them into the furnace.

The furnace is operated with a heated blast of air. It is frequently not necessary to employ the high blast temperatures customary in the operation of the conventional high-shaft furnaces but suffices to heat the air only up to temperatures of at most 500° C. Oxygen need not be added to the blast, although it is also possible and may offer advantages if oxygen-enriched air is used. In the latter case, it is not always necessary to preheat the blast.

According to a preferred embodiment of the invention, the process is carried out in a shaft furnace of rectangular cross section which has its two opposite long sides spaced from each other not more than about two meters. The tuyères for injecting the blast are all or mostly arranged at the long sides of the rectangular cross section. In other words, the two short sides of the rectangular cross section are equal to, or smaller than, about two meters at the

furnace inside, while the two other sides are longer. The small spacing between opposing tuyères has the advantage that the blast gases surely penetrated to the middle of the furnace charge and reach all parts of the fuel at a height close to the tuyère level, this being essential because of the low height of the furnace charge. The penetration of charge by the blast and the gases formed thereby is also facilitated by the substantially uniform and small size of the briquets or lumps throughout the entire charge column.

The temperature of the top gases is so chosen that a condensation of the tars in the top zone of the furnace is avoided.

The drawings represent examples of blast-furnace equipment designed and operative in accordance with the invention.

Fig. 1 shows a vertical cross section of a rectangular blast furnace with a centrally located charge supply pipe;

Fig. 2 is a horizontal cross section through the same furnace, the section being taken in the tuyère plane indicated at II—II in Fig. 1;

Figs. 3 and 4 show a modified design of the furnace top portion in two different stages of operation respectively;

Fig. 5 is a vertical central section through the top portion of another embodiment of the blast furnace;

Fig. 6 illustrates schematically a furnace according to Fig. 1 in conjunction with dust separating and tar distilling equipment.

The shaft furnace illustrated in Figs. 1 and 2 has a rectangular cross section measuring 1.3 × 3 meters at the inside. Arranged on the furnace wall along the two long sides of the rectangle are several tuyères. One additional tuyère **8** is disposed on each of the two short sides. The charge height, measured upwardly from the tuyère level, is about 4.5 meters. The bosh zone of the furnace tapers downwardly from the tuyère level to the furnace bottom at which the tap **10** for discharging the liquid metal is located. A tap **9** for the discharge of the cinder is located at a somewhat higher level but also below the tuyères.

The top of the furnace is covered by a hood **6**. Disposed above the furnace is a bin or hopper **1** whose outlet pipe **2** passes downwardly through the hood **6** to terminate in the interior of the furnace. Disposed at the lower end of pipe **2** is an extension **22** whose flange **23** is suspended from screws **24** so that the discharge opening of the charge supply can be adjusted to a desired level by means of screw bolts **25**. A pipe **4**, slanting downwardly and containing a valve **5**, opens into pipe **2**. Joined with hood **6** is an outlet pipe **7** for the top gases. Pipe **7**, as apparent from Fig. 6, leads to a dust separator **40** and to condensing equipment to be described in a later place.

When operating the blast furnace according to Figs. 1 and 6, the raw materials are charged through the hopper **1** into the furnace in the form of egg shaped briquets. The briquets have preferably a length of 60 mm., a width of 46 mm., a thickness of 37 mm. and a volume of about 40 ccm.

To present a complete and detailed example of a blast furnace operation according to the invention, reference is made hereinafter to analyses relating to one and the same actual operation of the above-described furnace. It will be understood from the foregoing that minerals

other than those hereinafter exemplified may be used and that then the respective analyses of the raw materials and the products will be correspondingly different. All percentages given in the following are by weight.

In the operation now to be described, the briquets consist of 41% bituminous mineral coal, 38.5% iron ore, 14.5% lime stone, 2% tar pitch, and 4% of thick tar produced in the condensation device 43 (Fig. 6) still to be described. The coal has a grain size of up to 5 mm. and the ore a grain size of up to 3 mm., the lime stone being also reduced to a similarly small size. The coal used is a non-weathering bituminous coal of 14% ashes and 26% volatile components. The analysis of the ore is as follows: 58.7% Fe, 12.4% SiO_2, 1.1% CaO, 3.7% Al_2O_3, 0.7% MnO, 0.15% P, 1.0% SO_3. The tar pitch has a softening point of about 68° C. These briquets are charged into the hopper 1 (Fig. 1), care being taken to keep the hopper filled during furnace operation. In this manner the charge passes continuously through the pipe 2 into the shaft furnace. The column of briquets within the charge supply pipe secures a practically sufficient seal at the furnace top. However, to safely prevent air from passing into the furnace through the supply pipe 2, an oxygen-free gas, for instance, cooled and tar-free top gas may be supplied through the pipe 4 under slight pressure.

The wind introduced into the furnace charge through the tuyères 8 consists of heated air of about 450° C. and has a pressure of 1000 to 1500 mm. (water column).

When the briquets reach the interior of the furnace, the fuel contained in the briquets is immediately subjected to smoldering (low-temperature carbonization). The smoldering vapors escape through the pipe 7 together with the other top gases originating from within the smelting zone of the furnace. The mixture of top gases leaves the furnace at a temperature of about 300° C. and passes first through the dust separator 40 (Fig. 6). This separator is preferably of the centrifugal type (cyclone). That is, the inlet duct of the separator extends tangential to the conical wall of the separator vessel so that the gas passing through the separator is caused to rotate with the effect that the dust is precipitated along the separator wall and drops to the bottom of the vessel from which it may be removed through a discharge pipe 41. From cyclone 40 the gas mixture passes through a pipe 42 into a first condensation device 43. In this device a thick tar is precipitated which leaves the apparatus through a pipe 47. The thick tar has the following composition: 45% pitch, 39% tar oil, 6% dust. This tar is thickly fluid to solid at 15° C. It is thereafter used as part of the binding agent for the production of the ore-coal briquets.

From the first condensing stage the top gases pass through a pipe 49 into a second condensing device 46. The thinly fluid tar precipitating in this device is drained through a pipe 48. This thin tar, if necessary, after purification or further processing, represents an industrially applicable or marketable product. From the second condensing stage, the tar-free top gases are withdrawn through a pipe 44 by a blower 45. The pipes 7, 42 and the cyclone 40 are preferably heat insulated to prevent premature condensation of the top gases.

After the briquets are carbonized in the top zone of the furnace as described in the foregoing, they drop gradually toward the furnace bottom and are progressively reduced. The reduced iron is smelted in the hot zone of the furnace and is drawn off from time to time through the tap 10. The pig iron thus produced from the minerals above-mentioned has about the following composition: 3.7% C, 2.8% Si, 0.2% P, 0.02% S, 0.55% Mn, remainder Fe. The cinder is drawn off from time to time through the cinder notch 9. Its composition is about as follows: 44% CaO, 35% SiO_2, 15% Al_2O_3, 1.5% MgO, 1.2% FeO, 0.6% MnO, 2.3% S.

Instead of the charge supply pipe shown in Fig. 1, the furnace may also have a lock or sluice type charging device automatically controlled by a movable feeler disposed in the furnace. For instance, the lock device may have a sector wheel driven from an electric motor which is automatically switched in by the feeler when the charge in the furnace drops below a given level. When the sector wheel is actuated, the height of the charge column increases and raises the feeler until, at a given other level, the feeler interrupts the current supply to the electric motor. The feeler may be designed so that the height of the charge column varies only within slight limits.

A device of the just-mentioned type is illustrated in Figs. 3 and 4. The supply of briquets passes through a pipe 12 in which the sector wheel of a lock device 13 is journalled. The lock wheel is driven by a belt 14 from an electric motor 15. Pivoted on the upper portion of the furnace hood 6 is a feeler lid 16, which carries a counterpoise 17 at the outside of the furnace. The counterpoise is so dimensioned that lid 16 has the tendency to move upwardly. Attached to the lid is a contact bridge 18 engageable with two stationary contacts 19 connected in the control circuit 20 of the motor 15. In the stage of operation represented in Fig. 3, the charge column 21 has dropped to such an extent that the lid 16 has become free to move to the illustrated upper limit position. Then the contacts 19 are electrically bridged by the lid contact 18. Hence, motor 15 is energized and drives the lock wheel 13. A supply of briquets now passes through the pipe 12 into the furnace 3. The height of the charge column 21 increases and the newly supplied briquets stow up in front of lid 16. As a result the lid is gradually forced to the lower limit position illustrated in Fig. 4. The contacts 19 are now interrupted so that motor 15 stops. Now the lock wheel 13 remains arrested and prevents a further supply of briquets. When thereafter the height of the charge column gradually decreases until it reaches the condition shown in Fig. 3, the lid swings back to its upper limit position in which the contacts 19 are again bridged so that the cycle of charging operation is repeated.

Fig. 5 illustrates an especially advantageous design of the charge supply devices. Two supply pipes are disposed opposite each other at the top of the furnace shaft 30. Connected to each of supply pipes 31 is a lock wheel device 32 driven from an electric motor 33 by a belt drive. Disposed above the lock wheel devices are pipes 36 which are connected with a bin or hopper continually charged with briquets. A movable lid 34 for controlling the supply of briquets is pivoted in the upper portion of each pipe 31. Each lid is equipped with a counterpoise 35 and with contacts 39 similar to the corresponding elements shown in Figs. 3 and 4.

Each contact 39 (Fig. 5) controls the energiz-

ing circuit of the pertaining motor 33 in the following manner. When the supply pipe 31 is empty, lid 34 is in its uppermost position and the pertaining movable contact has the position shown in Fig. 3. Consequently, the motor 33 is energized and operates the lock wheel device 32 so that a continuous supply of briquets passes from pipe 36 through pipe 31 into the furnace shaft. When pipe 31 is filled to a desired extent, the lid 34 is forced to the lowermost position so that the current supply to motor 33 is interrupted. Now the lock wheel device 32 is stopped. Thereafter, the charge accumulated in pipe 31 drops gradually. As soon as the lower edge of lid 34 becomes free, the lid is moved upwardly by its counterpoise and the energizing circuit of motor 33 is again closed to start another cycle of charging operation.

Connected to the top of the hood 38 according to Fig. 5 is a discharge pipe 37 for the top gases. Due to the fact that in the embodiment according to Fig. 5 two opposite charge supply pipes are provided, a hollow is formed at the top of the furnace charge. This has the advantage that the charge height in the middle of the furnace is lower than at the edges, so that the furnace gases encounter a correspondingly smaller flow resistance at the middle of the charge column. This secures with certainty a thorough action of the blast throughout the entire charge despite the small height of the column. It should be understood that while in Fig. 5 only two supply pipes 36 and pertaining lock and control devices are visible, at least two such pipes and pertaining devices are located and preferably evenly distributed at each long side of the rectangular furnace, making a total of four or more individually controlled supply inlets. As a result, the height of the charge column remains substantially constant also along the long furnace sides even in cases where the furnace cross section has a length considerably larger than its width.

Furnaces for operation according to the invention may also be given a circular cross section. In that case, preferably three charge supply pipes 31 are evenly distributed around the furnace.

For simplification, it is also possible to provide for two oppositely disposed charge supply pipes 31 only one movable lid 34 whose electric contact means control the circuits of both motors 33 for the lock wheels.

Instead of connecting the top end of the pipes 36 directly to a bin or hopper, it may also be advantageous to interpose a conveyor device, such as a rotatable conveyor disc, which is driven from the same electromotor 33 that operates the lock wheel 32.

I claim:

1. The process of smelting iron-bearing ore and conjointly producing gas products from coal in a low-shaft blast furnace, which comprises the steps of forming mixed briquets of up to about 300 cubic centimeters volume from granulated iron-bearing ore and granulated raw coal and a binding agent, the ore and the coal having a grain size maximum of 10 millimeters, forming a blast-furnace charge of about two to six meters height above the tuyère level and of up to about three meters width substantially all of the mixed briquets with their coal constituent still in the raw state, all of the fuel being incorporated in the briquets, passing an oxidizing blast through the charge to reduce and smelt the ore and to carbonize and gasify the coal, and recovering tar from the evolving top gases.

2. The process of smelting ore and conjointly producing gas products from coal in a low-shaft blast furnace, which comprises the steps of forming mixed briquets of up to about 300 cubic centimeters volume from granulated iron-containing ore and granulated raw coal and a carbonaceous binding agent, the ore and the coal having a grain size maximum of 10 millimeters, forming a blast-furnace charge of about two to six meters height above the tuyère level and of up to about three meters width substantially all of the mixed briquets with their coal constituent still in the raw state, passing an oxidizing blast through the charge to reduce and smelt the ore and to carbonize the coal and the binding agent, and recovering tar from the evolving top gases.

3. The process of smelting ore and conjointly producing gas products from coal in a low-shaft blast furnace, which comprises the steps of forming binder-containing briquets of up to about 300 cubic centimeters volume from granulated iron-containing ore and a blending of granulated raw lean coal and granulated raw baking coal, the ore and the coal having a grain size maximum of 10 millimeters, forming a blast-furnace charge of about two to six meters height above the tuyère level and of up to about three meters width substantially all of the briquets with their coal contents still in the raw state, passing an oxidizing blast into the charge to reduce and smelt the ore and to carbonize and gasify the coal, and recovering tar from the evolving top gases.

4. The process of smelting iron-containing ore and conjointly producing gas products from coal in a low-shaft blast furnace, which comprises the steps of forming mixed briquets of up to about 300 cubic centimeters volume from granulated ore and granulated raw coal with a granulated addition of lime and an addition of tar as a binding agent, the ore and the coal having a grain size maximum of 10 millimeters, forming a blast-furnace charge of about two to six meters height above the tuyère level and of up to about three meters width substantially all of the mixed briquets with their coal constituent still in the raw state, passing an oxidizing blast into the charge to reduce and smelt the ore and to carbonize and gasify the coal, and recovering tar from the evolving top gases.

5. The process of smelting ore and conjointly producing gas products from coal in a low-shaft blast furnace, which comprises the steps of forming briquets of rounded shape and a volume of about 40 to 80 ccm. from a mixture of granulated ore and granulated raw coal, the ore and the coal having a grain size maximum of 10 millimeters, forming a blast-furnace charge of about two to six meters height above the tuyère level and of up to about three meters width substantially all of the briquets with their coal constituent still in the raw state, and passing an oxidizing blast into the charge to reduce and smelt the ore and to carbonize and gasify the coal.

6. The process of smelting ore and conjointly producing gas products from coal in the low-shaft blast furnace, which comprises the steps of forming mixed briquets of up to about 300 cubic centimeters volume from granulated ore and granulated raw coal and a binding agent, the ore and the coal having a grain size maximum of 10 millimeters, forming a blast-furnace charge of about two to six meters height above the tuyère level and of up to about three meters width substantially all of the briquets with their coal constituent still in the raw state, passing an oxidizing

blast into the charge to reduce and smelt the ore and to carbonize and gasify the coal, subjecting the evolving vapors outside of the charge to fractional distillation under their own heat and in two steps, condensing a thick tar of thickly fluid to solid consistency at about 15° C. in the first step and a thinly fluid tar in the second step, and incorporating the thick tar as binding agent in the briquets.

7. The process of smelting ore and conjointly producing gas products from coal in a low-shaft blast furnace, which comprises the steps of forming mixed briquets of up to about 300 cubic centimeters volume from granulated ore and granulated raw coal and a binding agent, the ore and the coal having a grain size maximum of 10 millimeters, forming a blast-furnace charge of about two to six meters height above the tuyère level and of up to about three meters width substantially all of the briquets with their coal constituent still in the raw state, passing an oxidizing blast into the charge to reduce and smelt the ore and to carbonize and gasify the coal, maintaining a top gas temperature of about 300° C., withdrawing the top gases from the charge and recovering tar products therefrom.

8. The process of smelting iron-containing ore, which comprises producing briquets of up to 300 cubic centimeters volume from a binder-containing mixture of granular iron-containing ore and granular raw coal, the ore and the coal having a grain size maximum of 10 millimeters, preparing and gradually replenishing from said briquets with the coal constituent still in the raw state a furnace charge of an elongated cross section of up to about three meters width between the two long sides of the cross section and a charge height between about two and six meters, passing upwardly through the charge an oxidizing blast from said two long sides to smelt the ore and produce gas from the coal, and controlling the rate of supply of said briquets in accordance with the smelting operation to maintain said charge height approximately constant.

9. The process of smelting iron-bearing ore in a low-shaft blast furnace, which comprises producing pressed briquets of up to about 300 cubic centimeters volume from a mixture of fine-grained ore to be smelted and fine-grained raw coal together with a binder, the ore and the coal having a grain size maximum of 10 millimeters, preparing and gradually replenishing a furnace charge of up to about three meters width composed of approximately uniform-size pieces comprising the briquets and having substantially all of its fuel consist of the raw coal incorporated in said briquets, maintaining the charge at a substantially constant height of about two to six meters above the tuyère level, and passing an oxidizing blast upwardly through the charge to smelt the ore and carbonize the coal.

10. The process of smelting iron-bearing ore in a low-shaft blast furnace, which comprises producing pressed briquets of up to about 300 cubic centimeters volume from a binder-containing mixture of fine-grained ore and fine-grained raw coal, the ore and the coal having a grain size maximum of 10 millimeters, gradually introducing into the furnace a charge of about two to six meters height above the tuyère level and of up to about three meters width composed substantially all of the briquets and additional ore in a lump size similar to that of the briquets, said coal being still in its raw state when said briquets are being charged into the furnace, maintaining the charge at a substantially constant height of about two to six meters above the tuyère level, and passing an oxidizing blast into the charge to smelt the ore and carbonize the coal.

11. The process of smelting iron-bearing ore, which comprises mixing a fine-grained volatile raw coal and a fine-grained marly-gangue iron ore, the ore and the coal having a grain size maximum of 10 millimeters, pressing the mixture into briquets of up to about 300 cubic centimeters volume in which briquets the marly-gangue forms a binding agent, preparing and gradually replenishing from said briquets a furnace charge of a charge height between about two and six meters and a width of up to about three meters, said coal being still in its raw state when said briquets are being charged into the furnace, passing upwardly through the charge an oxidizing blast to smelt the ore and produce gas from the coal, and controlling the rate of supply of said briquets in accordance with the smelting operation to maintain said charge height approximately constant.

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