SHAFT FURNACE FOR TREATING
PELLETIZED MATERIALS

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ABSTRACT
The present invention relates to a process for treating peletized materials in shaft furnaces, especially vertical lime-heating or reducing kilns, dolomite pelet-heating kilns, peletheating or reducing blast furnaces, and the like, as well as furnaces for the retort-chamber process, in the furnace chambers of which the material to be processed, e.g., reduced, is exposed to hot gases which are channeled generally transversely of the longitudinal axis of the furnace.

3 Claims, 4 Drawing Figures
SHAFT FURNACE FOR TREATING PELLETIZED MATERIALS

CROSS-REFERENCE TO RELATED APPLICATION

This application is related to the disclosure of a pending Application Ser. No. 265,527, filed June 23, 1972 for "Methods and Apparatus for the Reduction of Metal Ores, Particularly Iron Ores."

BACKGROUND OF THE INVENTION

With conventional shaft furnaces, for example, lime heating or reducing kilns, pelletized material (e.g., limestone) is fed from the top and the processed material (e.g., calcined lime) is drawn off at the bottom. While fresh hot gas is blown into the furnace from the bottom in a direction opposite to the vertical descent of charge material to be processed, and the spent gas mixture is drawn off at the top of the furnace. As a result of the thermal action, undesirable constituents are expelled, in the gas phase, from the charge material being processed, said expelled gases consisting of carbon dioxide and water in the reduction of lime.

The particular disadvantage of processes of this kind is the difficulty of uniformly heating large plants. The furnace, being of large height, required a high throughput capacity, the charge material over the entire cross-section of the furnace by way of the central zone. This results in the irregular heating of the material between the peripheral zones and the central zones of the furnace, resulting in a non-uniform quality of the final product. Consequently, the object of the present invention is to provide a method which would avoid the drawbacks of the above-described process and additionally, permit the substantially uniform heating of the processed material over the entire cross section of the furnace charge.

SUMMARY OF THE PRESENT INVENTION

To accomplish this objective, a new and improved process is provided in which gases are introduced into the processed material through one of the furnace walls and are expelled again from the charge through the opposite furnace wall, and the flow direction of the hot gases permeating the processed material is periodically reversed. The hot gases are first injected into the charge from an inlet side wall and then are drawn off through the opposite furnace wall. Subsequently, for a period equal to that of the previous heat treatment phase, the gases are injected into the same or the subsequent charge in a countercurrent or reverse flow, at a point where there has been less heating of the material. This provides for an optimal utilization of the gases by way of a modified countercurrent effect.

Another characteristic of the process of the invention is that the hot gases, upon passing through the charge, are injected into the charge in a zone where the stage of heating is lower than that in the zone where the charge was traversed. The gas may be reheated after it has, at least once, traversed the processed material.

According to a further characteristic of the invention, it has been determined to be advantageous to direct the hot gas in a meandering way through a plurality of consecutive charge zones, each of which is in a correspondingly different stage of processing. An important feature of the process of the invention is that the hot gas flow is fed into, and drawn off from the furnace chamber, as a crosscurrent at points staggered, relative to one another longitudinally in the furnace chamber.

The hot gases may also be directed through the charge at a slant, so that in a shaft furnace the gases are injected into the charge at one point of the furnace wall, and are drawn off from the charge at a higher point in the opposite wall. After the gas flow-direction is reversed, which is done periodically, the gas is blown in at a lower point of the opposite wall, and drawn off at an upper location of the first mentioned wall. A countercurrent effect is thus also obtained in the new process, which is in all cases based on the above described transverse or countercurrent principles of heating the charge.

In a preferred embodiment of the process of the invention, the furnace employed has a circular cross-section and the gas flow is fed thereinto and drawn off radially, while the specific radial flow direction of the gas is changed gradually or intermittently in stepped fashion about the circumference of the furnace walls.

The successful execution of the process described above is based on the premise that direct communication or axial flow of the gas between two furnace charge levels (which are consecutively treated by the same gas) is precluded. To that end, according to an important feature of the invention, the total charge is subdivided into sublayers by means of intermediate layers of a gas-tight substance, and the thickness of such sublayers corresponds at most to the distance between any two gas streams being successively injected into the furnace in the longitudinal direction thereof. Therefore, so-called "short-circuit" gas currents are prevented. The intermediate layers are horizontal and extend substantially perpendicularly to the axial vertical path of travel of the charge.

When using a vertical shaft furnace in which the processed material sinks continuously or intermittently from the top downward, with the corresponding flattening of cone-shaped charges in the shaft, thin strata of fine-grained material, for example, with a thickness of about 200 cm, may be placed in the charge in a generally horizontal plane to establish the intermediate layers. These intermediate layers sink down through the furnace along with the charge sublayers.

Furthermore, the undesirable vertical flow of the hot gas may be prevented by placing plates of sheet metal, ceramics, or the like, between consecutive charge layers. These plates, having a thickness of a few centimeters, may be inserted into the charge at suitable intervals for descent therewith.

The process of the invention may be practiced in a shaft furnace comprising a shell, surrounding a furnace chamber. Inside the shell are disposed gas inlet and outlet nozzles opening into the furnace chamber, which nozzles are connected to a gas pipeline system carrying the hot gas supply to the furnace. In accordance with the invention, the furnace is characterized in that each nozzle may be selectively connected to the gas inlet or outlet lines of the piping system.

By using a furnace with a circular cross-section, according to a further characteristic of the invention, the gas inlet and gas outlet nozzles may be disposed about the furnace shell in an arcuate configuration and may be connected consecutively in a given rotational sense with appropriate gas feed and gas discharge lines; the radial direction of flow may be reversed by reversing the connections of nozzles to circuit gas lines.

The invention may be illustrated by way of the following two examples showing the differences between
heating of the charges unidirectionally (Example 1) and in accordance with the invention (Example 2):

EXAMPLE 1

A test shaft furnace having one-meter diameter charge was loaded with limestone of standard grain size. From one of the vertical furnace walls, hot gas was injected into the charge at a no-load velocity of approximately 1 meter per second. The no-load velocity is generally of the order of from approximately 0.5–5 meters per second. The inlet gas temperature was 1,250 degrees centigrade and the gas was drawn off from the opposite furnace wall.

In the cross section of the charge layer the following temperatures were measured at varying distances from the gas inlet, after a predetermined period unidirectional heating:

<table>
<thead>
<tr>
<th>Distance from Gas Inlet</th>
<th>Temperature (degrees centigrade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas inlet wall</td>
<td>1,100</td>
</tr>
<tr>
<td>1/2 distance across the furnace</td>
<td>950</td>
</tr>
<tr>
<td>3/4 distance across the furnace</td>
<td>850</td>
</tr>
<tr>
<td>Gas outlet wall</td>
<td>800</td>
</tr>
</tbody>
</table>

EXAMPLE 2

The charge of Example 1 was filled under the same conditions into the same shaft furnace, and heated with the above-mentioned gas in accordance with the invention (bidirectionally). Thus, in the process according to the present invention, the following temperatures in the charge were measured again as a function of the distance from the gas inlet side (the same gas inlet side as in Example 1):

<table>
<thead>
<tr>
<th>Distance from Gas Inlet</th>
<th>Temperature (degrees centigrade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas inlet wall</td>
<td>1,000</td>
</tr>
<tr>
<td>1/2 distance across the furnace</td>
<td>970</td>
</tr>
<tr>
<td>3/4 distance across the furnace</td>
<td>970</td>
</tr>
<tr>
<td>Gas outlet side</td>
<td>1,000</td>
</tr>
</tbody>
</table>

Thus, it is clear that with the bidirectional or crosscurrent heating process of the invention, a substantially more balanced and uniform heating of the charge was obtained in the furnace.

The apparatus for practicing the process of the invention is described in greater detail in the following description and is illustrated in the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic vertical cross-sectional representation of a lime-heating kiln or shaft furnace operating according to the simple crosscurrent principles of the invention;

FIG. 2 is a schematic vertical cross-sectional representation of a shaft furnace operating according to the multi-stage crosscurrent principles;

FIG. 3 is a schematic horizontal cross-sectional representation of a rotary kiln; and

FIG. 4 is a fragmentary schematic vertical cross-sectional representation of the charging shaft of a vertical furnace.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, FIG. 1 shows a lime-burning kiln having a gas inlet line 1 to a gas pipeline circuit having unions 2, 4, 10 and 12, and valves 3, 11, 14 and 15. The gas inlet line 1 and outlet line 13 communicate with nozzles 5 and 9. All gas lines and fittings are made of heat-resistant material. The vertical furnace shaft 6 is charged at the top with a charge 7 which exits from the bottom in the form of a product 8. During the first time-phase the hot treatment gas 1 is forced through union 2, open valve 3 (with valves 14 and 15 closed), through union 4 and nozzle 5 into the combustion zone of the furnace shaft 6. The gas flows radially across the furnace and through nozzle 9 and union 10, exiting the furnace 6 with valve 11 open through union 12 as spent or discharged gas 13.

During the second time phase, on reversing the conditions of valves 3, 11, 14 and 15, hot gas is forced through union 2 into nozzle 9 with valve 14 in the open position and valves 3 and 11 closed. The gas now radially permeates shaft 6 (transversely to the vertical descent of the charge) and exits through nozzle 5. The spent gas 13 flows from there (with valve 3 closed) through union 4 and the open valve 15 for discharge through union 12. The flow direction of the gas is periodically reversed in accordance with the invention.

The arrangement of apparatus shown in FIG. 2, operates according to the multi-stage, crosscurrent principle with a change in flow direction and includes gas pipeline unions 2, 29; valves 3, 28, 31 and 34; blowers 20, 24, 32 and 33; and nozzles 16, 19, 21, 23, 25 and 27. All gas lines, as well as fittings, nozzles, and blowers are made of heat-resistant material. In this embodiment of the invention, the charge is divided into substantially horizontal sublayers 17, 22 and 26 by means of gastight intermediate layers 58 which may be comprised of a fine-grained substance.

During the initial time-phase of the reduction process, a hot treatment gas 1 is forced through the union 2, with the valve 3 open and the valve 31 closed through the nozzle 16 into the charge sublayer 17 in the lowest portion of the furnace. The gas leaves the bottom layer through nozzle 19, and is forced (by means of blower 20) through nozzle 21 into the charge sublayer 22 located in the central portion of the furnace. After permeating this central sublayer 22 the gas is removed from the furnace through nozzle 23. The gas is then forced by blower 24 into nozzle 25. In the upper portion of the furnace, the gas serves for the preheating of charge material 18 in layer 26 before exiting the upper portion of the furnace through nozzle 27, open valve 28, and union 29, in the form of discharge or spent gas 30. During the initial phase, valve 34 is closed, as will be understood. During the second phase, gas 1 is forced through union 2, with valve 31 now open, and valve 3 now closed, through nozzle 19 into charge sublayer 17 in the bottom portion of the furnace. The gas exits layer 17 through nozzle 16 and is forced by the blower 32, through the nozzle 23 across the sublayer 22 and out the nozzle 21, which is connected with the blower 33, as shown. Thereafter, the gas is forced with valve 28 closed, into the upper furnace portion and across sublayer 26, exiting through nozzle 25, with valve 34 open, to pipeline union 29. From there it leaves the furnace as discharge gas 30.

An alternative embodiment of the invention may be operated without using the nozzles 21 and 23 and without employing the blowers 20, 24, 32 and 33 shown in FIG. 2. In this form of the new method, the hot gases are conducted through the charge in accordance with the so-called "cross-countercurrent" principle, i.e., the
gases travel from nozzles 16 and 19 located at the discharge end of the furnace, to nozzles 27, 25, respectively, disposed at the opposite or injection end of the furnace. After the gas flow direction is reversed, the charge will be permeated by gas flowing from nozzles 25, 27 to unions 19, 16, respectively. It is a prerequisite that the entire charge subjected to the crosscurrent flow be homogeneous.

The shaft furnace indicated as 53 in FIG. 3 has both the gas-inlet and gas-outlet nozzles 45, 46, respectively, disposed in a common horizontal plane and these are connected over valves 47, 49, respectively, to two independent gas lines 56 and 57. The gas is injected through gas line 57 (with valves 47, 47', 47'', 49', 49'' closed) and the open valve 47', into the charge layer while the opposite valve 49' is kept open. The gas is then directed radially across the charge, and it leaves the furnace through the gas outlet valve 49'. During the second time phase valves 47' and 49'' are opened, whereas the other valves remain closed. During the following sequential time phases the successive valves arranged opposite one another are opened in succession, one after the other, while all other valves remain closed. Upon reversing the gas flow direction in lines 56, 57, the gas will assume a countercurrent direction, as 25 will be understood. Thus, by means of this arrangement the entire cross-section of the charge layer may be uniformly heated.

Horizontal charge layers 37 are shown in a vertical shaft furnace 48 in FIG. 4. The individual layers are separated from each other by gas-tight intermediate layers 58. The pipelines 41, 44 are elements of a pipeline system into which reduction gas is fed. In accordance with the invention, the gas inlet/outlet nozzles 38 may be selectively connected to the pipelines 41, 44, in a manner whereby they alternatively constitute the gas inlet and gas outlet lines. The hot gas flow is indicated as 1 and 1', respectively. As shown in FIG. 4, in each case, the vertical spacing A of the two parallel horizontal gas flows, following one behind the other longitudinally of the furnace, matches the vertical spacing a of the consecutive intermediate layers 58 separating each of the layers 37.

While the methods and apparatus hereinabove disclosed are directed to preferred embodiments of the present invention, it is to be understood that the invention is not limited to the same and changes may be made therein without departing from the scope of the invention as defined in the following claims.

We claim:

1. A shaft furnace for heating and/or reducing a charge of pelletized materials therein and having a source of heated reducing gas and a gas outlet for spent reducing gas; the combination which comprises a vertically disposed reducing shaft chamber with an inlet at the top for receiving the material to be heated and/or reduced and an outlet at the bottom for the heated and/or reduced material; b. a plurality of pairs of diametrically opposed gas nozzles spaced apart vertically along said chamber; c. first means providing flow communication between said source and said nozzles; d. second means providing flow communication between said nozzles and said gas outlet; e. a plurality of valves disposed in said first and second flow communication means adjacent each of said nozzles for alternately connecting each of said nozzles selectively to said first or second flow communication means; and f. a plurality of segregation means disposed in said charged and spaced apart in said chamber defining a plurality of zones of pelletized material of increasingly heated and reduced condition and constructed to descend with said charge; g. whereby selectively opening and closing said pairs of valves introduces reducing gas radially of the direction of movement of said pelletized material in said zones in alternating reverse radial directions from said first to said second flow communication means, and vice versa and counter-currently of movement of said pelletized material.

2. Apparatus as recited in claim 1, in which a. said segregation means are spaced equidistant vertically of said chamber the same distance as between said pairs of diametrically opposed nozzles.

3. Apparatus as recited in claim 1, in which each vertically spaced level of said nozzles in (b) includes a. a plurality of pairs of diametrically opposed gas nozzles spaced apart circumferentially around said chamber; b. first said flow communication means (c) provides flow communication selectively between said source and said gas outlet and one each of each said pair of diametrically opposed gas nozzles on each vertical level; c. said second flow communication means (d) provides flow communication selectively between said source and said gas outlet and one each of each said pair of diametrically opposed gas nozzles on each vertical nozzle; d. whereby selectively opening and closing diametrically opposed pairs of said valves introduces reducing gas radially of the direction of movement of said pelletized material in said chamber sequentially around the circumference thereof on each vertical nozzle.

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