

PATENT SPECIFICATION

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(54) APPARATUS FOR COOLING A MOVING BED OF SOLID, GAS PERMEABLE PARTICLES

(71) We, MIDREX CORPORATION, a corporation organised under the laws of Delaware, United States of America, of One NCNB Plaza, Charlotte, North Carolina 28280, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to apparatus for cooling particles.

The invention is particularly, though not exclusively, suitable for use with vertical shaft-type furnaces which directly reduce iron oxide to metallic iron and have a cooling stage at the lower end thereof to cool the metallic particles. However, the invention may be used as a means for cooling any moving gas permeable bed of solid particles.

Vertical shaft furnaces employing counterflow have been found to be especially suited for heat treatment of pelletized, sized or lump iron ore whether the ore is to be indurated into oxide pellets in an oxide furnace or directly reduced from oxide pellets into metallic iron in a reduction furnace. With both types of furnace it is desirable to cool the pellets before discharging same into the atmosphere. Cooling is especially critical in a direct reduction furnace because the metallic iron (Fe) is in a very active state at the relatively high reduction temperature which is typically 1300-1500°F. If the metallic iron pellets are not thoroughly cooled to about 125°F., the pellets tend to become critically pyrophoric when exposed to air at ambient temperature.

To alleviate this tendency, cooling arrangements are employed in a cooling leg portion of such furnaces. One known cooling arrangement comprises an upright, hollow frusto-conical chamber with gas

directed into the interior thereof, but this is generally unsatisfactory because the cooling gas does not permeate sufficiently within the bed to adequately cool the bed. Another proposal employs a number of cooling gas pipes in axially spaced arrangement through the wall of a converging chamber, but as the fastest moving particles are at the center of the chamber these do not receive sufficient amounts of cooling gas, which is primarily directed at the slowest moving particles adjacent the converging walls.

According to the present invention there is provided cooling apparatus including a chamber through which a gas permeable bed of solid particles can be passed downwardly, and cooling means to introduce a cooling gas under pressure into said chamber to flow countercurrent to the descending bed, said cooling means including a support extending into the chamber to carry cooling gas therinto and a gas distributor secured to and supported by the support to receive gas therefrom, said support extending into, and said distributor being disposed within, a downwardly converging part of the chamber, and said distributor being of a generally downwardly-converging form and provided with peripherally spaced gas discharge ports arranged in arrays which are axially spaced along its height.

The gas distributor thus extends downwardly in converging configuration within the chamber and bed and includes a predetermined plurality of gas discharge ports peripherally spaced about the distributor in discrete arrays which are axially spaced along the height thereof. The number of ports and the net discharge area associated with each array may be such that the total area of the discharge ports in respect of each array is equal to or greater than the total area in respect of the array next

above. The intention of this arrangement is to obtain, in use, at the least, approximately equal discharge rates of the cooling gas from each discharge port array.

- 5 This configuration assures that the fastest moving particles at the centre of the descending bed are subjected to several streams of cooling gas they descend past the distributor to assure effective cooling of the entire bed.

- 10 The converging configuration of the gas distributor may be achieved by providing a plurality of successively smaller sized tiered gas discharge units, each nested within the one above. Each unit may comprise a side wall having a top end at which is formed an outwardly extending support flange. The support flange of any given unit is positioned at a given distance within the side wall of the next larger unit immediately thereabove. Thus the bottom end of the side wall of each gas unit defines an overhanging lip which surrounds the upper side wall portion of the smaller unit positioned directly below. This leading edge may prevent particles from flowing into the gas discharge ports which are preferably spaced closely adjacent the top end of each side wall. In the event that particles do enter the gas distributor, blockage may be prevented by an exit being provided as an opening in the end wall of the smallest and lowest gas unit at the bottom of the distributor. This opening adds to the net discharge area of that bottom gas unit. The discharge area of the bottom unit might otherwise not be sufficient to establish an adequate stream of cooling gas flow therethrough because of the small size of that unit.

- 40 The invention will be more clearly understood from the following description of one embodiment, which is given by way of example only, with reference to the accompanying drawings in which:

45 *Figure 1* is a vertical cross-section of a vertical shaft furnace provided with cooling apparatus of the present invention;

- 50 *Figure 2* is a similar view of the cooling apparatus of *Figure 1* on a larger scale; and

Figure 3 is a cross-section of the cooling apparatus taken along line 3-3 of *Figure 2*.

- 55 Shown in *Figure 1* is a refractory lined, vertical shaft reduction furnace 10 having a cooling leg 12 at the bottom thereof and a cooling means 13 extending into and disposed in the cooling leg for cooling a descending bed of gas permeable solid particles 14, which may be for instance iron oxide pellets, lumps or sized ore.

- 60 Shaft furnace 10 is equipped with a feed hopper 16 having an opening 18 at the top thereof to which are fed pellets from a 65 source. A pellet feed pipe 20 supplies the

pellets to the reduction furnace 10 wherein a first stockline 21 is established by the angle of repose of the pellets within the furnace. The bottom of furnace 10 is defined by a throat section 22 which leads into the cooling leg. Spaced above the throat section 22 is a bustle and tuyere arrangement 25 which receives hot reducing gas, shown as arrows 26, from a gas inlet pipe 28 which in turn is connected to a source of reducing gas 29. Reducing gas is introduced radially inwardly and downwardly into the shaft furnace by a series of wall ports 30 in the bustle and tuyere arrangement 25 and the reducing gas flows vertically upward in counterflow relationship to the descending bed 14. The reacted reducing gas exits from bed 14 at stockline 21 and thence through an off-take pipe 32.

Hot pellets, now reduced into metallic iron by the reducing gas, flow downwardly into the cooling leg 12 through throat 22 to establish a second stockline 33 within cooling leg. The cooling leg may be properly viewed as a discharge bin formed in part by an external wall closed about a predetermined periphery to define a chamber part of which converges downwardly. This chamber is shown herein as having a frusto-conical wall portion 35 which is disposed between a circular throat portion 36 at the bottom of the cooling leg and a larger circular wall portion 37 which defines a pellet retaining area at the top of the cooling leg. The gravitational rate of descent of the bed 14 of pellets within the cooling leg 12, furnace 10 and feed hopper 16 is controlled by a suitable belt feeder assembly 38 positioned below cooling leg throat 36 and driven by a motor 39.

The cooling means 13 disposed largely in the cooling leg 12 generally comprises a support mechanism 40 extending through and supported by frusto-conical wall 35 and in turn supporting a gas distributor 42 in the cooling leg 12. The gas distributor 42 depends downwardly therefrom and is centered on vertical centerline 43 of frusto-conical wall 35 which coincides with the centerline of the cooling leg and furnace 10. A pressurized cooling gas indicated by arrows 45 is directed from distributor 42 into bed 14 in a manner to be explained hereafter and leaves the bed at stockline 33 whereupon it exits from the cooling leg as a relatively hot gas through off-take pipe 46 adjacent stockline 33. The heated or spent cooling gas is then cleansed and cooled in a suitable cooler-scrubber 47 and pressurized in a compressor 49 before being introduced into the cooling means 13 to define a closed loop cooling circuit.

Referring now to *FIGURES 2* and *3*, support mechanism 40 is shown to com-

prise a bustle 50 circumferentially extending about frusto-conical wall portion 35 and a central discharge unit 52 positioned at the geometric center of bustle 50. Central discharge unit 52 is supported by four diamond shaped feed pipes 53 which are spaced 90 degrees apart from one another and extend radially inwardly towards the center of bustle 50 and through frusto-conical wall portion 35 which in turn supports the entire support mechanism 40. As best seen in FIGURE 2, central discharge unit is defined by a frusto-conical side wall 55 which is open at its bottom end 56 and closed at its top end by a top wall 57. Cooling gas enters bustle 50 through suitable connections (not shown) and exits from the bustle through feed pipes 53 into central discharge unit 52 and exits from the bottom thereof into gas distributor 42.

Generally described, gas distributor 42 extends downwardly into the cooling leg in a converging configuration characterized by a predetermined number of peripherally spaced gas discharge ports 60 arranged in axially spaced arrays 61 along the distributor length. More particularly, each port array 61 is contained within a gas discharge unit 63. Each discharge port 60 is shown herein to be equally sized and the number of ports which constitutes a given array 61 defines a net discharge area for that array. It is desirable for optimum cooling results that the net discharge area progressively increase for arrays progressively spaced from the top of the gas distributor 42. As a matter of practice, the size of gas distributor 42 may limit the net discharge area of the lowest arrays in which case it is desirable to maintain the area of such arrays as nearly equal to that of the higher arrays as possible.

Structurally, gas discharge units 63, and specifically identified as 63a to 63f with corresponding parts identified by like subscripts where applicable, are nested one within another and extend in a tiered arrangement which becomes progressively smaller in size from the top unit 63a to the bottom gas unit 63f. Each gas unit 63 is shown to comprise a peripherally extending open ended side wall 67. At the top of each side wall an outwardly extending support flange 68 is formed. Each support flange 68 of each gas unit 63 is positioned within and secured to the side wall 67 of that gas unit immediately thereabove. The side wall 67 of each gas unit thus extends below the support flange 68 of the next lower unit to define an overhanging lip 69 which circumscribes and shrouds the top portion of the side wall 67 of each gas unit. Each overhanging lip 69 thus forms a stockline 70 at each gas unit 63 to prevent

pellets from clogging distributor 42 by entering outlet ports 60 which importantly are spaced adjacent the top end of each gas outlet side wall 67 and thus shrouded by overhanging lip 69. In the event that some pellets do enter distributor 42, an exit path through the distributor is provided by an opening 72 in an end wall 73 at the bottom of the side wall of the smallest gas unit 63f. Opening 72 is included in the net discharge area for gas unit 63f. Distributor 42 is similarly connected to central discharge unit 52 of support mechanism 40 by the support flange 68 of the largest gas unit, being nested within frusto-conical side wall 55 in a manner similar to which other gas units 63 are connected to one another.

As thus described, streams of cooling gas will exit from each gas outlet unit 63 to effectively cool the bed of pellets as it passes downwardly by distributor 42. Cooling of the bed occurs because distributor 42 is optimized in design in accordance with geometric considerations involved in passing a moving bed of pellets through a converging area. That is, known flow considerations of the pellets establish that the pellets within the bed at the centerline 43 of the cooling leg 12 will be traveling the fastest of all the pellets within the bed, the pellets adjacent exterior frusto-conical wall 35 will have the slowest velocity of the pellets within the bed, and a velocity gradient will occur across the bed by which the speed of the other pellets can be determined accordingly. Because distributor 42 introduces the cooling gas adjacent the fastest moving pellets within the bed, such pellets are initially impinged by the gas while high in cooling quality. As the cooling gas permeates radially-outwardly through the bed, it loses its high cooling quality but the slower moving pellets are exposed to the cooling gas for a longer period of time to accordingly compensate for this loss.

It has been found, especially in cooling leg sections of shaft furnaces which directly reduce iron ore into metallic iron, that the introduction of only one stream of cooling gas into the illustrated cooling leg will not sufficiently cool the pellets passing through the cooling leg. Furthermore, it was found that providing a plurality of discharge ports at axially spaced locations along the length of the distributor did not result in optimum cooling of the bed because of static head pressure conditions within the bed. That is, the pressure gradient between stockline 33 and point of discharge into the cooling stream is a minimum at the uppermost gas unit 63a and a disproportionate amount of cooling gas thus tends to exit from the uppermost gas unit

which also establishes the shortest flow path through the bed. In accordance with the subject invention, the pressure gradient in effect is neutralized through the bed by the number of gas discharge ports 60 provided within each array 61 in distributor 42. More particularly, it has been found that if the net area of all discharge ports for each gas unit were at last made equal and preferably progressively larger for the smaller gas units, sufficient quantities of cooling gas would be supplied at each gas unit to effectively cool the bed of pellets as same passes by distributor 42. The distributor 42 is thus characterized as being positioned along its entire length closely adjacent to the fastest moving particles within the descending bed and having pluralities of peripherally spaced discharge ports 60 arranged in axially spaced arrays 61 with each array having a net discharge area defined by its ports which is sized with respect to the other array areas to produce sufficient quantities of gas leaving each array for effective cooling of the particle bed.

The invention has been described with reference to a preferred embodiment. Obviously, modifications and alterations will occur to others, upon reading and understanding the specification. It is our intention to include all such modifications and alterations insofar as they come within the scope of the present invention. The cooling mechanism has been shown applied to the cooling leg section of a shaft furnace for illustrative purposes only. It should be clear from the above description that the cooling mechanism may be applied to any moving bed of gas permeable solid particles heated by means other than a shaft furnace.

WHAT WE CLAIM IS:—

1. Cooling apparatus including a chamber through which a gas permeable bed of solid particles can be passed downwardly, and cooling means to introduce a cooling gas under pressure into said chamber to flow countercurrent to the descending bed, said cooling means including a support extending into the chamber to carry cooling gas thereinto and a gas distributor secured

to and supported by the support to receive gas therefrom, said support extending into, and said distributor being disposed within, a downwardly converging part of the chamber, and said distributor being of a generally downwardly-converging form and provided with peripherally spaced gas discharge ports arranged in arrays which are axially spaced along its height.

2. Cooling apparatus according to claim 1 wherein the total area of said discharge ports varies from array to array.

3. Cooling apparatus according to claim 1 wherein the total area of the discharge ports in respect of each array is equal to or greater than the total area in respect of the array next above.

4. Apparatus according to claim 1, 2 or 3, wherein the distributor includes a plurality of successively smaller sized tiered gas discharged units, each discharge unit being nested within the next above unit and each unit containing a said array.

5. Apparatus according to claim 4, wherein each unit has an outwardly extending support flange at its upper end, the support flange and array of each unit being positioned within the next above unit, above the lower end thereof, such that an overhanging lip surrounds the array of ports.

6. Apparatus according to claim 3 or 4, wherein the smallest, lowest gas unit has a bottom wall with a gas discharge port therethrough.

7. Apparatus according to any preceding claim wherein the support includes a plurality of radial passages connecting a bustle to the distributor.

8. Cooling apparatus constructed and arranged substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

9. A vertical shaft type furnace with cooling apparatus as claimed in any preceding claim connected to the bottom thereof.

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34

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