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APPARATUS FOR COOLING GRANULAR MATERIALS

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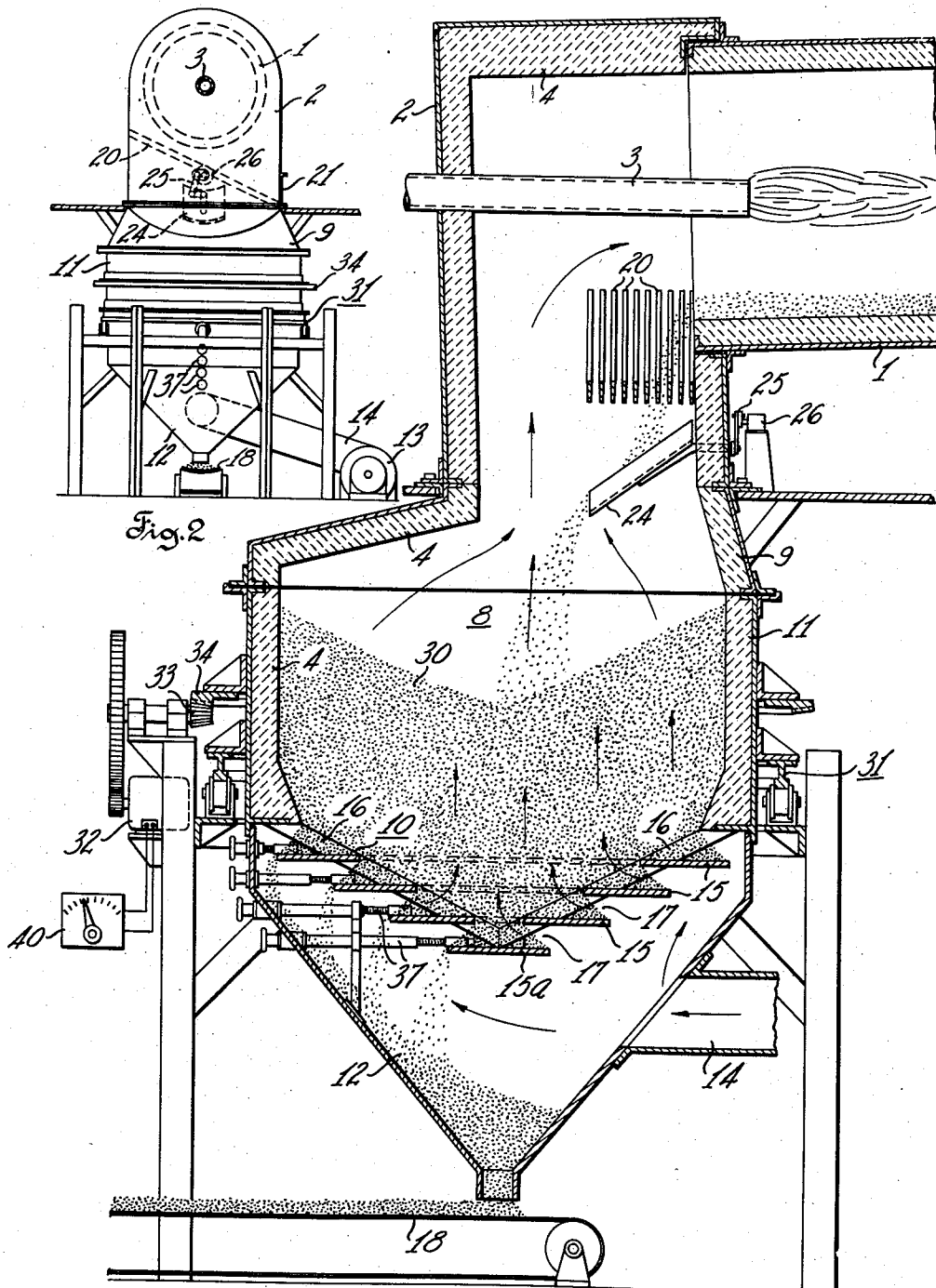


Fig. 1

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APPARATUS FOR COOLING GRANULAR MATERIALS

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This invention relates to apparatus for cooling granular material with gases. The invention is particularly useful for cooling the products of rotary kilns, for heat treating, burning, calcining, roasting or sintering lime, cement, dolomite, magnesite or other materials.

These materials are often white hot when they are discharged from a rotary kiln. These materials must then be cooled sufficiently for safe and easy handling. Considerable economic advantage is gained by returning the heat of cooled material back into the rotary kiln. Machines usually used for cooling such materials comprise a grate upon which the material discharged from a rotary kiln is moved by a shaking mechanism or other means placed along the grates. These grates may have a length of from forty to one hundred feet. Large volumes of cooling air are blown upwardly through such a grate and the layer of material on it. This type of cooler is known as a crosscurrent cooler because the air passes through the material at a ninety degree angle to the moving layer of material. It is desirable that after this cooling air has passed upwardly through the hot material received from the kiln and the air has thereby itself become heated, the now quite hot air should pass into the furnace and contribute to the fuel economy of the system. Cross-current coolers however require volumes of cooling air to be passed through the grate that are greater than the volume of air required in the kiln. The excess air is disposed of by passing it up and out a special stack provided for this purpose. Because only a portion of the air passing through a crosscurrent cooler finds its way into the kiln, the efficiency of heat recovery from the hot material with such apparatus usually reaches not above sixty-five percent.

The desire to reach heat recovery efficiencies above sixty-five percent resulted in the development of a type of cooler known as a countercurrent cooler. In this type of cooler, heated material is deposited in a vertical shaft and removed from the bottom of the shaft to provide a continuously descending column of the material having substantially greater depth than material carried on the grate of a crosscurrent cooler. Cooling air is supplied beneath the column of material and is blown upwardly through the descending column. The material to be cooled moves downwardly and the cooling air upwardly through the shaft and hence the name countercurrent cooler. Since all of the cooling air passes through a column of hot material having much greater depth than the material deposited upon the grate of a crosscurrent cooler, the cooling air passing through the hot material in a countercurrent cooler is raised to a much higher temperature than in a crosscurrent cooler. As the cooling air passes upwardly through a countercurrent cooler, the coolest air comes in contact first with the coolest of the material in the column and as it travels upwardly through the column the air becomes warmer as it reaches levels of hotter material in the column. The cooling air finally passes from the top of the column and into the kiln. Since the last material that the cooling

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air comes in contact with before entering the furnace is the high temperature material just discharged from the furnace the cooling air is steadily and continuously heated to a high temperature. Because the air passing through a countercurrent cooler is raised to a much higher temperature than the air passing through a crosscurrent cooler, each portion of such air performs a much greater amount of cooling and much less volume of cooling air is required for the countercurrent type cooler than is required for a crosscurrent type cooler. The volumes of air required for the countercurrent type cooler are reduced sufficiently so that all of the cooling air passing through the cooler may be passed on into the rotary kiln and no special stack is required to take away any excess air as is the case in a crosscurrent type cooler. As a result of the air passing through a countercurrent cooler being raised to a very high temperature and that all of the air passing through this type of cooler enters the rotary kiln a much higher efficiency of heat recovery from material discharged from the kiln can be achieved with the countercurrent type cooler than has been achieved with the crosscurrent type cooler. It has been determined that the efficiency of heat recovery with a countercurrent cooler is in the neighborhood of ninety percent of the heat contained in the material when it is discharged from the rotary kiln.

The economic significance of raising the efficiency of heat recovery from the sixty-five percent achieved by crosscurrent coolers to the ninety percent achieved by countercurrent coolers can best be appreciated by reference to an example. Consider a rotary kiln producing sintered dolomite having a capacity of 500 tons per twenty-four hours. Such a kiln operating 300 days a year will produce 150,000 tons of sintered dolomite per year. To sinter dolomite, extremely high temperatures are required and must be in the neighborhood of 3200° F. Sintered dolomite will be discharged from such a kiln to cooler at a temperature of about 2600° F. The specific heat of dolomite sinter is 0.25. Each B. t. u. recovered from the cooler where temperatures reach 2600° F. and returned to the kiln in combustion air saves not only that particular B. t. u. but also saves other B. t. u.'s that are required in view of losses to be wasted in order to place a B. t. u. in combustion gases in the 2600° F. to 3200° F. range. It has been calculated conservatively that each such B. t. u. recovered from the cooler and returned to the kiln with combustion air saves not just one but approximately 2.7 B. t. u.'s. If then, to produce sintered dolomite we consider the fuel as being coal costing ten dollars (\$10.00) per ton and having 12,500 B. t. u.'s per pound, the B. t. u.'s saved by increasing heat recovery from sixty-five percent to ninety percent for each pound of dolomite produced may be determined by the following: 2600 (the temperature in degrees Fahrenheit of dolomite entering the cooler) $\times 0.25$ (the specific heat of dolomite sinter) $\times 0.90$ (for heat recovery of ten percent) minus the product of $2600 \times 0.25 \times 0.65$ (for a cooler having sixty-five percent heat recovery), this difference being multiplied by 2.7 (the ratio of B. t. u.'s saved to B. t. u.'s recovered) equals 440 B. t. u.'s per pound of dolomite. For a kiln of the type described, this would represent a saving of fifty-two thousand five hundred dollars (\$52,500.00) per year for just a single kiln. The economic significance of even very small improvements in the efficiency of heat recovery can therefore be easily appreciated when expressed in terms of dollars and cents.

The nature of the present invention resides in further improvements to apparatus generally referred to as countercurrent. It is a principal object of the present invention to provide for increased efficiency of heat recovery from a cooler for use in a rotary kiln.

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Another object of the present invention is to achieve more efficient cooling of granular material by providing a cooler in which the material to be cooled will descend in a column having uniform depth throughout the column.

Another object of the present invention is to achieve more efficient cooling of granular material by providing a cooler in which the material to be cooled will descend in a column having uniform distribution of grain sizes throughout the column.

And another object of the present invention is to achieve more efficient cooling of granular material by providing a cooler in which the material to be cooled will descend in a column having uniform velocity of descent throughout the descending column.

According to a preferred embodiment of the present invention for cooling hot granular material and increasing heat recovered for the rotary kiln, particular advantages are attained by cooling hot material received from the furnace in a rotatably mounted container having a shaft above an inverted cone shaped grate forming the bottom of the shaft. The material to be cooled is thereby received and arranged in the shape of a column having a bottom surface corresponding to the inverted cone shape of the grate. In the preferred embodiment the shaft and grate are rotated around a vertical axis passing through the center of the shaft. Material to be cooled is delivered to the top of the shaft and evenly distributed in a homogeneous mixture of grain sizes to build up a column having a top surface corresponding to the bottom surface of the column and the shape of the grate to thereby provide a substantially uniform depth of material throughout the column. Air is blown up through this column to cool the material and this air which has now become heated may be utilized in the rotary kiln. The cooled material is scooped out of the container through concentric superimposed substantial annular openings in the grate in order to remove the cooled material in even layers from substantially the entire inverted cone shaped bottom surface of the column. The rate at which the shell is rotated and the material removed from the bottom of the column is controlled to establish and maintain a column of material having a predetermined depth. The depth may vary from twenty to one hundred times the average diameter of the grains to be cooled.

The invention will be better understood by reference to the following detailed description of a method and apparatus according to the present invention as particularly applied to cooling lime, dolomite or cement clinker or the like discharged from a rotary kiln and this description is to be considered together with the drawings, in which:

Fig. 1 is a vertical cross sectional view of apparatus embodying the invention; and

Fig. 2 is a vertical end view of the apparatus shown in Fig. 1.

Referring to the drawing, an illustrative embodiment of the present invention is shown in which a granular material, such as lime, dolomite or cement clinker is received from a rotary kiln to be cooled. A portion of the discharge end of a kiln assembly is shown having a rotatable cylinder 1. The open end of cylinder 1 is enclosed by a firing hood 2. A burner 3 projects through a front wall portion of the firing hood 2 and extends into the cylinder 1. Fuel is injected into the cylinder 1 through the burner 3 and burned within the cylinder 1 to create the temperatures necessary to burn, calcine or sinter material such as the raw materials that produce the mentioned products.

As granular material is advanced through the cylinder 1 from the feed end (not shown) to the discharge end of cylinder 1 enclosed by the firing hood, the material is progressively heated until at the point of discharge from cylinder 1 into firing hood 2 it may be white hot. From the cylinder 1 the hot material is dropped through the

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firing hood structure and is deposited in a cooler assembly 8. The cooler assembly 8 is connected to the firing hood by a stationary collar 9. The cylinder 1, hood 2, collar 9 and shaft 11 are all lined with a refractory material 4 which is usually firebrick. The cooler assembly 8 is essentially a rotating container comprising an inverted cone shaped grate 10, a substantially vertical brick lined shaft 11, and a wind box 12. The grate 10 is made up of a plurality of superimposed concentric metallic rings 15. All of the rings 15 except one are annular in shape. The bottommost ring 15a is disk shaped. The rings 15 are fastened to radial ribs 16, which are fixed to the shaft 11. The members 15 and 16 form a grate defining slots 17. The slots 17 between the rings 15 are filled with granular material which rests on the rings under angle of repose.

Material to be cooled is screened of oversize pieces of such size as will be too large to pass out of the cooler assembly 8 through slots 17 between the members 15, by means shown as a plurality of grizzly bars 20 fastened to kiln hood 2. The grizzly bars 20 are inclined, as shown in Fig. 2, and a door 21 is provided in the firing hood 2 for removing pieces from the top of the grizzly bars.

Material from cylinder 1 that passes grizzly bars 20 is fed into said cooler assembly 8 to cover the grate 10 with material to be cooled. Means for feeding material into the cooler assembly may comprise an oscillating heat resistant spreader 24 connected by a crank linkage to a motor 26. The motor 26 through the crank linkage 25 causes the preferably air cooled spreader 24 to oscillate and to scatter material received from cylinder 1 in a manner that will be described. As material from the cylinder 1 is deposited in the cooler assembly 8, means, which will be later described, which are operable to control the rate of discharge of material from the cooler assembly 8 can be controlled to establish a column 30 of the material to be cooled within the cooler assembly 8.

Air is blown upwardly through column 30 by means shown in Fig. 2 as a blower 13 connected to the stationary wind box 12 by a conduit 14. The blower provides the necessary volume of air to cool material in the shaft 11 and provide combustion air for the rotary kiln cylinder 1.

The column of material 30 is rotated around an axis passing through the center of the column. To rotate the column 30 means are provided to rotate the shaft 11 and grate 10 on a circular track assembly 31 that supports shaft 11 and grate 10. A variable speed electric motor 32 is drivingly connected to shaft 11 by means of a pinion gear 33 that meshes with a ring gear 34 secured around shaft 11 to rotate shaft 11 and grate 10 about their central axis and thereby rotate the column of material 30.

Treated material is scooped from substantially the entire bottom surface of the column 30 as the column rotates. Means for removing the material are shown as comprising a plurality of scraper arms 37 projecting inwardly through and adjustable inwardly and outwardly relative to the discharge rings 15. The inner ends of the scraper arms 37 project inwardly between the rings 15. As the grate 10, the shaft 11 and the column of material 30 within the shaft 11 all rotate relative to the scraper arms 37, the arms 37 extending between the members 15 will scoop out material in layers of uniform thickness from substantially the entire bottom surface of the column 30. The material scooped through the ring shaped slots 17 is dropped into wind box 12 and deposited on a conveyor 18. And while the arms 37 are removing a uniform layer of material from the bottom of the column 30 as the column rotates, the spreader 24 will be scattering an evenly distributed layer of a homogeneous mixture of the material received from the cylinder 1. The rate at which material is withdrawn through the grate 10 by the arms 37 will depend on the rotational speed at which the column 30 is being rotated relative to the arms 37 as well as the extent to which the arms 37 project inwardly.

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A controller 40 is provided to control the speed of the motor 32 which drives the shaft 11. The rotational speed of shaft 11 and grate 10 can therefore be controlled and the arms 37 adjusted and regulated so that the discharge from cylinder 1 into the cooler assembly 8 exceeds the rate at which the material is discharged through the grate 10, for the purpose of building up within the shaft 11 a column of material having a predetermined depth. Once the column 30 has been established with the predetermined depth the rate at which the material is discharged from the cooler assembly can be matched with the rate at which the cylinder 1 is discharging material into the cooler so that the column 30 will be maintained at this predetermined depth.

The described method of handling granular material to be cooled by air or gases and the apparatus described for performing the required steps not only establishes and maintains a column of material within the shaft 11 having a predetermined depth but also as a result of the material being scattered evenly across the top of the column and removed from substantially the entire bottom surface of the column, the depth of the material in the shaft 11 will be uniform from wall to wall. Rotating of the column of material 30 and the swinging motion of the spreader 24 act to prevent segregation of various sized grains once they have been deposited in the column. During a stabilized operation the rate of feeding the cooler on top is equal to the rate of discharging it at the bottom. As the feed is spread over the top surface in even, regulated layers and without segregation of grain sizes and discharged in uniform layers at the bottom, the cooling air flows through the body of grains at a uniform rate and rapidly without channeling. The depth of the column of material and the pressure of the cooling air are reduced about to one half compared with coolers which do not achieve and maintain such uniformity. By providing a uniform depth of material, a uniform distribution of grain sizes, and a uniform spreading on top and uniform removal from the bottom of layers of equal thickness of material, the column 30 moves downwardly through the shaft 11 and all particles in the column move downwardly at a uniform velocity and a uniform permeability to gases passing through the column is maintained. Instead of a swinging spreader 24 a stationary air or water cooled metallic chute of suitable shape, such as narrowing in width as it projects inwardly, can be used to spread the hot grains falling out of the rotary kiln uniformly and without segregation on top of rotating column 30.

Providing uniform gas permeability for a bed of material to be treated with a gas is a desirable goal for any type of granular material to be cooled with a gas. It is especially important in the particular embodiment shown wherein the material is a hot material such as lime, dolomite and cement clinker which is to be cooled by air. The reason for this is that if the material to be cooled does not have a uniform permeability throughout its mass, cooling air will seek out the path through the column having the least resistance and portions of the hot material will not be cooled to the desired degree. The failure to cool all portions of the material to the required degree also means that the temperature of the air going from the cooler into the furnace will not be as high as if it had done a more efficient job of cooling the material in the cooler and as a result heat recovery will be reduced. By the present method and apparatus for handling a granular material, a way has been provided to achieve a higher degree of uniformity throughout a body of material to be cooled and as a result a way has been shown to more efficiently treat any granular material with a gas and, in particular, to cool a hot material such as cement clinker, lime or the like, and to do it with an increased efficiency of heat recovery to the rotary kiln.

From the foregoing it will therefore be apparent that the illustrated embodiment of the invention provides improved means for handling heated materials such as lime, dolomite and cement clinker to more efficiently cool the

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clinker and increase the fuel efficiency of the rotary kiln. On the other hand it will also be obvious to those skilled in the art that the invention may be utilized to advantage in the treating of any granular material with a gas and therefore the disclosure herein is illustrative only and the invention is not intended to be limited thereto.

What is claimed is:

1. An apparatus for cooling granular material with gases comprising means for receiving and arranging granular material to be treated in the shape of a substantially vertical column having a substantially inverted cone shaped top and bottom surfaces, means for rotating said receiving means about its vertical axis, means for feeding material to the top of said column and evenly distributing said feed material to cover the entire top surface of said column with a homogeneous mixture of grain sizes, means for blowing gases upwardly through a bottom portion of the column and passed vertically upward through and out the top of the column to treat the material, and means for removing treated material in layers of uniform thickness from substantially the entire portion of the bottom surface through which gas is blown into said column and discharging the cooled material along a plurality of superimposed concentric paths around the bottom surface of the column to provide a descending column of material through said receiving means having a uniform velocity of descent.

2. An apparatus for cooling granular material with gases comprising a first device for receiving the granular material to be cooled, said first device comprising a substantially vertical shaft and an inverted cone shaped grate suspended from said shaft, said grate being made up of a plurality of superimposed concentric rings forming a conical grate defining a plurality of circumferential discharge slots, a second device comprising a plurality of discharge scrapers projecting inwardly relative to said plurality of slot openings, a feeder for feeding material to the top of said shaft and evenly distributing said feed material to cover said grate with a homogeneous mixture of grain sizes to build up within said shaft a column of the material to be cooled having uniform depth, a blower, means connecting said blower to said grate for blowing gases upwardly through a bottom portion of the column of material to cool the material, and means for rotating one of said devices about a vertical axis through the center of said shaft to cause said scrapers to scoop treated material in layers of uniform thickness from substantially the entire portion of the bottom surface through which gases are blown into said column to provide a descending column of material through said container having a uniform velocity of descent.

3. An apparatus for cooling granular material with gases comprising a container for receiving granular material to be treated, said container comprising first and second parts, said first part being a substantially vertical shaft and said second part being an inverted cone shaped grate made up of a plurality of concentric superimposed rings suspended from the lower end of said shaft, and said rings defining a plurality of circumferential discharge slots, a blower, means connecting said blower to said grate for blowing gases upwardly through a bottom portion of the column of material to cool the material, a plurality of discharge scrapers projecting inwardly through and movable inwardly and outwardly relative to said connecting means, the inner ends of said scrapers projecting inwardly between said rings of said grate, a feeder for feeding material to the top of said column and evenly distributing said feed material to cover said grate with a homogeneous mixture of grain sizes to build up within said shaft a column of the material to be cooled having uniform depth, and a motor connected to said shaft for rotating said shaft and said grate about a vertical axis through the center of said shaft and relative to said discharge scrapers to cause said scrapers

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to scoop cooled material from substantially the entire portion of the bottom surface through which gas is blown into said column and discharge the cooled material out through said grate to provide a descending column of material through said container having a substantially uniform velocity of descent.

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