

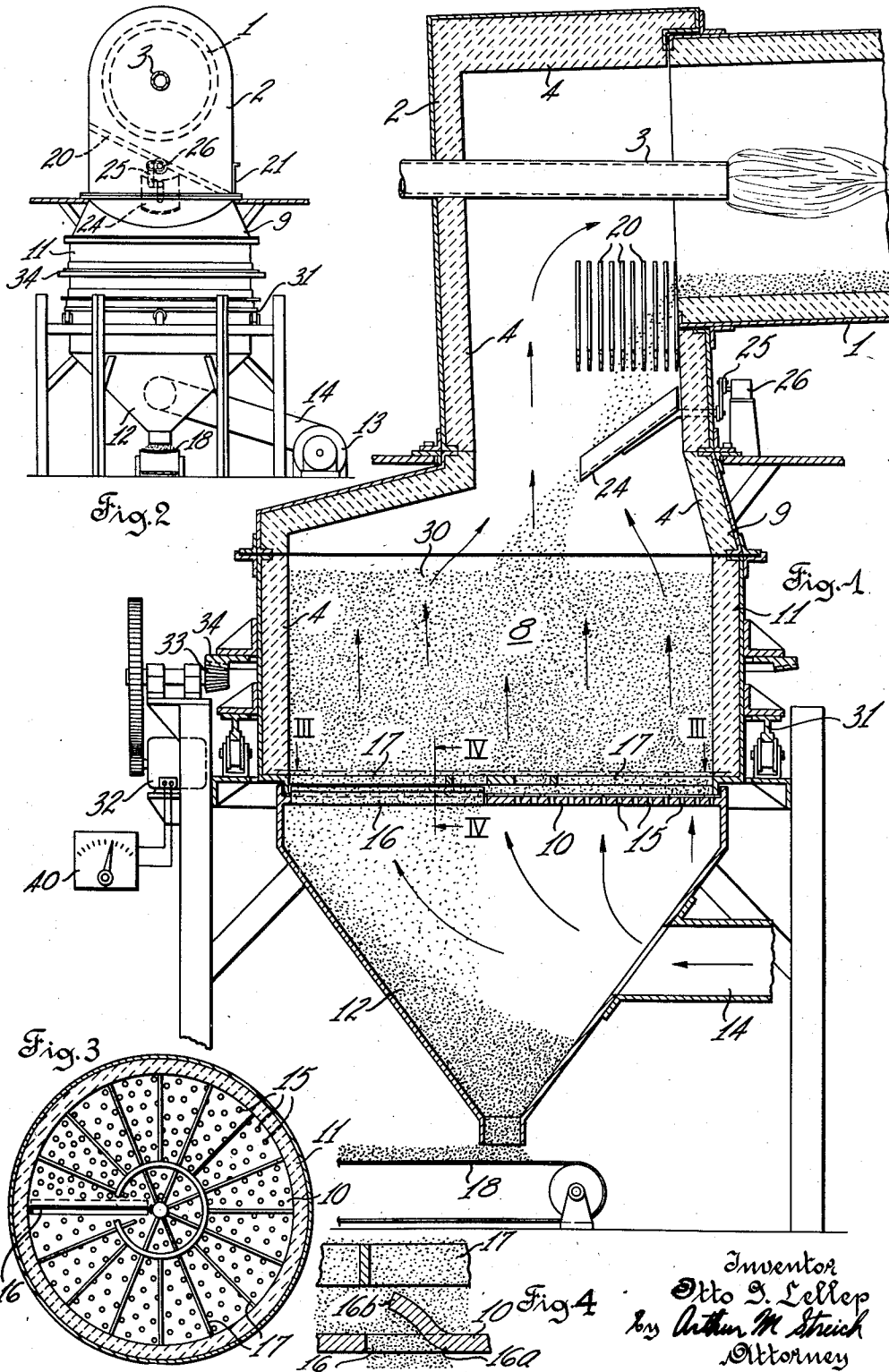
Nov. 25, 1958

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2,861,353

APPARATUS FOR COOLING GRANULAR MATERIALS

Filed June 14, 1956



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APPARATUS FOR COOLING GRANULAR MATERIALS

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Application June 14, 1956, Serial No. 591,352

2 Claims. (Cl. 34—61)

This invention relates to 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 furnace 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. Crosscurrent 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

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kiln. Since the last material that the cooling 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. 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 methods and 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.

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 the present invention, improvements in the efficiency of cooling granular materials with gases, such as air, and recovering heat for the rotary kiln is attained by cooling hot material received from the kiln in a container having a first and a second part, the first part being a grate and said second part being a shaft mounted on the grate. The material to be cooled is formed in the shape of a column having a bottom surface corresponding to the shape of the grate. In the preferred embodiment the shaft is rotated about a vertical axis passing through the center of the shaft. Material to be treated is delivered to the top of the shaft and evenly distributed in a homogeneous mixture of grain sizes over the grate to build up a column of the material within the shaft having a uniform depth of material throughout the column. Air is then blown up through this column to cool the material. The cooling air becomes heated and may be utilized in the rotary kiln to obtain the maximum possible fuel economy. The cooled material is discharged from the container through a radial slot in the grate extending substantially between the center and the periphery of the shaft in order to remove material in layers of uniform thickness progressively around the bottom of the column as the bottom surface of the column rotates over the slot. The rate at which the shaft 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, cement clinker or the like discharged from a rotary kiln and this description is to be considered together with the drawing, in which:

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

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

Fig. 3 is a view taken along line III—III in Fig. 1, looking in the direction indicated by the arrows; and

Fig. 4 is a fragmentary cross sectional view taken along line IV—IV in Fig. 1.

Referring to the drawing, an 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 2, 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 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 container comprising horizontally disposed grate 10, a substantially vertical shaft 11 mounted above a discharge wind box 12. The wind box 12 is covered by the grate 10. The grate 10 is provided with a plurality of holes 15 and a radial discharge slot 16 extending from the center to the periphery of the grate. A plurality of spokelike members 17 are provided at the bottom of the shaft 11 for a purpose that will appear.

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 the discharge slot 16, by means shown as a plurality of grizzly bars 20 fastened to 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 fill up the shaft 11 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 25 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 is connected to the stationary wind box 12 by a conduit 14. The blower provides the necessary volume of air to be blown into spout 12, through holes 15 and up through the column of material 30 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 on a circular track assembly 31 that supports shaft 11. 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 about its central axis. The spokelike members 17 act like a paddle wheel to push the material 30 to insure rotation of the column of material 30 with the shaft and relative to the grate 10.

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 including the discharge slot 16 and the spokelike members 17 that insure rotation of the bottom of the column of material 30 relative to the slot 16 when the shaft 11 is rotated by motor 32. The trailing edge 16a of slot 16 is provided with an upwardly projecting lip 16b to direct material out slot 16. As shaft 11 and the column of material 30 within the shaft 11 rotate relative to the grate 10, the slot 16 will divert and scoop out from between the members 17 material in layers of uniform thickness removed progressively around substantially the entire bottom surface of the column 30. The material removed from the bottom of column 30 is dropped into wind box 12 and deposited on a conveyor 18. And while a layer of material having uniform thickness is being removed 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

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from the cylinder 1. The rate at which material is withdrawn through the grate 10 by the slot 16 will depend on the rate or rotational speed at which the column 30 is being rotated relative to the grate 10. A controller 40 is provided to control the speed of the motor 32 which drives the shaft 11. The rotational speed of the shaft 11 can therefore be controlled so that the discharge from cylinder 1 into the cooler assembly 8 exceeds the rate at which the material is discharged through the slot 16 in grate 10, for the purpose of building up within the shaft 11 a column of material 30 having a predetermined depth. Once the column 30 has been established with the predetermined depth the rate at which 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 scattering action of 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 discharge 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 to about 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 swing spreader 24, a stationary air or water cooled 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 the 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 treated 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 required 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

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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 an improved way of handling heated material, such as lime, dolomite and cement clinker to more efficiently cool the 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. In an apparatus for cooling hot granular material, a first member comprising a substantially horizontal perforated grate, a second member comprising a substantially vertical shaft mounted over and adjacent to said grate, a motor connected to one of said members to rotate said one member about a vertical axis, means for delivering material to be treated to the top of said shaft, a distributor for distributing said material in a homogeneous mixture of grain sizes to cover said grate evenly to build up a column of material within said shaft having a substantially horizontal top surface, a blower for blowing gases upwardly through the column of material to cool the material, a radial slot in said grate extending substantially between the center and the periphery of said shaft to discharge cooled material in layers of uniform thickness progressively around the bottom of the column of material as said one of said members rotates to thereby lower the material through said shaft in a descending column of material having a substantially uniform depth and a controller for controlling the speed of said motor to vary the rate at which the material passes out said slot to maintain a predetermined depth of material in said shell.

2. In an apparatus for cooling hot granular material discharged from a furnace, a substantially horizontal perforated grate, a substantially vertical cylindrical shaft mounted over and adjacent to said grate, a motor connected to said shaft to rotate said shaft relative to said grate and about a vertical axis, means for delivering material to be treated to the top of said shaft, a distributor for distributing said material in a homogeneous mixture of grain sizes evenly across the top of said grate as said shaft rotates to build up a column of material within said shaft having a substantially horizontal top surface, a blower for blowing air upwardly through the column of material to cool the material, a radial slot in said grate extending radially substantially between the center and the periphery of said shaft to discharge cooled material in layers of uniform thickness progressively around the bottom of the column of material as the bottom surface of the column of material rotates over said slot to thereby lower the material through said shaft in a descending column of material having a substantially uniform depth and uniform distribution of grain sizes and provide uniform gas permeability through the column of material, and a controller for controlling the speed of said motor to vary the rate at which said shaft rotates and the material is passed over and out said slot to maintain a depth of material in said shaft of between twenty and one hundred times the average diameter of the grains.

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