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2,879,052

METHOD OF AND APPARATUS FOR TREATING CALCAREOUS MATERIALS

Filed Aug. 25, 1955

3 Sheets-Sheet 1

FIG. 1.

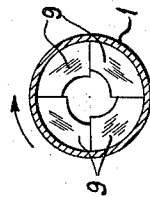
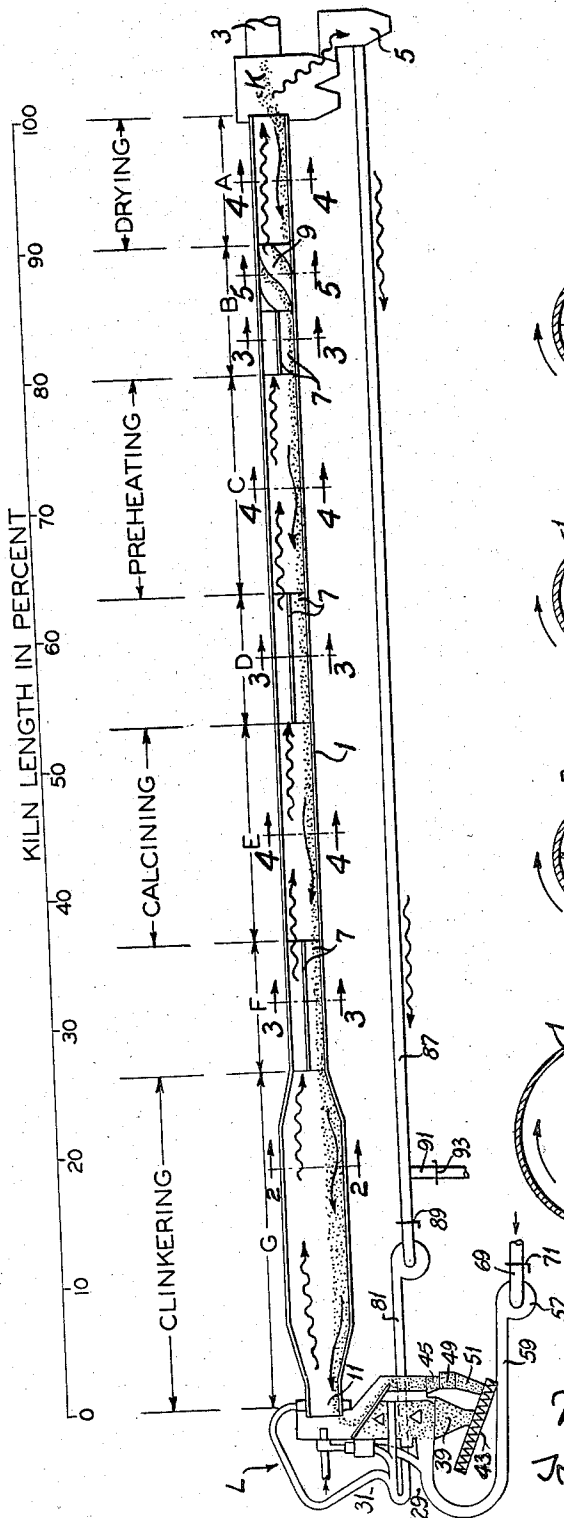


FIG. 5.

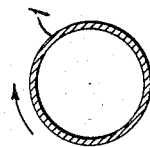


FIG. 4.

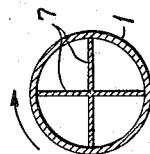


FIG. 3.

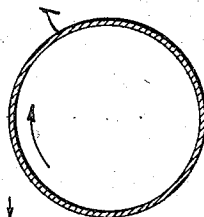


FIG. 2.

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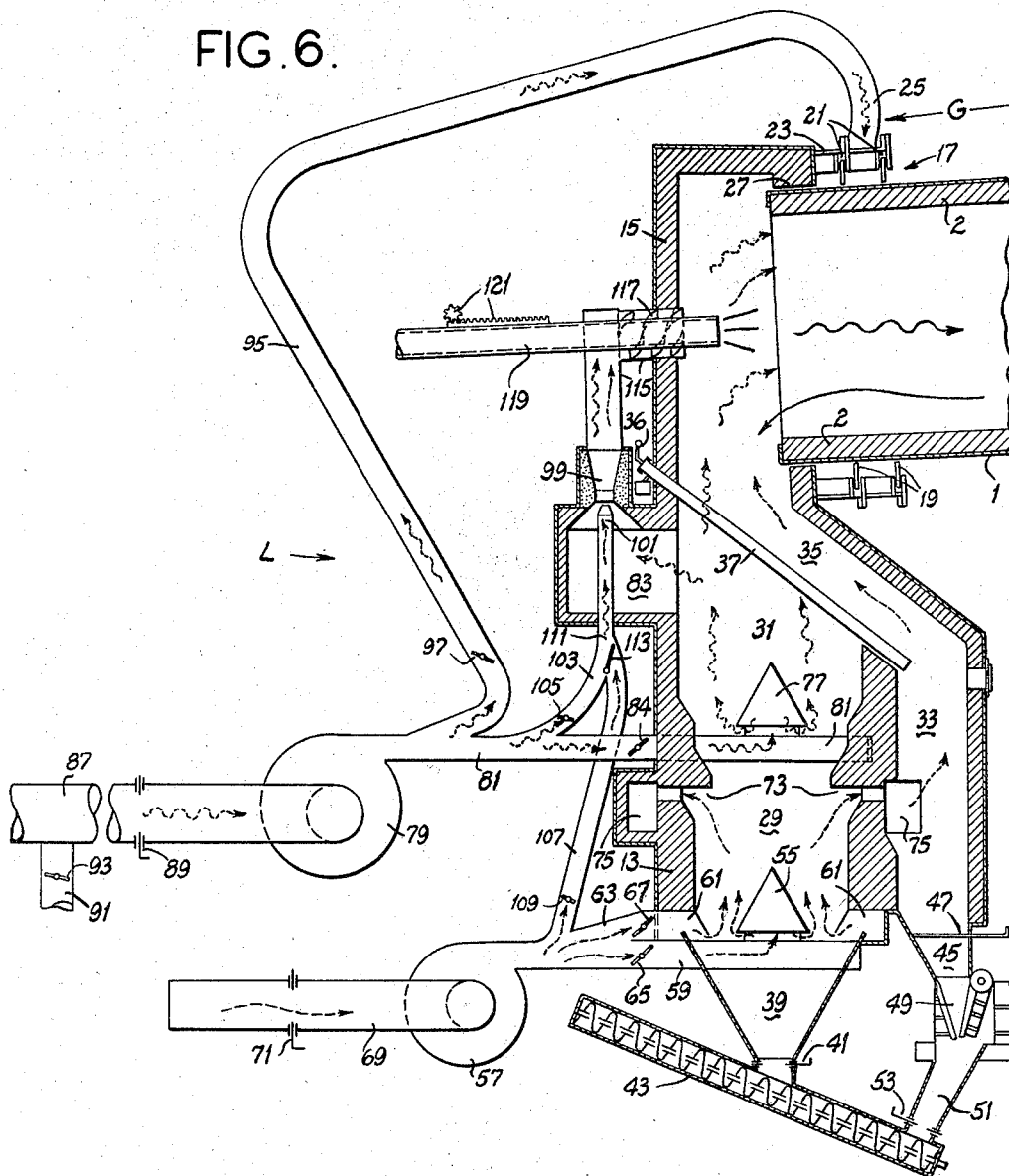
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FIG. 6.



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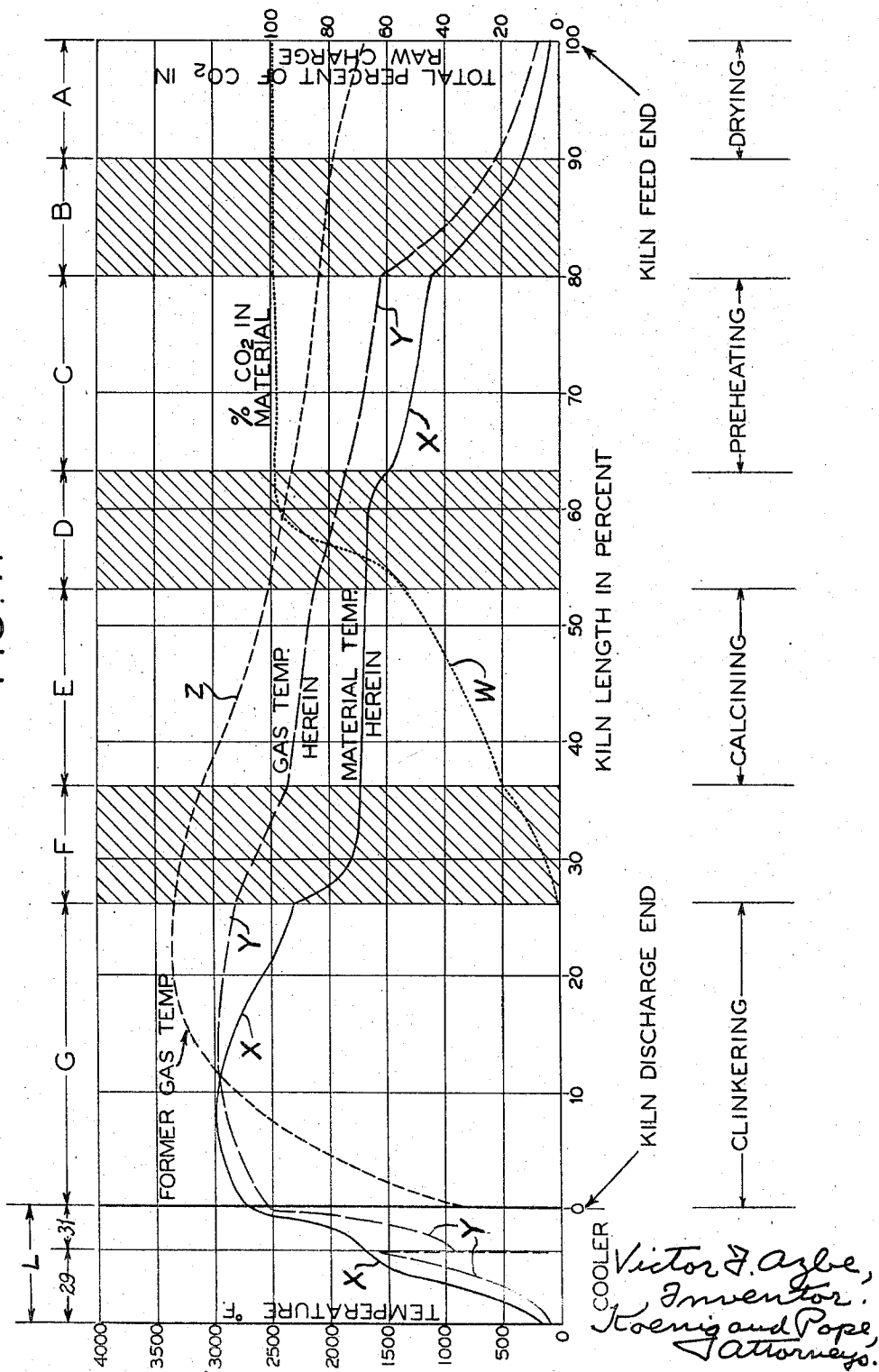
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FIG. 7.



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METHOD OF AND APPARATUS FOR TREATING CALCAREOUS MATERIALS

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Application August 25, 1955, Serial No. 530,573

8 Claims. (Cl. 263—33)

This invention relates to a method of and apparatus for treating calcareous materials, and more particularly for manufacturing Portland cement.

Among the several objects of the invention may be noted the provision of means for producing an improved Portland cement in which a larger proportion of cementitious particles are produced from fully developed clinker; the provision of means for obtaining a more complete combination of the calcareous and argillaceous components in the clinkering operation without deleterious effects from the calcining operation; the provision of means for performing the calcining operation without deleterious effects from preheating operations; and the provision of a rotary type of cement kiln of smaller size than heretofore, operating at lower temperature and at greater heat efficiency for a given production rate. Other objects and features will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, steps and sequence of steps, features of construction and manipulation, and arrangements of parts which will be exemplified in the structures and methods hereinafter described, and the scope of which will be indicated in the following claims.

In the accompanying drawings, in which one of various possible embodiments of the invention is illustrated,

Fig. 1 is a diagrammatic side elevation, partly in section, of apparatus incorporating my invention;

Fig. 2 is an enlarged cross section taken on line 2—2 of Fig. 1;

Fig. 3 is an enlarged cross section taken on lines 3—3 of Fig. 1;

Fig. 4 is an enlarged cross section taken on lines 4—4 of Fig. 1;

Fig. 5 is an enlarged cross section taken on line 5—5 of Fig. 1;

Fig. 6 is an enlarged vertical section of the cooler shown diagrammatically at the lower left in Fig. 1; and,

Fig. 7 is a chart showing typical relations between kiln length, reduction of CO₂ and temperature in my kiln, certain corresponding temperatures in former kilns being also plotted thereon.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

Referring now more particularly to Fig. 1, there is shown at numeral 1 a sloping circular steel drum having a heat-resistant lining 2, the drum being mounted for rotation by means known to the art and therefore not shown. The drum extends from an upper-level rotary connection, with a dust chamber K, the latter forming a connection with the stack 3 and including means for feeding calcareous (limestone) and argillaceous (clay) material to the drum. It includes an auxiliary dust collector 5. The details of the feeding and dust collection means are not shown, since these are also known to the art. Such means comprehend either the dry feed means for dry material or wet feed means for wet material.

The drum 1 is divided into definitely separated drying, preheating, calcining and clinkering zones A, C, E and G, respectively. These zones A, C, E, G are separated from

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one another by segmented stirring zones B, D and F, as shown in Fig. 1. Zone B separates zones A and C; zone D separates zones C and E; and zone F separates zones E and G.

As illustrated in Figs. 2 and 4, the circular form of zone G is larger in diameter than the diameters of the circular forms of zones A, B, C, D, E and F. As shown in Fig. 3, the segmented zones B, D and F are circular but each is divided by cross members 7 into quadrants. As shown in Fig. 5, the cross members in zone B are connected with inwardly directed spiral flanges 9 which serve to pick up incoming calcareous and argillaceous material to mix and propel them before they proceed by normal rotation and gravity through the remaining zones of the drum 1. These spiral flanges 9 also serve finally to swirl hot gases ascending the drum 1. Such final swirling action is desirable in order to obtain a degree of dust separation from the escaping gases within the rotary kiln shell proper.

The zones B, D and F, while physically forming axial connections between the zones on either sides of them for counterflow therethrough of solid materials and gases, also functionally separate the zones adjacent to them. This is in the sense that the processes (to be described) in adjacent zones are finished rapidly and completely in the zones B, D, F, as will be more apparent from Fig. 7. Thus in the cross-hatched zones B, D, F of Fig. 7, temperatures (see curves X and Y) change more rapidly than in the zones A, C, E and G. On the other hand, with former processes (as shown by curve Z) there is no such correlation, with disadvantages such as pointed out below. Likewise, zones D and F effect a rapid change in the driving off of CO₂. Zone B does not have such an effect because it is essentially a preheating zone and is of a temperature below that of CO₂ release by calcining reaction.

The lower end of the drum 1 has a rotary connection with a two-stage cooling apparatus. The latter is generally indexed L, being shown at the lower left of Fig. 1 and also in Fig. 6. This cooler consists in a hollow vertical shaft 13, formed at the top as a firing hood 15 into which the lower end of the drum 1 extends through a circular gland 17. The gland consists of rings 19 surrounding the drum 1, interdigitating within annular pockets 21 formed in a stationary annular structure 23 attached to the firing hood 15. The fit between rings 19 and the drum may be tight or loose, as desired, and the rings have a loose rotary fit within the pockets 21. A gas inlet 25 is connected to the annular structure 23 between the pockets 21. Thus gas can be introduced from the inlet 25 between the rings 19. Since, as will appear, the gas is under pressure, any leakage will be from between the rings 19, thus blocking off outward leakage from within the firing hood 15 through any space between the end of the drum 1 and the opening 27 within the hood which accepts the end of the drum. In other words, the gland 17 carries a pressure head around the end of the drum, tending to force some of the gas from the inlet 25 around the drum and into the firing hood 15, rather than having leakage occur outward from the firing hood around the end of the drum.

The lower portions of the vertical shaft 13 form a sectional, double-level cooler, the lower section of which is indexed 29 and the upper section 31. Adjacent the cooler 29, 31 is formed a scale and oversize clinker pocket 33. This has a lateral connection 35 with the firing hood 15. Grate bars 37 separate the connection 35 from the upper section 31 of the cooler. Shaking and water cooling means, if desired for the grate, is indicated at 36. Thus normal-size clinker, as determined by the grate spacing, may drop into the cooler, whereas oversize clinker and scale is screened out by the grates 37 to pass down the passage 35 into the oversize-clinker pocket 33.

It will be understood that, in operation, overfilling of both sections 29 and 31 of the cooler and the clinker pocket 33 is prevented by a proper rate of withdrawal of material from below. Thus there is at the lower end of the cooler a cooler discharge hopper 39, having at its lower end a control gate 41 leading to a variable capacity discharge conveyor 43. At the lower end of the clinker pocket 33 is a discharge hopper 45, having a control gate 47 and leading to a rocking jaw-type crusher 49. The crusher is connected to the conveyor 43 by a chute 51, also having a control gate 53.

The sections 29 and 31 of the cooler are established as follows: At the lower end of the shaft 13 is a central air inlet and distributing hood 55, connected with an air fan or blower 57 by means of a pipe 59. At this lower end is also an annular air inlet 61, connected with said pipe 59 (and therefore with the air fan 57) by means of a branch pipe 63. Control dampers 65 and 67 are employed in the pipes 59 and 63, respectively. An air inlet pipe 69, having a control orifice 71, supplies air to the fan 57. Thus air under pressure may be introduced at the lower end of the shaft 13 above the hopper 39. Since there is resistance against its escape downward through the filled hopper and screw conveyor 39, it will travel upward. In order to confine air cooling to the lower section 29, circumferential air outlets 73 are provided to establish the upper end of the lower cooling section 29. These connect with the clinker pocket 33 by means of an annular connection 75. Cool air rising through the lower section 29 of the cooler will tend to by-pass the upper cooler section 31 by flowing out through passages 73, 75, 33, 35 and 15 to the drum 1. The frictional resistance through the upper part of the clinker pocket 33 is less than that through the upper cooling section 31, wherein are more finely divided particles than in pocket 33, the latter consisting of oversize clinkers. Also, the friction head carried in the clinker pocket 33 may be maintained low with respect to that in section 31 by charge-level control at the gates 41 and 53 and by proper control of the speed of operation of the crusher 49.

The lower end of the upper section 31 is thus established just above the air outlet passages 73. At this point recirculated gases from the drum 1 are introduced at a central distributing hood 77. This hood is connected with a recirculating fan or blower 79 by means of a pipe 81 in which is a control damper 84. The fan 79 also supplies the recirculating gas under pressure to the inlet 25 of the gland 17, this being done by way of pipe connection 95 in which is a control orifice 97.

The upper end of the upper cooling section 31 is established beneath the grates 37 and opposite a lateral outlet passage 83. Thus recirculated gases supplied by the fan 79, which are warmer than the air supplied by the fan 57, rise in the upper section 31, abstract heat from the hot material therein and join with the air which has picked up heat from the cooler material in the lower section 29 and which has by-passed the upper section 31. Thus heated air and cooled recirculated gases, both of which are warm, join above the grates 37 and enter the drum 1 through the firing hood 15.

Recirculated kiln gases are supplied to the fan 79 through a pipe 87, having a control orifice 89. On the upstream side of the damper 89 is an air bleeder pipe 91 in which is a control damper 93. By proper manipulation of this damper 93, the temperature of the recirculated kiln gases may be modulated by cool air which is subsequently used for combustion.

As shown in Fig. 1, pipe 87 leads to the dust collector 5 and thus is in ultimate communication with the upper end of the drum 1, connection being accomplished through the dust chamber K.

The upper portion of the lateral outlet passage is formed as a venturi throat 99, associated with which is an induction nozzle 101. This nozzle receives recirculated kiln gas from the fan 79 by way of a pipe 103 (wherein is

a damper 105) and/or air from the fan 57 by way of a pipe 107 (wherein is a damper 109). The pipes 103 and 107 are joined at a Y 111, wherein is a mixing control gate 113. Pressure from either or both of the fans 57, 79 forces air and/or kiln recirculating gas to the induction nozzle 101. Ejection from the nozzle through the venturi 99 aspirates recirculating kiln gas from the upper cooling section 31 through the outlet passage 83 into angle pipe 115, which projects into the firing hood 15. In the inlet leg of the angle pipe 115 are stationary helical gas-swirling vanes 117. Projecting into the hood 15 through the inlet leg of pipe 115 and the vanes 117 is a fuel pipe 119 which is axially adjustable relative to pipe 115 and vanes 117. This pipe 119 supplies fuel under pressure into the drum 1 through the hood 15, which mixes with air and recirculated kiln gas rising from the clinker pocket 33 and cooler section 31. Axial adjustment of the fuel pipe 119 is accomplished by means of a rack and pinion drive 121.

In connection with Fig. 1, the solid-line undulated arrows signify descending solid material in the drum 1 and the serpentine solid arrows signify rising gases. In Fig. 6 the undulated dotted arrows signify the air component of the gases and the dotted serpentine arrows signify the recirculating kiln-gas component. The straight flaring lines at the end of fuel pipe 119 represent fuel which may be pulverized coal, natural gas, fuel oil or the like. Thus the upper solid serpentine arrows in both Figs. 1 and 6 represent a mixture of fuel, air and kiln-gas components in varying proportions along the length of the drum 1. Under progressive combustion, the ratio of kiln gas to air and fuel increases as the gases ascend in the drum, until only spent kiln gases and also water and CO₂ from the kiln charge are emitted at the upper end of the drum.

Operation is as follows:

Fuel is introduced through the fuel pipe 119 and ignited within the firing hood 15. The drum 1 is rotated, the orifices and dampers set, the blowers 57 and 79 turned on and the crusher 49 and conveyor 43 energized. Admixed calcareous and argillaceous materials are introduced at the upper end of the rotating drum 1. Under steady-state conditions and proper readjustments of the various controls, the two sections 29 and 31 of the cooler L are filled with relatively small-size clinker, whereas the clinker pocket 33 becomes filled with larger clinker and scale. Cooled clinker is withdrawn from cooler L by the conveyor 43 at a rate determined by the adjustments of the gates 41, 47 and 53. The pressurized gland 17 is then operative, and the material and gas flow proceed according to the arrows shown in Figs 1 and 6. The meanings of the various arrow forms have been given above.

Material entering the upper end of the drum is dried in the drying zone A, which in case of the wet process may contain chains. This places it in condition to be picked up by the spiral flanges 9 and sent through the cross member 7. In this connection, compare curves Y and Z of Fig. 7. The increased stirring and exposure afforded by the members 7 and 9 rapidly and completely terminates the drying process with a quick temperature increase as the solid dry materials are thoroughly intermixed. The rapid rise in temperature for terminating drying in zone B is illustrated by the right-hand cross-hatched rectangle in Fig. 7. Curves X and Y show this. The reduced heat loss by radiation in drying is implicit, since the loss by heat radiation is lower at lower drying temperatures in zone A (see the ends of curves X and Y). Thus drying is completely accomplished by the time the preheating zone C is reached.

In the preheating zone C an elevated temperature has been obtained which effects adequate preheating on the completely dried materials. An effect of the cross members 7 and spiral flanges 9 is to prevent drying operations from being carried over into the preheating zone, which

would require a much greater total length of zones A and C than is taken up by the presently provided zones A, B and C. The reason for this is that any simultaneous performance of the drying and preheating operations is less efficient than carrying them out substantially separately, as by providing the terminal zone B.

As the materials reach the lower end of the preheating zone C, they enter the quadrated zone D, which effects a rapid transfer of heat from the gas to the material, so as to bring it up to the temperature employed in the calcining zone E before that zone is entered. Thus preheating operations are not carried over into the calcining operations in zone E. Again, the length of the zones C and E would be greater than is the length of zones C, D and E, because the zone D, which definitely terminates preheating, prevents any inefficient simultaneous preheating and calcining operations.

In the calcining zone E, the temperature of the material is kept fairly constant, as indicated by curve X in Fig. 7. Calcination is rapidly terminated in terminal zone F (see the passage of curve X through the cross-hatched part F of Fig. 7). Thus the material enters the clinkering zone G at high temperature, all of the CO_2 having been removed from the calcareous component CaCO_3 to produce CaO for clinkering with the argillaceous component (note the termination of curve W in zone F). No further substantial calcining occurs in the clinkering zone G.

In the clinkering zone G, the material is subject to high clinkering temperatures under its own exothermic reaction. Finally the lower end of the drum 1 is reached. The clinkering operation is carried out efficiently because no calcining operation is carried out in the zone G, it having been substantially completely terminated before this zone is reached.

The prevention of calcining in the clinkering zone is important, for the reason that the cement-forming clinker reaction is exothermic, whereas the calcining reaction is endothermic. If any substantial calcining were allowed to occur in the clinkering zone, as heretofore, the temperature of exothermic clinkering reaction would be substantially offset by the lower temperature of the endothermic calcining reaction. This would require higher flame temperature and consequently the burning of more fuel in order to reach the clinkering temperature within the clinkering bed. In accordance with the system herein, the temperature-raising effect of the heating clinkering reaction in the clinkering zone G is not interfered with by any cooling effect of the calcining reaction, the latter being excluded from zone G. Thus a smaller amount of fuel is required to be burned in order to reach and maintain clinkering temperature in zone G. Moreover, lower and less troublesome combustion temperatures are required.

In view of the above, it will be seen that the usual overlapping functions of the various drying, preheating, calcining and clinkering zones in former cylindric rotary cement kilns have been eliminated, with consequent substantial reduction in length of rotary drum required, and reduction in resulting heat losses. There are several reasons for the reduction in heat loss. First, fuel is saved because the attainment of clinkering temperatures is aided by the unimpeded exothermic reaction in the clinkering zone G. Second, the increased heat-absorbing surfaces aid in the transferring of heat and also in better mixing and better exposure of all particles of the charge to heat of the gases. Third, this leads to a smaller drum in length and diameter and a lower radiation loss. Fourth, there is the regenerative heat in cooling, which would otherwise be lost.

Curve Z demonstrates how in former cement kilns the carrying over of calcination into the clinkering zone reduced clinkering temperatures at the points where high temperatures are desirable, i.e., in the finishing of the clinkering operation. It is in this respect that

the present method improves the cement product by thoroughly finishing it.

The clinkered material from zone G spills from the lower end of the drum 1 into the cooler L, where it is segregated, the smaller lumps filling the cooling sections 29 and 31 and the larger lumps filling the clinker pocket 33. The greater bulk of them constitute those which enter the sections 29 and 31. In section 31 they are very hot and are initially cooled by the recirculating kiln gases. Upon reaching the lower section 29, they are cooler but more heat is extracted from them in this lower section by the cooler air from blower 57. This air does not all pass through the upper cooling section 31, but by-passes it by moving through the clinker pocket 33, wherein hot clinkers to be cooled raise its temperature further than occurs during its passage through section 29. This heated air meets and mixes with the recirculating gases issuing from the upper end of the upper cooling section 31. They then enter the drum 1. Some of the hot recirculating gases from the upper section 31 are drawn into the pipe 115 by air and/or recirculating gases ejecting from nozzle 101. These gases enter the firing hood 15 around the fuel pipe 119. Thus all of the air which is supplied for combustion from blower 57 is preheated and mixed with recirculated kiln gases for controlled modulated combustion. Separate passage of hot air from the lower cooling zone 29 and recirculating gases passing through the upper cooling zone 31 is desirable for quick quenching of clinker in zone 31 from the highest temperature and also for reducing the pressure necessary to force the gases through the bed of clinker.

Summarizing, the advantages of the invention are:

(1) In general, the prevention of the overlapping of the drying, preheating, calcining and clinkering functions in the various zones of the kiln provided therefor, by use of the quadrated terminal stirring zones B, D, F, and in particular:

(a) The prevention in the clinkering zone G of any offset to exothermic heating in the clinkering reaction by any cooling calcining reaction and;

(b) Super-heating of calcium oxide (CaO) only in the calcining, rather than in the clinkering zone, thus preventing unnecessary heating in the clinkering zone.

(2) The maintenance of a large temperature differential between the heating gas and heat-absorbing material in each zone C, E, G, which assures a rapid heat transfer from gas to material under treatment and in effect reduces the length of kiln which would otherwise be required in order to subject the materials to the necessarily greater heating time required in passing through the process. Nevertheless, the final temperatures of kiln gases escaping from the upper end of drum 1 are relatively low. This implies a low heat loss.

(3) Efficient regenerative recovery of sensible heat of the high-temperature clinker, afforded by recirculated kiln gases for cooling in addition to the cooling effect of the air used for combustion. Without the additional heat-absorbing capacity of these recirculating gases, the air required for combustion would be insufficient properly to cool the clinker, and it would not be desirable to employ excess air for the purpose, and then either to discharge the air along with its heat, or to employ the air as excess air for combustion. In the former case the sensible heat of the air is lost, and in the latter case it shortens the combustion flame, resulting in poor efficiency of clinkering and calcination.

(4) Delay of combustion and the preservation of a radiant flame for the calcining zone, i.e., one having high carbon luminosity by preventing the high carbon luminosity from being dissipated in the clinkering zone, as was the case heretofore in the absence of sufficient controls for the admixture of gases entering the rotary drum 1.

(5) Reduction in kiln size, with consequent reduction in radiant heat losses and structural costs.

In general, the improvements herein may be expected to increase kiln efficiency now ranging between 20% and 40% to a range of 60% to 70%, while at the same time increasing the kiln cement-making capacity from two to three times for a given size of kiln.

It will be understood that while the invention is primarily applicable to the manufacture of Portland cement, certain phases of it (excluding the clinkering operation) are applicable to the manufacture of lime; for it is also important to lime manufacture that the division of the rotary drum 1 into the respective zones mentioned, by means of cross-membered stirring sections, shall be at strategic points at which ordinary heat transfer is the poorest and heat waste the greatest.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions and methods without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. Cement manufacturing apparatus comprising a vertical cooler having an upper firing hood, a dust chamber, a downwardly sloping rotary drum having a lower material outlet and gas inlet connection with said firing hood and having an upper material inlet and kiln-gas outlet connection with said dust chamber, three cross-segmented sections in the drum spaced from one another and from the drum ends to provide spaced clinkering, calcining, preheating and drying zones in order from the lower end to the upper end of the drum, said cooler having lower and upper cooling sections for receiving clinkers from said clinkering zone, a fuel nozzle in said hood adapted to direct fuel into the drum, a kiln-gas recirculating connection between said dust chamber and the lower end of said upper cooling section, a fresh air connection with the lower end of said lower cooling section, means for injecting gas from the upper end of said upper cooling section into said firing hood, and means for carrying air from the upper end of said lower cooling section into the drum through said firing hood without passing through said upper cooling section.

2. Apparatus made according to claim 1, wherein said last-named means comprises a clinker pocket separated from said upper cooling section by grate means adapted to direct smaller clinkers to said upper and lower cooling sections and larger clinkers to said pocket for exposure to said air passing from the upper end of the lower cooling section to the firing hood.

3. Apparatus made according to claim 2, including a blower in said fresh air connection, and a blower in said kiln-gas recirculating connection, and wherein said injecting means includes an induction nozzle having conduits connecting with the respective blowers.

4. A vertical cooler of the class described comprising an upper firing hood adapted for connection with a rotary kiln drum, an upper cooling section in alignment for receiving material by gravity from said firing hood, a lower cooling section below said upper cooling section, means for introducing air at the bottom of the lower cooling section, means for exhausting air from the top and side of the lower cooling section, means for introducing recirculating gases from the kiln drum at the bottom of the upper cooling section near the location of said air-exhausting means, said gases escaping from the upper end of the upper cooling section, and means whereby the stream of said air exhausted from the upper end of said lower cooling section and the stream of recirculating gases from the upper end of said upper cooling section are brought together in said firing hood.

5. A clinker cooler connected with the drum of a rotary cement kiln, comprising a firing hood having a connection with said drum, portions extending downward from the firing hood to form an upper cooling section and a lower cooling section in alignment for receiving clinker by gravity from said drum, a grate above the upper cooling section, said portions also forming an oversized clinker pocket adjacent said upper and lower cooling sections adapted to receive oversize clinkers from the grate, said lower cooling section having a lower pressurized fresh air connection and an upper air connection with said clinker pocket, said upper cooling section having a lower externally pressurized kiln-gas connection, the upper portions of the upper cooling section and of the clinker pocket being connected with said drum through said firing hood.

6. A clinker cooler made according to claim 5, wherein said upper cooling section has an additional by-pass kiln-gas connection with said firing hood and a fuel nozzle associated therewith.

7. A clinker cooler connected with the drum of a rotary cement kiln, comprising a firing hood having a connection with said drum, portions extending downward from the firing hood to form an upper cooling section in alignment for receiving clinkers by gravity from said drum, and a lower cooling section therebeneath, said portions also forming an oversized clinker pocket adjacent said upper and lower cooling sections and divided therefrom by grate means above said upper section, said lower cooling section having an upper lateral connection with said clinker pocket and a lowered pressurized fresh air connection, said upper cooling section having a lower pressurized kiln-gas connection, the upper portions of the upper cooling section and of the clinker pocket being connected with said drum through said firing hood, a fuel nozzle for the firing hood, and a direct by-pass connection to the firing hood from the upper portion of said upper cooling section and independent of the other connections with said drum.

8. A cooler of the class described comprising a firing hood adapted for connection with a kiln, controllable fuel injection means in said firing hood, an upper cooling section in alignment for receiving material by gravity from said firing hood, a lower cooling section below said upper cooling section, adjustable means for introducing air under pressure at the bottom of the lower cooling section, means for exhausting air from the top of the lower cooling section without entry into the bottom of the upper cooling section, adjustable pressurized means for introducing recirculating gases from the kiln at the bottom of the upper cooling section, said gases escaping from the upper end thereof, and means whereby the stream of air from the upper end of the lower cooling section and the stream of recirculating gases from the upper end of said upper cooling section are brought together in said firing hood, and adjustable means for introducing both air and recirculating gases into said firing hood independently of the gases which reach it through said cooling sections.

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