March 30, 1965 R. RETALI ETAL 3,175,302

GRAVITY-TYPE HEAT EXCHANGER FOR TREATING PARTICULATE SOLID MATERIAL

Filed Jan. 2, 1962

3 Sheets-Sheet 1

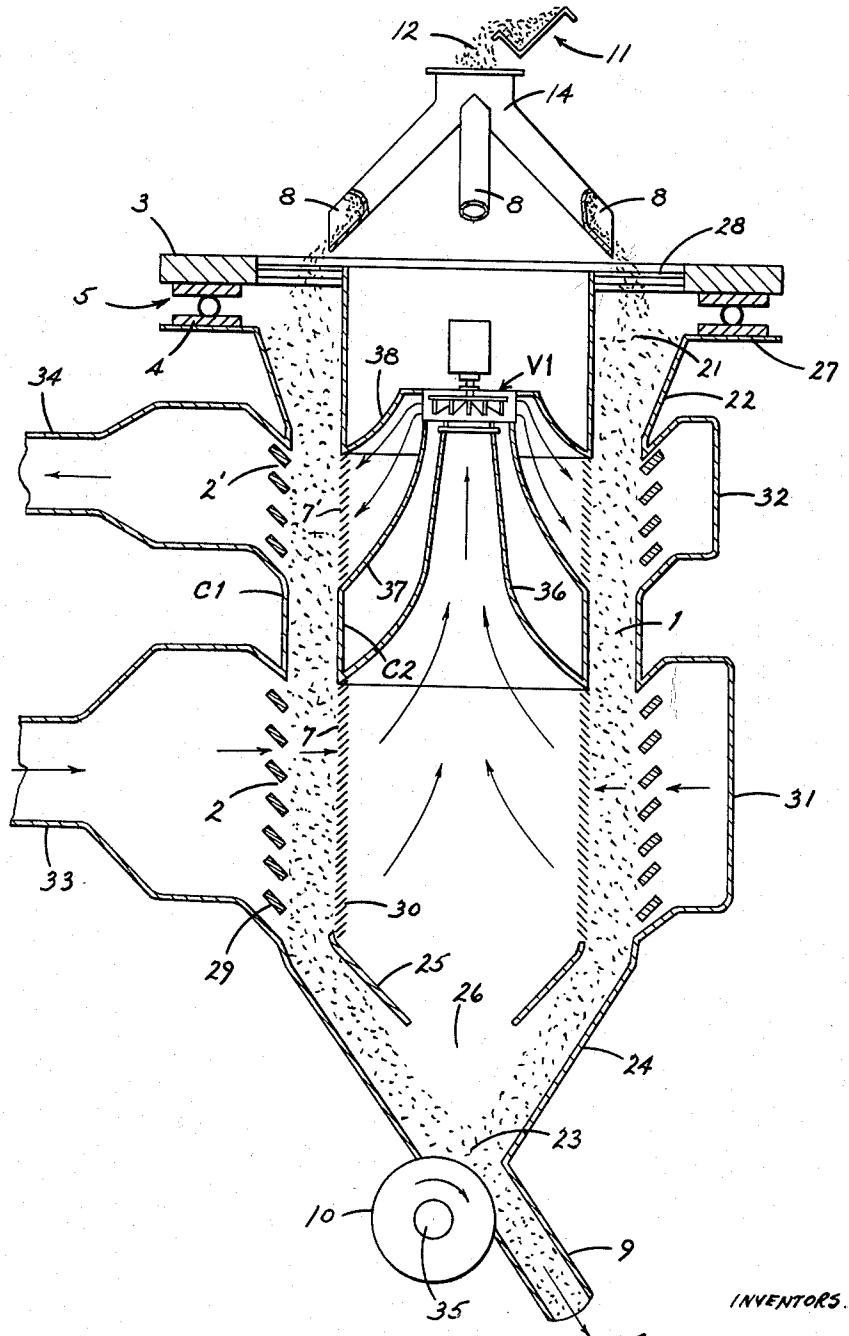


Fig. 1

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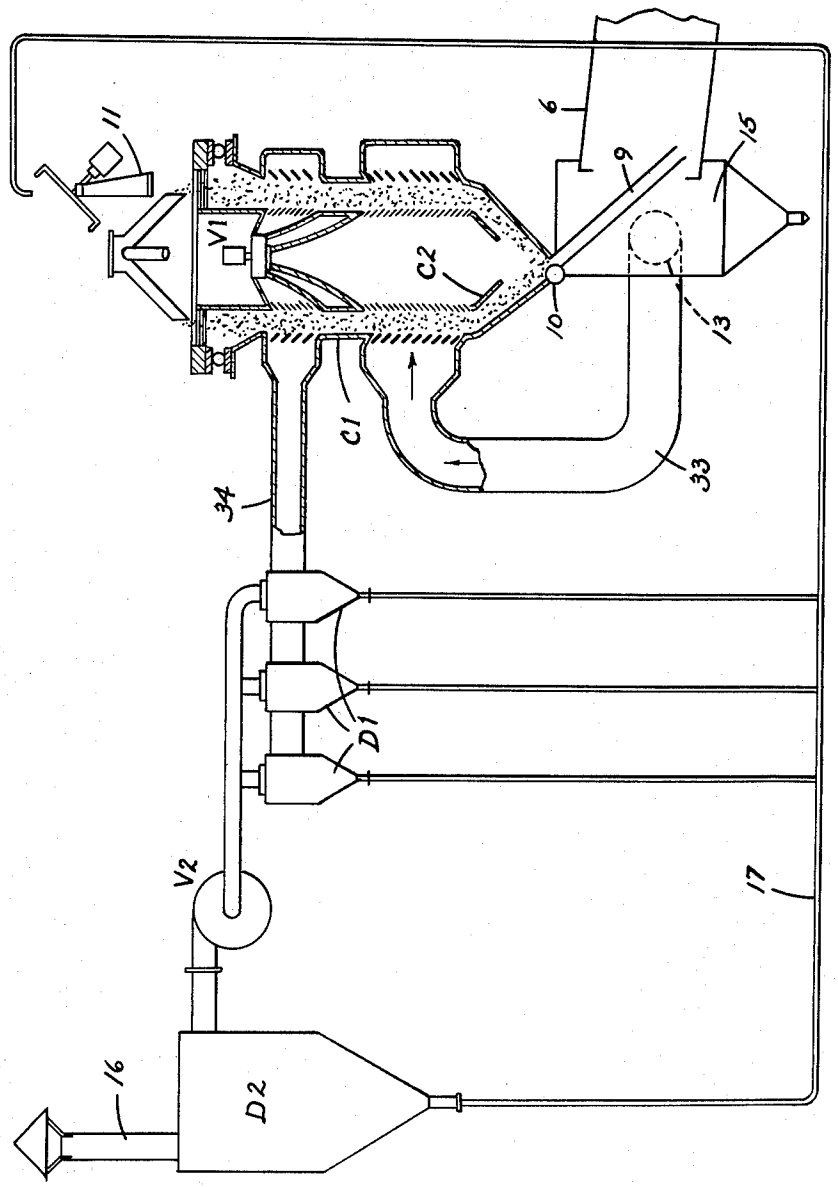


FIG. 2

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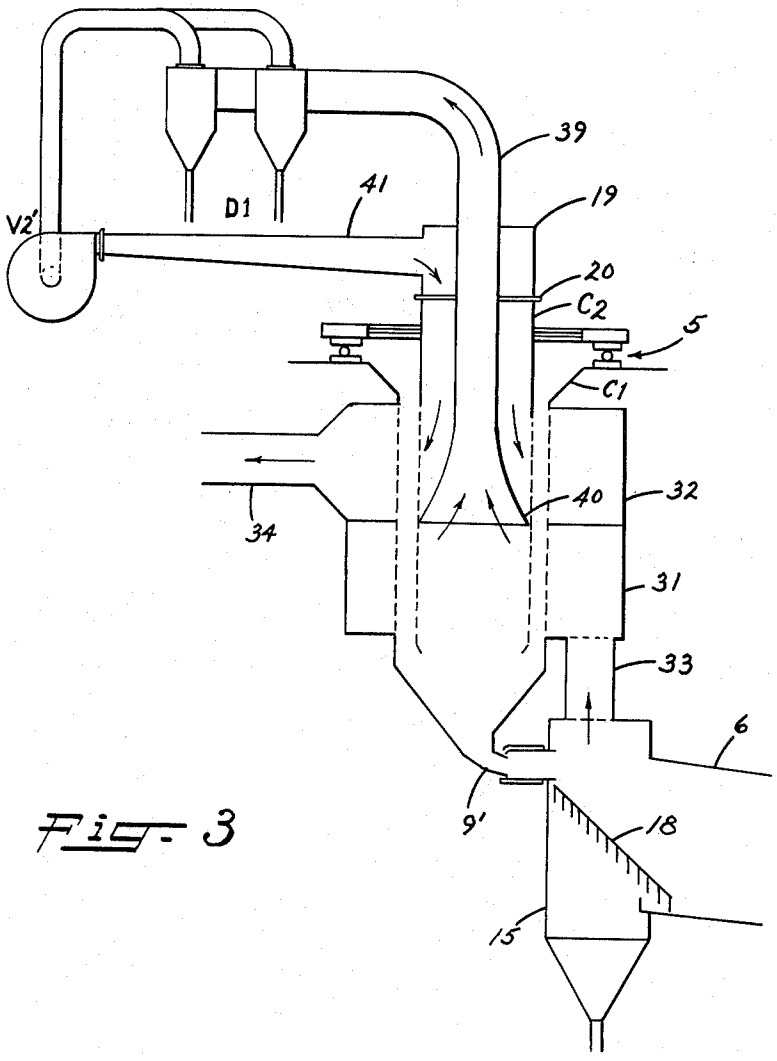


Fig. 3

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3,175,302

GRAVITY-TYPE HEAT EXCHANGER FOR TREATING PARTICULATE SOLID MATERIAL

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4 Claims. (Cl. 34—174)

This invention relates to apparatus for transferring thermal energy between materials in contact with each other, and more particularly to a heat exchanger in which thermal energy is transferred between a stream of a fluid, such as a gas, and particulate solid material.

The most effective known devices for transferring thermal energy between a particulate solid, such as a granular material, and a stream of fluid such as a gas, rely on grates on which the solid is moved in a layer in a substantially horizontal path through a heat exchange zone where the gas is passed vertically through the solid layer. Such heat exchangers offer better control and are capable of transferring more thermal energy within a given space than other known heat exchangers.

It is a disadvantage of the otherwise desirable heat exchangers of the described type that they use moving parts, such as grates and their supports. These are necessarily relatively fragile and have to be exposed to extremes of temperature gradients, and to high temperatures. It is difficult to feed a stream of gas to a moving grate in such a manner as to force the gas through the grate without a portion of the fluid by-passing the solid or the grate.

The primary object of this invention is the provision of a device for transferring thermal energy between a stream of fluid and a solid material which avoids the shortcomings of the grate-type heat exchanger while retaining its high thermal efficiency.

More specifically, it is an object of the invention to provide such a heat exchanger which may be entirely free of moving parts exposed to high temperature or to steep temperature gradients.

Another object is the provision of a heat exchanger which may be constructed of heavy and durable elements without impairing the performance characteristics of the exchanger.

A further object is the provision of a heat exchanger in which by-passing of the solid by the fluid from which or to which thermal energy is to be transferred is safely avoided.

Other objects and many of the attendant advantages of this invention will become readily apparent as the disclosure proceeds with reference to the attached drawing illustrating a preferred embodiment of the invention, and in which:

FIG. 1 shows a heat exchanger of the invention of approximately upright cylindrical shape in axial elevational section;

FIG. 2 illustrates the cooperation of the heat exchanger of FIG. 1 with other elements of a cement plant in an elevational, partly sectional view; and

FIG. 3 shows a modified version of the heat exchanger of FIG. 1 in a corresponding view on a smaller scale.

Referring now to the drawing, and initially to FIG. 1, there is seen a heat exchanger of the invention having two substantially cylindrical coaxial walls C_1 and C_2 which define an annular space 1 therebetween. This space constitutes a conduit extending from a feed opening 21 at the top, which is wider than the main portion of the conduit 1 because of the flaring shape of the corresponding top portion 22 of the outer wall C_1, to a central discharge opening 23 provided in a conical bottom portion 24 of the

outer wall C_1. The outer wall C_1 is fixedly mounted in a conventional manner on a supporting foundation structure not further illustrated.

The inner wall C_2 extends upwardly beyond the feed opening 21 and its bottom portion 25 is frustoconical. The smaller base 26 of the frustum is directed downward and is open. The inner wall C_2 is supported on a horizontal annular flange 27 which is coaxially fastened on the top portion 22 of the outer wall C_1. Arms 28 radially project from the top of the inner wall C_2 and are fixed to one race 3 of a trunnion ball bearing 5 the other race 4 of which is fastened on the flange 27. The inner wall C_2 is rotatable on the bearing 5 about the common axis of the walls. Rotation of the inner wall C_2 is actuated by tangential pressure exerted on the arms 28 in any desired manner. Double-acting hydraulic jacks (not illustrated) may cooperate with the arms 28 to impart to the wall C_2 slow reciprocating rotary movement.

The load bearing elements of the walls C_1 and C_2 are preferably constructed of sheet steel and are protected in the conduit 1 by a lining of refractory brick or the like, as the process temperature may require. Since such linings are well known, they have not been shown in the drawing.

Two axially spaced sections 2, 2′ of the outer wall C_1 are perforated, and radial passages are provided in a similar manner in two portions 7, 7′ of the wall C_2 aligned with the wall portions 2, 2′. Openings in the wall C_1 extending over the entire axial length of the wall portions 2, 2′ are partly obstructed by guide slats 29 of heat resisting material having a circularly arcuate cross section in a radial plane and a rectangular cross section in the axial plane of FIG. 1. The upper faces of the slats 29 which face the feed opening 21 are obliquely inclined downward and inward of the conduit 1. The corresponding wall portions 7, 7′ of the inner wall C_2 are provided with similar slats 30 also arranged in such a manner that their guide faces which face the feed opening 21 are obliquely inclined inward of the conduit 1 and downward.

The outer wall C_1 is encircled by two annular ducts 31 and 32 on the level of respective perforated wall portions 2, 2′. The ducts communicate with the passages between the slats 29. A gas feed conduit 33 is connected to the lower duct 31 and a gas discharge conduit 34 to the upper duct 32.

A disc granulator 11 is partly visible above the heat exchanger and discharges a granulated material 12 into a hopper 14 equipped with four chutes 8 equiangularly displaced about the axis of the heat exchanger and having discharge orifices vertically aligned with the feed opening 21 of the conduit 1 for uniformly distributing the granulated material 12 about the circumference of the conduit 1.

The treated granulated material is discharged from the bottom of the heat exchanger through a discharge chute 9 communicating with the central discharge opening 23. A feeder 10 is partially arranged in the chute 9 to control the discharge rate. The feeder illustrated consists of a cylinder mounted on a driven shaft 35 for rotation in such a manner that the portion of the cylinder in the chute 9 rotates in the direction of outward movement of the treated granular material.

The cylindrical axial cavity of the wall C_2 encloses a motor-driven centrifugal circulating fan V_1, the intake orifice of which is connected to the lower perforated portion 7 and the open bottom 26 of the inner wall C_2 by a conduit defined by the wall C_2 and a partition 36 of approximately conical shape. Two similar partitions 37, 38 connect the output orifices of the fan V_1 with the upper perforated portion 2′ of the wall C_2. The fan V_1 is supported on the wall C_2 by the partitions 36, 37, 38 and rotates with the inner wall about its axis.

The aforedescribed apparatus operates as follows:

Granulated material, such as the partly calcareous moisture-bearing raw material for a cement furnace, is fed from the granulator **11** at ambient temperature through the hopper **14** in preferably continuous flow into the conduit **1**, which in the normal operating condition of the heat exchanger is filled with the solid material, from the feed opening **21** to the discharge opening **23**. The material moves downwardly through the conduit **1** by gravity at a rate controlled by the speed of rotation of the feeder **10**. Arching within the moving mass is prevented by the slow reciprocating rotation of the inner wall C_2 which also tends to break up agglomerations of material.

The hot exhaust gases from a cement furnace the feed chute of which may be integral or identical with the discharge chute **9** are led into the heat exchanger through the gas feed conduit **33**. They pass through the heat exchanger in the manner indicated by arrows. The gases enter the duct **31**, then pass sequentially between the slats **29** in the perforated wall portion **2**, through the interstices in the granulated material **12**, and the passages between the slats **30** into the axial space defined within the wall C_2 and the partition **36**, through the circulating fan V_1, the annular conduit between the partitions **37**, **38**, the passages between the slats **30** in the upper perforated portion **7'** of the wall C_2, a layer of granulated material **12**, and the passages between the slat **29** in the upper perforated portion **2** of the wall C_1, into the upper annular duct **32** to be discharged from the heat exchanger through the gas discharge conduit **34**.

The solid material **12** vertically descending through the conduit **1'** thus is passed on two levels by horizontally flowing gas streams. At the upper level the granulated material is cold, and the furnace exhaust gases have been previously partially cooled by a first passage through the solids being heated. At the upper treating zone defined by the wall portions **2'**, **7'**, the raw material for the cement furnace is dried and preheated. When it contacts the fresh furnace gases on the lower level of the wall portions **2**, **7**, the preheated material is brought to the higher temperature at which it is charged into the furnace.

Entrainment of the solid material by the stream of gas is reduced by the shape and positioning of the slats **29**, **30**. The guide faces of the slats deflect the granular material toward the center of the conduit **1**, and the slats provide baffle surfaces in the passages defined between the slats which tend to precipitate entrained solids and to return them to the conduit **1**. The spacing and size of the slats **29**, **30** are suitably selected for best retention of the solid material.

Escape of the gas from the intended path is preferably prevented by the spacing of the perforated wall portions **2**, **2'**, **7**, **7'** from each other and from the openings **21**, **23**, and by suitable selection of the capacity of the fan V_1 and of an exhaust fan connected to the discharge conduit **34** in a manner that will become apparent from the subsequent description of FIG. 2. The flow resistance of the body of particulate material in the conduit **1** between the feed opening **21** and the level of the upper wall portions **2'**, **7'** is usually sufficient to prevent upward escape of gas if the feed opening **21** is spaced from the perforated wall portions by a distance which is about three times the uniform radial width of the central portion of the conduit **1**. The spacings between the upper pair of perforated wall portions **2'**, **7'** and the lower pair **2**, **7**, and the spacing of the lower pair of wall portions from the discharge opening **23** may be selected following similar considerations, but gas leakage there is less harmful.

Escape of furnace gas in an undesired direction is also prevented by the pressure levels established by the fan V_1 and the exhaust fan not seen in FIG. 1. The suction of the latter is selected or throttled in a known manner to avoid substantial inward leakage of air through the feed opening **21** into the conduit **1**.

The effective flow section of the perforated lower wall portions **2**, **7** is preferably made much larger than that of the upper wall portions **2'**, **7'**, as clearly seen in FIG. 1, in order to keep the gas velocity at the lower level at a relatively low value for maximum heat transfer between the gases and the granulated material, and to maintain relatively rapid gas flow through the drying and preheating zone for removal of water vapor.

The cooperation of the heat exchanger of the invention illustrated in FIG. 1 with known elements of a Portland cement plant is illustrated in FIG. 2. The discharge chute **9** of the heat exchanger is the feed chute of the conventional rotary cement furnace **6** of which only the feed end is seen in FIG. 2. The furnace is equipped with a separator **15** which communicates with the gas feed conduit **33** through an orifice **13** of the latter.

The gas discharge conduit **34** of the heat exchanger leads to a battery D_1 of three cyclone separators from which the gas is exhausted by an exhaust fan V_2, further cleaned of entrained solids in a cyclone separator D_2 and finally released to the atmosphere through a stack **16**.

The fines collected in the cyclone separators D_1 and D_2 are returned to the granulator **11** by a system of conveying pipes **17**, not shown in detail, which may include devices for lifting the fines to higher levels, such as spiral conveyors, as is conventional.

The apparatus illustrated in FIG. 2 combines a primary raw material supplied in a known manner to the granulator **11** from a source not further illustrated with fines removed from the exhaust gases, granulates the raw feed, brings it to a temperature close to the temperature of the cement furnace by heat exchange with the furnace gases, and then delivers it to the furnace. The furnace gases are cooled by double passage through layers of raw material, separated from entrained fines of the raw material and are released to the atmosphere after having been stripped of their valuable thermal energy.

A modified heat exchanger of the invention is illustrated in FIG. 3. The inner and outer walls C_1 and C_2 of the modified heat exchanger are substantially identical with the corresponding elements of the heat exchanger illustrated in FIG. 1. The outer wall C_1 supports the inner wall C_2 by means of a trunnion ball bearing **5** in the afore-described manner and is encircled by two ducts **31**, **32**. The hot exhaust gases are fed to the lower annular duct **31** by a conduit **33**, and the cooled gases are withdrawn from the duct **32** through a conduit **34** to be further treated by devices similar to those shown in FIG. 2 for the same purpose.

The heated granular raw material for the furnace **6** is transferred from the heat exchanger to the furnace **6** through a chute **9'** which differs from the chute **9** shown in FIG. 1 by terminating at a point above screen **18** in the separator **15** by means of which fines are removed from the heated material later to be returned to the granulator which has been omitted from the showing of FIG. 3 for the sake of clarity. It will be understood though that granulated raw material is fed cold and moist to the top of the heat exchanger in the same manner as described hereinabove.

The inner wall C_2 is fitted with a stationary cap **19** which covers the top of the axial cavity in the wall C_2, and is connected to the top edge of the wall C_2 by a mechanical seal which permits the afore-described rotation of the wall C_2 by means of hydraulic jacks or otherwise without escape of gas.

A funnel shaped duct **39** connects the lower portion of the axial cavity in the wall C_2 with a battery D_1 of cyclone separators. The duct **39** is fixedly fastened to the cap **19** through which it passes axially in sealing engagement, and is provided with a packing **40** which engages the inner surface of the wall C_2 in a substantially gas tight manner. The cyclone separators D_1 are

connected to a circulating fan V_2' the discharge port of which communicates with the interior of the cap **19** through a pipe **41**.

The apparatus illustrated in FIG. 3 functions substantially in the same manner as the heat exchanger shown in FIG. 1. Hot exhaust gases are drawn from the cement furnace **6**, are passed twice horizontally through layers of descending granulated feed material whereby they give up most of their thermal energy to the solid material. To provide the pressure gradients necessary for the passage of the gas through the interstices in the granulated solids, the gas is drawn from the inner wall C_2 after a first passage into the conduit **39** as indicated by arrows, and forced through the colder layer of solid material at a higher level of the walls C_1, C_2 by the exhaust pressure of the fan V_2'.

The embodiment of the invention illustrated in FIG. 3 has the advantage of a fan location remote from the heat exchanger. The apparatus of FIG. 1 has a fan located in the axis of the apparatus, where it is readily accessible from above, but may require more external cooling in a manner well known in itself than is necessary with the remotely located fan V_2'.

It is an outstanding advantage of the apparatus of FIG. 1 that it entirely obviates the need for gas-tight seals between moving parts except for the conventional packings in the fan V_1. Escape of gas is otherwise prevented entirely by the flow resistance of layers of the material being heated, by pressure differentials in the gases being cooled, or by both.

In the specific embodiment illustrated for the purposes of the disclosure, two passes of hot gas through a colder solid material have been described since such an arrangement has been found to give excellent results in the preheating of raw material for a cement furnace. It will be appreciated, however, that the invention is not limited to any specific number of passes of the gases through the solids. A single pass may be sufficient for many purposes, and the number of passes may be increased by duplicating elements of the structure described if such multiple passes are required for the process to which the apparatus is to be adapted.

The sequence of the several transverse passes of a gas through a solid descending vertically by gravity may be reversed, if so desired, although the countercurrent flow arrangement illustrated will most frequently be employed. The apparatus not only permits heating of a solid by a gas but will serve for cooling the solid and for heating the gas without any structural changes.

It is evident that liquids may replace the furnace gases mentioned in the exemplary embodiments of the invention without changing the basic mode of operation of the apparatus. The particle size of the solid material whose thermal energy is interchanged with that of a fluid in the heat exchanger of the invention may influence dimensional factors and the thermal efficiency of the apparatus but fluid-pervious very fine powders or coarse lumps may be heated or cooled by passage through the heat exchange zone or zones of the device transversely to the direction of movement of a fluid and the term "particulate" material is being employed to cover the wide range of particle sizes between coarse lumps and fine powders.

The interaction of the solid and fluid materials need not be limited to the predominantly physical effects described hereinabove. Decomposition of calcium carbonate has been found to occur in the heating zone of an exchanger employed in conjunction with a cement furnace, and binary reactions in which both the fluid and the solid participate may be performed to advantage in one zone of a heat exchanger of the type specifically described whereas heat exchange between a solid reactant and a gaseous reaction product takes place in the other zone. Many other applications of the apparatus of the invention will readily suggest themselves to those skilled in the art. The term "apparatus for transferring thermal energy," as employed in the appended claims, will therefore be understood to refer to a field of application in which the apparatus disclosed and claimed has particular utility but not to limit the scope of the claims to the use of the apparatus for such purposes.

It will thus be appreciated that the foregoing disclosure relates to only preferred embodiments of the invention and that it is intended to cover all changes and modifications of the examples of the invention herein chosen for the purpose of the disclosure which do not constitute departures from the spirit and scope of the invention set forth in the appended claims.

What we claim is:

1. In an apparatus for transferring thermal energy between a fluid and a solid material, in combination:

(*a*) a first wall of substantially circular cross section about a vertical axis;

(*b*) a second wall of substantially circular cross section about said axis, said walls defining therebetween an annular vertically extending conduit having a feed opening and a discharge opening downwardly spaced from said feed opening, said walls each having a plurality of substantially imperforate axially spaced portions and a plurality of perforated axially spaced portions, corresponding ones of the perforated portions of said walls being axially coextensive to constitute a pair of perforated portions, and respective ones of said imperforate portions being interposed in each wall between said feed opening and an upper one of said perforated portions, between said upper perforated portion and a lower perforated portion, and between said lower perforated portion and said discharge opening;

(*c*) bearing means connecting the axially terminal top portions of said walls for supporting one of said walls on the other wall for rotation about said axis;

(*d*) means for feeding a particulate solid material to said feed opening;

(*e*) means for supplying a stream of fluid to one member of one of said pairs of perforated wall portions for sequential passage of said fluid through said one member, said conduit and the other member of said one pair of members;

(*f*) fan means for withdrawing said fluid in a stream from the other member of said one pair and for supplying the withdrawn stream to one member of another pair of said perforated wall portions for sequential passage of said withdrawn fluid through said one member of said other pair, through said conduit, and through the other member of said other pair; and

(*g*) means for actuating relative rotation of said walls on said bearing means about said axis.

2. In an apparatus as set forth in claim 1, said first wall being stationary and said second wall being supported on said first wall by said bearing means for movement about said axis.

3. In an apparatus as set forth in claim 2, said fan means being supported on said inner wall.

4. In an apparatus for transferring thermal energy between a fluid and a solid material, in combination:

(*a*) a first wall of substantially circular cross section about a vertical axis;

(*b*) a second wall of substantially circular cross section about said axis, said walls defining therebetween a vertically extending conduit having a feed opening and a discharge opening downwardly spaced from said feed opening, said walls having respective radially aligned perforated axial portions intermediate said openings;

(*c*) bearing means connecting the axially terminal top portions of said walls for rotatably supporting one of said walls on the other wall;

(*d*) means for feeding a particulate solid material to said feed opening;

(*e*) means for supplying a stream of fluid to one of said perforated portions for sequential passage of said fluid through said one perforated portion, said conduit, and the other perforated portion; and

(*f*) means for actuating rotation of said one wall relative to said other wall on said bearing means about said axis.

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