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3,206,865

METHOD AND APPARATUS FOR HEAT EXCHANGE IN A FLUIDIZED BED

Filed Nov. 2, 1960

3 Sheets-Sheet 1

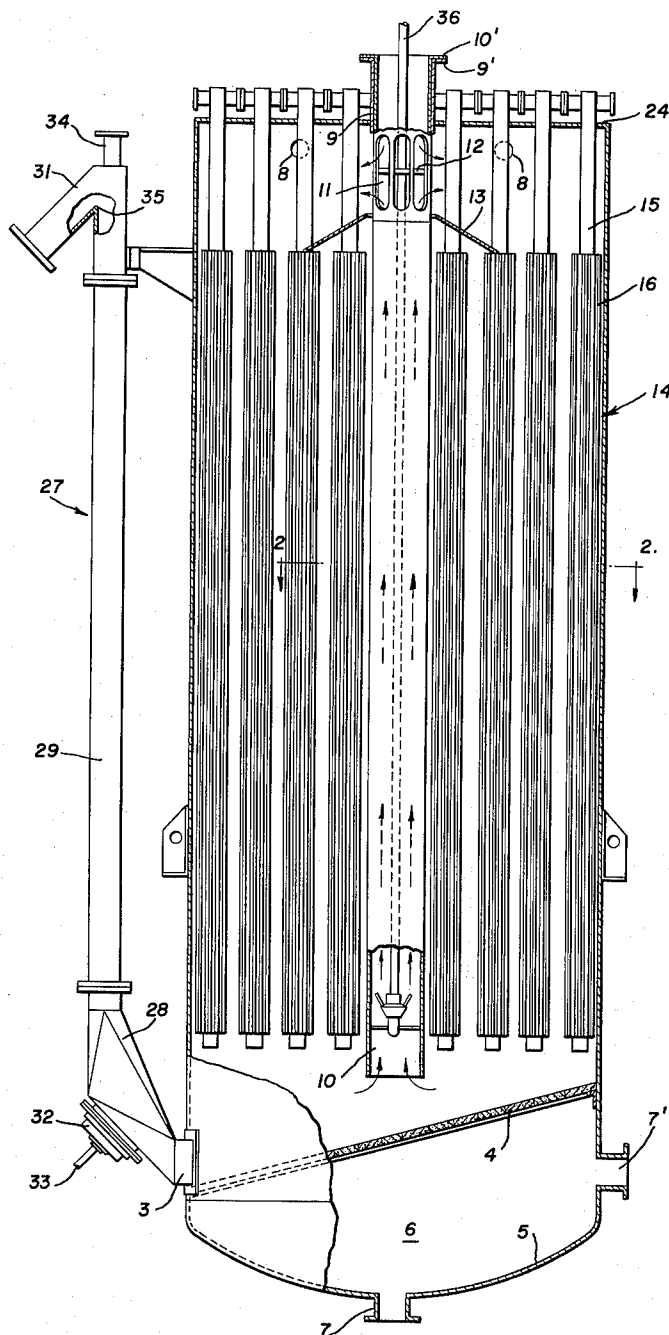


FIG. 1

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FIG. 3

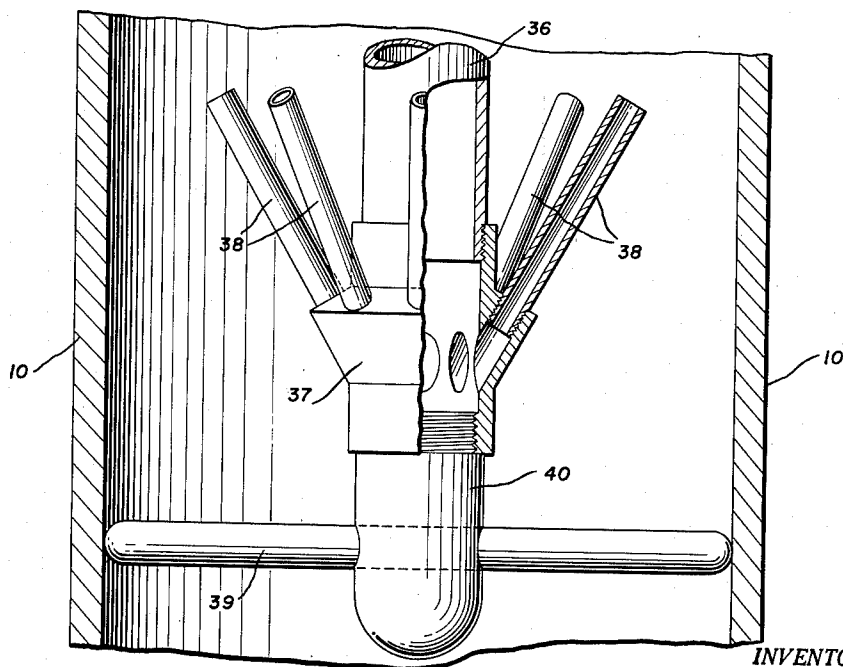
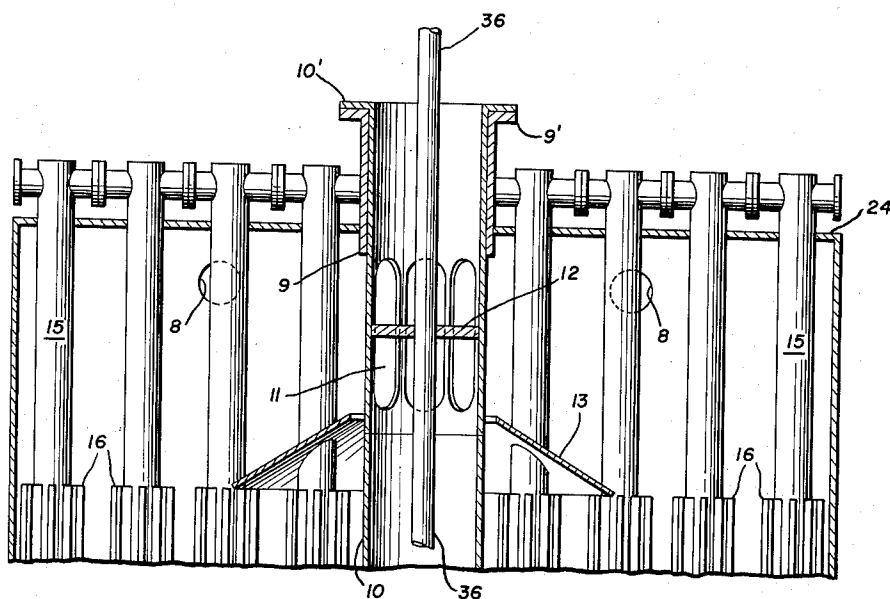


FIG. 4

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3 Sheets-Sheet 3

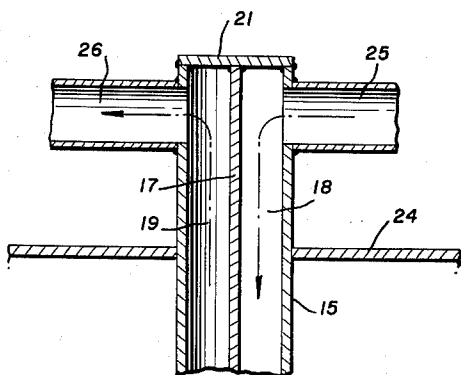


FIG. 5

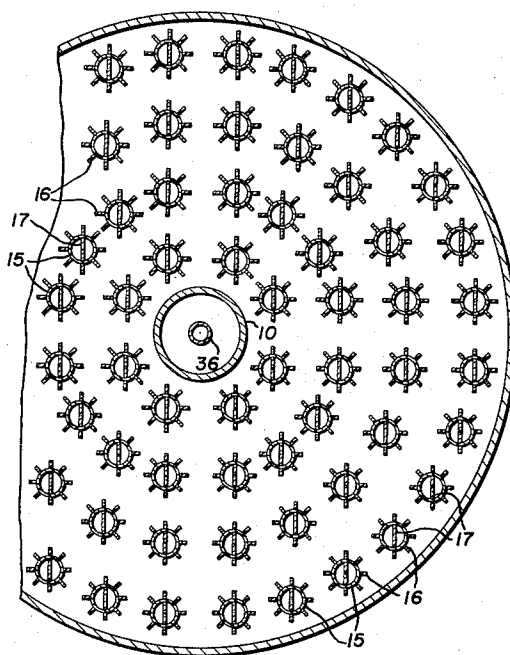


FIG. 2

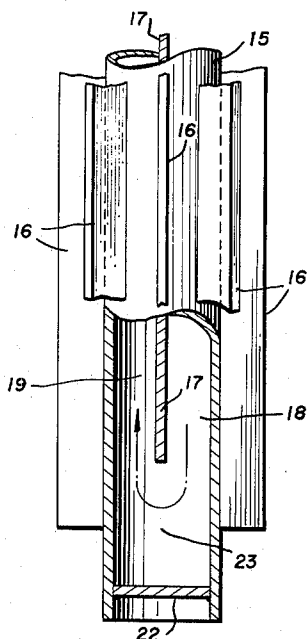


FIG. 6

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METHOD AND APPARATUS FOR HEAT EXCHANGE IN A FLUIDIZED BED

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10 Claims. (Cl. 34-10)

The present invention relates to heat exchange with materials, and particularly pulverulent or granular materials in fluidized beds. It is primarily concerned with the control of the flow of the material during the heat-exchange operation to provide a more effective and efficient transfer of heat between the material and the heat-exchange medium.

In my co-pending application Serial No. 41,967, filed July 11, 1960, I have disclosed a method and apparatus for the exchange of heat with pulverulent or granular materials in a vertically-elongated, preferably upright casing having therein a plurality of heat-transfer members including extensive heat-transfer surfaces, such as fins. The heat-transfer members occupy a large portion of the cross-sectional area of the casing and extend substantially longitudinally between the inlet and the outlet of the casing. Means are provided for maintaining a relatively high velocity of the material along the heat-transfer surfaces to prevent coating or build-up of material thereon.

Under certain circumstances, it is difficult to provide an adequate volumetric rate of flow of the material through a heat-exchange casing of convenient size while still obtaining the desired heat exchange. An illustration of such circumstance is that of the finished cooling of ground hydraulic cement. When the cooler for such material is not a closed circuit, so that a substantial flow of material is possible, a cooler casing of convenient vertical and horizontal dimensions may be employed. However, the considerably smaller volume of ultimate or finished product, if cooled in a casing of this type, would not provide sufficient material velocity along the heat-transfer surfaces to prevent coating or build-up of the material thereon. A very narrow casing of extreme height would be required.

In general, the preferred form of apparatus of the present invention comprises an elongated, preferably upright casing having means for maintaining the material therein in a fluidized state. The material inlet and the material outlet of the casing are spaced from each other a substantial distance. Between the inlet and the outlet, and in the space occupied by the fluidized material, the casing is provided with a plurality of heat-transfer members having extensive heat-transfer surfaces, such as fins. The heat-transfer members occupy a large portion of the volume and cross-sectional area of the casing.

More particularly, the casing is provided with means for re-circulating the material therein. In this manner, it is possible to increase the volume and velocity of material moving past the heat-transfer members to a value far greater than the rate of feed and discharge of the material to and from the casing. Preferably, the material is recycled from a region adjacent the outlet to a region adjacent the inlet of the casing so that the recycled material, which has been partially cooled, is thoroughly mixed with the incoming material to effect an initial cooling thereof, and to aid in the distribution of such incoming material about the interior of the casing.

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The invention will be further described in connection with the accompanying drawings and description which illustrate a preferred form of apparatus.

In the drawings:

FIG. 1 is a vertical sectional view of a fluidized cooler embodying the preferred form of apparatus;

FIG. 2 is a horizontal sectional view, on an enlarged scale, of a portion of the cooler, said view being taken along lines 2-2 of FIG. 1;

FIG. 3 is a vertical sectional view, on an enlarged scale, of the upper portion of FIG. 1;

FIG. 4 is a vertical sectional view, on an enlarged scale, of the lower end of the gas lift pipe for causing re-circulation of the material in the casing;

FIG. 5 is a vertical cross-sectional view, on an enlarged scale, through the upper end of one of the heat-transfer members and the top wall of the cooler casing; and

FIG. 6 is a vertical cross-sectional view, on an enlarged scale, through the lower end of one of the heat-transfer members.

The invention will be particularly described with respect to a fluidized cooler for pulverulent or granular material, such as cement.

Referring to FIG. 1, the cooler comprises an elongated vessel or casing 1, which may be of any suitable cross-sectional shape, and which is shown here in the preferred form of a vertically-extending cylinder. The casing 1 has a material inlet 2 at its upper end and a material outlet 3 in its lower region. A gas-permeable deck 4 forms a floor of the casing and slopes downwardly toward the outlet 3. The gas-permeable deck preferably is formed of filter stones or similar heat-resisting material, or if temperature permits, may comprise a tightly woven fabric. The permeability of the deck preferably is as uniform as possible throughout its full area. The deck is spaced from the bottom wall 5 of the casing to provide a plenum chamber 6 therebetween. An air or gas inlet pipe 7 is provided in the bottom wall 5 for introducing fluidized air or gas under pressure into the plenum chamber 6 to pass upwardly through the gas-permeable deck 4 to fluidize overlying material. When desired, an alternate gas inlet 7' may be formed in the side wall of the casing beneath the gas-permeable deck 4.

Air separating from the upper surface of the material fluidized in the casing 1 and collecting in the upper portion of the casing is discharged to atmosphere through vent openings 8 in the upper portion of the side walls of the casing.

The material inlet 2 is in approximately the center of the top of the casing. A nipple 9 extends downwardly and axially into the interior of the casing for a short distance from the inlet 2. A pipe 10 is centrally disposed in the casing and extends from a position adjacent but slightly above the gas-permeable deck upwardly to the top of the vessel. Its upper end is received within and supported by a nipple 9. The upper end of the pipe 10 may be welded or otherwise secured to the nipple, but preferably has an outwardly-extending flange 10' at its upper end which rests upon and is supported by a corresponding outwardly-extending flange 9' of the nipple 9. The inlet opening 2 of the casing is through the top of the pipe 10. The lower end of the pipe is open for reasons which will subsequently appear.

The upper portion of the pipe 10, just below the nipple 9, has a plurality of longitudinally-extending slots 11 cir-

cumferentially spaced from one another about the full periphery thereof.

The interior of the pipe 10 is divided by a transverse partition or deflector plate 12 located at approximately the longitudinal midpoint of the slots 11.

Positioned about the pipe 10 and just below the lower ends of the slots 11 is a frusto-conical distributor plate 13. Hot material fed to the upper end of the pipe 10 through the inlet 2 falls downwardly through the upper end of pipe 10 upon the deflector plate 12 and is deflected by it through the upper ends of the slots 11 from which it falls downwardly onto the distributor plate 13. The incoming material flows downwardly along the upper surface of the distributor plate and is spread by it and formed into an annular, downwardly-flowing stream.

A plurality of longitudinally-extending heat-transfer members 14 are positioned in the casing 1 in a substantially symmetrical arrangement, preferably in concentric arrangement with respect to pipe 10 and with respect to the cross-sectional area of the casing, as shown in FIG. 2. The heat-transfer members are in such number as to provide a relatively small cross-sectional open area between the respective heat-transfer members and between the heat-transfer members and the casing for flow of material through the casing from the inlet 2 to the outlet 3. The heat-transfer members 14 each comprise a single pipe 15 having spaced, longitudinally and radially-extending heat-conducting fins 16 on its outer surface. A transverse diametrical partition 17 divides the interior of the pipe 15 into a pair of channels 18 and 19 and extends from the top end wall or cap 21 of the pipe to a point spaced from the lower end wall 22 thereof to form a gap 23 therebetween for the flow of heat-transfer medium from one channel to the other. The upper ends of the pipes extend through the top wall 24 of the casing. The pipes extend for substantially the full length of the casing but terminate in a horizontal plane slightly above the gas-permeable deck 4. The lower ends of the transfer members may be secured in proper spaced position with respect to one another by any suitable means, such as by the use of suitable braces.

The upper portion of each pipe which protrudes above the top wall 24 of the casing is connected to an inlet pipe 25 for a heat transfer medium communicating with channel 18 and an outlet pipe 26 communicating with channel 19. The heat-transfer members 14 may be operated in parallel or may be connected to operate in series arrangement, as by connecting the outlet pipe 26 of one heat-transfer member with the inlet pipe of another such member.

The material outlet 3 communicates with the lower end of a discharge conduit 27. This conduit includes a lower leg 28 extending upwardly and outwardly from the outlet 3 and a leg 29 which is connected to and extends vertically upwardly from the upper portion of the lower leg 28. The vertically-extending leg 29 discharges at its upper end into an overflow leg 31. The leg 29 and the overflow leg 31 may be separate conduits or may be formed within a single conduit as shown in my foresaid co-pending application.

The lower wall of the lower leg 28 is provided with an aerator 32 at a position to underlie the vertical leg 29 to deliver aerating air upwardly therethrough. This aeration comprises a gas-permeable wall forming a portion of the bottom of the lower wall of the lower leg 28 and an underlying plenum chamber into which a gas is introduced through the pipe 33 to flow upwardly through the gas-permeable wall and into the overlying pulverulent material in the vertical leg 29 to fluidize it and to cause it to rise in the leg 29 to be discharged through the overflow leg 31.

The level of the overflow edge 35 from the vertical leg 29 into the overflow leg 31 will determine the level of the material in the vessel, but due to wall friction of the material in the vertical leg 29, the level of the

material in the vessel may be somewhat above the level of the overflow edge 35. Preferably, means, such as those disclosed in my foresaid co-pending application, are provided for raising or lowering the overflow edge 35.

An air supply pipe 36 extends downwardly through the central pipe 10 to a position slightly above the lower end thereof. The air supply pipe 36 terminates in a fitting 37 having a plurality of upwardly and outwardly extending, circumferentially-spaced pipes or nozzles 38. The fitting 37 is maintained in a central location within the lower end of the pipe 10 by a plurality of laterally-spaced legs 39 engaging the inner wall of the pipe 10. These spacer legs protrude horizontally outwardly from a plug 40 which closes the lower end of the fitting 37.

In operation, hot pulverulent finished cement is introduced into the cooler through the inlet 2 until the temperature of the material in the cooler is above the dew point of the air or other gas which is to be used to fluidize the pulverulent material in the casing 1, in order to avoid condensation of moisture on the surface of the heat-transfer members. When this heated condition is reached, a cooling medium, preferably water, is introduced into the heat-transfer members 14 through the respective inlet pipes 25. The cooling medium flows downwardly through the channels 18 to the bottom of the pipes 25 and then reverses its direction of flow, passing through the space 23 and upwardly through the channels 19 to the outlet pipe 26.

The hot finished cement introduced to the cooler through the inlet 2 falls downwardly through the upper end of pipe 10 until it hits the deflector plate 12. The deflector plate deflects the material laterally through the upper portion of the slots 11. Simultaneously, air is supplied to the plenum chamber 6 beneath the gas-permeable deck 4, and through the air supply pipe 36 to the fitting 37 and nozzle pipes 38. The material in the casing is thus fluidized by the air passing through the gas-permeable deck 4. A portion of the material fluidized in the casing passes into the lower end of the pipe 10 and is elevated therein by the action of the jets of air rising from the nozzle pipe 38. The material in the pipe 10 continues upwardly until it engages the lower face of the partition or deflector plate 12 which diverts it laterally and causes it to pass through the lower ends of the slots 11. Upon emerging from the lower portions of the slots 11, the recirculated material impinges against the incoming hot material discharged from the upper end of the pipe 10 through the upper ends of the slots 11. The recirculated material is mixed with the incoming hot material by the agitating action of the elevating air, which is discharged from the pipe 10 along with the recirculated material through the lower ends of slots 11. The mixed materials flow onto the frusto-conical distributor plate 13 and are evenly distributed by it laterally onto the material load in the casing.

The initial cooling, or the first shock of cooling, is imparted to the hot incoming material by previously cooled material recirculated upwardly through the pipe 10, rather than by contact with the cooled heat-exchanger surfaces. Therefore, there is little or no chance of the initial thermal shock which would tend to cause adherence of the incoming hot material to the heat-transfer surfaces. The recycled material and the tempered incoming material mixed therewith then descend through the casing around and in contact with the heat-transfer surfaces at a velocity sufficient to cause both repeated contact of various particles of the material with the cooled surfaces of the heat-transfer members and to prevent dead spots of aerated material in any locality adjacent the heat-transfer members. With the surfaces of the heat-transfer members thus maintained in a relatively clean condition, and with repeated, agitated contact of the material with the surfaces, an efficient heat transfer is possible.

The amount of material fed to the cooler casing through the inlet 2 is so correlated with the amount of

cooled material which is caused to flow upwardly through the discharge conduit 27 to the overflow leg 31 for discharge from the cooler as to maintain a predetermined level of the material in the casing. Because of the friction of the material passing upwardly through the vertical leg 29 with the walls thereof, this level will be slightly above the level of the overflow edge 35.

The actual velocity of the total material moving through the cross-section of the casing preferably is in the order of three feet per minute. However, because of constant recirculation of a portion of the cooled material upwardly through the pipe 10 to mix with the incoming hot material, the velocity of the material passing over the heat-transfer members will be substantially greater. The recirculation of the cooled material in the cooler casing permits a very accurate adjustment of the velocity of the material passing over the surfaces of the heat-transfer members.

While the invention has been particularly described with respect to an apparatus for cooling hot finished cement product, it is to be understood that it may be used in coolers of other types and also may be used in apparatus for heating pulverulent or granular material.

Various changes may be made in the particular form of the cooler described herein and in the method of operating it without sacrificing any of the advantages thereof or departing from the scope of the claims appended hereto.

I claim:

1. Heat-exchange apparatus comprising a vessel having an inlet in its upper region for the introduction of material to be treated and an outlet for the discharge of the treated material, spaced heat-exchange members in said vessel in the path of flow of the material from said inlet to said outlet, means for maintaining substantially the entire body of material in said vessel in a fluidized state, a conduit extending in a generally vertical direction in said vessel, means whereby material fluidized in said vessel may enter into a lower portion of said conduit, means for recycling fluidized material entering said conduit upwardly therethrough, said material inlet communicating with the upper portion of said conduit, a partition extending transversely across said conduit, said conduit having openings therein above said partition for the flow of incoming material into the space in said vessel in which the heat-exchange members are located and having openings therein below said partition for the flow of material recycled upwardly through said conduit into said space within said vessel whereby material recycled upwardly through said conduit is mixed with said incoming material substantially immediately after it enters said space.

2. Heat-exchange apparatus as set forth in claim 1, in which the openings in said conduit for the flow of incoming material and recycled material communicate with one another, and said partition is located in said conduit in a plane intermediate the upper and lower ends of said openings.

3. Heat-exchange apparatus as set forth in claim 2, in which said openings are circumferentially spaced slots extending longitudinally of the conduit, and the partition is positioned at the longitudinal midsection of said slots.

4. Heat-exchange apparatus as set forth in claim 3, which includes a frusto-conical distributor plate surrounding said conduit and having its upper edge positioned at a level below the bottom of the slots.

5. Heat-exchange apparatus comprising a vessel having an inlet in its upper region for the introduction of material to be treated and an outlet for the discharge of the treated material, spaced heat-exchange members in said vessel in the path of flow of the material from said inlet to said outlet, means for maintaining substantially the entire body of material in said vessel in a fluidized state, a conduit extending in a generally vertical direction in said vessel, means whereby material fluidized in said vessel may enter into a lower portion of said conduit, means

for recycling fluidized material entering said conduit upwardly therethrough, said conduit having a recycle outlet in an upper portion thereof for the discharge of such recycled incoming material, the last-named outlet being located to discharge such recycled material into the space within said vessel which receives the material entering through said inlet, said recycle outlet being arranged to discharge recycled material into the incoming material whereby material recycled upwardly through said conduit is mixed with said incoming material substantially immediately after it enters said space and a distributor plate extending downwardly and outwardly from a position adjacent said conduit and from a level below the bottom outlet in said conduit through which material recycled upwardly is discharged.

6. Heat-exchange apparatus comprising a vessel having an inlet for the introduction of material to be treated and an outlet for the discharge of treated material, spaced heat-exchange members in said vessel in the path of flow of material from said inlet to said outlet, a conduit extending in a generally vertical direction in said vessel, means whereby material in said vessel may enter into a lower portion of said conduit, means for recycling material entering said conduit upwardly therethrough, said material inlet communicating with the upper portion of said conduit, a partition extending transversely across said conduit and said conduit having openings therein above said partition for the flow of incoming material from the upper portion of said conduit into the space in said vessel and having other openings therein below said partition for the flow of material recycled upwardly therethrough from said conduit into the space in said vessel in which the heat-exchange members are located at a point adjacent to which incoming material fed to said vessel enters such space, whereby the material recycled upwardly through said conduit is mixed with said incoming material substantially immediately after it enters said space.

7. Heat-exchange apparatus as set forth in claim 6, in which the openings in said conduit for the flow of incoming material and recycled material are circumferentially spaced slots extending longitudinally of the conduit, and the partition is located in said conduit in a plane intermediate the upper and lower ends of said slots.

8. Heat-exchange apparatus comprising a vessel having a plurality of spaced heat-exchange members, an inlet centrally disposed and located in the upper region of the vessel above said heat-exchange members, an outlet for the discharge of said material located below the lower extremities of the heat-exchange members, means for maintaining substantially the entire body of incoming material in the vessel in a fluidized zone below said inlet, a conduit extending in a generally vertical direction in said vessel, means whereby the incoming material fluidized in said vessel may enter a lower portion of said conduit, means for recycling upwardly said fluidized material entering said conduit, said conduit having a recycle outlet immediately adjacent said inlet for discharging such recycled material into contact with the incoming material above said fluidized zone.

9. In a method of effecting heat transfer between a material and a heat-exchange medium in a confined zone in which the material is introduced to said zone; is maintained in a fluidized bed within said zone; is brought into heat-exchange relation with a heat-exchange medium therein and is thereafter discharged from said zone, the improvement comprising the steps of introducing the incoming material downwardly into said zone, removing a portion of said fluidized material, which has been subjected to heat-exchange from the zone, recycling said removed portion of material upwardly into direct contact with the downward flowing, incoming material and passing the mixture of recycled material and incoming material into said zone.

10. In the method of claim 9, the further improvement

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in which the recycled material contacts, as a continuous stream, a stream of incoming material.

References Cited by the Examiner

UNITED STATES PATENTS

83,255	10/68	Chichester	34—57
2,493,911	1/50	Brandt	34—102
2,550,722	5/51	Rollman.	
2,571,380	10/51	Penick	34—10

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8

2,585,984	2/52	Alexander et al.	
2,607,666	8/52	Martin	34—57
2,767,128	10/56	Burtis	23—288.3
2,901,421	8/59	Bourguet et al.	23—288.3
3,026,626	3/62	Smith	34—57

10