

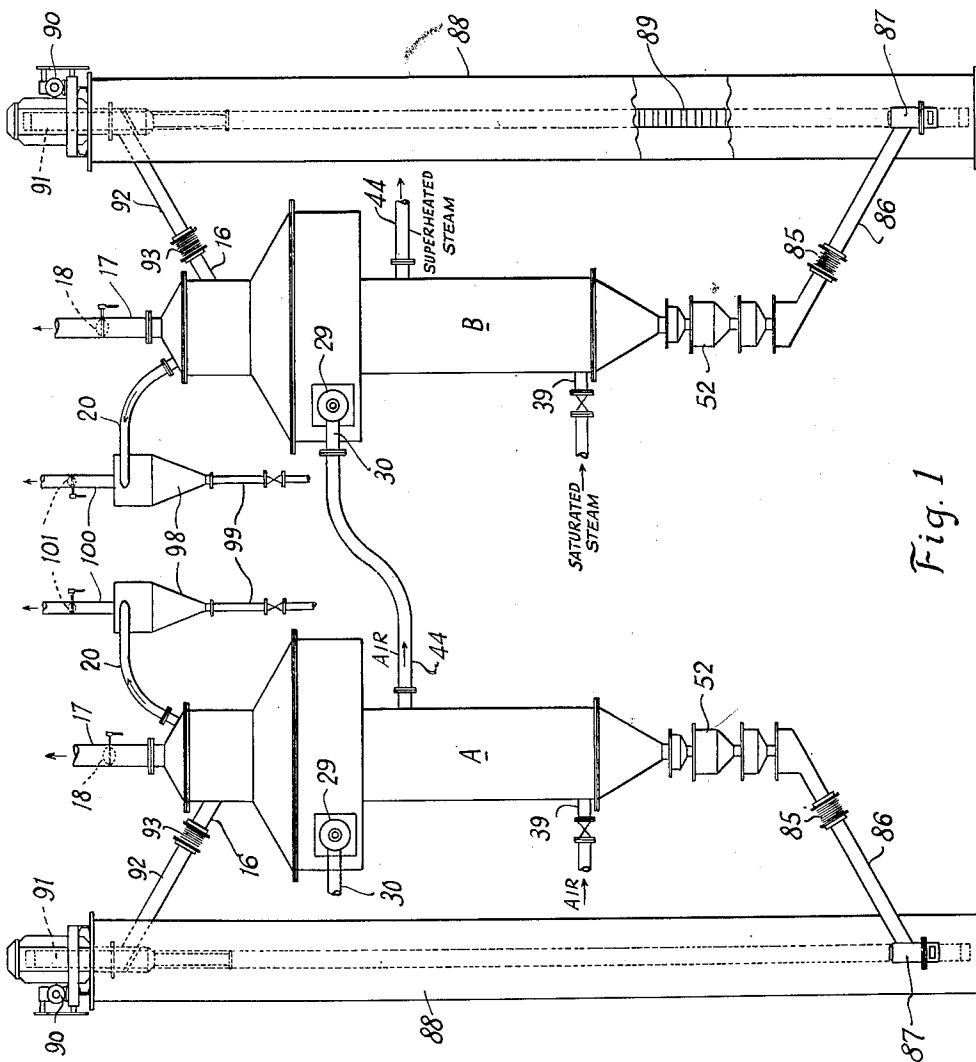
Aug. 29, 1950

C. L. NORTON, JR
FLUID HEATING

2,520,164

Filed July 4, 1944

4 Sheets-Sheet 1



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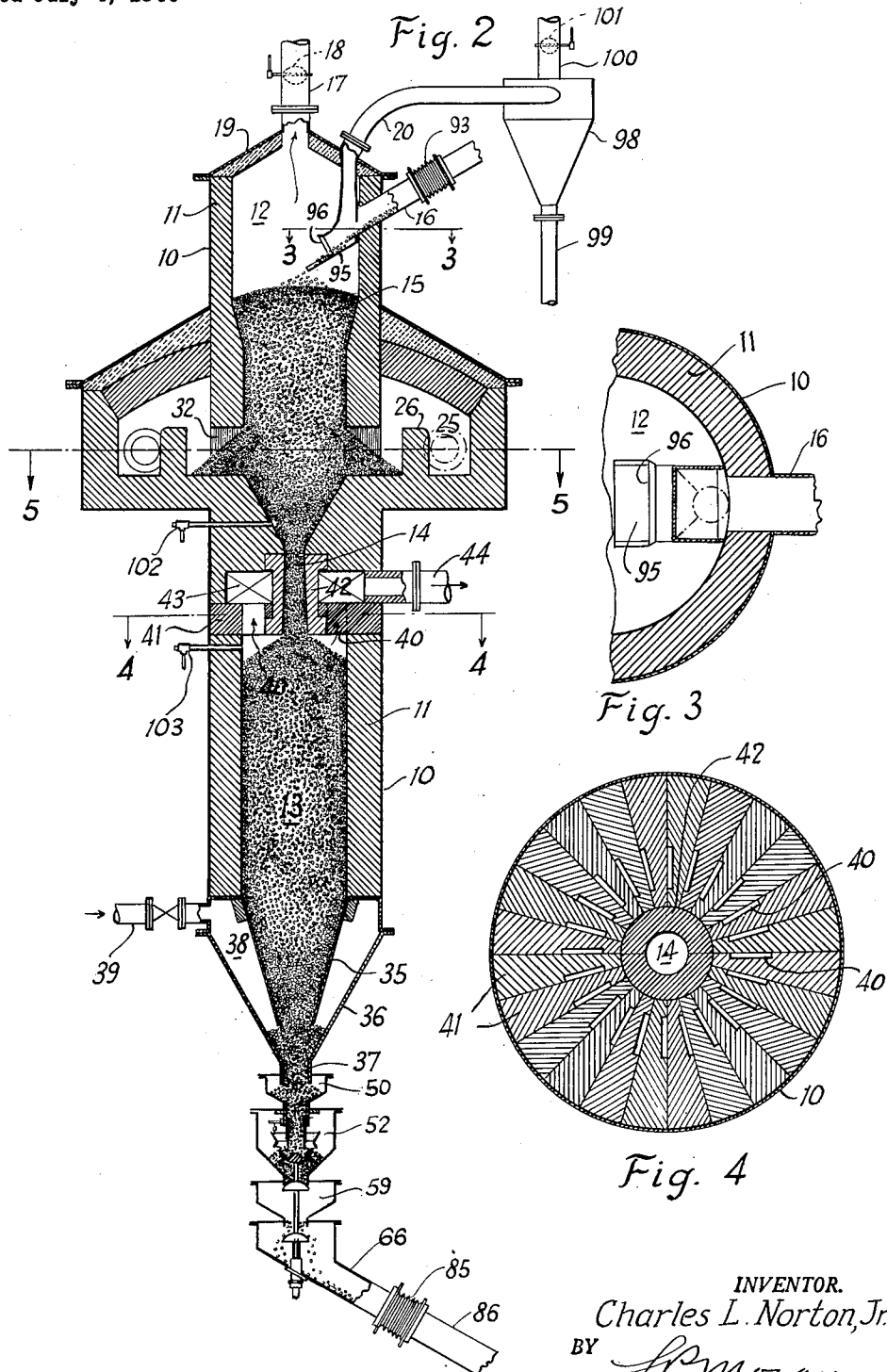
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4 Sheets-Sheet 2



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FLUID HEATING

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4 Sheets-Sheet 3

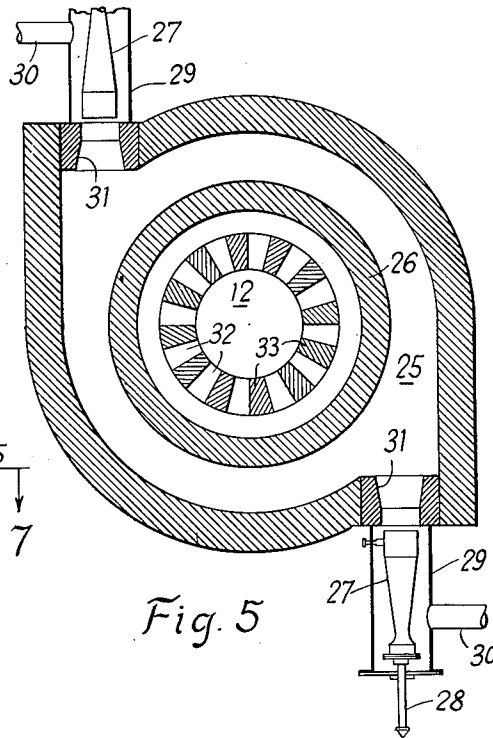
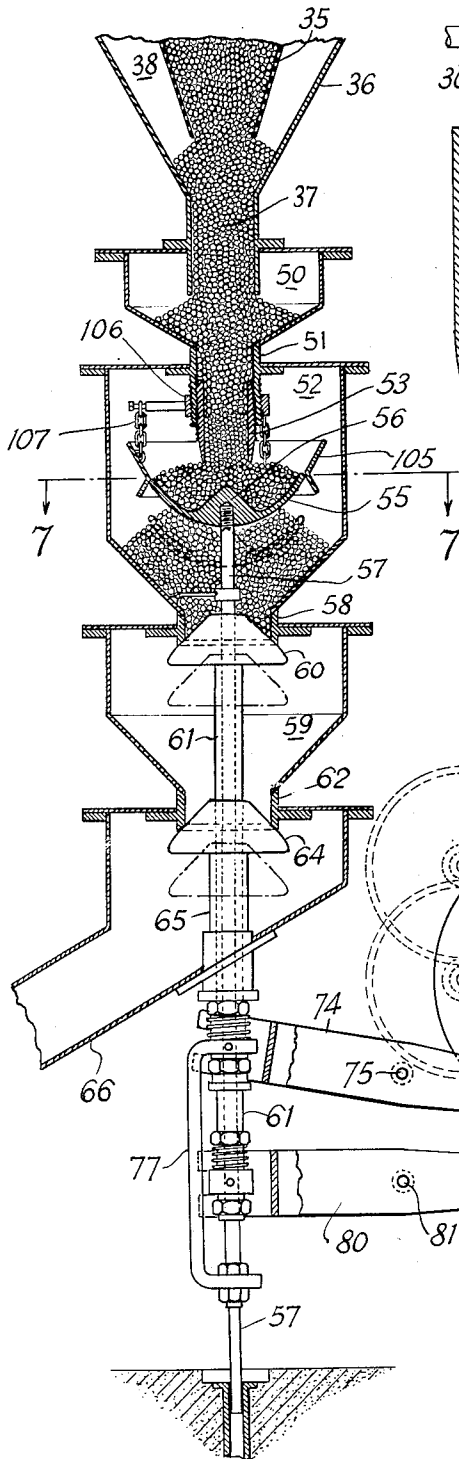


Fig. 5

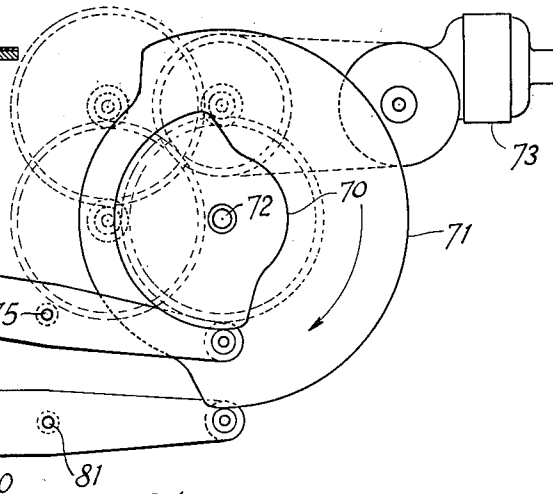


Fig. 6

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4 Sheets-Sheet 4

Fig. 7

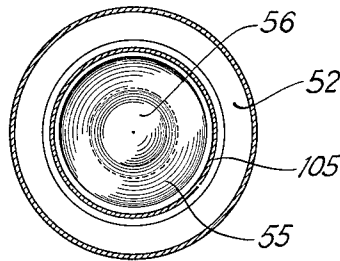
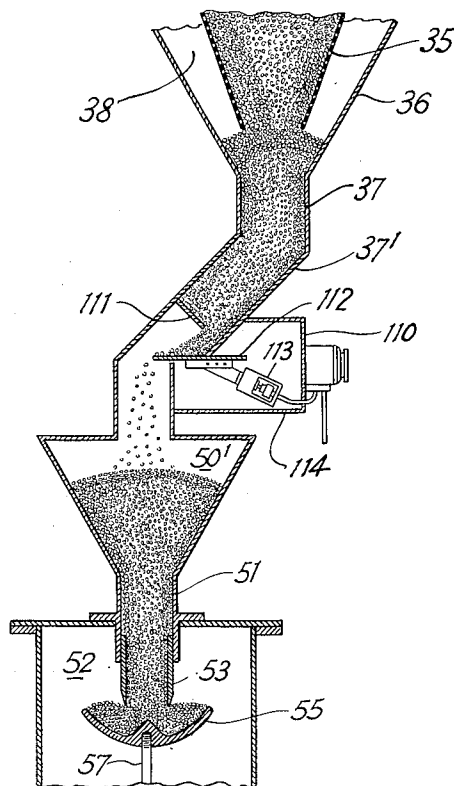


Fig. 8



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UNITED STATES PATENT OFFICE

2,520,164

FLUID HEATING

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Application July 4, 1944, Serial No. 543,441

11 Claims. (Cl. 263—19)

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My present invention relates to the construction and operation of fluid heating apparatus of the general type disclosed in a copending application of E. G. Bailey and R. M. Hardgrove, Serial No. 502,580, filed Sept. 16, 1943, now Patent No. 2,447,306 of August 17, 1948, in which a fluent mass or column of refractory heat transfer material is substantially continuously circulated downwardly through superposed heating and cooling chambers or zones in which the heat transfer material is first heated to a high temperature by the passage of a heating fluid in heat transfer relation therewith, and then cooled by heat transfer contact with a fluid to be heated, the heat transfer material then being returned to the upper end of the heating zone by suitable external elevating means. Fluid heating apparatus of this type are frequently referred to as "pebble" heaters, although a wide range of heat transfer materials other than pebbles can be used therein.

Apparatus of the character described has been found suitable for continuously heating fluids to final temperatures considerably higher than the fluid temperatures for which ordinary steel or alloy steel tubes can be safely and economically used. The final temperature of the heated fluid is mainly dependent upon the maximum temperature of the heat transfer material in the cooling zone and the time of heat transfer contact of the fluid to be heated with the heat transfer material. The cross-sectional flow area for the mass of heat transfer material should be designed to provide uniform distribution of the heating and heated fluids therein and avoid overheating of parts of the descending mass of heat transfer material, thus maintaining substantially uniform temperature conditions throughout each level of the mass. High capacity operation depends upon the maximum flow velocity permissible of the fluid to be heated through the mass of heat transfer material without excessive lifting and carryover of the heat transfer material with the outgoing heated fluid. A further desirable operating characteristic is to have the heat transfer material discharging from the cooling zone at a temperature at which it is not subjected to a thermal shock sufficient to crack or rupture the pieces of heat transfer material and at which the heat transfer material can be safely handled by metallic feeding and elevating means without causing binding and seizing of such metal parts due to excessive thermal expansion. A low entrance temperature and counterflow of a fluid to be

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heated is therefore normally required to insure a suitable discharge temperature of the heat transfer material. The resulting low entrance temperature for the heat transfer material and low exit temperature of the heating fluid provides a high thermal efficiency for the apparatus and the heating process.

The general object of my invention is the provision of an improved method and apparatus of the character described for continuously heating a fluid at relatively high capacities to a uniform final temperature in a temperature range whose upper limit is dependent only upon the physical limitations of the heat transfer material and heater wall refractories employed, while maintaining little or no mixing of the fluid being heated with the fluid used for heating the heat transfer material. A further and more specific object is the provision of an improved construction of a pebble heater unit which is characterized by a fluid outlet construction providing a uniform discharge of the heated fluid, a substantial reduction in the carryover of heat transfer material with the outflowing fluid, and a minimum heat radiation loss from the throat section of the heater. A further specific object is the provision of improved separating means for eliminating dust and undersize pieces of heat transfer material from the unit. A further specific object is the provision of an improved mechanism for controlling the discharge of a fluent mass of solid material from a chamber under a positive pressure, such as the discharge of heat transfer material from the cooling zone of the apparatus described, while maintaining an effective gas seal at the lower end of the chamber. A further specific object is the provision of an improved mechanism for controlling the discharge of a fluent mass of solid material from a chamber under a positive pressure, such as in a pebble heater of the character described, which insures a continuous discharge of the solid material from the chamber while maintaining an effective gas seal at the discharge end of the chamber. A further specific object is the provision of a multiple fluid heater construction and arrangement for securing a final temperature of the fluid being heated substantially higher than that obtainable in a single unit of similar construction, while maintaining the heat transfer material discharging from each unit within a desirable low temperature range.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming

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a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described preferred embodiments of my invention.

Of the drawings:

Fig. 1 is a somewhat diagrammatic elevation of a multiple fluid heater unit constructed in accordance with my invention;

Fig. 2 is an enlarged sectional elevation of a portion of one of the fluid heater units shown in Fig. 1;

Figs. 3, 4 and 5 are horizontal sections taken on the lines 3—3, 4—4, and 5—5, respectively, of Fig. 2;

Fig. 6 is an enlarged sectional elevation of the solid material discharge mechanism shown in Figs. 1 and 2;

Fig. 7 is a horizontal section taken on the line 7—7 of Fig. 6; and Fig. 8 is a partly diagrammatic sectional elevation of a modified form of solid material discharge mechanism.

In the fluid heater construction illustrated in Figs. 1-7, each pebble heater unit has a vertically elongated fluid tight metal casing 10 of circular cross-section lined with an annular wall of suitable high temperature refractory material 11. The fluid heater interior is divided into an upper chamber 12 and a lower chamber 13 connected by a vertically elongated uninterrupted throat passage 14 of substantially reduced cross-section. The chambers 12 and 13 and throat 14 are normally filled to the levels indicated with a continuous fluent mass or column of refractory heat transfer material 15 of a character hereinafter described.

A heat transfer material inlet pipe 16 is connected to the upper part of the chamber 12 and a heating gas outlet pipe 17, controlled by a valve 18, opens centrally into the conical top 19 of the chamber. The material inlet pipe 16 discharges into the lower portion of an auxiliary heating gas outlet pipe 20, which opens into the chamber 12. A substantially annular combustion chamber 25 is formed by an enlarged section of the casing 10 around the lower part of the chamber 12. As shown in Figs. 2 and 5, the inner side of the combustion chamber is formed by an annular bridge wall 26 extending upwardly for part of the height of the chamber and over which flow the heating gases generated by the combustion of any suitable fuel in the surrounding combustion space. As shown, premixed air and gas burner nozzles 27 are arranged at diametrically opposite points and substantially tangential to the combustion chamber 25. Each nozzle 27 is supplied by a valve controlled fuel pipe 28 and an air casing 29 to which a secondary air supply pipe 30 is connected. The ignited mixture of fuel and air discharges through a burner block 31 into the combustion chamber 25 under a positive pressure, with the heating gases generated flowing over the top of the bridge wall 26 and through a circular series of inwardly tapering gas inlet ports 32 formed between wedge shaped firebrick 33 and opening into the lower part of the chamber 12. The firebrick 33 extend substantially the same height as the bridge wall 26 and form the corresponding portion of the wall of the chamber 12. The chamber 12 is formed with an inverted conical bottom section extending from the lower end of the ports 32 to the top of the throat passage 14. With this ar-

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range the heat transfer material in the chamber 12 tends to flow outwardly through the gas ports 32 against the bridge wall until the material assumes its normal angle of repose, thus providing a subdivision of the inlet ports 32 facilitating distribution of the entering heating gases throughout the horizontal area of the chamber 12. The chamber 12 is flared outwardly near the normal top of the mass of material 15 therein to reduce the gas flow velocity in, and thereby the lifting effect on, the upper portion of the mass.

The lower chamber 13 is shown as of substantially uniform circular cross-section from its upper end to a point spaced from its lower end, the lower end portion of the chamber being downwardly tapered and defined by an inverted frusto conical metal screen 35. The lower part of the casing 10 surrounding the screen 35 is downwardly tapered in a cone 36, having a bottom discharge opening 37 which is spaced below the open lower end of the screen 35 to permit any heat transfer material passing through the screen to reach the outlet 37. The parts 35 and 36 cooperate to define an annular fluid inlet chamber 38 to which one or more valve controlled fluid supply pipes 39 are connected for the admission of a fluid to be heated under a positive pressure. The upper end of the lower chamber 13 is a flat firebrick arch in which a multiplicity of radial narrow outlet slots 40 are formed in wedge shaped firebrick 41, as shown in Figs. 2 and 4. The inner ends of the firebrick 41 are interlocked with one or more ceramic tile members 42 defining the downwardly flaring throat passage 14. An annular fluid outlet duct 43 surrounds the tile 42 and into which open the outlet slots 40. One or more fluid discharge pipes 44 are connected to the duct 43.

A relatively wide range of refractory materials can be used as the heat transfer material 15, the material chosen depending upon the operating conditions to be maintained. In general the material selected should have a high strength, hardness, resistance to thermal shock, and a high softening temperature. Such materials may be ceramic refractories or corrosion resistant alloys and alloy steels, in small pieces of regular or irregular shape, such as sized grog, pebbles or crystals of mullite, silicon carbide, alumina, or other refractories. As disclosed in said copending application of E. G. Bailey et al., substantially spherical pellets of uniform shape and size and formed of a mixture of calcined Georgia kaolin, raw Georgia kaolin and a binder, fired to 2850-3000 F. have been successfully used. The pellets are made of a diameter small enough to minimize thermal shocks and impact stresses, and to provide a large amount of heat transfer surface, and yet large enough to withstand the desired gas velocities through the pellet mass without lifting. Pebble diameters $\frac{1}{2}$ " and $\frac{3}{4}$ " have been found suitable.

The downward flow of heat transfer material through the upper chamber 12, throat 14, and lower chamber 13, is controlled by a pressure-tight feeder receiving material from the pellet outlet 37, while maintaining a fluid seal on the lower end of the chamber 13. The outlet pipe 37 opens into a small fluid-tight expansion chamber 50 constructed to provide a space above the pellets at their normal angle of repose therein. The expansion chamber 50 has a bottom outlet pipe 51 provided with an adjustable sleeve extension 53 having a sharp-edged lower end de-

termining the effective position of the outlet in a subjacent valve chamber 52. The feeder mechanism is constructed to provide a periodic discharge of a small amount of pellets from the lower end of the sleeve 53. The mechanism for this purpose comprises a valve member 55 in the chamber 52 having a concave upper surface, preferably in the form of a bowl or cup having an inner central conical portion 56. The cone 56 acts to deflect the pellets outwardly on the valve member and facilitates its movement upwardly and the discharge of pellets therefrom. The cup valve member 55 is vertically movable by means of a rod 57 between an upper position shown in full lines in Fig. 6 at which the normal angle of repose of the pellets on the upper surface of the valve member is greater than the angle formed between the outer periphery of the valve member and the lower end of the sleeve 53, so that the pellets do not tend to flow over the periphery of the valve member when the latter is in its upper position, and a lower position indicated in broken lines at which the angle between the periphery of the valve member and the bottom of the sleeve will be greater than the angle of repose of the pellets on the valve member, so that a gravity flow of the pellets over the periphery of the valve member can take place when the valve is moved to this position. The flow of pellets is thus dammed when the cup-shaped valve member 55 is moved to its upper position without requiring any contact between the valve member and the lower end of the sleeve 53 which might tend to crush pellets therebetween.

The valve chamber 52 has a central valve controlled bottom outlet 58 opening into a third chamber 59. The passage of pellets from the chamber 52 through the outlet 58 into the chamber 59 is controlled by a vertically movable bell valve member 60 slidable relative to the rod 57 in the chamber 59 and mounted on a hollow rod 61 surrounding the rod 57. The valve 60 is timed to open after the cup valve member 55 reaches its upper position and stops the pellet flow from the lower end of the sleeve 53. The downward movement of the valve 60 permits the pellets accumulated in the bottom of the chamber 52 to drop into the chamber 59 which has a discharge opening 62 concentric with the opening 58 and closed by a bell valve member 64 similar to the valve member 60. The valve 64 surrounds and is movable relative to the operating rods 57 and 61 and is mounted on a third hollow rod 65 surrounding the rods 57 and 61. The opening of the valve member 64 permits the pellets to drop into an inclined discharge pipe 66. The valve 64 is normally closed when the valve 60 is open and vice versa to minimize fluid leakage from and thus preserve the fluid pressure conditions in the chamber 13. The described valve parts are coaxially arranged with the operating rods extending through a guide bearing in the discharge pipe 66.

The cup valve member 55 and bell valves 60 and 64 are intermittently operated to effect a fluid seal at all times on the lower end of the chamber 13. The operating mechanism for this purpose consists of a pair of cam members 70 and 71 rotated by a shaft 72 through suitable gearing and a belt drive from an electric motor 73. A lever 74 is pivotally mounted at 75 and arranged with one end in contact with the periphery of the cam member 70. The opposite end of the lever 74 has a forked pivot connec-

tion with the lower end of the hollow valve rod 65 and a bracket 77 connects the same also to the innermost valve rod 57. With this arrangement movement of the lever 74 will cause simultaneous raising and lowering movements of the cup valve 55 and bell valve 64. The bell valve member 60 is alternately raised and lowered by a second lever 80 pivotally mounted at 81 with one end in contact with the periphery of the cam member 71. The opposite end of the lever 80 has a forked pivot connection with the lower end of the hollow rod 61. The cam members 70 and 71 have their cam surfaces shaped and relatively arranged on the shaft 72 to effect a cyclic movement of the cup valve 65 and bell valves 60 and 64. With the arrangement of the parts shown in Fig. 6, the cup member 55 and bell valves 60 and 64 are in their upper positions, the cup member having just been raised to its upper position to dam the pellet flow from the chamber 50 and the valve 64 closed after having delivered pellets from the chamber 59 to the pipe 66. The pellets previously discharged while the valve 55 is in its lower position accumulate in the bottom of the chamber 52 and the valve 60 is about to open to allow this pellet accumulation to drop into the chamber 59, the bottom outlet of which is now closed by the valve 64. The pellets drop into the chamber 59 and the valve 60 is then moved to its top closing position, after which the cup member 55 and valve 64 are simultaneously moved to their lower positions. The opening movement of the valve 64 permits the pellets in the chamber 59 to drop into the discharge pipe 66, while the descent of the cup member permits a new batch of pellets to flow over its periphery and accumulate on the bottom of the chamber 52. The parts are proportioned and timed to minimize the possibility of any pellets becoming jammed between the valves 60 and 64 and their respective seats, while the cup member 55 is arranged so that it does not actually seat on any surface. Any upward movement of the column of pellets in the sleeve 53 during the rising movement of the cup member 55 is absorbed in the expansion chamber 50 by the movement of the pellets into the available space therein.

To insure that no pellets will be accidentally displaced and fall over the edge of the valve member 55 when the latter is in its upper or flow damming position, an annular shroud or shield 105 may be arranged to contact with the peripheral edge of the valve member in that position. The shroud is preferably of oppositely flaring vertical cross-section with its minimum diameter portion of the same diameter as the valve member peripheral edge, to avoid binding of the parts. The depending outlet 51 serves as a support for a vertically adjustable ring 106 connected by flexible supporting chains 107 to the shroud member 105. As the valve member moves upwardly it enters the lower flared section of the shroud, and contacts therewith in its upper position. If any pellets should be caught between these parts, the flexible support of the shroud permits it to be moved upwardly by the valve member.

The discharge pipe 66 is connected through an expansion joint 85 to a second inclined pipe 86 leading to a box 87 at the foot of an elevator casing 88. The box 87 opens into the elevator casing and is provided with openings through which pellets can be added or taken from the system. The elevator casing 88 is of welded gas

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tight construction, and encloses an elevator 88, indicated as being the slow speed continuous bucket type having overlapping buckets which are partly filled with pellets at the normal rate of pellet circulation. The elevator is driven by an electric motor 90 having a drive connection with the elevator headshaft. The buckets empty into a vertical discharge pipe 91 which has its lower end opening into an inclined pipe 92, connected through an expansion joint 93 to the inlet pipe 16. With this arrangement a substantially continuous circulation of the heat transfer material is maintained externally of the fluid heater between the bottom discharge opening 37 and the top inlet pipe 16, so that the mass or column of heat transfer material within the chambers 12 and 13 and throat 14 will descend at a predetermined rate.

To avoid contamination of the outgoing fluids by any dust and pellet fragments formed during the circulation of the pellets, the heat transfer material entering through the inlet pipe 16 is preferably subjected to a scavenging effect by a controllable portion of the heating gases leaving the chamber 12 through the auxiliary gas outlet conduit 20. The lower portion of the conduit 20 is arranged to form an extension of the inlet pipe 16, as shown in Figs. 2 and 3. The lower section of the conduit is of rectangular cross-section having an inclined bottom 95 and a laterally flared end 96. The bottom 95 is extended beyond the end 96 to insure a horizontal travel of the entering pellets in contact with the outgoing gases. The upper portion of the pipe 20 is of circular cross-section and extends externally to a cyclone separator 98 having a bottom outlet 99 for separated solid material and a vent pipe 100 controlled by a valve 101 for discharge of the gases. With this arrangement the valves 18 and 101 can be regulated either manually or automatically to control the portion of the heating gases leaving the upper chamber 12 through the auxiliary outlet 20, and thus maintain the gas velocity conditions necessary to secure the desired scavenging effect on the entering heat transfer material.

In the normal operation of the described apparatus the heating gases generated in the combustion chamber 25 enter the chamber 12 through the interstices of the pellets in the gas inlets 32 under a predetermined pressure, and are substantially uniformly distributed throughout the horizontal area of the adjacent portion of the mass of refractory heat transfer material. The heating gases flow upwardly through the mass in intimate contact with the descending heat transfer material which reaches its maximum temperature at the level of the heating gas inlet. The heat transfer material continues its descent through the throat passage 14 into the chamber 13. The fluid to be heated, such as air, steam, or other gas or vapor, enters at a predetermined temperature and pressure through the supply pipe 39 and inlet chamber 38 and flows through the annular screen 35 into the lower end of the heat transfer material in the chamber 13, passing upwardly through the interstices in the material in intimate counterflow contact with the descending pellets. The entering gas is at a relatively low temperature to insure a low discharge temperature for the pellets which will provide a high thermal efficiency, lessen thermal shock on the pellets, and permit safe handling of the pellets by the pressure-tight feeder and elevator. The fluid to be heated reaches its maximum tempera-

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ture at the top of the chamber 13 flowing out through the slots 40, duct 43 and discharge pipe 44. As disclosed in said pending application of E. G. Bailey et al., mixing of the fluid atmospheres in the chambers 12 and 13 can be avoided by maintaining predetermined relative pressures in the two chambers to provide a zero fluid flow through the throat 14. Pressure taps 102 and 103 are indicated for measuring the pressure differential across the throat, and variations in this condition from a predetermined standard are utilized to control the position of the valves 18 and 101 and thereby the gaseous pressure in the chamber 12 to control the relative pressures in the two chambers. The return of the pellets through the feeder and elevator to the inlet pipe 16 has been previously described.

While the feeder valve operating mechanism described is normally operated to complete a cycle in a relatively few seconds, and thus provide a substantially continuous discharge of pellets from the outlet 37 and downward movement of the pellet column in the chambers 12 and 13, the high rate of heat transfer in the chamber 13 in conjunction with the periodic dwell of the pellets in the chamber even with the rapid cycle of feeder operation described will result in a slight variation in the heated fluid outlet temperature. While such temperature variation may be negligible for most uses of the invention, in some cases a uniform final temperature of the heated fluid may be important.

A continuous discharge of pellets from the outlet 37 while maintaining the feeder under pressure is provided by the modified feeder mechanism shown in Fig. 8. In this construction the outlet pipe 37 has an inclined lower section 37' in which a vibrating feeder unit 110 is incorporated. The flow area of the inclined pipe section 37' is reduced by a plate 111 therein restricting the pellet flow to one side of the pipe section below which a horizontally extending vibrating plate 112 is located. The vibrating plate is supported and actuated by an electrically operated vibrator unit 113 in a fluid tight casing 114. The vibrating plate 112 extends into the pipe 37' for a distance sufficient to cause the pellet stream to assume an angle of repose thereon and stop the pellet flow when the plate 112 is stationary. In operation the pellets continuously discharge from the inner end of the plate 112 at a rate depending upon the vibrating frequency and drop into an expansion chamber 50' having a volumetric capacity sufficient to provide an expansion space above the normal level of pellets therein. The pellets periodically discharge from the chamber 50' through the outlet pipe 51 and feeder mechanism previously described. With this feeder construction, the pellet column will continuously descend through the chambers 12 and 13 at a controllable rate.

While a single fluid heater unit of the character illustrated in Figs. 2-7 is capable of continuous operation at relatively high capacities to heat a fluid passed through the chamber 13 to a high temperature, still higher fluid final temperatures can be attained by the multiple unit arrangement illustrated in Fig. 1. The fluid heater units A and B shown therein are of similar construction, each having superposed heating and cooling chambers 12 and 13 respectively connected by a throat 14, with the pellet mass or column circulated there-through by a pressure-tight feeder and elevator, all as shown in Figs. 2-7 or Fig. 8.

In accordance with my invention, the fluid

heater A is utilized to heat one of the combustion constituents, either fuel or an oxygen-containing gas, such as air, for the combustion chamber of the fluid heater B, to a high temperature to substantially increase the maximum temperature of the heating gases generated in the heater B. In view of the substantially greater combustion air requirements, it is more efficient to preheat the air than the fuel to be used in heater B. With such an arrangement and all or a major portion of the combustion air continuously preheated to a uniform or substantially uniform temperature substantially above the fuel ignition temperature, the temperature maintained in the combustion chamber of the heater B will be considerably in excess of the maximum temperature obtainable in heater A. The pellets entering the lower chamber 13 of the heater B will consequently be at a substantially higher temperature than the pellets at the same location in the fluid heater A, and thus correspondingly increase the final temperature of the fluid heated in the heater B. The fluid heated in the heater B may be the same or different from the fluid heated in the heater A. By way of example and not of limitation, in Fig. 1 I have indicated an arrangement for superheating steam to a high temperature in the heater B. Air at room temperature is supplied to the heater A through the pipe 39 and ascends through the pellet mass in the lower chamber 13, being continuously heated to a uniform temperature, such as 2000° F., before leaving through the fluid outlet pipe 44. The air so heated is delivered to the combustion air inlet pipes 30 of the heater B, the parts contacting with the high temperature air being made of suitable heat resistant material. The high temperature combustion air so supplied mixes with the fuel or combustible mixture entering the combustion chamber of the heater B and a substantial increase in combustion chamber temperature results. For example, combustion chamber temperatures of over 3000° F. can be easily secured. The saturated steam to be superheated enters the heater B through the fluid inlet pipe 39, flows upwardly through the heated pellet mass in the lower chamber, and in a highly superheated condition, such as at 2500-3000° F., leaves through the outlet conduit 44. A high thermal efficiency is attained and continuous operation of the units is insured by the reduction of the pellet temperature by the entering low temperature fluid in each unit to a temperature at which the pellets can be safely handled by the feeder and elevator mechanism and pellet breakage minimized.

The multiple unit arrangement described is not limited to the two unit arrangement shown, but any number of such units can be interconnected as shown to obtain operating temperatures up to the permissible use temperature limits of the pellets and the refractory materials used in the fluid heater unit construction. In such arrangements, the fluid to be finally heated is heated in the last heater unit of the series and the preceding units are utilized for heating a combustion constituent, such as fuel or air, which is used in the combustion chamber of a subsequent unit of the series. My invention also contemplates the preheating of both the fuel and air constituents in separate fluid heaters of the character described and their delivery to a third such fluid heater to provide the combustion constituents thereof. Fluids can thus be continuously and efficiently heated by the combustion of ordinary fuels, such as oil or gas, to uniform final tem-

peratures heretofore considered unattainable with such fuels. The material discharge mechanisms shown in Figs. 6-9 are disclosed and claimed in my copending divisional application, Serial No. 625,239, filed October 29, 1945.

I claim:

1. The method of heating a fluid to a high temperature which comprises maintaining a flow of a fluent mass of heat transfer material through heating and cooling zones in a fluid heater, heating said mass of heat transfer material to a high temperature while in said heating zone, cooling the heated mass of heat transfer material while in said cooling zone by heat transfer to a fluid combustion constituent flowing through said cooling zone in heat transfer relation with said heat transfer material, maintaining a flow of a second fluent mass of heat transfer material through heating and cooling zones in a second fluid heater, heating the second mass of heat transfer material to a high temperature while in said second heating zone by heating gases generated by a combustion process utilizing the heated fluid combustion constituent from said first cooling zone, and cooling the mass of heated heat transfer material while in said second cooling zone by heat transfer to a fluid flowing through said second cooling zone in heat transfer relation with said heat transfer material.

2. The method of heating a fluid to a high temperature which comprises maintaining a flow of a fluent mass of heat transfer material downwardly through superposed heating and cooling zones in a fluid heater, heating said mass of heat transfer material to a high temperature while in said heating zone, cooling the heated mass of heat transfer material while in said cooling zone by heat transfer to a fluid combustion constituent flowing through said cooling zone in direct contact with said heat transfer material, maintaining a flow of a second fluent mass of heat transfer material downwardly through superposed heating and cooling zones in a second fluid heater, heating the second mass of heat transfer material to a high temperature while in said second heating zone by heating gases generated by a combustion process utilizing the heated fluid combustion constituent from said first cooling zone, and cooling the mass of heated heat transfer material while in said second cooling zone by heat transfer to a fluid flowing through said second cooling zone in direct contact therewith.

3. The method of heating a fluid to a high temperature which comprises maintaining a substantially continuous flow of a fluent mass of heat transfer material downwardly through superposed heating and cooling zones in a fluid heater, heating said mass of heat transfer material to a high temperature while in said heating zone, cooling the heated mass of heat transfer material while in said cooling zone by heat transfer to a fluid combustion constituent flowing through said cooling zone in counterflow direct contact with said heat transfer material, maintaining a substantially continuous flow of a second fluent mass of heat transfer material downwardly through superposed heating and cooling zones in a second fluid heater, heating the second mass of heat transfer material to a high temperature while in said second heating zone by heating gases generated by a combustion process utilizing the heated fluid combustion constituent from said first cooling zone, and cooling the mass of heated heat transfer material while in said second cool-

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ing zone by heat transfer to a fluid flowing through said second cooling zone in counterflow direct contact with said heat transfer material.

4. The method of heating a fluid to a high temperature which comprises maintaining a flow of a fluent mass of heat transfer material downwardly through superposed heating and cooling zones in a fluid heater, heating said mass of heat transfer material to a high temperature while in said heating zone, cooling the heated mass of heat transfer material while in said cooling zone by heat transfer to a stream of air flowing through said cooling zone in direct contact with said heat transfer material, maintaining a flow of a second fluent mass of heat transfer material downwardly through superposed heating and cooling zones in a second fluid heater, heating the second mass of heat transfer material to a high temperature while in said second heating zone by heating gases generated by a combustion process utilizing the heated air from said first cooling zone, and cooling the mass of heated heat transfer material while in said second cooling zone by heat transfer to a fluid to be heated flowing through said second cooling zone in direct contact with said heat transfer material.

5. Fluid heating apparatus comprising a pair of fluid heater units, each of said units having walls defining an upper chamber and a lower chamber connected thereto, a continuous fluent mass of refractory heat transfer material in said upper and lower chambers, and means providing a flow of said heat transfer material downwardly through said chambers, means for heating the heat transfer material in the upper chamber of one of said heater units, means for passing a fluid combustion constituent through the lower chamber of said heater unit in heat transfer relation with the heated heat transfer material therein, means for heating heat transfer material in the upper chamber of the second heater unit by heating gases from a combustion process utilizing the heated fluid combustion constituent from said first heater unit, and means for passing a fluid to be heated through the lower chamber of said second heater unit in heat transfer relation with the heated heat transfer material therein.

6. Fluid heating apparatus comprising a pair of fluid heater units, each of said units having walls defining an upper chamber and a lower chamber connected thereto, a continuous fluent mass of refractory heat transfer material in said upper and lower chambers, and means providing a flow of said heat transfer material downwardly through said chambers, means for heating the heat transfer material in the upper chamber of one of said heater units, means for passing a fluid combustion constituent through the lower chamber of said heater unit in direct contact with the heated heat transfer material therein, means for heating the heat transfer material in the upper chamber of the second heater unit by heating gases from a combustion process utilizing the heated fluid combustion constituent from said first heater unit, and means for passing a fluid to be heated through the lower chamber of said second heater unit in direct contact with the heated heat transfer material therein.

7. Fluid heating apparatus comprising a pair of fluid heater units, each of said units having walls defining an upper chamber, a lower chamber, and a throat passage of reduced cross-section between said upper and lower chambers, a continuous fluent mass of refractory pellets in

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said upper and lower chambers and throat passage, and means providing a substantially continuous flow of pellets downwardly through said chambers and throat passage, means for heating the pellets in the upper chamber of one of said heater units, means for passing a fluid combustion constituent through the lower chamber of said heater unit in counterflow heat transfer relation with the heated pellets therein, means for heating pellets in the upper chamber of the second heater unit by heating gases from a combustion process utilizing the heated fluid combustion constituent from said first heater unit, and means for passing a fluid to be heated through the lower chamber of said second heater unit in counterflow heat transfer relation with the heated pellets therein.

8. A fluid heater comprising a wall structure defining a chamber, a fluent mass of refractory heat transfer material in said chamber, means for introducing a stream of heating gases into said chamber in direct contact with said heat transfer material, means for effecting a flow of heat transfer material downwardly through said chamber comprising an elevating means arranged to receive heat transfer material from the lower end of said chamber and a conduit receiving heat transfer material from said elevating means and returning the same to the upper part of said chamber above the level of heat transfer material therein, and a heating gas outlet in the upper part of said chamber constructed and arranged to cause the outgoing heating gases to scavenge the entering heat transfer material of undersize particles.

9. A fluid heater comprising a wall structure defining a chamber, a fluent mass of refractory heat transfer material in said chamber, means for introducing a stream of heating gases into said chamber in direct contact with said heat transfer material, means for effecting a flow of heat transfer material downwardly through said chamber comprising an elevating means arranged to receive heat transfer material from the lower end of said chamber and a conduit receiving heat transfer material from said elevating means and returning the same to the upper part of said chamber above the level of heat transfer material therein, a heating gas outlet in the upper part of said chamber constructed and arranged to cause the outgoing heating gases to scavenge the entering heat transfer material of undersize particles, and a gas and solid separator receiving heating gases from said gas outlet.

10. A fluid heater comprising a wall structure defining a chamber, a fluent mass of refractory pellets in said chamber, means for introducing a stream of heating gases into said chamber in direct contact with said pellets, means for effecting a flow of pellets downwardly through said chamber comprising an elevating means arranged to receive pellets from the lower end of said chamber and a conduit receiving pellets from said elevating means and returning the same to the upper part of said chamber above the level of pellets therein, and a heating gas outlet in the upper part of said chamber constructed and arranged to cause the outgoing heating gases to scavenge the entering pellets of undersize particles.

11. A fluid heater comprising a wall structure defining a chamber, a fluent mass of refractory heat transfer material in said chamber, means for introducing a stream of heating gases into said chamber in direct contact with said heat

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transfer material, means for effecting a flow of heat transfer material downwardly through said chamber comprising an elevating means arranged to receive heat transfer material from the lower end of said chamber and a conduit receiving heat transfer material from said elevating means and returning the same to the upper part of said chamber above the level of heat transfer material therein, a heating gas outlet in the upper part of said chamber constructed and arranged to cause the outgoing heating gases to scavenge the entering heat transfer material of undersize particles, a gas and solid separator receiving heating gases from said gas outlet, a second heating gas outlet from said chamber, and damper means for regulating the distribution of heating gases to said outlets.

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