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TUBE HEATER WITH FLUE GAS RECIRCULATION
AND HEATING METHOD

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3 Sheets-Sheet 1

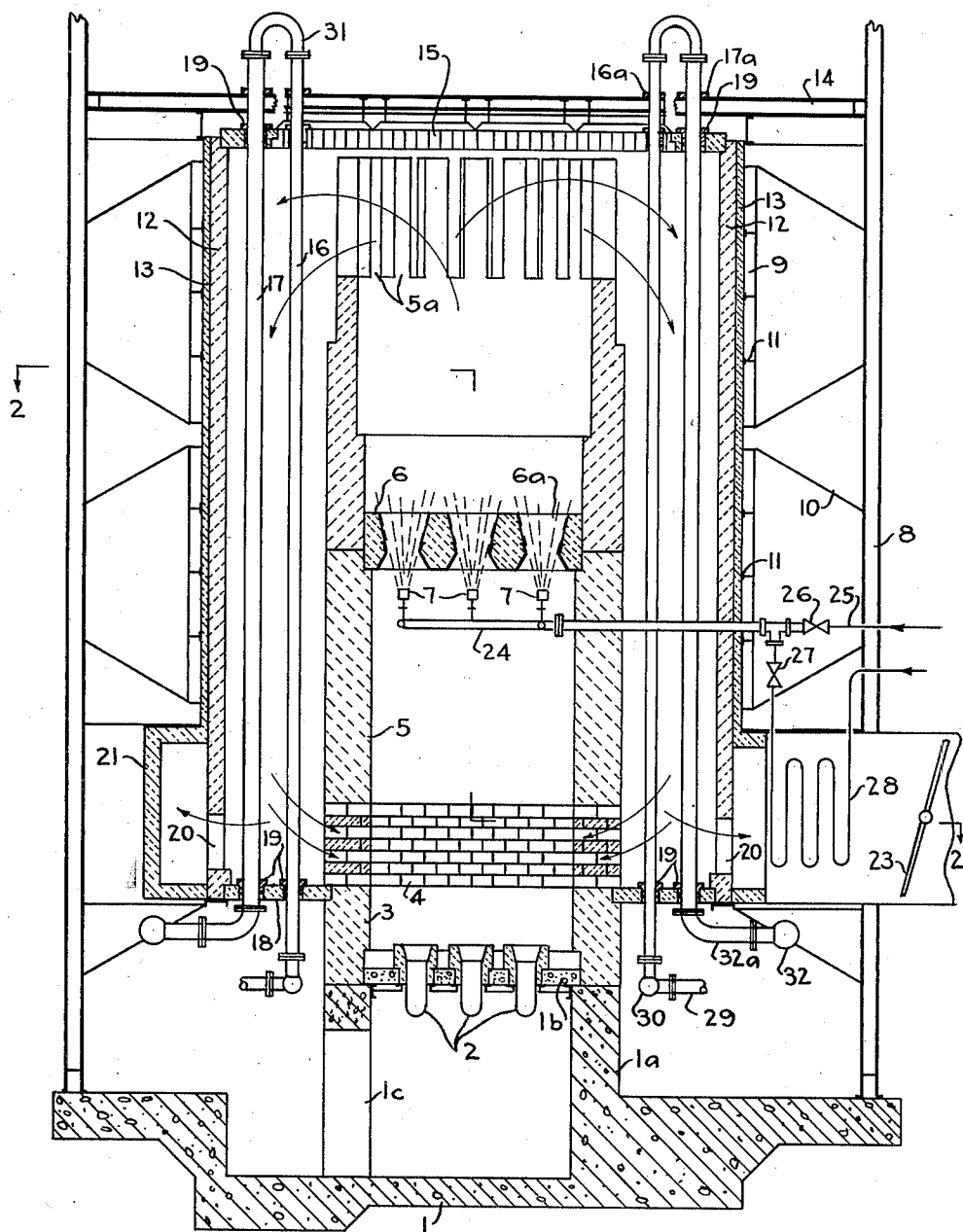


FIG. 1

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3 Sheets-Sheet 2

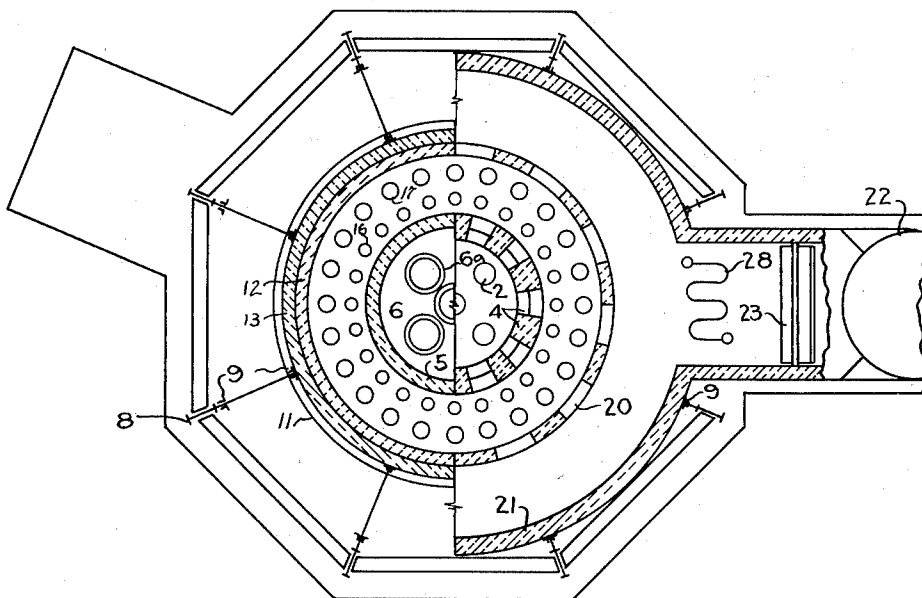


FIG. 2

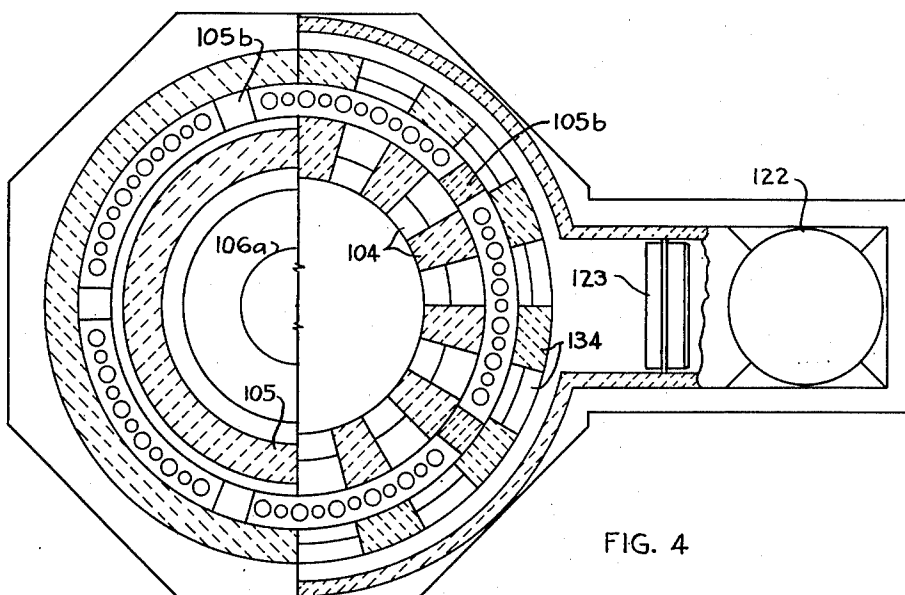


FIG. 4

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TUBE HEATER WITH FLUE GAS RECIRCULATION AND HEATING METHOD

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15 Claims. (Cl. 122-275)

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This invention relates to improvements in combustion furnaces for heating fluids flowed through tubes, and to an improved method of heating such fluids, wherein the heating tubes are arranged within a heating space so as to cause hot combustion gases to flow longitudinally with respect to the heating tubes, and wherein the combustion gases are recirculated. The heater and method according to this invention are, for example, particularly useful in the carrying out of endothermic chemical reactions, such as the dehydrogenation of alcohols or other gaseous hydrocarbons which takes place at about 1000° F. Other examples are the conversion of ethylene dichloride into vinyl chloride and hydrochloric acid at about 960° F., the cracking of hydrocarbon oil, and catalytic dehydrogenation processes.

In heaters of this class difficulty is frequently experienced because of uneven heating of the tubes, resulting in local overheating. It is already known to provide a more gentle heating by recirculating the flue gases, but this has resulted in operating difficulties. With the heaters heretofore known the use of steam injectors for effecting circulation was not satisfactory because the primary and recirculated combustion products were not always completely mixed and different tubes were not heated equally.

It is an object of this invention to provide an improved tube heater and an improved method of heating flowing fluids wherein heat of substantially uniform intensity is distributed among the several heating tubes, and the tubes are heated substantially evenly along their lengths.

It is a further object to provide an improved tube heater and an improved method of heating flowing fluids wherein recirculation of combustion products or flue gas is induced by the injection of a gas, such as steam, in a flow arrangement which will insure substantially even distribution of heat to the several heating tubes. Ancillary thereto, it is an object to provide an improved method of heating and an improved heater wherein the flue gas recirculation rate can be easily controlled.

Still another object is to provide a heater having a combustion chamber fitted with one or more Venturi constrictions downstream from the burner or other source of combustion gases and having a nozzle for expanding and discharging a gas, such as steam or air or combustion gas, into the Venturi throat in a manner to induce circulation of the flue gas through the combustion chamber, in combination with flow passage ways for flowing the resulting augmented stream of combustion gases in heat exchange with the heating tubes and to effect the recirculation of flue gas through the combustion chamber. Ancillary thereto, it is an object to arrange the discharge port, through which excess or non-recirculated

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flue gas is withdrawn from the heater, in such relation to the Venturi constriction as to facilitate regulation of the recirculated gas.

Still further objects of the invention will be apparent from the following description, taken in connection with the drawings forming a part of this specification, wherein:

Fig. 1 is a vertical sectional view of a preferred embodiment of the invention, parts being shown in elevation;

Fig. 2 is a sectional view taken on line 2-2 of Fig. 1;

Fig. 3 is a vertical sectional view showing a modified construction; and

Fig. 4 is a sectional view taken on line 4-4 of Fig. 3.

Briefly, according to the instant invention combustion gases are recirculated within the enclosure of the heater proper by means of the jet effect of a gas, such as saturated or superheated steam, air, or combustion gases which have been compressed. I prefer to inject steam as the jet gas to avoid formation of an oxidizing atmosphere, and because it is readily available in furnace installations. However, the invention is not limited to the use of steam and any gas, including air, may be used as the jet gas. The jet gas is ejected from one or more expanding nozzles and directed as one or more jets through one or more Venturi throats, thereby entraining combustion gases. The hot combustion gases, from any source, such as a liquid fuel burner, are commingled with the recirculated flue gas after the latter has passed in contact with the heating tubes and before flowing through the Venturi throat. The stream of hot combustion gases is therefore, successively augmented with recirculated flue gas and with jet gas and, as a result, undergoes a decrease in temperature. The augmented and partially cooled stream is then passed through one or more elongated convection heating passages containing the heating tubes through which the fluid to be heated is passed, the flow of the augmented gas stream being parallel to the axis of the heating tube and either concurrently or counter-currently to the direction of flow of the fluid in the tubes. The reduced temperature and increased volume of the augmented gas stream minimize the temperature gradient along the heating tubes and also equalize the heat transfer rate from the gas to the heating tubes along the length and about the circumference of the heating tubes.

By my method of mixing the fresh combustion gases with the recirculated gases prior to passage through the Venturi throat (whereby the Venturi throat is disposed upstream from the heating passages) insures a complete mixing of

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the fresh and the recycled combustion gas and the jet gas; this results in a more uniform heating of the heating tubes.

Excess gases are withdrawn from the circulating gas stream at any desired point in the circuit, and I prefer to withdraw them (approximately at a rate equal to the sum of the rate of admission of fresh combustion gases and jet gas) just after the gas has traversed the heating tubes.

The method will be understood more completely from a consideration of the apparatus illustrated in the drawings, which illustrate certain preferred embodiments of the invention, it being understood that the invention is not limited to the specific arrangement of flow passages shown therein.

Referring to Figs. 1 and 2, the heater is supported on a concrete foundation 1 having a central or inner wall 1a supporting a horizontal bulkhead 1b lined on its upper face with refractory fire bricks supporting a plurality, for example, five burners 2. These burners receive combustion air via opening 1c. The wall 1a is continued upwardly by a refractory brick section 3, a checker brick section 4, and a refractory section 5 having slots 5a near the top. The space above the burners 2 and within these sections is herein referred to as the combustion space. The combustion space is fitted with a transverse partition or Venturi block 6 having a plurality, for example, five perforations 6a forming Venturi throats. The lower portions of these throats may be lined with metallic sheathing as shown. Expansion nozzles 7 are mounted beneath each of the Venturi openings and disposed to discharge jet gas upwardly substantially tangent to the walls of the Venturi throats.

An outer furnace wall is provided surrounding the sections 4 and 5 and spaced therefrom. This wall may be supported in any conventional manner. As shown in Figs. 1 and 2 it is suspended from a steel framework comprising H-columns 8 resting on the foundation 1 and supporting vertical angle sections 9 through gusset plates 10. The angle sections 9 support arcuate angles 11 from which fire resistant tile blocks 12 are suspended by well known means, not shown, including suspension lugs. A sheathing of heat insulating material 13 surrounds the blocks 12 and is also suspended from the angles 11. Horizontal I-beams 14 extend across the top of the furnace, being secured to the H-columns 8 and forming supports for the suspended refractory roof 15 and for the heating tubes 16 and 17. The tubes are suspended by collars 16a and 17a. These tubes extend vertically within the annular connection heating space between the combustion chamber walls and the outer furnace wall, extending downwardly through openings in a lower, annular refractory wall 18, supported from the steel framework. The heating tubes are sealed to the roof 15 and lower wall 18 by means of refractory bushings 19.

The lower portion of the outer wall has a series of openings 20 communicating with an annular flue box 21 connected at one side to a stack 22. A damper 23 is provided in the connection between the box 21 and stack.

The nozzles 7 are connected by a manifold 24 to a steam line 25 which is connected to a source of saturated or superheated steam, not shown. The valve 26 is open and the valve 27 is closed. For superheating and/or generating the steam I may provide a steam coil 28 in the stack or in the

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flue box 21; in this case the valve 26 is closed and the valve 27 is open.

The fluid to be heated is passed from inlet 29 to a manifold 30 connected to the bottoms of the heating tubes 16. In this embodiment the heating tubes are arranged to vaporize liquid and the tubes 16 function as preheaters and are of relatively small diameter to effect the turbulence necessary for efficient heat transfer. The vapors pass into the main heating tubes 17 via U-connectors 31. The tubes 17 are of relatively large diameter to accommodate vapors and provide the necessary space velocity for the particular use to which the furnace is put. The fluid is discharged via radial pipes 32a to a circular exit header 32.

In the operation of the heater, hot combustion gases are generated by the burners 2 and passed upwardly through the combustion chamber, radially outwardly through the slots 5a downwardly through the annular heating space enclosing the heating tubes, and out through the flue box 21 and stack 22. A portion of the flue gas is recirculated through the checkerbrick 4, augmenting the stream of combustion gases and cooling the latter. Circulation is induced by the action of the nozzles 7 and the Venturi block 6, wherein the augmented stream is entrained and still further augmented by the jet gas. The pressure in the upper portion of the heater, above the Venturi block, may be atmospheric or slightly above atmospheric, while the pressure beneath the Venturi block may be somewhat less than atmospheric, although the invention is not limited to operation at such pressures.

The recirculation rate is regulated by the rate of flow of jet gas issuing from the nozzles 7 and by the damper 23. By "recirculation rate" I mean the weight ratio of the flue gas flowing radially in through the checker brick 4 to the combustion gases generated by the burners 2. The recirculation rate may be varied, depending upon the desired temperature of the mixed gases flowing downwardly through the annular heating space. By way of example, and without limiting the invention thereto, it may be stated that the circulation rate may in typical installations be between about 1:0.5 and 1:3. Thus, when the recirculation rate is 1:2, the quantity of gas passed through the heating space is between 3 and 4 times as great as the quantity generated (consisting of one part of fresh combustion gases, two parts of recirculated flue gas, and a small amount, usually less than one part, of jet gas).

Heat losses are minimized in this heater by placing the hottest portion inside the inner, cylindrical sections 4 and 5 and by venting the excess flue gas into the flue box 21 at its lowest temperature. It is, further, desirable to avoid excess combustion air in order to improve the thermal efficiency and to avoid formation of an oxidizing gas mixture which rapidly deteriorates the tubes and brickwork.

The augmented stream of combustion gas is usually cooled in flowing through the Venturi throats because the jet gas is cooler than the gas stream entrained thereby.

The central location of the combustion chamber and the recirculation of flue gas make it possible to use less resistant walls for the outer furnace walls and minimizes heat lost by radiation. The heating tubes are evenly spaced in the annular heating space whereby the individual tubes at different points of the circumference of the heater receive an equal amount of heat. This axial symmetry, while particularly useful with

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the heater disclosed, is also useful in cases where the Venturi throat and jet nozzle 7 are omitted and the flow of flue gas is effected by thermosiphon action or by fans or the like, and the invention, in one aspect, resides in this arrangement of flow channels, regardless of whether means for inducing circulation are provided or of the type of such means employed.

An important feature of the invention is the arrangement whereby an augmented stream of heating gas is flowed along the heating tubes at a reduced temperature, whereby the temperature gradient lengthwise of the tube surface is reduced and the heat transfer rate in the direction of the length and circumference of the heating tubes is nearly equalized. Another important feature resides in the location of the Venturi throats immediately downstream from the point of juncture of the fresh, hot combustion gases and the recirculating flue gas. This arrangement insures complete mixing of the fresh and recycled gases and the jet gas and results in the more uniform heating of the tubes.

By suspending the heating tubes from the top by collars resting on the exterior steel framework they are easily removed from the top, it being only necessary to disconnect them from the bottom manifolds. By connecting the preheating tubes 16 to the main heating tubes 17 at the top, wherein no vertical movement due to thermal expansion takes place, the provision of fluid-tight connections are facilitated.

The heater may be modified in several respects. For example, the discharge of excess flue gases may be effected from the top or from an intermediate level of the heating space, whereby the heating of the tubes may be varied to meet particular conditions. The outer walls may be made entirely of refractory or of insulating material, instead of containing a layer of each. Further, it is not necessary to arrange the combustion chamber vertically or to place the heating tubes entirely around the combustion chamber; however, the arrangement shown is preferred in that it provides a symmetrical arrangement and thereby promotes even distribution of heating gases. Finally, the suspension of the outer furnace wall and the tubes from a steel framework is not a part of the invention, and I may employ any other construction such as, for example, that illustrated in Figs. 3 and 4.

Referring to Figs. 3 and 4, the furnace comprises a concrete foundation 101 with a cylindrical portion 101a lined with refractory fire bricks 103 and 103a and insulating brickwork 133, and provided with a plurality of premix burners 102 adapted to generate combustion gases by burning a previously partly or fully mixed stream of fuel and air. Above this brickwork there are checker brickwork 104 and a cylindrical refractory section 105 having slots 105a at the top. The section 105 has a plurality, e. f., five, radial fins 105b extending outwardly and subdividing the annular heating space into a plurality of smaller heating spaces. A single Venturi block 106 having a throat 106a is fitted within the section 105 and provided with a plurality of nozzles 107 for expanding jet gas into the Venturi throat.

The outer furnace wall comprises checker brickwork 134 and a cylindrical wall 112 which may be of suitable heat-resistant concrete or of refractory brick. The furnace top 115 rests on the wall 112 and is covered by heat insulat-

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ing material 135 and a steel plate 136. Heating tubes 117 extend vertically within the vertical heating spaces between the walls 105 and 112 and fins 105b and are suspended from the steel plate 113b by collars 117a. The tubes are connected at the top to a manifold 130 and at the bottom to a circular header 132 via radial connectors 132a.

The flue exit duct is in the form of an annular flue box 121 in communication with the heating space through the checker brickwork 134. It is connected to a stack 122 through a passageway fitted with a damper 123. The nozzles 107 are supplied with jet gas by a manifold 124, pipe 125 and valve 126.

The heater is operated in the same manner as that according to Figs. 1 and 2, except that no preheating tubes are provided. The fluid to be heated may be flowed either upwardly or downwardly through the heating tubes, depending upon the type of heating desired. For example, in endothermic reactions, wherein the conversion temperature is to be maintained as uniformly as possible, it is usually important to avoid too great a difference in temperature between the reacting gas mixture and the heating gas in the part of the heating tube where the reaction takes place, i. e., the outlet part of the tube. At the inlet end greater differences in temperature are permissible without causing any detrimental effect. In such a case heating in concurrent flow with the heating gas is most suitable and the reaction mixture is flowed downwardly through the tubes 117. For other applications of the heater countercurrent flow may, of course, be more appropriate, and the mixture may be flowed upwardly through the heating tubes.

I claim as my invention:

1. A tube heater comprising an enclosing wall structure forming a central vertical combustion chamber, a source of hot combustion gases near the bottom of said combustion chamber, an outer wall spaced from and surrounding said wall structure to form a vertically elongated heating space therebetween, vertical convection heating tubes located entirely outside of said enclosing wall structure and within said heating space, passageways interconnecting the combustion chamber and the heating space both at the top and at the bottom, means located within said combustion chamber for inducing upward movement of combustion gases and flue gas upwardly within said combustion chamber, whereby gases may circulate through said chamber and space, and a flue for discharging flue gas.

2. The tube heater according to claim 1 wherein there are a plurality of interconnecting passageways at each end of the heating space and the heating tubes and the passageways are spaced substantially evenly about the combustion chamber.

3. The tube heater according to claim 1 wherein the heating tubes are arranged in pairs, the tubes of each pair being interconnected at the one vertical end of the heating space.

4. A tube heater comprising an enclosing wall structure forming a central vertical combustion chamber, a source of hot combustion gases near the bottom of said combustion chamber, an outer wall spaced from and surrounding said wall structure to form a vertically elongated heating space therebetween, a plurality of radial partitions extending from the enclosing wall structure to said outer wall and subdividing said

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heating space into a plurality of circumferentially contiguous vertical smaller heating spaces, vertical convection heating tubes located entirely outside of said enclosing wall structure and within said smaller heating spaces, passageways interconnecting the combustion chamber and the smaller heating spaces both at the top and at the bottom, means located within said combustion chamber for inducing upward movement of combustion gases and flue gas upwardly within said combustion chamber, whereby gases may circulate through said chamber and smaller heating spaces, and a flue for discharging flue gas.

5. A tube heater comprising an enclosing wall structure forming a combustion chamber, a source of hot combustion gases near one end of the chamber, a second wall structure forming, together with said first wall structure, an elongated convection heating space, convection heating tubes within the heating space and located to be shielded by said enclosing wall structure from direct radiation from the said source of combustion gases extending longitudinally with respect to the heating space, passageways interconnecting the ends of said heating space with spaced points in said combustion chamber, a Venturi constriction within said combustion chamber intermediate said spaced points, nozzle means for discharging a fluid jet into the throat of said Venturi constriction, and a flue for discharging flue gas.

6. A tube heater comprising a first inner wall of refractory material forming a vertical combustion chamber, a source of hot combustion gases near the bottom of said combustion chamber, a second outer wall of insulating-refractory material surrounding said first wall and spaced therefrom to form a vertically elongated heating space therebetween, vertical convection heating tubes located entirely outside of said first inner wall and within said heating space, passageways interconnecting the ends of said heating space with spaced points in said combustion chamber above said source of combustion gases, a Venturi constriction within said combustion chamber intermediate said spaced points, nozzle means for discharging a fluid jet upwardly into the throat of said Venturi constriction, and a flue for discharging flue gas.

7. The tube heater according to claim 6 wherein the flue is connected to the bottom of said heating space.

8. The tube heater according to claim 6 wherein there are a plurality of passageways at each end of the heating space, the heating tubes and passageways are spaced substantially evenly about the combustion chamber and the flue comprises an annular flue box surrounding the outer wall and in communication with said heating space through a plurality of passageways disposed circumferentially with respect to the heating space.

9. A tube heater comprising an inner wall structure of refractory material forming a vertical combustion chamber, said wall structure comprising an open checkerwork section near the bottom and a solid section above said checkerwork section, a plurality of circumferentially spaced openings at the top of said solid section, a Venturi block within said solid section having one or more Venturi constrictions, a source of hot combustion gases beneath said open checkerwork section, an outer wall of insulating or refractory material surrounding said inner wall

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and spaced therefrom to form a vertically elongated heating space therebetween, said space being in communication with the combustion chamber through said open checkerwork section and said openings, a plurality of vertical convection heating tubes within said heating space spaced substantially evenly about the combustion chamber, a second, outer wall structure surrounding said inner wall and forming a flue box, passage-ways interconnecting said heating space and said flue box at a plurality of points, a flue for discharging flue gas from said flue box, and a damper for controlling the discharge of the flue gas.

10. The heater according to claim 9 wherein the flue box is located near the bottom of the heating space.

11. A method of heating flowing media comprising flowing the medium to be heated through a tube, flowing an augmented stream of combustion gases, described hereafter, through an elongated convection heating space longitudinally with respect to said tube, thereafter admixing at least a portion of the combustion gases with fresh, hot combustion gases, to form an augmented stream of combustion gases, forcing flow of the augmented stream toward said convection space through the entraining action of a jet, thereby establishing a circulating stream of combustion gases, and removing a portion of said circulating stream.

12. The method according to claim 11 wherein the portion of the circulating stream is removed from the augmented stream immediately after passage thereof through the convection space.

13. The method according to claim 11 wherein the flow of the augmented stream is induced by injecting a jet of a gas into a Venturi constriction.

14. A method of heating flowing media comprising flowing the medium to be heated through a plurality of vertical tubes, flowing an augmented stream of combustion gases, described hereafter, downwardly through a vertically elongated convection heating space along said heating tubes, thereafter admixing a portion of the combustion gases with fresh, hot combustion gases, to form an augmented stream of combustion gases, inducing upward flow of the augmented stream externally of said convection space toward the top of said convection space by means of the entraining action of a jet, thereby establishing a circulating stream of combustion gases, and removing a portion of said circulating stream.

15. The method according to claim 14 wherein the upward flow of the augmented stream is induced by injecting a jet of steam into a Venturi constriction.

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