Nov. 30, 1943. T. H. SHERMAN 2,335,317

FLUID HEATER

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Fig. 1.

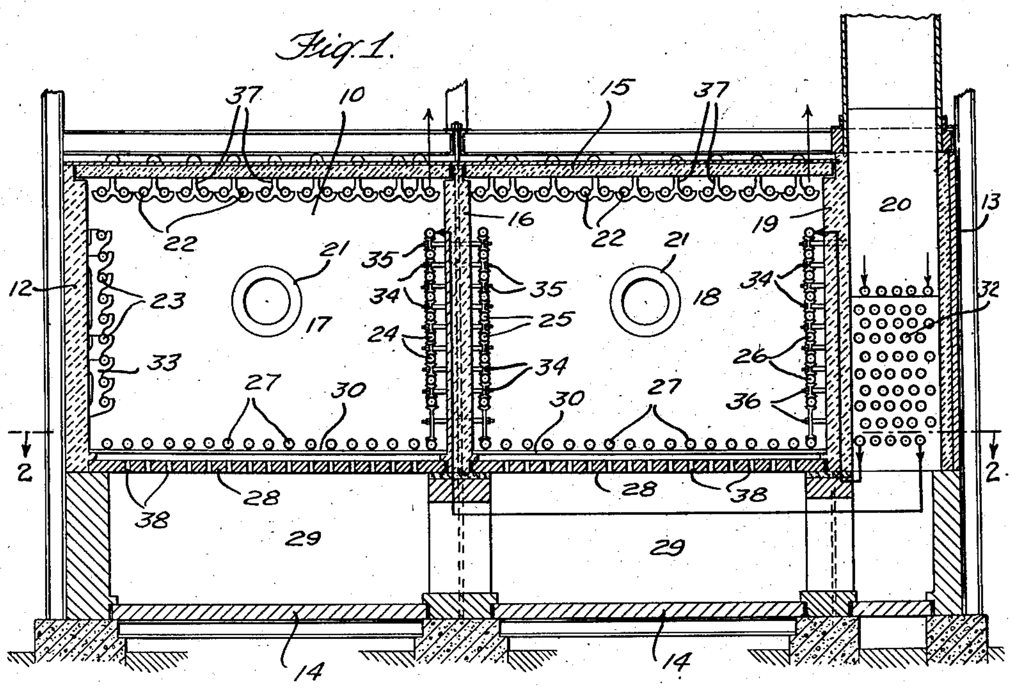

Fig. 2.

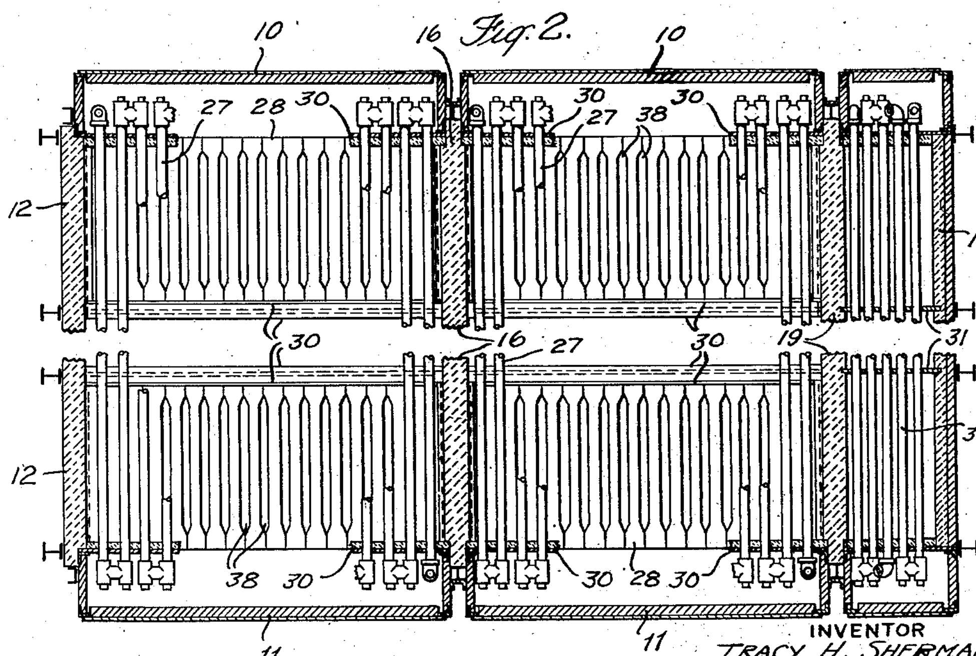

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Fig. 3.

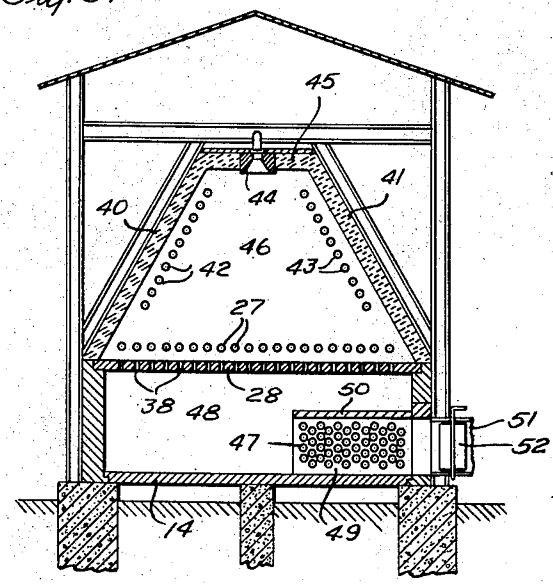
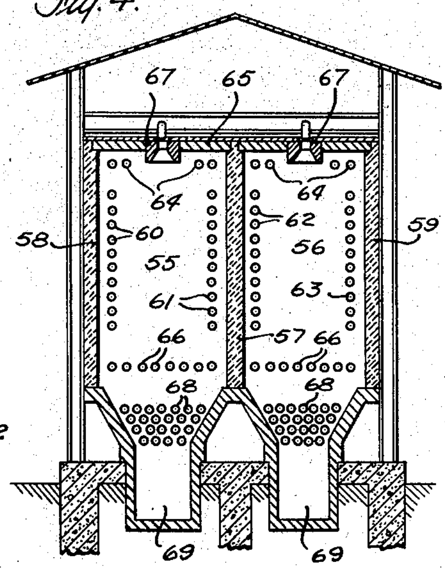


Fig. 4.



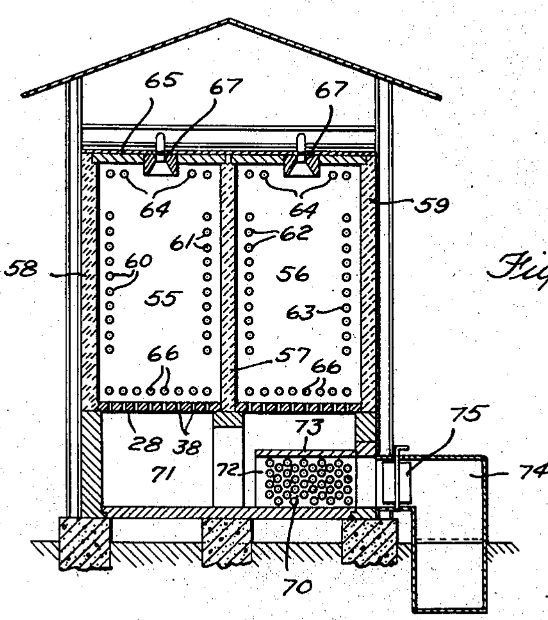


Fig. 5.

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Fig. 6.

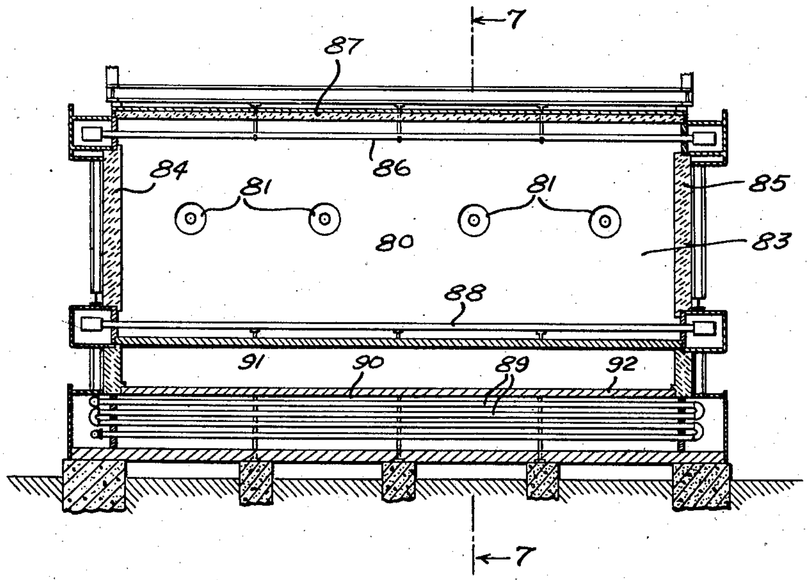
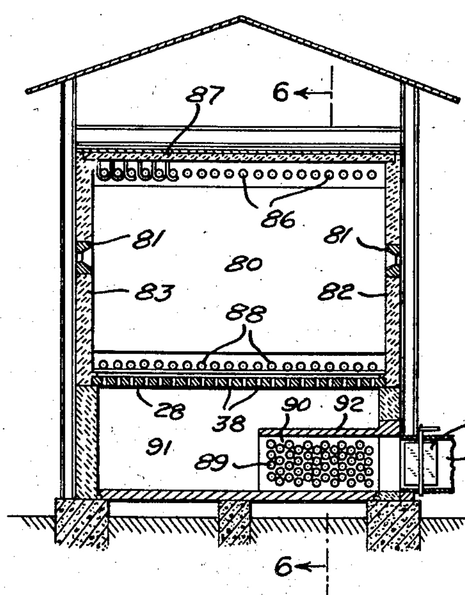


Fig. 7.



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Patented Nov. 30, 1943

2,335,317

UNITED STATES PATENT OFFICE

2,335,317

FLUID HEATER

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Application March 13, 1940, Serial No. 323,706

7 Claims. (Cl. 122—356)

This invention relates to heating, and more particularly pertains to apparatus for the heating of fluids such as petroleum and the like.

Controlled uniform heating is of prime importance when heating fluids, such as petroleum, that break down and produce undesirable substances when overheated. Hence the rate of applying heat must be within a maximum allowable limit and it is most desirable that all of the tubes of a tube still which are exposed directly to the source of heat, absorb heat at or near the maximum allowable rate for their entire length. An arrangement of this type is preferable to an arrangement in which tubes in cooler parts of the furnace absorb heat at considerably below the maximum allowable rate due to the fact that the latter arrangement is uneconomical because of wasteful use of heating surface.

The present invention provides heating apparatus which fulfill the requirement of uniform heating of the tubes in a practical manner. In one form of the invention, oil or gas is burned in conventional burners located in one of the walls of a combustion chamber, proportioned to insure complete combustion of the fuel and uniform temperature throughout, and heat absorbing tubes are symmetrically arranged about this source of heat in a casing lined with refractory material. As the hot gases cool because of heat radiated to the heat absorbing surface of the surrounding tubes, the gases fall by gravity to the bottom of the chamber because of their increased density. The gas outlet is at the bottom of the chamber and some of the heat absorbing tubes extend across the gas outlet in spaced relationship to each other, so that the cooled gases stream between these tubes and are collected in a chamber below the combustion chamber and thereafter are passed countercurrent between the tubes of a convection bank or an economizer at high velocity induced by the pull of a stack or induced draft fan. The stack draft also assists the gravity flow of furnace gases between the tubes at the bottom of the furnace chamber, and, to insure the gases being distributed substantially evenly over the entire horizontal area of the furnace chamber, the bottom tubes are closely spaced, or a distributing baffle is located below or on these tubes. The bottom tubes are subjected to heating by convection as well as radiation, but because the mass flow of gases past these tubes is very low, the heating by convection is definitely moderated and serves to compensate for a deficiency of radiant heat absorbed by these tubes due to their location in the cooler part of the furnace. The convection bank or economizer may be located in a separate chamber outside the casing of the furnace chamber, or in the chamber directly below it, as determined by local conditions or whether an overhead or underground flue is desirable. While the foregoing describes one form of the invention, it will be understood that other forms of the invention may be utilized without departing from the principles of the invention.

The preferred heater arrangement utilizes a rectangular furnace chamber of the required length which is lined with heat absorbing surface on all four sides. The furnace gases flow naturally from the bottom of the furnace chamber, thus dispensing with bridge walls. In consequence of the omission of bridge walls it is possible to proportion the furnace more nearly on the basis of liberation of heat units per cu. ft. of furnace volume and the relative location of burners and heating surface. The result is greatly reduced overall dimensions and economy of space occupied.

Heater arrangements embodying the invention are flexible inasmuch as small gas burners can be arranged in the roof or side walls closely spaced for the full length of the furnace, the room required being provided between tubes. Other fuel burners may be located in the end walls if desired or required. One or more heater cells each independently fired and having individual or collective economizers or convection sections may be employed. In consequence, any number of streams can be heated in one heater with adequate control of the heat supplied to each. Sufficient radiant heat absorbing surface can be provided economically to prevent excessive furnace temperatures with a minimum quantity of excess air, so that stack losses are reduced to a minimum. Because the arrangement lends itself to small overall dimensions, radiation losses from the walls of the casing are minimized. For these reasons the thermal efficiency is high with corresponding low fuel consumption.

Heaters embodying the invention combine the following advantages:

1. The entire length of every tube is uniformly exposed to the source of heat.

2. The average rate of heat absorption is not limited by the possibility of over absorption of any particular parts of the exposed surface as where bridge walls or baffles are used.

3. The design is flexible in that many different arrangements are possible.

4. The design is most compact.

5. The construction follows well understood practice and because of its simplicity, is inexpensive.

6. High thermal efficiency at low furnace temperature results in good fuel efficiency.

7. As all refractory lining of the furnace is protected by heat absorbing surface no particular part of which is subjected to overheating, the cost of upkeep is small.

The invention will be understood from the following description when considered in connection with the accompanying drawings forming a part thereof, and in which:

Fig. 1 is a transverse vertical sectional view showing more or less diagrammatically, a heater embodying one form of the invention;

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

Fig. 3 is a transverse vertical sectional view showing more or less diagrammatically, another form of heater embodying the invention;

Fig. 4 is a view similar to Fig. 3, showing a further form of the invention;

Fig. 5 is a view similar to Fig. 4, illustrating a further form of the invention;

Fig. 6 is a longitudinal vertical sectional view on line 6—6 of Fig. 7, showing a further form of heater embodying the invention, and

Fig. 7 is a transverse vertical sectional view taken on line 7—7 of Fig. 6.

Like characters of reference refer to the same or to similar parts throughout the several views.

Referring to the drawings, the form of heater shown in Figs. 1 and 2, has two independently fired furnaces with the convection bank of tubes disposed at one side of one of the furnaces. The same general arrangement may be employed with a single furnace, or with more than two furnaces. As shown, the heater has front and rear walls 10 and 11, side walls 12 and 13, a bottom 14, and a roof 15, which form a substantially rectanglar enclosure. A vertical wall 16 parallel to the side walls 12 and 13 divides the enclosure into two furnaces 17 and 18, and a similar vertical wall 19 separates furnace 18 from the convection heating zone 20. Each furnace 17 and 18 is fired by a fuel burner 21 located in the front wall 10. A plurality of burners may be utilized to fire each furnace if desired.

Heat absorbing tubes are symmetrically arranged about the burner in each furnace. A bank of roof tubes 22 is supported just below the roof 15 of each furnace, and a bank of wall tubes is supported adjacent each side wall of each furnace. In furnace 17, tube bank 23 is disposed adjacent side wall 12, and tube bank 24 is located adjacent wall 16, while in furnace 18, tube bank 25 is supported adjacent wall 16, and tube bank 26 is mounted in front of wall 19. A row of tubes 27 defines the bottom of each furnace chamber 17 and 18. These tubes are closely spaced and extend parallel to the roof tubes 22 as shown, and at a somewhat greater vertical distance from the burner 21 than the roof tubes, although this distance may be varied as desired.

In the embodiment of the invention illustrated in Figs. 1 and 2, a distributing baffle 28 extends parallel to and below the tubes 27 of each furnace in closely spaced relationship thereto. Each baffle is provided with elongated slots or narrow gas passages 38 which are disposed in alignment with each of the tubes 27 with the exception of the tubes at each end of the bank. The slots or passages 38 in the distributing baffle 28 have a dimension in a direction transverse to the axes of the tubes 27, which is substantially no greater than the outside diameter of the tubes with which they are in alignment. It will be understood, however, that the distributing baffles may be omitted if desired, in which event, the tubes 27 will be spaced sufficiently close to insure that the gases produced in each furnace will be distributed substantially evenly over the entire horizontal area of the furnace chamber.

The space between the bottom 14 and the distributing baffle 28 is divided longitudinally into a plurality of gas passages 29 by tube supports 30, and the gas passage through the convection section 20 is similarly divided by tube supports 31 from the bottom thereof to an elevation above the convection tube bank 32. If desired, a series of dampers or other fluid flow control devices not shown on the drawings, one for each of the gas passages, may be utilized above the convection bank 32, whereby the flow of gas through each of the gas passages may be independently controlled and the distribution of the heating effect over the lengths of the furnaces may be controlled.

The fluid to be heated is delivered to the upper end of the convection bank 32 simultaneously at two points, and flows downwardly through the bank in parallel paths countercurrent to the upflowing gases. One stream of fluid after passing through the convection bank is delivered to the top row of side wall tubes 24 in furnace 17 and flows downwardly through that bank of tubes to the right hand end, as viewed in Fig. 1, of the bottom tubes 27, through the bottom tubes to the left hand end of the row thereof and into the lowest row of the wall tubes 23, upwardly through these tubes 23 and into the left hand end of the roof tube bank 22, and after flowing through all the tubes of this bank, the heated fluid is discharged from the right hand end of the bank. The other stream of fluid is delivered to the top tube of wall tube bank 26 and flows through this bank, the bottom bank, wall bank 25 and roof tube bank 22 in furnace 18 in the same manner as in furnace 17. The flow of the fluid to be heated may be otherwise, with the sequence of flow through the several tube banks as desired.

Any suitable means may be utilized for the support of the tubes in the heater and also for the support of the distributing baffle if used. As shown, the convection bank of tubes 32 is supported from the foundation. The bottom tubes 27 are also supported from the foundation independently of the support of the distributing baffle. The tubes 27 are supported adjacent their ends and at spaced points intermediate their ends on the tube supports 30. The side wall tubes 23 are supported on side wall 12 by a plurality of spaced supporting brackets 33 which extend through the wall and are secured to the steel framework of the heater setting. The wall tubes 24, 25 and 26 are supported from the heater foundation. The bottom tube of each of these wall tube banks is supported by spaced pedestals which rest on the foundation, and each of the other tubes in the bank is supported on the tube next below by a plurality of spacing blocks 34 having arcuate tube engaging surfaces. The spacing blocks for the tubes 24 and 25 are secured together by bolts 35 which extend between blocks at the same elevation and which pass through sleeves to maintain the blocks in proper spaced relationship. The spacing blocks for the wall tubes 26 are maintained in position by bolts 36 which pass through sleeves and are secured to the wall 19. These blocks are proportioned to hold the tubes firmly when hot, thereby avoiding the accumulated expansion of a long support made in one piece. This tube supporting arrangement will permit of the easy removal and replacement of the wall tubes. The roof tubes 22 are supported in hangers 37.

In the event the distributing baffle 28 is employed and is disposed below the bottom tubes as shown in Figs. 1 and 2, it is supported preferably, entirely by the heater foundation and completely independently of the bottom tubes 27. This manner of supporting the distributing baffle possesses certain advantages, among which the following advantages are included. If the tubes distort, the baffle is not affected in any way. Since the baffle is spaced from the bottom tubes, better radiation of heat from the baffle to the lowermost portions of the bottom tubes is obtained, so that with the heat radiated from the furnace, the entire circumference of each of the bottom tubes is exposed to radiation. One or more of the bottom tubes can be removed and replaced without affecting the baffle.

In operation, as the hot gases produced by the burner in each of the furnaces become cooled due to heat radiated to the heat absorbing surface of the tubes in the furnace, the gases fall by gravity to the bottom of the chamber due to their greater density. The cooled gases stream between the bottom tubes, and where a distributing baffle is employed, the gases pass through the slots in the baffle and into the gas passage 29 at the bottom of the heater, whence they flow over the convection tube bank 32 and out to the stack. The stack draft assists the gravity flow of the furnace gases between the bottom tubes and induces a high velocity of gas flow over the tubes 32 of the convection bank. The bottom tubes are subject to heat absorbed both by convection and radiation, but due to the face that the mass flow of the gases past the bottom tubes is very low, the heating by convection is greatly modified but serves to compensate for a deficiency of radiant heat absorbed by these tubes due to their location in the cooler part of the furnace. The spacing of the bottom tubes 27 as previously mentioned, or the use of the distributing baffle 28, or both, assures a control of the flow of the gases in each furnace chamber so that the gases are distributed substantially evenly over approximately the entire horizontal area of each furnace chamber. Distribution of the heating effect over the length of each furnace is also controlled by controlling the flow of gases through each of the gas passages 29 as hereinbefore mentioned. It is understood that the fluid after having passed through the tubes of the convection bank 32 may be introduced into any one or more of the tube banks in each furnace chamber, and that the fluid circuit through either or both of the furnace chambers may be varied as desired.

The form of heater shown in Fig. 3 differs from the arrangement shown in Figs. 1 and 2, essentially in the location of the burners and the convection section, and in the vertical inclination of the side walls. In Fig. 3, the side walls 40 and 41 above the distributing baffle 28, are inclined toward each other and are lined with side wall tubes 42 and 43 respectively. One or more burners 44 are disposed in the roof 45 so as to fire vertically downwardly into the combustion or furnace chamber 46. The convection section 47 is disposed in the chamber 48 below the distributing baffle 28 in a gas passage 49 formed in part by the wall 50. Gases leaving the convection section flow out of a flue 51 which is controlled by a damper 52. The operation is substantially the same as the operation of the heater shown in Figs. 1 and 2. This heater may have one or a plurality of furnaces, and one or more burners may be disposed in one or both side walls, or in one or both end walls, instead of, or in addition to, the roof burners. It will be understood that the distributing baffle 28 may be omitted, in which event the spacing of the bottom tubes 27 will be close enough to provide for substantially even distribution of the gases over the entire horizontal area of the furnace chamber.

In Fig. 4, the arrangement is like the heater shown in Figs. 1 and 2 with the principal exceptions of the omission of the distributing baffle, the location of the burners and the convection sections, and the use of roof tubes and underground flues. The heater is divided into two furnace chambers 55 and 56 by a vertical partition wall 57 located midway between the side walls 58 and 59. Furnace 55 has wall tubes 60 and 61, and furnace 56 has wall tubes 62 and 63. Each furnace has roof tubes 64 below the roof 65, and bottom tubes 66 which are spaced sufficiently closely to provide substantially even distribution of the gases over the entire horizontal area of the furnace chamber. One or more burners 67 are disposed in the roof of each furnace in such manner that they fire vertically downwardly. A convection section 68 is located below the bottom tubes 66 of each furnace chamber, and after the gases from each furnace flow over the section 68, they enter an underground flue 69. The operation is substantially the same as the operation of the heater shown in Figs. 1 and 2 with the exception of the function performed by the distributing baffle 28. The burners may be mounted in the end or side walls, or both, either in lieu of, or in addition to the burners 67 in the roof. The roof tubes may be omitted, and tubes may be mounted adjacent one or both of the end walls, if desired. Additionally, a distributing baffle may be used below the bottom tubes 66.

The form of heater shown in Fig. 5 is the same as that shown in Fig. 4 with the exception of the distributing baffle, and the location of the convection section. The convection section 70 is similar to the convection section 47 of Fig. 3, and is disposed in the gas chamber 71 below the distributing baffle 28. Section 70 is located in a gas passage 72 which is formed in part by a partition wall 73. After the gases have passed over the tubes of the convection bank 70, they enter a flue 74 which is controlled by a damper 75. From the description of the operation of the forms of heaters previously described, the operation of this form of heater will be apparent.

In the embodiment of the invention shown in Figs. 6 and 7, the heater has a single furnace chamber 80, with a plurality of burners 81 in opposed walls of the furnace. As shown, these burners are located at approximately the same elevation in the front and rear walls 82 and 83, but they may be located, if desired in the side walls 84 and 85. Roof tubes 86 are supported below the roof 87, and a row of bottom tubes 88 are maintained above the distributing baffle 28. The convection section 89 is like the convection section in Figs. 3 and 5, and is positioned in a gas passage 90 formed in the chamber 91 partly by the partition 92. A damper 93 controls the flue 94. As in the case of some of the previous embodiments of the invention, the distributing baffle 28 may be omitted if desired, and if omitted, the bottom tubes will be spaced to ensure substantially equal distribution of the gases throughout the horizontal area of the furnace chamber. Tubes may be utilized on the front or rear wall, or both, and additional burners may be used which fire downwardly through the roof 87. In view of previous descriptions of the operation of prior forms of heaters, the operation of the form shown in Figs. 6 and 7 will be apparent.

It will be understood that the invention is not limited to the particular embodiments of the invention which have been selected for illustration and description. It will be apparent to those skilled in the art that changes may be made in the form, location and relative arrangement of the several parts of each of the embodiments disclosed without departing from the principles of the invention. For example, more than a single row of tubes extending across the gas outlet of each furnace may be used, either with or without a distributing baffle or the equivalent. With two or more rows of these tubes without a distributing baffle, the tubes in each row will ordinarily be staggered with respect to the tubes in the adjacent row or rows, and the spacing of the tubes in each row and the spacing of the rows will be such as to control the flow of gases so that substantially equal distribution of the gases through the horizontal area of each furnace will be obtained. Additionally, control of the flow of the gases out of the furnace and consequent distribution of the gases through the horizontal area of the furnace may be obtained by providing one or more of the rows of the bottom tubes with extended surfaces. One such arrangement would consist of longitudinally extending fins for the bottom tubes of the furnace. These fins would be diametrically opposed on each bottom tube with all the fins lying substantially in a horizontal plane and with adjacent fins of adjacent tubes spaced apart a distance sufficient to provide gas outlet openings for the flow area required for the gas distribution desired. Or, a single longitudinally extending fin on each bottom tube may be used, the arrangement being such that the fins all lie substantially in a horizontal plane and extend from the same side of each tube, with the outer longitudinal edge of each fin being spaced from the wall of the adjacent tube to provide the size of gas outlet desired. Ordinarily, these fins will be welded to the tubes but they may be secured permanently thereto by other means, or they may be removably attached to the tubes by having the oppositely disposed fins secured to arcuate straps at spaced intervals, and hanging the straps and the fins on the tubes.

In lieu of using a distributing baffle which is entirely independent of the bottom tubes, means which perform the function of the distributing baffle may be supported directly on or by the bottom tubes. For instance, if the bottom tubes are provided with horizontally extending fins as previously described, refractory or tile slabs or blocks may be laid on the fins and spaced apart to provide the size of gas ports desired. Or, if two or more rows of tubes extend across the gas outlet, the distributing baffle, or the component parts thereof, may be supported directly upon, or from, the lowermost row of these bottom tubes. Other means for performing the same function will occur to those skilled in the art and may be utilized.

Any suitable firing arrangement may be utilized for the furnaces, inasmuch as the invention lends itself readily to the use of any desired number of burners in any or all of the side walls of each furnace as well as in the roof thereof. Any combination of burners with respect to number and location may be employed within practical limits.

From the foregoing it will be understood that the invention is not to be limited excepting by the scope of the appended claims.

What is claimed is:

1. Fluid heating apparatus comprising walls forming an unobstructed furnace having its bottom open to provide an outlet for the gases of combustion in the furnace, fluid fuel burner means for firing the furnace in one of said walls, substantially straight fluid conducting tubular members adjacent oppositely disposed enclosing walls of the furnace adjoining said one wall, said burner means being located substantially equidistantly between said oppositely disposed walls, other substantially straight, parallel tubular members extending across said outlet in a substantially horizontal row in substantially uniformly spaced relationship in said row, the spacing of said other tubular members being sufficiently close to provide substantially even distribution of the furnace gases over substantially the entire horizontal area of the furnace chamber, tubular members in said row being connected in series, the arrangement being such that the hot gases of combustion are cooled by radiating heat to the cooler tubular members thereby becoming more dense and falling to the bottom of the furnace and flowing over the tubular members extending across the outlet, and means forming a gas passage through which the cooled gases are withdrawn from the region below the tubular members extending across the gas outlet.

2. Fluid heating apparatus comprising walls forming an unobstructed furnace having its bottom open to provide an outlet for the gases of combustion in the furnace, fluid fuel burner means in one vertically extending wall of the furnace for firing the furnace, fluid conducting tubular members adjacent opposed vertically extending walls of the furnace adjoining said one wall, said burner means being located substantially equidistantly between said oppositely disposed walls, other substantially straight, parallel tubular members extending across said outlet in a substantially horizontal row in substantially uniformly spaced relationship in said row, the spacing of said other tubular members being sufficiently close to provide substantially even distribution of the furnace gases over substantially the entire horizontal area of the furnace chamber, tubular members in said row being connected in series, the arrangement being such that the hot gases of combustion are cooled by radiating heat to the cooler tubular members thereby becoming more dense and falling to the bottom of the furnace and flowing over the tubular members extending across the outlet, and means forming a gas passage through which the cooled gases are withdrawn from the region be-

low the tubular members extending across the gas outlet.

3. Fluid heating apparatus comprising walls forming an unobstructed furnace having its bottom open to provide an outlet for the gases of combustion in the furnace, fluid fuel burner means in the roof of the furnace for firing the furnace, fluid conducting tubular members adjacent oppositely disposed vertically extending walls of the furnace, said burner means being located substantially equidistantly between said oppositely disposed walls, other substantially straight, parallel tubular members extending across said outlet in a substantially horizontal row in substantially uniformly spaced relationship in said row, the spacing of said other tubular members being sufficiently close to provide substantially even distribution of the furnace gases over substantially the entire horizontal area of the furnace chamber, tubular members in said row being connected in series, the arrangement being such that the hot gases of combustion are cooled by radiating heat to the cooler tubular members thereby becoming more dense and falling to the bottom of the furnace and flowing over the tubular members extending across the outlet, and means forming a gas passage through which the cooled gases are withdrawn from the region below the tubular members extending across the gas outlet.

4. Fluid heating apparatus comprising walls forming an unobstructed furnace having its bottom open to provide an outlet for the gases of combustion in the furnace, means for firing the furnace, substantially straight fluid conducting tubular members adjacent at least one enclosing wall of the furnace, other substantially straight, parallel tubular members extending across said outlet in substantially uniformly spaced relationship, the spacing of said other tubular members being sufficiently close to provide substantially even distribution of the furnace gases over substantially the entire horizontal area of the furnace chamber, tubular members extending across said outlet being connected in series, the arrangement being such that the hot gases of combustion are cooled by radiating heat to the cooler tubular members thereby becoming more dense and falling to the bottom of the furnace and flowing over the tubular members extending across the outlet, baffle means below the tubular members extending across the gas outlet, said baffle means having elongated openings of a width not substantially greater than the outside diameter of said last mentioned tubular members, and means forming a gas passage through which the cooled gases are withdrawn from the region below said baffle means.

5. Apparatus for heating fluids comprising walls forming an unobstructed furnace having its bottom open to provide an outlet for the gases of combustion in the furnace, burner means in an end wall of the furnace for firing the furnace, substantially horizontally extending fluid conducting tubular members adjacent the inner sides of the side walls of the furnace, said burner means being located substantially equidistantly between said side walls, a substantially horizontal row of substantially straight, parallel tubular members extending across said outlet in substantially uniformly spaced relationship in said row, tubular members in said row being connected in series, the spacing of the tubular members in said row being sufficiently close to provide substantially even distribution of the furnace gases over substantially the entire horizontal area of the furnace chamber, the arrangement being such that the hot gases of combustion are cooled by radiating heat to the cooler tubular members thereby becoming more dense and falling to the bottom of the furnace and flowing over the tubular members extending across the outlet, and means forming a gas passage through which the cooled gases are withdrawn from the region below the tubular members extending across the gas outlet.

6. Apparatus for heating fluids comprising walls forming an unobstructed furnace having its bottom open to provide an outlet for the gases of combustion in the furnace, burner means in the roof of the furnace for firing the furnace, oppositely disposed walls of the furnace being vertically inclined and sloping outwardly toward the bottom thereof, substantially horizontally extending fluid conducting tubular members adjacent the inner sides of said oppositely disposed walls of the furnace, said burner means being located substantially equidistantly between said oppositely disposed walls, a substantially horizontal row of substantially straight, parallel tubular members extending across said outlet in substantially uniformly spaced relationship in said row, tubular members in said row being connected in series, the spacing of said other tubular members being sufficiently close to provide substantially even distribution of the furnace gases over substantially the entire horizontal area of the furnace chamber, the arrangement being such that the hot gases of combustion are cooled by radiating heat to the cooler tubular members thereby becoming more dense and falling to the bottom of the furnace and flowing over the tubular members extending across the outlet, and means forming a gas passage through which the cooled gases are withdrawn from the region below the tubular members extending across the gas outlet.

7. Apparatus for heating fluids comprising walls forming an unobstructed furnace having its bottom open to provide an outlet for the gases of combustion in the furnace, burner means in a vertically extending wall of the furnace for firing the furnace, substantially horizontally extending fluid conducting tubular members adjacent the inner side of the roof of the furnace, a substantially horizontal row of substantially straight, parallel tubular members extending across said outlet in substantially uniformly spaced relationship in said row, tubular members in said row being connected in series, said burner means being located substantially equidistantly between the tubular members adjacent the roof and said row of tubular members, the spacing of said other tubular members being sufficiently close to provide substantially even distribution of the furnace gases over substantially the entire horizontal area of the furnace chamber, the arrangement being such that the hot gases of combustion are cooled by radiating heat to the cooler tubular members thereby becoming more dense and falling to the bottom of the furnace and flowing over the tubular members extending across the outlet, and means forming a gas passage through which the cooled gases are withdrawn from the region below the tubular members extending across the gas outlet.

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