Feb. 24, 1942. F. H. PRAEGER 2,274,256

FLUID HEATER

Filed Aug. 24, 1939 3 Sheets-Sheet 1

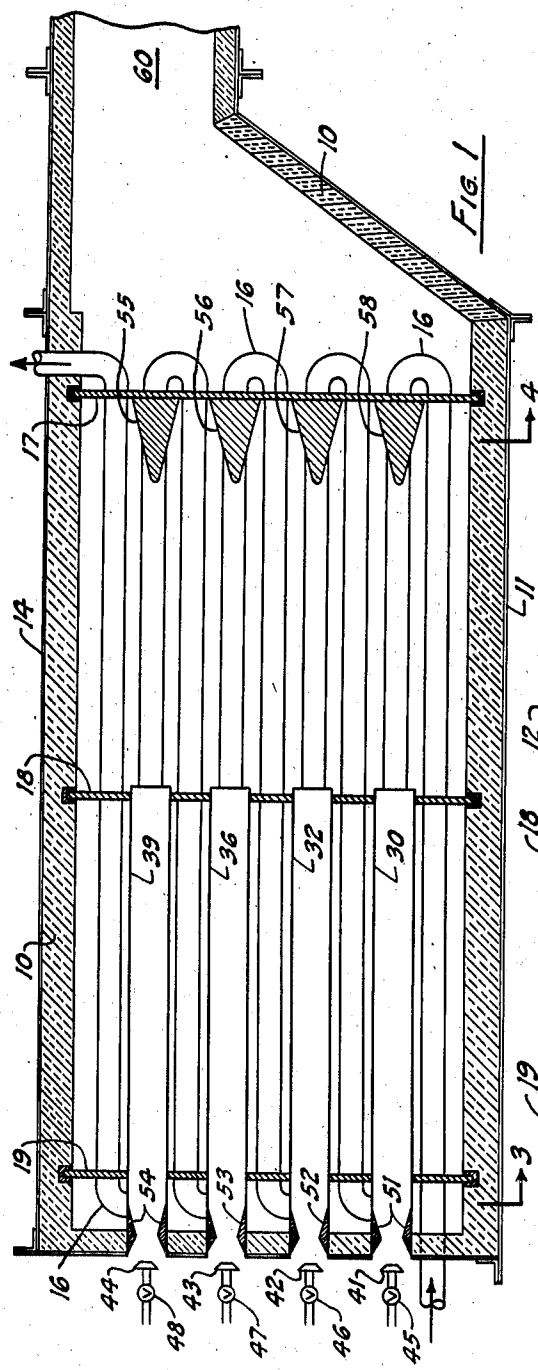


FIG. 1

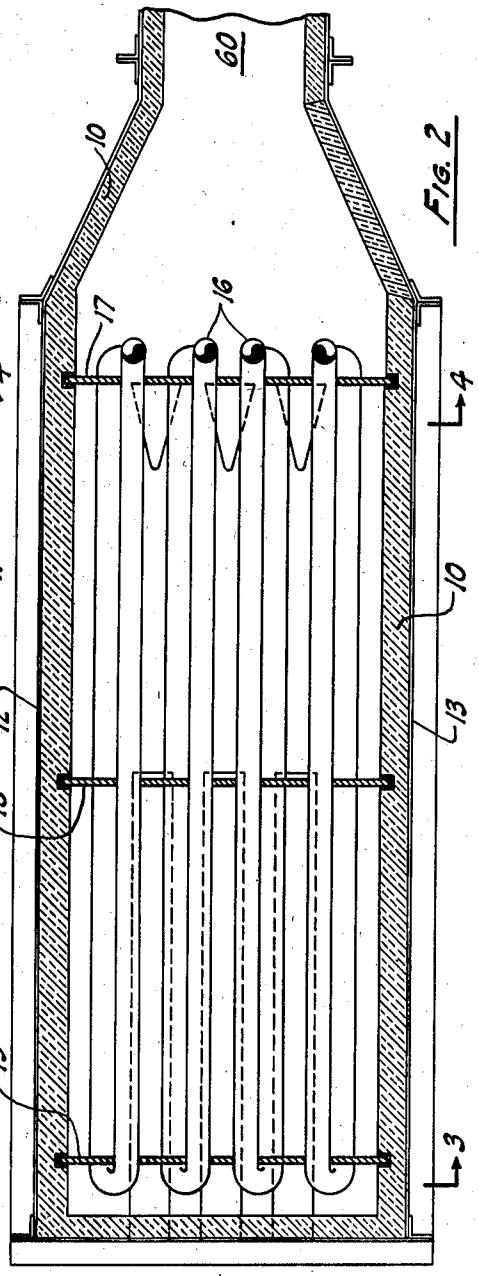


FIG. 2

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FLUID HEATER

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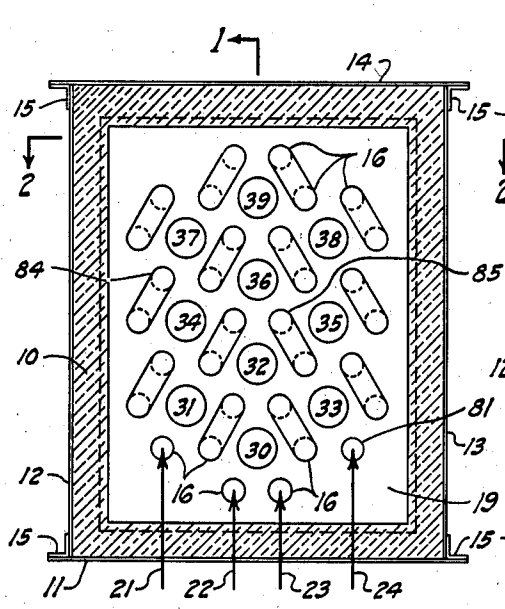


FIG. 3

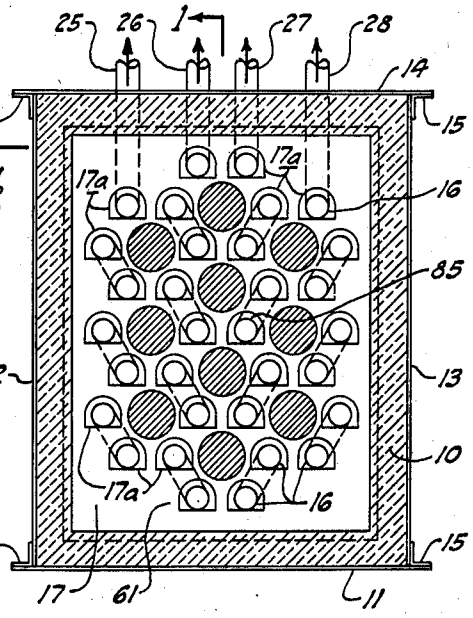


FIG. 4

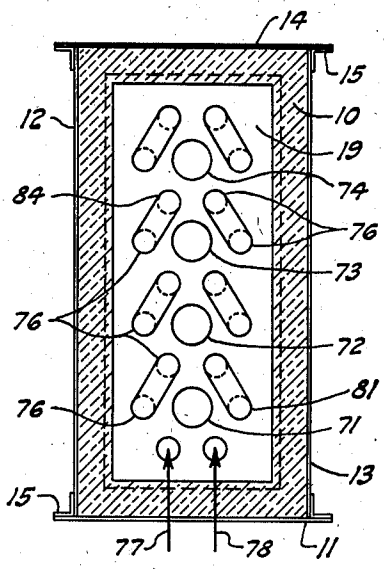


FIG. 5

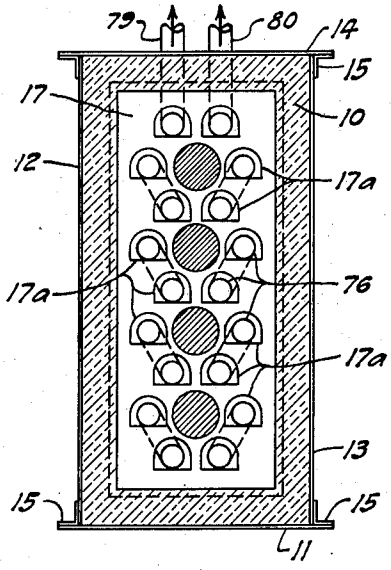


FIG. 6

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FLUID HEATER

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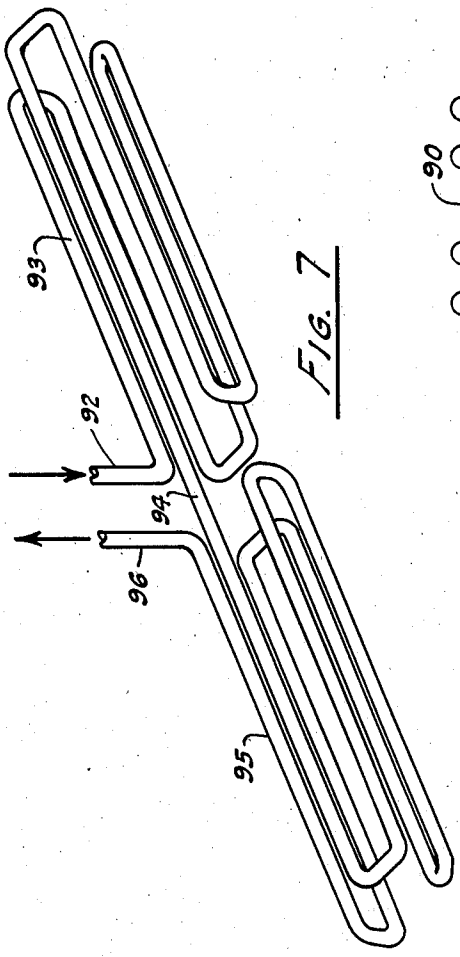


FIG. 7

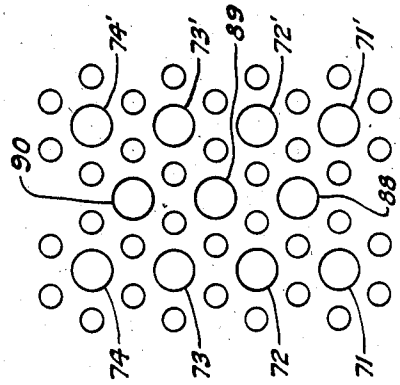


FIG. 11

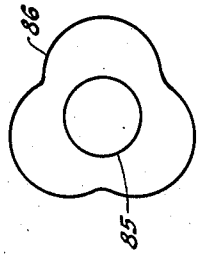


FIG. 10

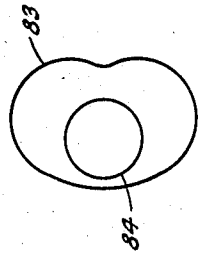


FIG. 9

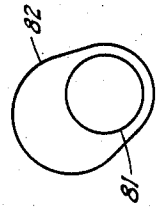


FIG. 8

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UNITED STATES PATENT OFFICE

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FLUID HEATER

Frank H. Praeger, Cynwyd, Pa., assignor to Alcorn Combustion Company, Philadelphia, Pa., a corporation of Delaware

Application August 24, 1939, Serial No. 292,313

8 Claims. (Cl. 122—356)

My invention relates to fluid heaters of the tubular type, more particularly to methods of and apparatus for elevating the temperature of a fluid, and has for an object the provision of a heater of exceptionally low cost and which is entirely satisfactory for its intended purposes.

In the petroleum industry there is frequently need for a heater capable of transferring one to ten million B. t. u.'s per hour to a fluid and in cost so low that the economies effected by the use of the heater are not diminished or lost as a result of high first cost and maintenance. For example, within this classification are the heaters used in pumping lines to lower the pumping cost by reduction in the viscosity of the oil or petroleum.

Another type of application is where steam is to be heated to a temperature of between 800° F. and 1000° F., the quantity of steam needed being much less than would warrant the installation of expensive boiler and superheater equipment.

It is an object of my invention to provide a fluid heater meeting the requirements of low cost, but in which the distribution of heat over the heating surface is relatively uniform, and the transfer rates therein well within permissible rates.

In carrying out my invention in one form thereof, I provide a plurality of muffles, or elongated tubular combustion chambers which extend centrally of adjacent circular or regular geometrical arrays of tubes. Within the muffles the combustion of fuel is initiated and to large extent completed, the muffles themselves being heated to incandescence or to a temperature for radiation at high rate from the walls thereof of heat to the tubes. The still burning gases issuing from the muffles, which are not at an excessively high temperature, pass generally axially of, but in increasingly greater convective contact with, the heat-asborbing tubes, and thence to a stack.

My invention, together with other objects and advantages thereof, will be more fully understood upon reference to the following description and the accompanying drawings forming a part of the specification and of which:

Fig. 1 is a vertical section taken through the center of a heater embodying my invention, and along the section line 1 of Fig. 3 or Fig. 4;

Fig. 2 is a horizontal section taken on the section line 2 of Fig. 3 or Fig. 4;

Fig. 3 is a vertical section taken on the section line 3 of Fig. 1 or Fig. 2;

Fig. 4 is a vertical section taken on the section line 4 of Fig. 1 or Fig. 2;

Fig. 5 is a vertical section of a modified form of a heater embodying my invention, the position at which the section is taken corresponding with Fig. 3;

Fig. 6 is a vertical section of the modified form of my invention, the position at which the section is taken corresponding with Fig. 4;

Fig. 7 illustrates a modified tube arrangement for a different flow of fluid through a heater;

Figs. 8 to 10 show heat-density curves illustrative of the operation of my invention; and

Fig. 11 illustrates a further modified arrangement of heat absorbing tubes within a heater embodying my invention.

Referring to the drawings, I have shown my invention in one form as applied to a petroleum heater comprising walls 10 formed of firebrick or equivalent refractory and encased in and supported by a structural steel frame comprising a base member 11, side wall members 12 and 13, and a roof member 14, the upper and lower members 11 and 14 overlying the members 12 and 13, Figs. 3 and 4, for the reception of angle supports 15 at each of the four corners thereof. The angle supports 15 may be riveted, welded or bolted to the frame members.

The fluid-conducting heat-absorbing structure comprises a plurality of tubes 16 disposed within the heater and supported by tube sheets 17, 18 and 19. The tubes may be connected for any desired sequence of flow therethrough, or in as many parallel groups as may be required from consideration of pressure drop therethrough. Referring particularly to Fig. 3, it will be observed that the tubes 16 are connected for the flow of four streams of fluid, which enter respectively at the firing end of the heater by way of inlet lines 21, 22, 23, and 24. As viewed in Fig. 3, the stream 21 passes through the left-hand row of tubes; the stream 24 through the right-hand row; and the streams 22 and 23 respectively through the intermediate vertical row of tubes 16; each of the streams, Fig. 4, leaving the heater at the stack end thereof by way of exit lines 25, 26, 27 and 28.

The tubes of the several vertical rows are disposed symmetrically about firing muffles or elongated tubular combustion chambers 30–39, the tubes about each combustion chamber being shown as located at the apices of a hexagon, and the plurality of hexagons being contiguous. While the hexagonal arrangement may be preferred, in accord with my invention the tubes

may be disposed in other geometrical relations as, for example, an octagon, or there may be some departure from a purely symmetrical or regular geometrical arrangement and a polygonal arrangement used.

Each of muffles **30–39** is constructed of a material which may be heated to incandescence, or to a temperature at which radiant heat may be effectively transmitted to the heat-absorbing surfaces. For example, the muffles may be constructed of silicon carbide, though I prefer a refractory metal having a high heat conductivity, such, for example, as one of the high heat-resistant alloys now known to the art and of which may be mentioned as exemplary an alloy comprising nickel 12%, chromium 30%, carbon .35%, and iron. With an alloy of this character the wall of each muffle may be extremely thin, as for example, five-sixteenths of an inch, or less, with the result that a very substantial proportion of the total heat generated may be transferred by direct radiation to the fluid-conducting, heat-absorbing tubes.

In operation fuel, oil, or gas, or both, is by a burner introduced into the inlet end of each muffle in mixture with an adequate amount of air to insure rapid combustion thereof within each muffle. All burners may be of the same construction, and as diagrammatically illustrated in Fig. 1, the burners **41–44** respectively under the control of valves **45–48** project fuel into the muffles **30**, **32**, **36**, and **39**. For the introduction of air each muffle may be provided with an insert forming one or more constrictions. For the muffles **30**, **32**, **36** and **39** the inserts **51–54** have been illustrated. In lieu of the Venturi sections provided by the inserts **51–54**, air for combustion may be mixed with the fuel in other ways known to the art.

While the combustion of fuel may be substantially complete within the muffles, nevertheless the gases, which may still be burning, are in any event highly radiant, in terms of the amount of radiant heat which may be transmitted to the tubes. From the ends of the muffles, the gases are projected horizontally, and with substantial velocity, so that impingement upon the tubes **16** is minimized. To prevent escape of radiant heat from the fluid-conducting, heat-absorbing zones, and to insure flow of the gases in intimate heat-exchange with a part of the tubes, heat insulating or refractory material which may be in the form of targets, may be secured to the tube sheet **17** to form targets for the gases from the muffles. The targets also protect those portions of the tube sheet directly opposite the muffles. As shown in Fig. 1 refractory cones **55**, **56**, **57** and **59** are opposite the muffles **30**, **32**, **36**, and **39**, while in Fig. 4 there is shown in cross section a cone opposite each of muffles **30–39**.

While the tube sheets **18** and **19** may be relatively imperforate except for the openings for the reception of the heat-absorbing tubes, and the muffles, the tube sheet **17** is provided with openings **17***a*, Fig. 4, for the exit of the combustion gases to a flue or duct **60**, leading to a stack not shown. The openings **17***a* extend on opposite sides of each tube and upwardly thereabove, the net cross-sectional area of each opening available for the passage of gases therethrough, being large enough so that the maximum quantity of gases which may be generated as a result of the combustion of fuel in the muffles may readily pass to the flue **60**. As an example and not by way of limitation, for a one million B. t. u. per hour heater, Figs. 5 and 6, with 3½ inch outside diameter tubes, a net area for each opening of about eleven square inches would be adequate for a heater having some 18 horizontally disposed tubes.

In the operation of my invention, the fluid to be heated, oil in liquid or vapor phase, water or steam, or other fluid, may be circulated through the tubes **16**, and fuel supplied to the burners under the control of the individual valves **45–48** or jointly under the control of a main valve, not shown. The fuel in mixture with combustion-supporting air is burned within each of the muffles, rapidly raising them in temperature until radiant heat in large quantity is transmitted to the fluid-conducting, heat-absorbing tubes. The hot combustion gases, as they issue from the muffles, also radiate heat in large quantity and at high rate to the tubes directly exposed thereto. Those portions of the tubes to the right of the discharge ends of the muffles, as viewed in the drawings, also receive heat by convection, and in the region approaching the tube sheet **17** a substantial quantity of heat is transmitted by convection. Danger of overheating the tubes beyond the discharge ends of the muffles is minimized by providing muffles of such length that the temperature of the gases issuing from the muffles, and the completeness of the combustion within the muffles is sufficient to prevent overheating, or excessive rate of transfer thereto. For many designs of heaters, the muffles should be about one-fourth the length of the tubes as between tube sheets **17** and **19**, though they may be longer, and possibly somewhat shorter.

With respect to the modification of my invention shown in Figs. 1 to 4, I provide especially efficient heat-absorbing surface, since each of the muffles **30–39** is surrounded by tubular heat-absorbing surface, which receives radiant heat. Moreover, all tubes in all modifications other than the outermost tubes of the assembly, receive heat directly by radiation from two or more muffles; and a large proportion of the tubes of a group or assembly receive radiant heat directly from three muffles. The result of transmitting heat by radiation from muffles circumferentially spaced with respect to a particular tube is to supply heat uniformly and at high rate throughout the circumferential area of that tube. This eliminates uneven heating of tubes, and the effective heat-absorption area of the tube is greatly increased; also, mechanical and thermal strains are minimized by the uniform application of heat throughout the entire circumferential surface of each tube, and there is a correspondingly greater absorption of heat, quantitatively considered. As a result of the foregoing, for a heater of given capacity, the size and cost is greatly reduced, and the heating conditions obtaining are satisfactory.

It is to be understood that the number of muffles and the number of tubes are to be selected with reference to the capacity of the heater, which may be of any desired size, depending upon the number of muffle and tube assemblies utilized, and for any size of heater, the heat-load is carried by a plurality of burners, muffles, and tube-assemblies, the burning of fuel from a plurality of burners contributing to uniformity of heat application.

Since the tubes of each group or assembly, for example the hexagonal group about muffle **33** are equidistant from a center line through the unobstructed space extending longitudinally of the tubes, the heat application is equalized as between adjacent tubes. For the outermost tubes within

the fire chamber, the heat-density curves are represented by curve 82 of Fig. 8 plotted from the circumference of a typical tube, 81, and represents the heat application throughout the radiant section, as between the tube sheets 18 and 19. As shown the application of heat is greatest over that portion of tube 81 which "sees" the muffle 33.

For the next adjacent row of tubes, those receiving heat from two radiant sources of muffles, the heat-density curves are represented in Fig. 9 by the curve 83 plotted from the circumference of typical tube 84 of, and common to, the hexagonal groups around muffles 34 and 37. The heat application is relatively uniform over more than half the circumferential surface of tube 84, and is distributed over the surface in view of muffles 34 and 37.

For the remaining tubes still nearer the center of the fire chamber than the first and second outer rows, such for example as typical tube 85, radiant heat is received from sources (the muffles and gases) displaced from each other by approximately 120°, so that throughout the entire circumferential area radiant heat is applied at uniformly high rate. The heat density curve 86 of Fig. 10 represents the heat application to these inner tubes, and is plotted from the circumference of typical tube 85. Stated in another way, when all the tubes of a group also comprise tubes of other groups maximum uniformity of heat application is secured. Illustrative of this fact are the groups about muffles 32 and 36 of Fig. 3, all tubes of which form one or more tubes of other groups such as the groups about muffles 30, 31, 33, 34, 35, 37, 38, and 39. In all cases the maximum rate of application of heat per unit area remains the same as shown by equality of the greatest ordinates in Figs. 8–10. The heat input, however, is greater for the tubes heated from more than one muffle.

Referring to Figs. 5 and 6, for a relatively small heater, for example, of about one million B. t. u.'s heat input per hour, only a single row of muffles 71, 72, 73, and 74 need be provided. Each muffle is provided with its own burner, valve, and Venturi section, as described above. In this modification of my invention I have also illustrated the tubes 76 disposed in hexagonal grouping around the respective muffles 71–74, with inlets 77 and 78 and with outlets 79 and 80. In this modification of my invention all but the outer rows of tubes receive heat from at least two muffles spaced circumferentially of each particular tube. In accord with this modification of my invention, no difficulty was encountered in superheating steam to upwardly of 1000° F.

For heaters of capacity intermediate the previously described embodiments, two heaters of the type shown in Figs. 5 and 6 may be assembled so that the adjacent tubes of the two heaters form hexagonal groups within which may be disposed muffles 88, 89 and 90. The hexagonal groups about muffles 71–74 bear the same reference numerals as in Figs. 5 and 6, and the duplicate assemblies or groups around muffles 71' and 74' the same numbers primed to indicate a construction similar to Figs. 5 and 6. In accord with the embodiment of my invention as shown in Fig. 11, the heat input is disproportionately higher than twice the unit heater of Figs. 5 and 6. Without increasing either the maximum tube wall temperature, or the number of tubes, the two units constructed as shown, with muffles 88–90, will develop at least 2.75 times the heating capacity of one of the heating units. This result is possible by the double duty imposed on the tubes forming the hexagonal groups around muffles 88—90 and the gases issuing therefrom. The maximum tube-wall temperature is not increased since the heat developed by muffles 88–90 is not applied to the heat absorption areas exposed to the heat generated from muffles 71–74 and 71'–74', but to heat absorption surfaces shielded therefrom. In consequence the average heat input to the tubes in hexagonal array around muffles 88–90 is increased without rise in the maximum tube-wall temperature.

In the modifications of my invention described above, the heat absorbing tubes extend between opposite end walls or tube sheets 17 and 19 of the heater, with the heating fluid alternately subjected to radiant and convection heat. In accord with the arrangement of Fig. 7, the fluid is first heated in the convection section comprising a hexagonal group of tubes 93 with inlet at 92, and outlet 94 from the convection section being a tube of a hexagonal group 95 comprising the radiant section. A firing muffle omitted for sake of clarity is concentric with a central axis of the hexagonal groups and extends three to six feet within the radiant section 95, or about one-fourth or more of the length of radiant and convection sections 93 and 95. Radiant heat is applied to the tubes of section 95 substantially solely by radiation and to the tubes of section 93 by convection and radiation. The fluid outlet is shown at 96.

If desired, the arrangement of Fig. 7 may be applied to the preceding modifications with slightly modified sequence of flow as required by cross overs between radiant and convection sections, only one of the hexagonal groupings being shown in Fig. 7.

In all modification, I have shown simple return bends, which may be welded to the ends of the tubes, but any suitable type of return bend may be utilized.

While I have shown particular embodiments of my invention, it will be understood that I do not limit myself thereto, since many modifications may be made and I therefore contemplate by the appended claims to cover any such modifications as fall within the spirit and scope of my invention.

What I claim is:

1. A fluid heater comprising a plurality of elongated tubular muffles formed of a heat radiating material, a plurality of tubes disposed in spaced relation with, and circumferentially of, each of said muffles, certain of the tubes being disposed in said circumferential relation with respect to at least two of said muffles for receiving concurrently therefrom radiant heat on different heat-absorption areas thereof, means located within the region occupied by said muffles for supporting said tubes and said muffles, a tube-sheet for supporting said tubes in spaced relation from the discharge ends of said muffles, said last-named tube-sheet having openings around the sides and above each of said tubes for the passage therethrough of combustion gases in convection heating relation with said tubes, and means for circulating through said tubes fluid to be heated.

2. A fluid heater comprising a plurality of groups of fluid-conducting, heat-absorbing tubes, each group having a plurality of tubes symmetrically disposed around a center line for that group which is parallel to the axes of the tubes, and a

plurality of tubes of one group being common to and forming part of, the symmetrical arrangement of the tubes of another group, an elongated tubular muffle disposed centrally of the tubes of each of said groups, said muffles of adjacent groups being disposed to radiate heat directly to spaced circumferential areas of a plurality of said tubes to equalize and maintain a high heat input throughout the circumferential area thereof, tube supports spaced lengthwise of said muffles for the support of the muffles and of the tubes, and at least another tube support disposed adjacent the ends of the tubes remote from said muffles, said last-named tube support having a plurality of openings for the exit of gases therethrough in intimate convection heat exchange with said tubes, and means for burning fuel within each of said muffles for the transfer by radiation from each of said muffles of a substantial portion of the generated heat.

3. A fluid heater comprising an outer and an inner row of tubes, said tubes of both rows being disposed in groups with the tubes of each group generally symmetrical about and equidistant from a central line for that group, a muffle disposed co-axially of each of said central lines for radiating heat to said tubes, said tubes of said inner row receiving heat by direct radiation from at least two of said muffles, a convection bank comprising tubes disposed in groups of the same general configuration as said first-mentioned groups of tubes and disposed individually to receive combustion gases from one of said muffles for convective heating of fluid therein, and means connecting all of said tubes for passage of fluid therethrough.

4. A fluid heater comprising an outer and an inner row of tubes, said tubes of both rows being disposed in groups generally symmetrical about and equidistant from a line central of each group, a muffle disposed co-axially of each central line for radiating heat to said tubes, said tubes of said inner row receiving heat by direct radiation from at least two of said muffles, a convection bank with the tubes disposed in groups of the same general configuration as said first mentioned groups and each group of convection tubes receiving convection gases directly from one of said muffles for convection heating of fluid therein, and means connecting all of said tubes for passage of fluid first through said convectively heated tubes and then through said radiantly heated tubes.

5. A fluid heater comprising a fire chamber, an outer and a plurality of inner rows of tubes within said chamber, said tubes of said rows being disposed in groups with the axes of the tubes of each group parallel and generally symmetrical about and equidistant from a central line for that group, and a tubular muffle disposed co-axially of each of said central lines for radiating heat to the tubes of each group, some of the tubes of one group comprising tubes of another group whereby tubes of said outer row receive heat largely from muffles individual thereto, and tubes of the next adjacent row receive heat from two muffles individual thereto, and the remaining tubes receive radiant heat from at least three of said muffles, each of the tubes receiving radiant heat from more than one muffle receiving it on heat absorption areas circumferentially spaced one from the other and not to substantial degree overlapping each other, a convection bank with the tubes thereof disposed in groups of the same configuration as said first-mentioned groups and each group of convection tubes disposed individually to receive combustion gases from one of said muffles for convection heating of the fluid, and means connecting all of said tubes for passage of fluid therethrough.

6. A fluid heater comprising a fire chamber, an outer and a plurality of inner rows of tubes within said chamber, said tubes of said rows being disposed in groups with the axes of the tubes of each group parallel and generally symmetrical about and equidistant from a central line for that group, and a tubular muffle disposed co-axially of each of said central lines for radiating heat to the tubes of each group, some of the tubes of one group comprising tubes of another group whereby tubes of said outer row receive heat largely from muffles individual thereto, and tubes of the next adjacent row receive heat from two muffles individual thereto, and the remaining tubes receive radiant heat from at least three of said muffles, each of the tubes receiving radiant heat from more than one muffle receiving it on heat absorption areas circumferentially spaced one from the other and not to substantial degree overlapping each other, a convection bank with the tubes disposed in groups of the same general configuration as said first-mentioned groups and each group of convection tubes disposed to receive gases from one of said muffles for convection heating of fluid therein, and means connecting all of said tubes for passage of fluid first through said convectively heated tubes and then through said radiantly heated tubes.

7. A fluid heater comprising a plurality of elongated tubular muffles formed of a heat radiating material, a plurality of tubes disposed in spaced relation with, and circumferentially of, each of said muffles, certain of the tubes being disposed in said circumferential relation with respect to at least two of said muffles for receiving concurrently therefrom radiant heat on different heat-absorption areas thereof, means located within the region occupied by said muffles for supporting said tubes and said muffles, a tube-sheet for supporting said tubes in spaced relation from the discharge ends of said muffles, said last-named tube-sheet having openings around the sides and above each of said tubes for the passage therethrough of combustion gases in convection heating relation with said tubes, means for circulating through said tubes fluid to be heated, and means for withdrawing gases from the heater on the side of said tube-sheet remote from said muffles.

8. A fluid heater comprising a plurality of tubes disposed parallel to each other and with their centers forming apices of adjoining hexagons, muffles for burning fuel in streams concentrically of, and individual to, each hexagonal group of tubes, spaced tube sheets for supporting said tubes in said hexagonal relationship, the tube sheet remotely located from said muffles having openings around the sides and top of the tubes extending therethrough for the passage of combustion gases in convective heating relation with said tubes, and means for withdrawing the gases from the heater without return thereof to the region in which said muffles are located.

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