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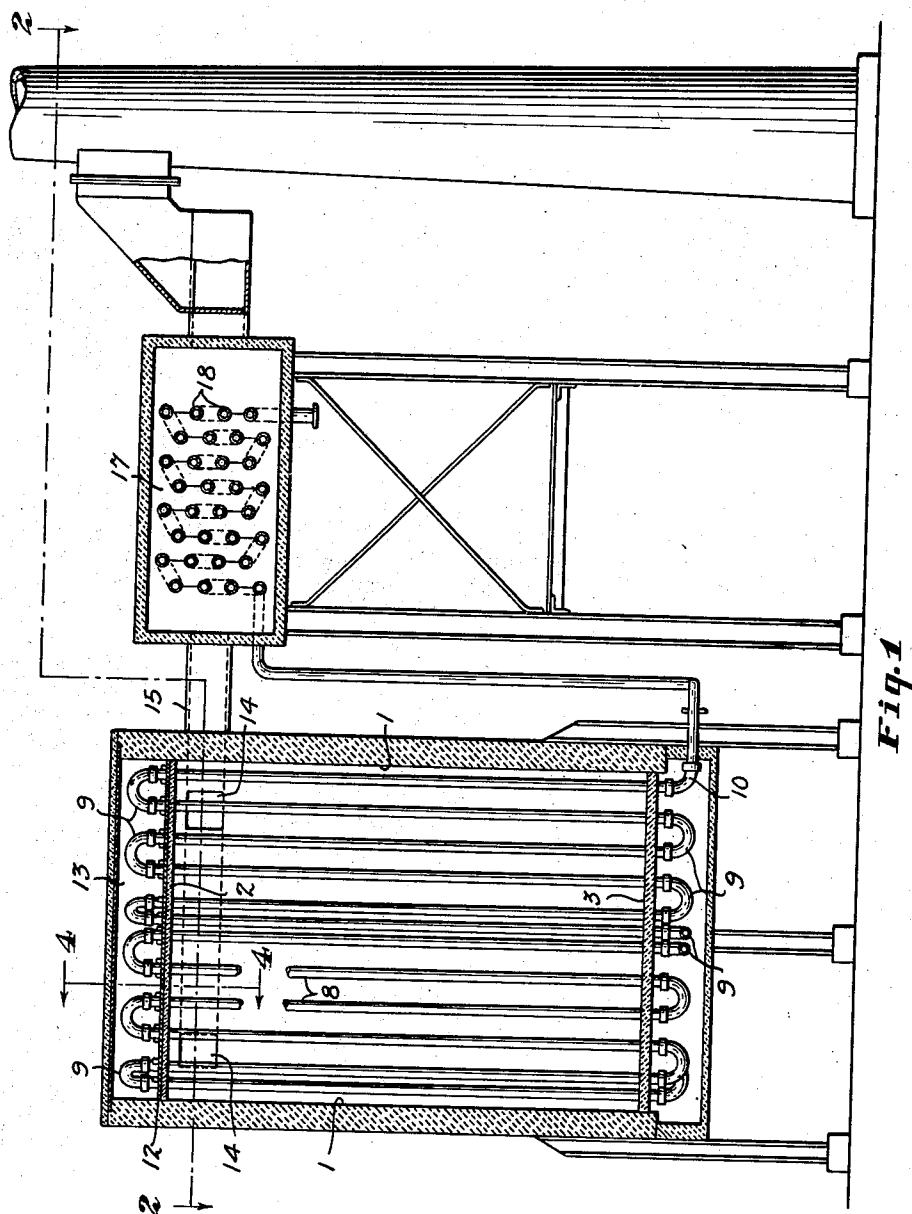
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2,211,903

OIL CRACKING AND POLYMERIZING HEATER

Filed Feb. 10, 1937

4 Sheets-Sheet 1



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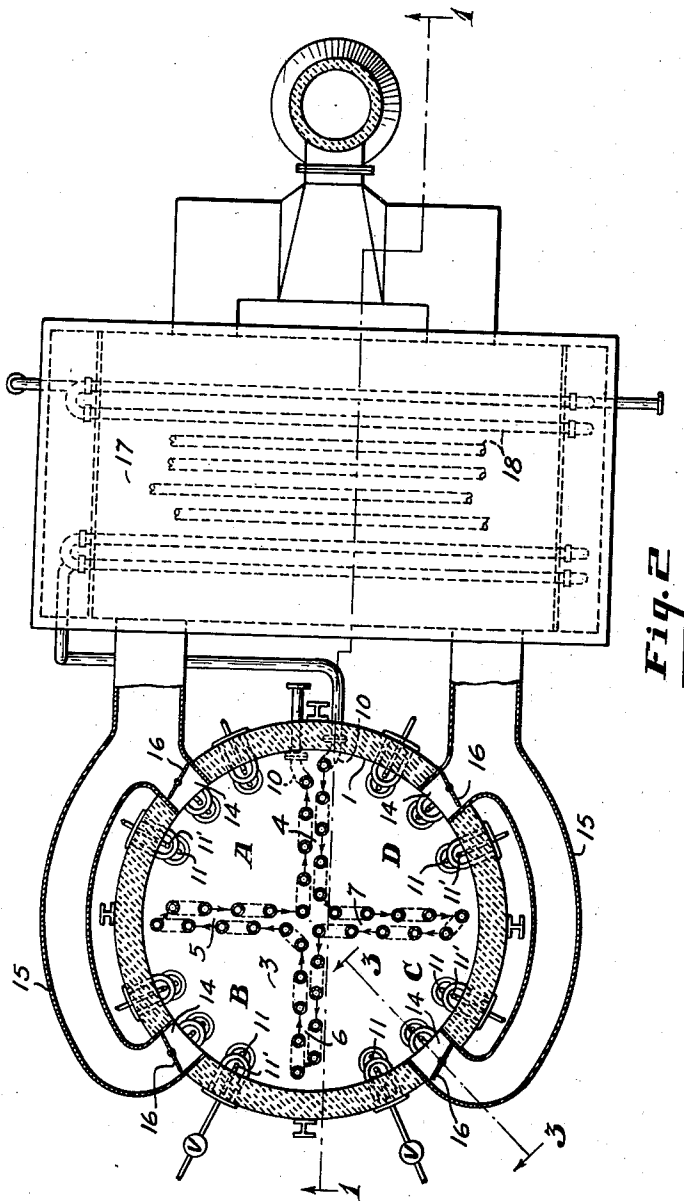
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OIL CRACKING AND POLYMERIZING HEATER

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4 Sheets-Sheet 2



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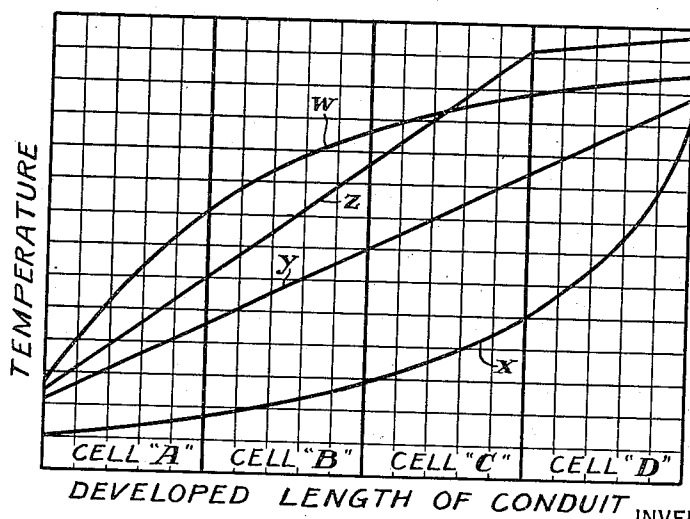
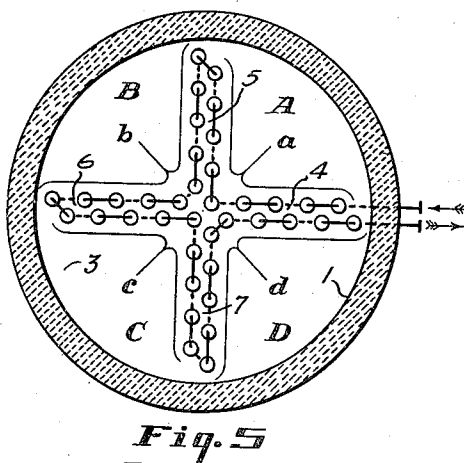
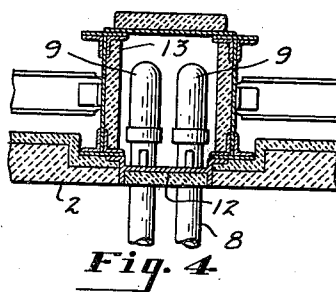
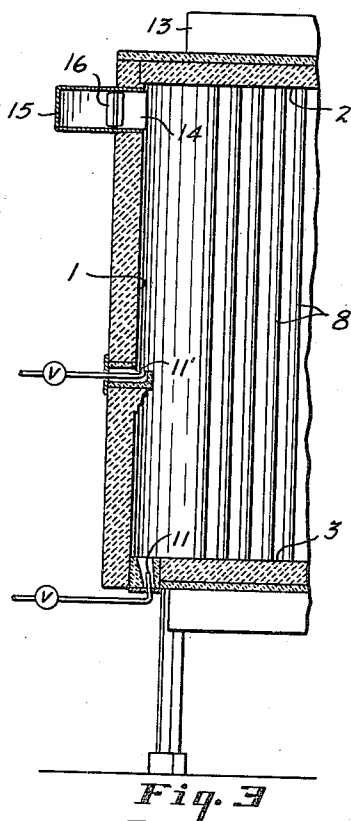
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OIL CRACKING AND POLYMERIZING HEATER

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4 Sheets-Sheet 3



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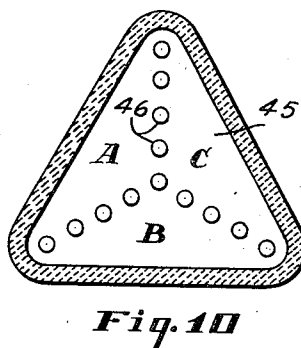
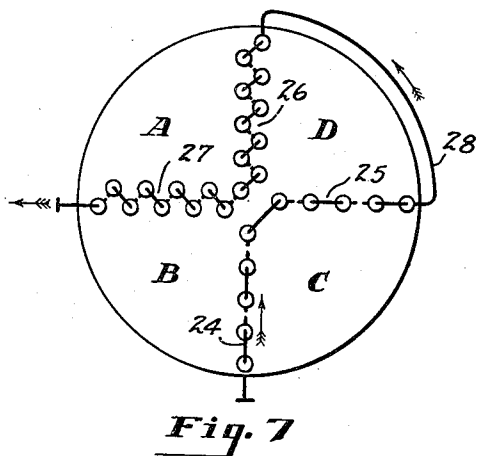
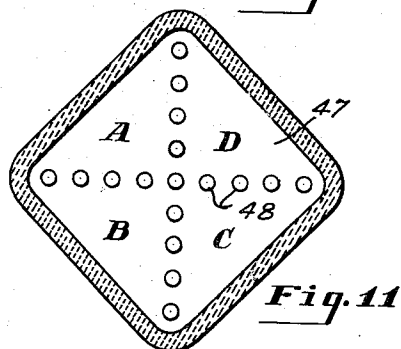
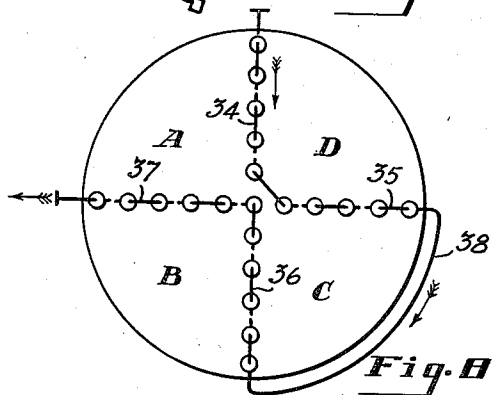
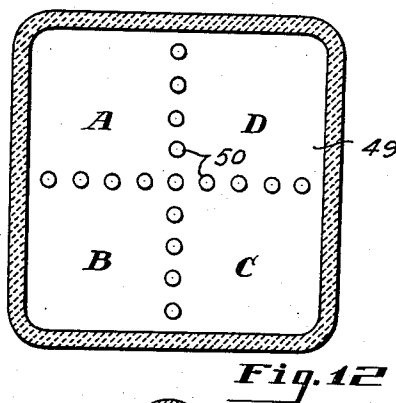
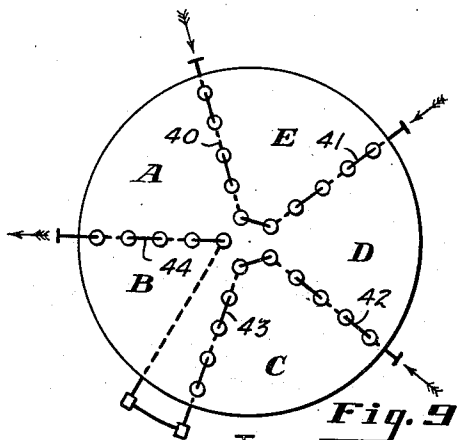
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OIL CRACKING AND POLYMERIZING HEATER

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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

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OIL CRACKING AND POLYMERIZING
HEATER

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Application February 10, 1937, Serial No. 125,079

21 Claims. (Cl. 122—356)

This invention relates to the heating of fluids and, particularly, to high temperature heat treatment of hydrocarbon oils, vapors and gases, to effect pyrolytic conversion.

5 An object of the present invention is the provision of means for heating fluids during their passage through a conduit of restricted cross section, in such manner that both sides of the tubes forming the conduit may be subjected to direct radiation from the material undergoing combustion and from the hot refractory wall of the combustion chamber, thus obtaining more heating through the wall of the tubes forming the conduit and transferring a greater amount of heat through a given area of conduit surface than in prior art practice.

15 Another object is to provide a heater of simple and relatively inexpensive construction in which heat may be applied to the fluid being heated in a series of controlled stages, and in such manner that the temperature at each stage may be closely controlled over a wide range.

20 An additional object is to provide a heater in which the rate of heating in each of the several heating stages may be accurately controlled at any desired rate over a wide range, and in which the rate of heating of the tubes forming the conduit may be varied and controlled at different points along the length of the tubes.

25 An additional object is the provision of an improved heater in which several fluids may be simultaneously and separately heated, the fluid conduits and heating means being so disposed that the heating of each of the fluids may be independently controlled.

30 A further object of the invention is the provision of a heater in which tube or conduit supports within the heating chamber are not required, and in which refractory partition walls or bridge walls are unnecessary.

35 The above mentioned features of the invention are particularly desirable in heaters for use in the cracking of hydrocarbon oils and in the thermal polymerization of light hydrocarbons, also in heaters used for the hydrogenation of oil or oil and carbon mixtures, or for other fluid heating operations wherein extremely high temperatures or pressures are required.

40 Apparatus embodying the invention is particularly flexible in its adaptability to various processes wherein it may be used and the improved range and degree of control, as compared with other prior art furnaces, is of particular advantage. Apparatus embodying the invention also

provides a very efficient arrangement of the heating surfaces with respect to the furnace structure, with resulting high thermal efficiency, also the apparatus may be built at a low cost as compared to heaters of the same capacity heretofore used. 5

The structure comprising the invention and its operation will be readily understood from the following description, read in conjunction with the appended drawings in which

Figure 1 shows a sectional elevation of the furnace structure taken along a plane indicated by line 1—1 in Fig. 2; 10

Fig. 2 is a sectional plan of the furnace taken along a plane indicated by line 2—2 of Fig. 1;

Fig. 3 is a partial sectional elevation taken on a plane indicated by line 3—3 of Fig. 2, and shows a typical arrangement of the fuel burners provided in each cell; 15

Fig. 4 is an enlarged section through the upper tube support and header box housing and is taken on line 4—4 of Fig. 1; 20

Fig. 5 is a plan view of the heating coil showing the course of the fluid through the coil;

Fig. 6 is a chart illustrating several types of heating curves which may be obtained by regulation of the heating means; 25

Figs. 7 to 12, inclusive, show various ways of arranging the conduit or conduits within the heating chamber and various arrangements of the heating chamber to vary the heating action and for varying the course of travel of the fluid to be heated. 30

The conduit and flow arrangements and types of furnace structure shown in Figs. 7 to 12 are used as illustrative of the flexibility of furnaces embodying the invention. The invention is not limited in scope to any of the particular arrangements shown. It is obvious that a great variety of heater structures may employ the relative arrangements of conduit and structure set forth in the claims without departing from the principles of the invention. 35

Referring to Figs. 1 and 2 of the drawings, the main furnace structure comprises a vertical, cylindrical, refractory side wall 1, a roof 2, and a floor 3. The fluid conduit is in the form of a series of banks 4, 5, 6 and 7, radially disposed about an axis that is preferably located at the center of the furnace. Each bank preferably consists of a multiplicity of vertical tubes 8 arranged in one or more rows and extending from the axis to the side walls 1 of the furnace. In the particular arrangement shown in the drawings, adjacent tubes of the same row are connected at their 45 50 55

ends by suitable tube end connectors or return bends 9, and the several tube banks are similarly connected one to the other to form the conduit for the fluid to be heated. Terminal fittings 10 are provided at the inlet and outlet of the fluid conduit. The radially disposed banks 4, 5, 6 and 7 divide the interior of the furnace into a series of combustion cells as indicated at A, B, C and D in Figs. 2 and 5.

One or more primary burners 11, which may be jet burners of conventional design, are provided at the lower end of each cell and each is preferably arranged to impinge a flame angularly against the refractory wall 1. Additional or secondary burners 11' are provided in the side wall 1 of each cell, at one or more points along the path of the combustion products. The purpose of the auxiliary or secondary burners 11' is to maintain a more uniform intensity of radiation throughout the vertical length of the tube bank than can be obtained by using burners at the lower end only.

This employment of auxiliary burners is an extremely desirable feature in a vertical heater, and particularly in a vertical heater of large capacity in which long tubes are employed. In the present invention the use of the auxiliary burners is facilitated by the form and construction of the heater, by reason of the fact that the entire vertical wall of the furnace is available as a radiating surface, being unobstructed by conduits or conduit supports of any kind, so that any reasonable number of burners may be located therein at desired elevations.

In the operation of the heater, uniform heating along the vertical length of the tubes is best accomplished by introducing the major portion of the fuel through the lower burner 11, and operating this burner with a maximum of excess air, thus lowering the flame intensity. At the same time the auxiliary burners 11' are operated with a restricted or slightly insufficient air supply, so that a portion of the fuel introduced therein combines with the excess air introduced at the lower burner 11. If a number of burners progressively smaller in size toward the top are used in the cells A, B, C and D, the uniformity of heat radiation can be increased, because the fuel and flame are more evenly distributed throughout the length of the cell.

An important improvement over other heaters, accomplished by heaters embodying my invention, is the fact that four or more controllable heating stages are readily arranged within a single structure without resorting to the use of any intermediate refractory walls. Intermediate refractory walls such as heretofore used are subject to intense heat on both sides and, because of this, special expensive materials are required and construction and maintenance costs are high. The present invention eliminates the intermediate refractory walls without sacrificing any advantages attributable to the use of such walls.

A further advantage is the utilization of the entire refractory wall of the combustion chamber as a radiating surface. It can be shown that higher rates of heat transfer result from an increase in the ratio of the area of the radiating surface to the area of exposed conduit surface.

The tubes 8, that form the restricted conduit, are supported at their upper ends by an insulated tube sheet 12 as shown in Fig. 4. This tube sheet is attached to and is part of the header box housing 13. Flue openings 14 are located at the upper end of each cell and connect to ducts or

breechings 15 which carry the gases or combustion products to the convection section of the heater. Dampers 16 are provided in the flue opening 15 from each cell, so that, by proper regulation of the dampers, the intensity of stack draft may be controlled for each of the several cells. The combustion products are thereby caused to flow vertically through each cell and any tendency of the gases to short circuit through the heater is overcome.

An important advantage of the apparatus of the present invention over prior cell type heaters is in the elimination of the conduit hangers formed of heat resistant alloy required in prior art commercial structures to support the tubes forming the conduits at a number of points intermediate the ends of the tubes. When horizontal tubes are used, as in prior commercial multi-cell heaters, it is necessary to support the tubes at several intermediate points between the ends of each tube. When, in addition, horizontal tubes are subjected to heat applied from both sides, the difficulties of the problem of support are further increased. Prior art heaters, of the multiple combustion chamber type wherein direct radiant heat is applied to both sides of the conduits, have in all cases, in so far as I am aware, made use of horizontal conduit tubes suspended in the form of double vertical rows. In this prior commercial construction the hanger or conduit support is placed between the two rows of horizontal tubes and the shielding effect of the tubes protects the hanger member from the intense heat radiated to it from all sides. Expensive heat resistant alloys must be used for such hangers or conduit supports and the expense of these parts is an important item in the cost of the heater. If existing heaters were to attempt the use of tube banks in the form of a single row of tubes subject to direct radiant heat from both sides of the tubes, the problem of support would be very serious because substantially no protection would be afforded the supporting member, and the life of such equipment under high temperature operating conditions would be very short. In a typical prior art heater using thirty foot horizontal tubes, five or six sets of spaced alloy tube supports would be required. In addition to requiring a large number of supports, the alloy used for the conduit support in such prior art heaters is necessarily more expensive than the alloy employed in types of heaters embodying the present invention because of the greater severity of the heating conditions to which the conduit supports of prior art heaters are subjected.

In accordance with the present invention the tubes forming the fluid conduit are suspended in a substantially vertical position by supports at their upper ends, and are free to expand at their lower ends, thereby providing a simple and relatively inexpensive structure. The rows of tubes form partitions that divide the heating chamber into a plurality of cells. It is to be noted in this connection that the conduit supports are located in the zone of lowest temperature of the heating section, being subjected to heat from the under side only, and exposed to relatively lower temperatures on the upper side. In addition, the conduit supports are protected by suitable insulating materials. It is thus seen that, in the present invention, a single group of conduit supports are required at the upper end only of the tubes.

Leaving the combustion cells, the combustion gases pass through the breaching or duct 15 to a

conventional type of convection heating section 17, consisting of a multiplicity of tubes 18 connected at their ends to form a continuous fluid conduit. As is usual in heating apparatus of this type, the oil or fluid to be heated flows first through tubes 18 of the convection section and then through tubes 8 of the radiant heating section. Preferably, in the convection section the flow of the fluid to be heated is counter to the flow of the products of combustion, the fluid in the conduit leaving the convection heating section at the point of entry of the combustion gases. The gases leaving the convection section pass to the stack or chimney. If desired, an air pre-heater or other means of heat recovery may be disposed in contact with the gases before said gases pass to the stack. Also, if desired, the convection section can be eliminated, and an air pre-heater or other means of heat recovery used in its place.

Referring to Fig. 5, the tubes of the banks 4 and 5 which border the cell A, and which receive the greatest amount of heat from the cell A, are designated *a*, the tubes of the banks 5 and 6, which border the cell B, are designated *b*, the tubes of banks 6 and 7, which border the cell C, are designated *c*, and the tubes of banks 7 and 4, which border the cell D, are designated *d*.

Considering any cell of the group, for example cell A, the heat transferred to the tube surface from the materials undergoing combustion in cell A and from the hot refractory wall forming the outer panel of cell A, will, according to the best present methods of calculating such heat transfer, be about as follows:

Of the total heat transferred to the fluid conduit surface of the heater, approximately 65% will be received by the surfaces of the tubes *a* which are directly exposed to cell A, approximately 30% will be received by those portions of tubes *b* and *d* which are adjacent and parallel to tubes *a* and a small amount of heat approximately 5% of the total transferred to the entire conduit from cell A will be received by the balance of the conduit surface. It will be apparent, therefore, that the heat absorbed by tubes *a* is dominated by the intensity of heat available from the materials undergoing combustion in cell A and the hot refractory wall forming the outer panel of cell A.

Likewise, the heat absorbed by the other portions of conduit indicated by *b*, *c*, and *d* is governed by the radiant heat available respectively from cells B, C and D.

The quantity of heat supplied to the portion of conduit *a*, may, therefore, be increased as compared to the quantity of heat supplied to portions of conduit *b*, *c*, and *d*, by maintaining more severe firing conditions in cell A as compared to the firing conditions of cells B, C, and D.

Likewise, any single cell, group of cells, or combination of cells A, B, C, and D, may be fired at higher rates than are maintained in the other cell or cells of the heater, and will, therefore, transfer a greater amount of heat to the portions of conduit facing them.

It will be apparent, therefore, that the interior of the heater may be considered as divided into a series of combustion cells or heating zones such as A, B, C, and D which control the heat input to the respective portions *a*, *b*, *c*, and *d* of the conduit, and that the heating operation is divided into four independently controlled heating stages.

The control obtainable over the heating curve in the above heater may be best understood by referring to Fig. 6 of the appended drawings,

which shows several heating curves which can be obtained with the tube arrangement shown in Fig. 5. It can be seen from inspection of Fig. 5 that the fluid to be heated flows in a single stream in series through the entire fluid conduit.

Furthermore, the arrangement of flow is such that, as the fluid progresses through the coils formed by the conduit, it is successively subjected to direct heating from cells A, B, C and D in the order mentioned. Furthermore, approximately equal increments of conduit are subjected to said direct heating from each cell. For this particular tube arrangement curve W illustrates a decreasing rate of temperature rise throughout the entire fluid conduit. This form of heating curve is ordinarily obtained by firing each successive cell at less severe firing conditions as the fluid progresses from one cell to the next.

In connection with this statement, it must be understood that in the case of hydrocarbon oils, to which this discussion of heating curves refers, as the temperature of the oil increases the total heat required per unit rise in temperature also increases, that is, the specific heat increases with increasing temperature. It is, therefore, possible in certain cases to obtain this form of curve with uniform firing conditions in all cells, or even with slightly increasing rates of firing in the successive cells. The firing conditions, however, are regulated to obtain the form of heating curve desired.

Curve X illustrates an increasing rate of temperature rise throughout the entire fluid conduit. This form of curve may be obtained by progressively increasing the severity of firing in the successive cells. Almost any intermediate form of heating curve may be obtained by proper regulation of the severity of firing in the different cells.

Curve Y, for instance, illustrates a uniform rate of temperature rise throughout the heating conduit. This is ordinarily obtained by maintaining progressively increasing firing conditions in successive cells, the increase in firing conditions in successive cells being so regulated as to supply the necessary additional heat required at higher temperatures for a unit rise in temperature, as mentioned in connection with curve W.

Curve Z illustrates a rapidly and uniformly rising temperature for the first three cells and a slowly rising or almost constant temperature for the last cell. This is normally obtained by maintaining relatively severe and progressively increasing firing conditions in the first three cells and a mild firing condition maintained in the last cell.

In this case again, however, the statement does not necessarily hold for all oils, for example, certain types of oil, at the higher temperature obtaining in the last cell may undergo cracking to such an extent that the amount of heat required to supply the heat of reaction due to cracking may be greater than that required in any of the first three cells to obtain the rapid temperature rise, in which case the last cell would necessarily be fired at a harder rate than the first three cells.

A similar condition may be obtained where an oil is undergoing vaporization, the extent of vaporization increases as the temperature rises and as the fluids approach the outlet of the conduit, a greater amount of heat may be required in the latter portions of the conduit to maintain the progressive vaporization and slowly increasing temperature.

In either of these cases, as for the previous curves discussed, the heat input to the several

cells is regulated to obtain the desired form of curve.

Numerous modifications of the above general type of heating curves may be obtained by modifying the arrangement of conduit.

For example, in naphtha reforming operations and certain cracking operations it is desirable to heat the fluid as rapidly as possible to a given temperature, and then maintain it at that temperature for a certain definite time, with a reduced rate of heat input during this period. This can best be accomplished by using two tube banks 24 and 25 in single row and two tube banks 26 and 27 in double row, as shown in Fig. 7. The fluid passes first through the single row banks of tubes 24 and 25, thence through a tube indicated diagrammatically at 28 to the outer end of the double row bank 26 and then through the double row of tubes of the banks 26 and 27. The conduit in single row is subject to maximum heat input on both faces of the tube and transfers heat to the fluid at proportionately higher rates, thus rapidly raising its temperature. The heat input to the tube banks arranged in single row is so regulated as to obtain the desired temperature at the outlet of the single-row section. The oil then passes to the two tube banks arranged in double row, where the rate of heat input is reduced by the complementary shielding action of the adjacent rows, one for the other. The combustion cells controlling the heat input to these banks are then fired at sufficient intensity to maintain the desired temperature during the soaking period.

In certain heating operations maximum obtainable rates of heat transfer are desirable. This requirement may be due to the nature of the heating process or may in some cases be desirable as a means of economy in the cost of a heater, in that the amount of tube or conduit surface required for a given heat input to the fluid may be reduced. For example, for heaters used in hydrogenation processes the usual practice is to provide heating tubes and tube end connectors of expensive alloy materials, in which case the cost of tubes and end connectors alone may represent 75% or more, of the entire cost of the heater. In cases of this kind, the tube arrangement shown in Fig. 8 may be used, wherein each of the tube banks 34, 35, 36 and 37 consists of a single row of tubes, the fluid passing through tubes of bank 34 to center, through tubes of bank 35 to the peripheral wall, through a tube 38 to bank 36 and then through banks 36 and 37. The very high rate of heat input obtained because of the fact that both sides of all tubes are subject to direct heating, permits a material reduction in the amount of tubing and end connectors required, effecting a substantial economy in the cost of the heater.

An additional operating advantage of the invention consists in the ability of the apparatus to simultaneously pass several separate fluid streams through a single furnace, and at the same time maintain positive control over the outlet temperatures and heat input to each fluid stream. This is sometimes desirable in a multi-coil cracking unit wherein the several streams may be heated in a single furnace. Again referring to the conduit arrangement of Figure 5, of the drawings, if it is desired to accomplish the above, the portions *a*, *b*, *c* and *d* of the conduit, instead of being connected in series to form a single fluid conduit as shown, may be arranged as four distinct coils, each coil comprising two

rows of tubes facing a common combustion cell, said two rows of tubes being connected in series and provided with inlet and outlet connectors. Temperature indicators at these inlet and outlet points enable the operator to maintain suitable firing conditions in each cell to control the heating of the separate streams. It should be apparent to one familiar with the art that the heat input to the fluid in each of the coils *a*, *b*, *c*, and *d* may be controlled by proper regulation of the firing conditions in the cell facing the coil. Thus, four separate fluid streams may be simultaneously heated with controlled outlet temperatures.

A different arrangement is shown in Fig. 9, wherein the heating chamber is divided into five cells by single rows of tubes 40, 41, 42, 43 and 44, rows 40 and 44 forming walls of cell A, row 40 being in series with row 41 and row 44 being in series with rows 43 and 42. The single row tube arrangements of Figures 8 and 9 are used when the principal object to be obtained is maximum rates of heat input to the conduit.

In Fig. 10 the heating chamber 45 is triangular in shape and is divided into three cells by tubes 46.

In Fig. 11 the heating chamber 47 is rectangular and divided into four triangular cells by tubes 48 arranged in diagonal rows.

In Fig. 12 the heating chamber 49 is rectangular and divided into four rectangular cells by rows of tubes 50.

While one design of my invention and several modifications of it have been shown in the appended drawings and described in detail in the foregoing specification, it is to be understood that my invention is not limited thereto, but includes all changes and modifications which fall within the scope of the appended claims.

What I claim is:

1. A heater for fluid comprising a heating chamber, fluid conducting tubes extending vertically through the chamber, said tubes arranged in banks more than two in number and the banks radiating substantially from the central portion of the chamber to divide the chamber into a plurality of heating cells more than two in number, at least one cell being disposed on each side of each of said banks, the tubes in one bank connected in series with the tubes of another bank whereby the fluid being heated flows successively through a plurality of banks in a single heating chamber, and means for individually heating the cells to different temperatures to expose opposite sides of the tube banks separating adjacent cells to different degrees of heat.

2. The method of heating a fluid which comprises passing the fluid in a substantially vertical direction over a first group of substantially parallel courses of relatively small individual cross-sectional area, burning fuel and directing the flame and hot gases in a substantially vertical direction over a substantially unobstructed path substantially paralleling the courses to provide a first substantially vertical source of intense radiant heat, subjecting one side of said first group of courses to said radiant heat, burning fuel and directing the flame and hot gases therefrom in a substantially vertical direction over a substantially unobstructed path separated from said first mentioned fuel path by a group of fluid courses and substantially parallel to said path and the first mentioned fluid courses to provide a second substantially vertical source of intense radiant heat, subjecting another side of

said first group of courses to said second source of radiant heat, passing the heated fluid in a substantially vertical direction over a second group of substantially parallel courses of relatively small individual cross-sectional area, subjecting one side of said second group of courses to said second source of radiant heat, burning fuel and directing the flame and hot gases in a substantially vertical direction over a substantially unobstructed path separated from said previously mentioned fuel paths by groups of fluid courses and substantially parallel to said paths and the fluid courses previously mentioned to provide a third substantially vertical source of intense radiant heat, subjecting another side of said second group of courses to said third source of radiant heat, passing the heated fluid from said second group of courses in a substantially vertical direction over a third group of substantially parallel courses of relatively small individual cross-sectional area, subjecting one side of said third group of courses to said third source of radiant heat, subjecting another side of said third group of courses to a source of intense radiant heat other than said second and third sources, and carrying off the hot gases from said heat sources in directions substantially preventing flow of hot gases between the individual courses of the groups.

3. The method of heating a fluid which comprises continuously passing the fluid in a substantially vertical direction successively through a number of courses more than two of relatively small cross-sectional area, continuously burning fuel at different rates from a plurality of spaced apart burners and directing the several flames and gaseous products of combustion over a plurality of substantially vertical unobstructed paths individually of small horizontal extent relative to their vertical heights to create a plurality of substantially vertical sources of intense radiant heat of different degrees of temperature substantially paralleling the fluid courses and said paths being substantially without horizontal or transverse flow of the gases across the fluid courses, to heat the fluid primarily by radiation, subjecting one side of the fluid in one of said courses to radiant heat from a first one of said radiant heat sources and the other side to radiant heat from a second one of said radiant heat sources, subjecting one side of the fluid in another of said courses to radiant heat from said second radiant heat source and the other side to radiant heat from a third one of said radiant heat sources, and subjecting one side of the fluid in a third of said courses to radiant heat from said third radiant heat source and the other side to radiant heat from one of said radiant heat sources other than said second and third radiant heat sources, to heat the fluid in a series of stages in each of which the fluid is subjected to radiant heat from two sources of intense radiant heat and which sources are different for each of said courses.

4. The method of heating a fluid which comprises continuously passing the fluid in a substantially vertical direction over a group of substantially parallel courses of relatively small individual cross-sectional area, passing a flame and gaseous source of intense radiant heat over a substantially vertical and substantially unobstructed path of small horizontal extent relative to its vertical height substantially paralleling said fluid courses, continuously conducting fluid previously passed over said group of courses over

a second group of substantially parallel courses of relatively small individual cross-sectional area and in a substantially vertical direction, subjecting one side of each of said groups of courses to primary radiant heat directly from said source, absorbing heat from said source on the opposite side thereof from said groups of courses, radiating substantially all of the absorbed heat back through said path to the groups of courses to subject said courses to secondary radiant heat, and subjecting another side of each of said groups of courses to independent sources of intense radiant heat.

5. A fluid heater of the character described having a vertical wall enclosing a heating chamber, vertical tubes within the chamber arranged in banks radiating from adjacent the center of the chamber to adjacent the vertical wall to divide the chamber into cells, said tubes being connected for the serial flow of fluid through the tubes of the several banks, independently controlled burners at different heights in each cell, some of said burners being disposed intermediate the ends of the tubes, and means for removing combustion products from one end of each of the cells.

6. A furnace for heating fluids, comprising an enclosed heating chamber having a substantially vertical wall, vertical tubes arranged in three or more banks within said chamber, each of said tube banks extending from adjacent the center of said chamber to adjacent the wall of the chamber, combustion cells defined by each pair of adjacent tube banks and a portion of the chamber wall, independently controllable burner means at one end of each cell, an individual outlet flue at the end of each cell opposite the burner means, said flue means being arranged to remove combustion products from the chamber in a direction away from the tubes and substantially out of contact with the tubes, and independently controllable damper means in each said flue.

7. A fluid heater comprising a substantially vertical wall enclosing a heating chamber, a plurality of substantially vertically disposed heat absorbing and fluid conducting tubes arranged in banks in said chamber, a plurality of substantially vertically extending heating cells in the chamber, each cell being substantially enclosed by a portion of said wall and at least two of said banks of tubes, said tube banks being angularly disposed with respect to one another and arranged in spaced relation with respect to said wall to receive heat by direct radiation from said wall and each bank having a heating cell on each side thereof, heating means in each cell arranged to provide direct radiant heat to said tubes and to heat said wall, the wall portion of each cell being in obstructed heat-radiating relationship to the wall portions of the other cells, and means for connecting the heat-absorbing tubes of one bank in series with the heat absorbing tubes of another bank to direct the fluid to be heated for progressive flow serially through a plurality of tube banks in the heating chamber.

8. A fluid heater comprising a substantially vertical wall enclosing a heating chamber, a multiplicity of substantially vertical heat-absorbing fluid conducting tubes extending through the heating chamber, said tubes arranged in banks and the banks positioned to substantially separate the chamber into a plurality of substantially vertically extending cells disposed at intervals around and adjacent the enclosing wall, each cell being substantially enclosed between one or more

banks of said tubes and a portion of the chamber wall and having a horizontal extent less than the corresponding horizontal extent of the heating chamber, means for separately introducing combustibles adjacent one end of each cell, and means for separately removing combustion products from adjacent the other end of each cell so that the paths of the combustion products through the several cells are of small horizontal extent relative to their vertical height and are substantially parallel to the tubes and in substantially non-convective heat exchanging relation to said tubes, and means for connecting the tubes to one another to direct the flow of fluid serially through a number of said tube banks for the progressive absorption of heat by the fluid from the several cells.

9. A heater for fluid, comprising a substantially vertical refractory enclosing wall, a multiplicity of substantially vertical fluid-conducting tubes arranged in banks, said tube banks being positioned at spaced intervals along the inside of the vertical enclosing wall and each bank extending laterally from the vertical wall to intersect other tube banks in the central part of the heater and form a plurality of heating cells adjacent the enclosing wall, each cell being defined in part by a portion of said vertical refractory wall and being separated from adjacent cells by tube banks common to the cells separated thereby, separate heating means for each cell, and means for connecting the tubes of the several banks for the progressive flow of fluid serially through a number of said banks.

10. A fluid heater comprising substantially vertical walls enclosing a heating chamber, a multiplicity of substantially vertical fluid conducting tubes extending through the chamber, said tubes being arranged in a plurality of banks disposed in substantially vertical intersecting planes extending transversely through the heating chamber toward the center thereof from the enclosing walls to provide a plurality of radiant heating zones in the chamber substantially enclosed from one another by the tube banks, means for separately introducing combustibles into each heating zone, means for separately removing gaseous products of combustion from each heating zone, said introducing means and said removing means being arranged so that the paths of the combustion products through the heating zones are substantially parallel to one another and to the fluid conducting tubes and are in substantially non-convective heat exchanging relation to said tubes whereby the tubes are heated primarily by radiation from the combustion products in the several heating zones, and means for connecting the tubes for the progressive flow of fluid to be heated successively through tubes receiving radiant heat from different radiant heating zones.

11. A fluid heater comprising a substantially vertical enclosing wall having a series of heat radiating portions, a cage-like structure of vertical heat absorbing tubes disposed in spaced confronting relation to each wall portion to cooperatively define therewith a substantially vertically extending cell separated from the other cells of the heater by tubes, said tubes being supported vertically in the heater and in parallel relation to one another, means for connecting the tubes to conduct fluid serially through tubes simultaneously receiving radiant heat directly from different wall portions, and means for separately heating said wall portions.

12. A heater for fluid, comprising a substan-

tially vertical heat radiating wall enclosing a heating chamber, a multiplicity of substantially vertical fluid conducting tubes arranged in banks, said tube banks being positioned at spaced intervals along the inside of the vertical enclosing wall and each bank extending laterally from the vertical wall toward the interior of the chamber to divide the chamber into a plurality of heating cells separated from adjacent cells by one or more banks of tubes, each cell having a side wall formed by a portion of said vertical enclosing wall, said wall portions each having substantially its entire surface unobstructed to permit the direct radiation of absorbed heat therefrom to the tubes, means for separately introducing combustibles into each cell at one end thereof, means for separately withdrawing hot gases from each cell at the opposite end thereof to effect a flow of the combustibles and gases through the chamber over paths substantially paralleling the tubes and individually of small horizontal extent relative to the heights of the paths and in substantially non-convective heat exchanging relation to the tubes, said introducing and withdrawing means for each cell being disposed so that the combustibles and hot gases are in contact with and sweep over the respective radiant heating wall portions throughout substantially the entire lengths of said paths and means for connecting the tubes for the progressive flow of fluid serially through a number of banks.

13. A heater for fluid, comprising a substantially vertical wall enclosing a heating chamber, a multiplicity of substantially vertical fluid conducting tubes arranged in banks, said tube banks being positioned at spaced intervals along the inside of the vertical wall and each bank extending laterally from the wall toward the interior of the chamber to divide the chamber into a plurality of heating cells separated from adjacent cells by one or more banks of tubes, each cell having a side wall formed by a portion of said wall, said cell wall portions each having substantially its entire surface unobstructed to permit the direct radiation of absorbed heat therefrom to the tubes, primary means for introducing combustibles into each cell at one end thereof, means for withdrawing hot gases from the cells at the opposite ends thereof from the primary means to effect a flow of combustibles and hot gases through the cells of the chamber over paths substantially paralleling the tubes and individually of small horizontal extent relative to the heights of the paths and in substantially non-convective heat exchanging relation to the tubes, and secondary means for introducing additional combustibles into the cells between the ends of the tubes and substantially in the path of the combustibles and gases from the primary means, said introducing and withdrawing means for each cell being disposed so that the combustibles and hot gases are in contact with and sweep over the respective radiant heating wall portions throughout substantially the entire lengths of said paths.

14. The method of heating a fluid, which comprises continuously passing the fluid serially and in substantially vertical directions over separate groups of substantially parallel courses of relatively small individual cross-sectional area, passing a plurality of flames and gaseous sources of intense primary radiant heat over substantially vertical unobstructed paths substantially paralleling the courses and of individually small horizontal extent relative to the heights of the paths, subjecting opposite sides of each group of

courses to primary radiant heat directly from different heat sources, absorbing heat from the heat sources other than by the fluid and on sides of the sources opposite the fluid courses, radiating the absorbed heat through the paths as secondary radiant heat, subjecting each group of courses to said secondary radiant heat from different sources, subjecting a plurality of said separate groups of courses to primary radiant heat from each source, and subjecting a plurality of said separate groups to said secondary radiant heat from each source.

15. In a fluid heater, a tube arrangement in which the tubes are substantially vertical, an upright enclosing wall formed of radiant refractory material around the tubes to provide a heating chamber, said tubes being arranged in banks which divide the chamber into cells adjacent and around the enclosing wall, separate heating means for each cell arranged to directly heat portions of the enclosing wall adjacent the several cells to provide a source of intense radiant heat in each cell, which source is spaced from the like heat sources of the other cells, an individual flue outlet for each cell, the tubes being disposed in the chamber across the spaces between the several radiant heat source portions of the enclosing wall so that every radiant heating wall portion is screened by tubes from every other radiant heating wall portion of the heater to prevent the unobstructed radiation of heat from the wall portion associated with one cell to all the other wall portions of the heater and to intercept direct radiant heat from different sources so that the tubes are subjected on opposite sides to said heat from different sources, and connections for the ends of the tubes providing a continuous path for the flow of fluid to be heated serially through a multiplicity of the tubes in the one heating chamber.

16. A heater for fluid comprising an upright enclosing wall around a heating chamber, substantially vertical tubes extending through the chamber and arranged in banks which divide the chamber into substantially vertically extending cells, individual flue means at one end of each cell for carrying off gaseous products of combustion, primary burners at the ends of the cells opposite the flue means for introducing combustibles which move over paths in the cells paralleling the tubes and burn therein to create a number of spaced sources of intense radiant heat which are on opposite sides of the several tube banks, each of said tube banks being directly exposed on opposite sides to intense radiant heat from different paths of combustibles, secondary burners intermediate the ends of the tubes and between the primary burners and flue means for introducing additional combustibles into the several paths in the cells to replenish heat lost to the tubes by the hot gases from the primary burners, and means for connecting the tubes for the flow of fluid to be heated serially through a number of banks to successively absorb heat from a number of heat sources in different cells.

17. A heater for fluid comprising a substantially vertical wall enclosing a heating chamber, a multiplicity of substantially vertical heat absorbing tubes extending through the chamber and arranged in a plurality of separated banks extending laterally from adjacent the enclosing wall toward the central portion of the chamber to substantially enclose off portions of the wall from other like portions thereof by said vertical tubes, and a plurality of means for burning fuel ad-

jacent the ends of the tubes and moving the combustibles and combustion products through the heating chamber over a plurality of substantially vertically extending paths parallel to the tubes, each path being spaced from the other paths and the paths being separated from one another by the tube banks, said paths each being of small horizontal extent relative to the height thereof and the paths being disposed at intervals around the inside of the enclosing wall and closely adjacent said wall throughout substantially the entire lengths of the paths.

18. The method of heating a fluid which comprises burning fuel at a plurality of spaced points and moving the combustibles and gaseous products of combustion in substantially vertical directions over paths which are substantially vertical and unobstructed to create a plurality of spaced substantially parallel, vertical, radiant heating sources, moving the fluid to be heated in vertical directions over a plurality of substantially vertical courses substantially parallel to and between adjacent heat sources to absorb unobstructed radiant heat directly from the sources, substantially all the individual courses which are subjected to the unobstructed direct radiant heat from each source being grouped about such source, the grouped courses being arranged in a non-rectilinear bank disposed in confronting relation to such heat source, subjecting opposite sides of each vertical course to direct radiant heat from different vertical sources, and introducing and burning additional fuel substantially in each of said paths at portions thereof vertically spaced and removed from the first named fuel burning points and between the ends of the fluid courses.

19. The method of heating a fluid which comprises burning fuel at a plurality of spaced points and moving the combustibles and gaseous products of combustion in substantially vertical directions over paths which are substantially vertical and unobstructed to create a plurality of spaced substantially parallel, vertical, radiant heating sources, moving the fluid to be heated in vertical directions over a plurality of substantially vertical courses substantially parallel to and between adjacent heat sources to absorb unobstructed radial heat directly from the sources, substantially all the individual courses which are subjected to unobstructed direct radiant heat from each source being grouped about such source, subjecting opposite sides of each vertical course to direct radiant heat from different vertical sources, introducing and burning additional fuel substantially in each of said paths at portions thereof vertically spaced and removed from the first named fuel burning points and between the ends of the fluid courses, and withdrawing heat from said vertical sources on one side thereof and radiating substantially all of said withdrawn heat across the path of the sources to the fluid courses as secondary radiant heat to subject opposite sides of the fluid courses to said secondary radiant heat in addition to the direct radiant heat.

20. The method of heating a fluid which comprises burning fuel at a plurality of horizontally spaced regions, moving the combustibles and gaseous products of combustion in substantially vertical directions over paths which are substantially vertical and unobstructed to create a plurality of spaced substantially parallel, vertically extending radiant heat sources, passing the fluid to be heated in vertical directions over a plurality of substantially vertical courses arranged in sev-

eral individual banks separating the heat sources from one another to subject substantially all the individual courses to unobstructed direct radiant heat, the courses thus directly heated by each source being grouped about such source in a non-rectilinear bank so that the courses intercept radiant heat passing between the sources and each course is subjected on opposite sides thereof to direct radiant heat from different heat sources, conducting heated fluid from courses in one of the banks over courses in another of said banks, and introducing and burning additional fuel in said paths at portions thereof vertically spaced and removed from said regions of first mentioned fuel burning and between the ends of the courses.

21. A heater for fluid comprising an upright wall enclosing a heating chamber and having spaced radiant heating portions in opposed confronting relation to one another, a plurality of means for burning fuel at intervals around the inside of the enclosing wall and moving the flame and combustion products in a plurality of substantially vertically extending paths through the heating chamber, which paths are spaced from

one another and individually heat the several radiant heating portions of the wall, a multiplicity of substantially vertical heat absorbing tubes extending through the chamber in spaced parallel relation to one another and to the flame paths, said tubes being arranged in banks which extend inwardly toward the central part of the heating chamber from adjacent the enclosing wall and between the several flame paths and the several radiant heating wall portions to be heated on opposite sides by radiant heat from different flame paths and which tube banks are disposed across the spaces between the said confronting radiant heating wall portions to intercept and be subjected on opposite sides to radiant heat from different radiant heating wall portions, and means for connecting the tubes for the progressive flow of the fluid to be heated serially through a plurality of tube banks so that the major portion of the heat received is successively imparted to the fluid from a number of said paths and said radiant heating wall portions.

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