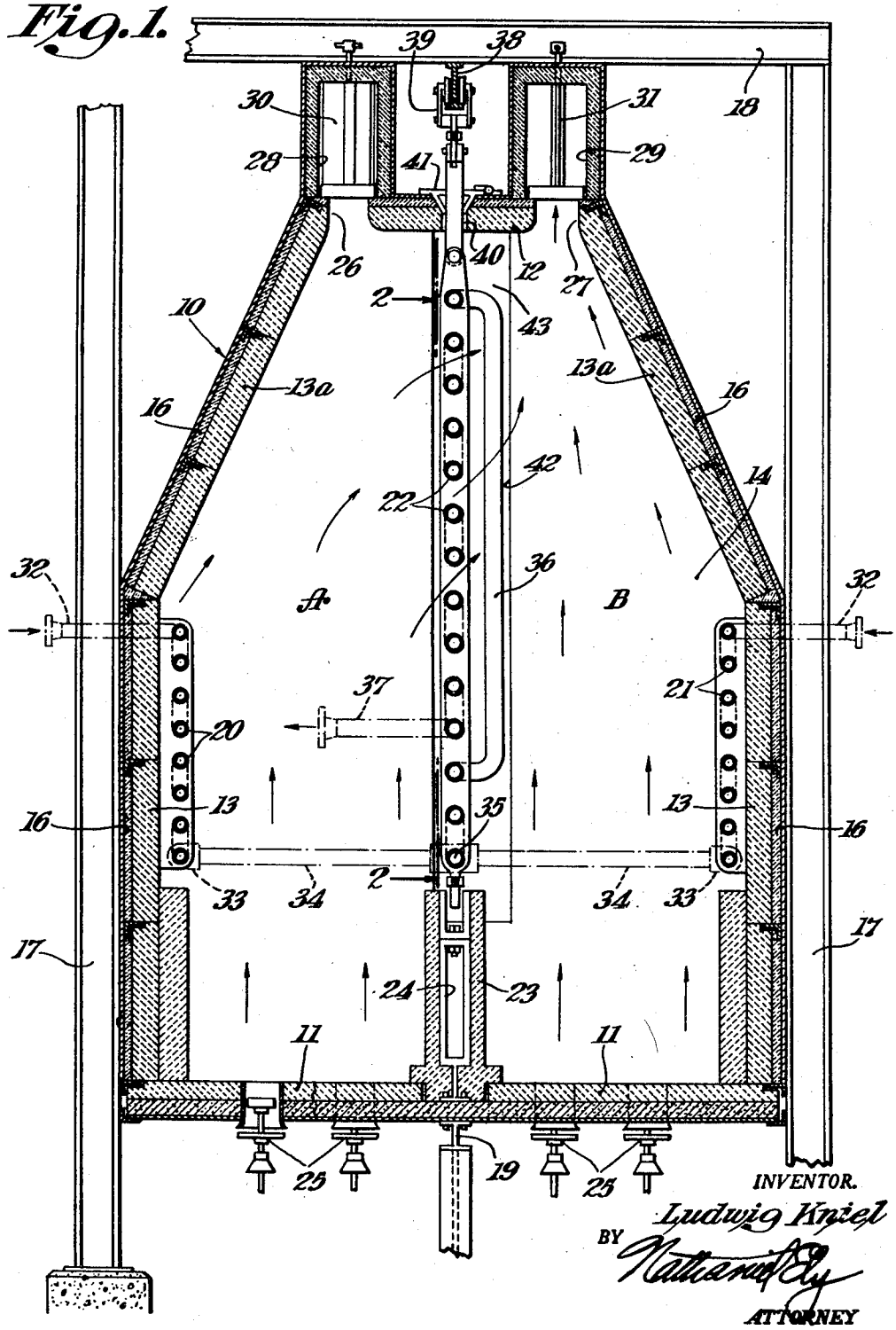
Dec. 21, 1948. L. KNIEL 2,456,787

PROCESS AND APPARATUS FOR HEATING HYDROCARBON FLUIDS

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Fig. 1.



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Fig. 2.

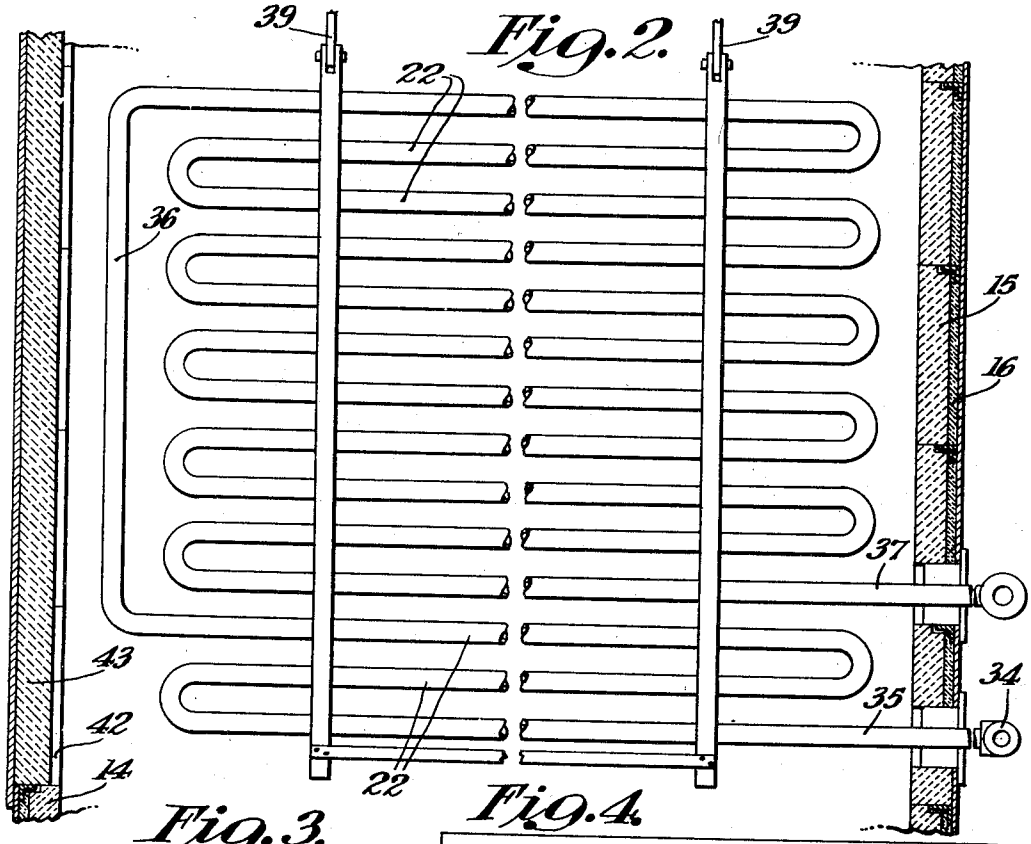


Fig. 3.

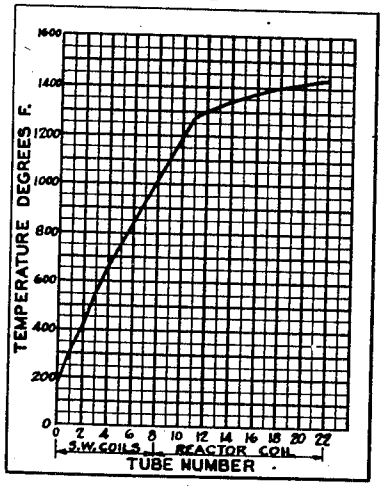
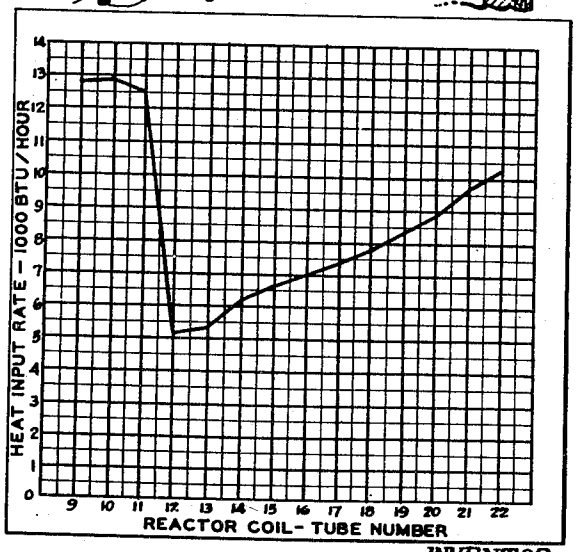


Fig. 4.



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PROCESS AND APPARATUS FOR HEATING HYDROCARBON FLUIDS

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Application March 9, 1946, Serial No. 653,289

9 Claims. (Cl. 196—110)

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This invention relates to an apparatus and a method for heating a hydrocarbon fluid by passage of the fluid through banks of tubing within a furnace chamber in which the fluid is heated predominantly by radiant heat. More particularly, the invention relates to an apparatus and a method in which the tubes which are subjected to the greatest heat are protected from overheating by passing through them fluid at a relatively lower temperature than the fluid in other parts of the same tube bank. This application is directed to improvements over the disclosure of copending application, Serial Number 594,410, filed May 18, 1945, by Ludwig Kniel, Pierre Lambert and Herbert R. Treat, for Heating of hydrocarbon fluids.

An important object of this invention is to provide a heating apparatus of high thermal efficiency in the heating of a hydrocarbon fluid, and also to effect economy in the apparatus.

Another object of the invention is to provide an apparatus for heating a hydrocarbon fluid in which the flow of fluid is so arranged as to limit the maximum temperature which the hottest tubes in the apparatus attain.

Another object of the invention is to provide an apparatus and a method for heating a hydrocarbon fluid in which the life of the tubes is at a maximum, and in which coke deposition within the tubes is minimized.

Further objects will be obvious from a reading of the following description in connection with the accompanying drawings in which:

Figure 1 is a vertical transverse section of a furnace embodying my invention:

Figure 2 is a partial vertical section on the line 2–2 of Figure 1;

Figure 3 is a graph showing the temperature of the fluid as it passes through each of the various tubes in my apparatus; and

Figure 4 is a graph showing the rate of heat input into the fluid as it passes through the tubes in the central or reactor tube bank of my apparatus.

My invention is of particular utility in the thermal cracking of propane to obtain ethylene as a desired end product, as in the case of the furnace described in the aforementioned copending application. In furnaces of this type the hydrocarbon fluid is passed through banks of tubes which are heated primarily by radiant heat. The central or reactor bank, or banks, of tubes being subjected on both sides to radiant heat, rather than on one side as in the case of side wall tubes, have a much greater heat input rate than

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the side wall tubes. Those tubes in the central bank which are nearest to the burners are exposed to the highest heat input rate. In prior constructions in which the path of flow of fluid in the reactor, or cracking, bank has been in straight countercurrent relation to the combustion gases, the tubes nearest the burners have been exposed to especially high temperatures, which has the undesirable effect of reducing the tube life and necessitating frequent shut downs for replacement of tubes or for their repair. Such a condition obviously reduces the efficiency of a furnace in requiring its being shut down for such replacement or repairs and in the cost of tubes. My invention is designed to eliminate this condition, or at least substantially to reduce it so as to give increased tube life and to minimize the frequency of required shut downs for repairs.

Referring to the embodiment of the invention shown in Figures 1 and 2 of the drawing, the furnace chamber 10 is a box-like form having a flat floor or hearth 11, a flat roof 12, opposite side walls 13, and vertical end walls 14 and 15. The lower portions of the side walls 13 are vertical, and the upper portions 13a converge upwardly to the roof. The chamber is constructed of blocks or slabs of refractory material sheated with heat insulation 16. The furnace is supported in a position elevated from the ground or from a foundation by a metal frame structure comprising columns 17 and upper and lower girders 18 and 19.

Within the furnaces chamber a pair of outer tube banks, 20 and 21, are supported in vertical positions directly inwardly of the vertical portions of the side walls 13, and a central, or intermediate, tube bank 22 is supported in a vertical position between said outer banks. This central bank is arranged parallel to the outer banks. A relatively low wall 23 extends upwardly from the floor of the furnace chamber. This wall is formed of refractory blocks or slabs and internal metal structures 24 spaced along the wall. The central tube bank extends from the wall 23 substantially to the roof 12, and together with said wall divides the furnace chamber into two combustion zones, A and B. At the bottom of each of said zones, there are rows of burners 25, the rows extending longitudinally along the furnace chamber and the burners being in staggered positions in the rows and directed upwardly through ports in the floor. The burners are adjustable to vary the heat input in the two zones. The roof of the furnace chamber has two outlets, 26 and 27, opening from the zones A and B into

exhaust ducts 28 and 29, discharging products of combustion from the furnace chamber. The outlets 26 and 27 and the ducts 28 and 29 preferably extend substantially the length of the furnace chamber, and the ducts have dampers 30 and 31 for adjusting the draft through the furnace.

Each of the three tube banks comprises a single vertical row of spaced horizontal tubes, all in a common vertical plane and connected by return bends for flow of the charge in a serpentine course through all of the tubes in succession. Fluid flows serially through the tubes of the outer banks and serially through the tubes in sections of the central bank. Each of the outer tube banks has an inlet 32 at its upper end connected to a charge line. At its lower end, each outer bank has an outlet 33. Through detachable tube connections 34, said outlets are joined to the inlet 35 of the central bank at its lower end. At a few tubes from the bottom of the central bank, preferably an odd number of such tubes, a crossover or transfer line 36 conducts the fluid to the top tube of the central bank, and thereafter the fluid flows downwardly through the remainder of the tube bank until it finally exits from the furnace, as through the discharge line 37. All of the banks, including their return bends, are confined within the furnace chamber and extend throughout most of the length of the chamber.

The tubes of the central bank are subjected to greater heat than the tubes of the outer banks, and they consequently require more frequent servicing and replacement. Therefore, provision is made for ready renewal of the central bank. The frame structure which supports the furnace carries a horizontal track 38 extending over the top of the furnace. This track lies in the vertical plane of the central tube bank and, through a plurality of suspension connections 39, the bank is supported by the track. The suspension connections extend through slots 40 in the roof 12. Hinged closures 41 close the portions of the slot between the suspension connections 39 and also close the portions adjacent the ends of the furnace chamber. These closures are formed on their inner sides of refractory material. The end wall 14 of the furnace chamber has a vertically elongated aperture or slot 42 in register with the adjacent side edge of the bank 22 and meeting the slot 40 through the roof. The slot 42 is normally closed by a hinged closure or door 43 formed at its inner side of refractory material. After detaching the pipe connections 34 and 37 and opening the top doors 41 and side door 43, the tube bank 22 may be pulled along its track outwardly through the slot 42 to the exterior of the furnace chamber where it may be conveniently serviced.

In Figure 3, I have shown the temperature of the fluid as it passes through the various tube coils in the furnace. In the graph, the side wall tube banks have been assumed to have eight tubes each, and the central or reactor tube bank has been shown as having fourteen tubes, the lower three of which are the first ones into which fluid from the side wall tubes flows.

In Figure 4, I have used the same tube numbering in showing the rate of heat input, but only for the tubes in the central or reactor tube bank.

In the operation of this furnace, the charge to be heated is continuously introduced into the upper ends of the outer tube banks 20 and 21 and passed progressively downward therethrough in parallel. It is to be understood that this arrangement is not an essential part of my invention,

and that any other paths of flow of the fluid through the side wall banks may be employed, such, for example, as having the fluid enter the bottoms of said tube banks and flow upwardly through them. Within the banks the charge is qiuckly preheated predominantly by radiant heat, including that received directly from combustion within the zones A and B and that received through re-radiation from the wall 23. While the tubes of these banks are heated predominantly upon one side, there is no danger of coke deposition, since the charge is cool when it enters the banks and does not remain therein long enough to reach a coking temperature. The provision of these banks avoids the requirement for the customary convection heating bank and the chamber containing such a bank and effects more efficient and quick preheating than can be attained by convection heating.

The preheated charge is passed from the lower ends of the banks 20 and 21 through the connections 33, 34, and 35 to the lower end of the central tube bank 22. This central tube bank is subjected to radiant heat directly from the products of combustion in zones A and B and also to heat reradiated from the walls 13, including their upper, sloping portions 13*a*. This bank, particularly in its upper tubes, may also be subjected to heat of convection as one of the dampers 30 and 31 is normally closed and the other one open, so that the products of combustion in both zones A and B exit through the same outlet 26 or 27. Thus, the products of combustion in one zone, for example, zone A, must pass between the tubes in bank 22 to reach the exit, when damper 30 is closed and damper 31 is open. It will be understood, of course, that the furnace may instead be operated with both dampers 30 and 31 open, in which arrangement the products of combustion would flow directly upward to outlets 26 and 27 and there would be substantially no flow of gases through the tubes in central bank 22.

In the bank 22, the charge passes progressively upward, preferably through an odd number of tubes to the crossover connection 36 through which it passes to the upper tube of the bank 22, and then passes progressively downward through the remainder of bank 22 to discharge connection 37. The number of tubes included between the connection 35 and 36 in the lower, and first, section of bank 22 is preferably an odd number for the reason that the inlet 35 and the outlet 37 of said bank 22 preferably pass through the same end wall 15 of the furnace, as indicted in Figure 2. There being no connection of the central tube bank 22 to the other end wall 14 of the furnace, provision is thereby made for expansion and contraction of the tubes with changes in temperature. By virtue of passing the preheated fluid first through the lower tubes of the intermediate bank 22 while the fluid is still at a relatively low temperature, the lower tubes, which are subjected to the greatest degree of heat, are prevented from overheating, as the fluid quickly absorbs and carries away the heat which is applied to the tubes. Thus, the fluid flowing through the lower section of bank 22, as will be seen from an inspection of the graph in Figure 3, at reactor coil number 9 in the graph, has not yet attained a maximum temperature, and therefore, more readily absorbs heat from the hotter tubes of the lower section of bank 22. This rapid absorption of heat is graphically illustrated in Figure 4, where it will be seen that the rate of absorption of heat in the lower and first tubes numbered 9,

10 and 11, in central bank 22, is much greater than that in the other tubes of the reactor coil, numbered 12 through 22.

This arrangement of fluid flow makes possible an unusually efficient and reliable furnace requiring a minimum of upkeep. As described in the previously mentioned copending application, the provision of side wall tube banks 20 and 21 permits rapid preheating of the charge, but at the same time does not permit coking in the side wall tubes, as the fluid does not attain a sufficiently high temperature for coke to form. The exit temperature from the side wall tube bank is kept below approximately 1000° F. Due to the fact that they are kept relatively cool, the side wall tubes can be made of low carbon steel and hence are of comparatively low cost. The tubes in the center row are made of allow steel to withstand the higher temperatures to which they are subjected.

Coking is also minimized in other parts of the furnace, because the tubes are so disposed that there are few, if any, relatively cold spots where coke deposition wiuld be likely to occur. Coking or carbon deposition is inhibited by the tubes in which the fluid is at a high enough temperature for carbon deposition, that is, those in the central or reactor coil, being heated substantially uniformly about their peripheries.

The exit from the lower part of the center row of tubes through the transfer tube is arranged to take place at a temperature just before coking tends to occur. Up to this temperature, the amount of coke which may form is sufficiently low so that the velocity of vapors through the transfer tube will effectively carry all of it to the top of the tubes, after which it will pass through the tubes aided by graviy and, therefore, without tending to clog the tubes.

Another advantage of my invention is that feeding of the preheated fluid first into the hottest tubes of the reactor coil accomplishes a rapid rise in the temperature of the fluid to a cracking temperature. This can be seen from an inspection of Figure 3, in which the steepest rise of the temperature curve is at tubes 9, 10 and 11, and of Figure 4, which shows that in those tubes the rate of heat absorption is greatest. This rapid rise of temperature is important because it suppresses carbon deposition, which occurs more readily when the temperature rise is slower.

Finally, in the furnace of my invention, I overcome a disadvantage found to occur in prior constructions of this general type, namely, the tendency of tubes which are subjected to the greatest heat to fail frequently and to require replacement or repair.

It is to be understood that the embodiment shown in the accompanying drawings and described above is merely illustrative, and that my invention may take other specific forms, such, for example, as a furnace having three combustion chambers and two intermediate tube walls, as shown in the above-mentioned copending application. Forms and embodiments other than those shown in this and the previous application, are likewise within the scope of my invention, and are to be considered as included by it where they are within the scope of the appended claims.

Having thus clearly described my invention, what I claim as new and desire to secure by Letters Pattent is:

1. The method of heating a hydrocarbon fluid, comprising conducting combustion within two side-by-side zones to effect a high degree of heating within regions of one end of the zones and progressively diminishing heating toward the opposite end of the zones, conducting said fluid in separate streams along confined courses within said highly heated regions and at the remote sides thereof and, within said courses, effecting preheating of the fluid predominantly by radiant heat, uniting said streams of the fluid thus preheated and conducting the preheated fluid along a relatively short confined course between said highly heated regions and in substantially equal exposure to radiant heat from said regions simultaneously and from the two regions together around substantially the entire cross section of the course, conducting the fluid from said relatively short course to a point between regions of the opposite end of the zones and thence along a longer confined course between the zones and in substantially equal exposure to radiant heat from said zones simultaneously and from the two zones together around substantially the entire cross section of the course, and, in said longer course, advancing the fluid progressively toward said highly heated regions, and conducting combustion gases of at least one of said zones over said longer course to heat the fluid therein by convection also.

2. The method of heating a hydrocarbon fluid, comprising conducting combustion within two side-by-side zones to effect a high degree of heating within regions at one end of the zones and progressively diminishing heating toward the opposite end of the zones, conducting said fluid in separate streams along confined courses within said highly heated regions and at the remote sides thereof and, within said courses, effecting preheating of the fluid predominantly by radiant heat, uniting said streams of the fluid thus preheated and conducting the preheated fluid along a relatively short confined course between said highly heated regions and in substantially equal exposure to radiant heat from said regions simultaneously and from the two regions together around substantially the entire cross section of the course, and conducting the fluid from said relatively short course to a point between regions of the opposite end of the zones and thence along a longer confined course between the zones and in substantially equal exposure to radiant heat from said zones simultaneously and from the two zones together around substantially the entire cross section of the course, and, in said longer course, advancing the fluid progressively toward said highly heated regions.

3. A method of heating a hydrocarbon fluid, comprising conducting combustion predominantly within lower regions of two side-by-side zones, passing said fluid in two separately confined streams and in the same general vertical direction along two substantially coextensive serpentine courses at the opposite outer sides of said zones to preheat the fluid predominantly by radiant heat, combining said streams after passage through said courses, passing the fluid of the combined streams along a relatively short confined course between said lower regions and substantially midway between said first courses, passing the fluid from said relatively short course to a point a substantial distance above the latter and thence downwardly along a relatively long serpentine course between said zones and substantially midway between said first courses,

and applying radiant heat from both of said zones simultaneously and substantially equally to opposite sides of the cross section of said relatively short course and said relatively long course to further heat the fluid.

4. The method claimed in claim 3 and including the step of reflecting radiant heat from said combustion predominantly upon opposite sides of said relatively long course.

5. A heater for hydrocarbon fluid, comprising a furnace chamber substantially symmetrical with respect to a central plane, a pair of outer banks of tubes within said chamber, arranged substantially symmetrically with respect to said plane, adjacent opposite side walls of the chamber and defining first courses for the fluid, a single row of spaced substantially parallel tubes located within said plane between said outer banks and dividing the chamber into two substantially duplicate combustion zones, a minor number of tubes of said row at one end of the row being serially connected and defining a second course for the fluid with an inlet and an outlet, and the remaining tubes of the row being serially connected and defining a third course for the fluid with an inlet at the opposite end of the row and an outlet adjacent said second course, a fluid delivery connection between each outer bank and the inlet of said second course, a fluid delivery connection between the outlet of said second course and the inlet of said third course, burner means arranged to conduct combustion within regions of said zones adjacent said second course and at opposite sides thereof, and outlet means disposed for passing products of said combustion from regions adjacent the inlet end of said third course.

6. A heater for hydrocarbon fluid comprising a furnace chamber, a pair of outer banks of tubes within said chamber, adjacent opposite side walls thereof and defining first courses for the fluid, a single row of spaced substantially parallel tubes located within a plane substantially midway between said outer banks and dividing the chamber into two side-by-side combustion zones, a minor number of tubes of said row at one end of the row being serially connected and defining a second course for the fluid with an inlet and an outlet and the remaining tubes of the row being serially connected and defining a third course for the fluid with an inlet at the opposite end of the row and an outlet adjacent said second course, a fluid delivery connection between each outer bank and the inlet of said second course, a fluid delivery connection between the outlet of said second course and the inlet of said third course, burner means arranged to conduct combustion within regions of said zones adjacent said second course at opposite sides thereof, and outlet means disposed for passing products of said combustion from regions of said zones adjacent the inlet end of said third course.

7. A heater as claimed in claim 6 wherein the portion of said row of tubes defining said third course extends materially beyond said outer banks, and the opposite walls of the chamber have portions thereof disposed to reflect radiant heat of said combustion predominantly upon opposite sides of the tubes defining said third course.

8. A heater as claimed in claim 6 wherein the said burner means comprises a plurality of burners within each zone spaced longitudinally of the tubes of said row and directed toward the regions adjacent the inlet end of said third course.

9. A heater for hydrocarbon fluid comprising a combustion chamber substantially symmetrical with respect to a central plane, a single row of spaced substantially parallel tubes within said plane and dividing the chamber into a pair of substantially duplicate combustion zones, a minor number of tubes of the row at one end of the row being serially connected and defining a relatively short course for the fluid with an inlet and an outlet, and the remaining tubes of the row being serially connected and defining a relatively long course for the fluid with an inlet at the opposite end of the row and an outlet adjacent said short course, means to deliver the fluid to the inlet of said short course, a fluid delivery connection between the outlet of said short course and the inlet of said long course, and burner means arranged for combustion of fuel within regions of said zones adjacent said short course and at opposite sides thereof, for radiant heating of the tubes of the row, the individual tubes of the row being exposed transversely around substantially their entire circumference to receive radiant heat from both zones simultaneously and substantially equally, and outlet means disposed for passing products of said combustion from regions of said zones adjacent the inlet end of said longer course.

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