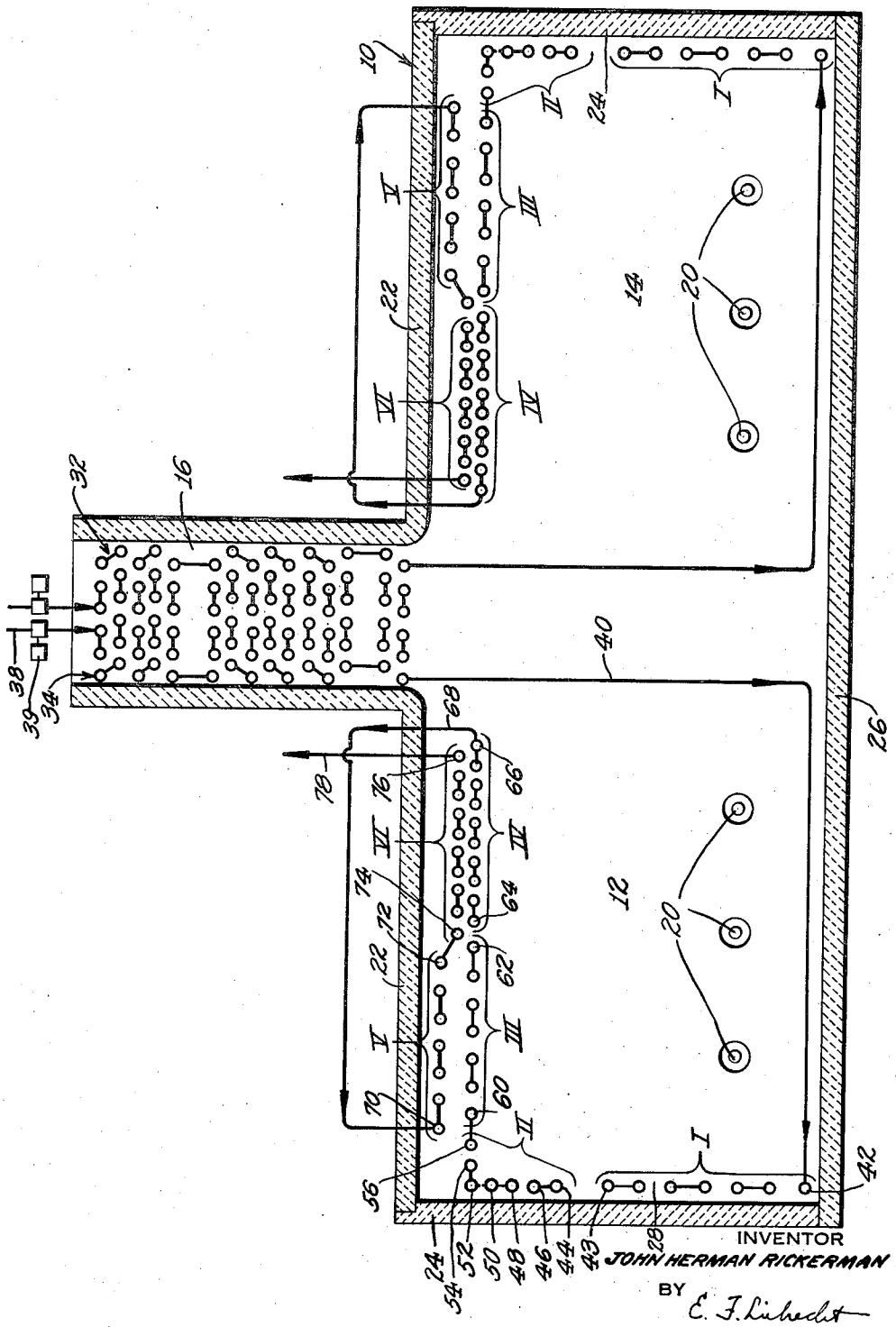
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HEATING HYDROCARBON FLUID

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HEATING HYDROCARBON FLUID

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This invention relates to heating apparatus adapted for heating fluids and more particularly relates to heating hydrocarbon fluids to conversion temperature.

In the conversion of hydrocarbon fluids for the production of motor fuel it is desired to quickly raise the temperature of the hydrocarbon fluid as it passes through the furnace or heating apparatus to quickly approach the conversion temperature. At this stage of the heating the danger of carbon or coke deposition in the heater tubes or coil is relatively small and large amounts of heat may be added per unit of heating surface or the rate of heating of the hydrocarbon fluid may be relatively high. After the hydrocarbon fluid has reached a conversion temperature the rate of heating of the hydrocarbon fluid must be decreased and controlled to minimize carbon deposition and coke formation in the heater tubes, but sufficient heat must be added per unit of heating surface to effect the desired extent of conversion.

According to my invention heater tubes are so arranged and spaced in a radiant heating section of a heating apparatus to control the heating of the hydrocarbon fluid passing through the heater tubes. I have shown a box-type furnace as a specific form of my invention in which the furnace is provided with a radiant heating section and a convection section, the radiant heating section being provided with heater tubes extending longitudinally of the furnace. The heater tubes are interconnected to form a heater coil or continuous passage for the hydrocarbon fluid. In the specific form of apparatus shown in the drawing there are included communicating radiant heating sections preferably heated by combustion of fuel and a common overhead convection section for receiving combustion products from the radiant heating sections. The invention is not to be limited to this showing as a single radiant heating section and a single convection section may be used. My invention may also be used with other types of furnaces. The radiant heating sections as shown are substantial duplicates and separate streams are preferably passed through the separate radiant heating sections.

The heating of one of these streams will now be described briefly. Hydrocarbon fluid to be heated is passed through heater tubes in a common convection heating section and is then passed through heater tubes in the one radiant heating section. The hydrocarbon fluid is first passed through a group of wall heater tubes in the radiant heating section which are spaced relatively far apart so that a large amount of heat per unit of heating surface is added to the hydrocarbon fluid passing through the first group of wall heater tubes. The heated hydrocarbon fluid is then passed through another group of wall tubes and part of an exposed row of roof tubes. In the second group of heater tubes, the tubes are spaced closer together than the tubes in the first group to reduce the amount of heat per unit of heating surface being added to the hydrocarbon fluid passing through this second group of heater tubes.

The heated hydrocarbon fluid is then passed through a third group of heater tubes which includes an exposed row of roof tubes. The tubes in this third group are spaced further apart than the tubes in the second group and are spaced at distances about equal to the distance between tubes in the first group. The hydrocarbon fluid passing through the third group is further heated but at a slower rate than the rate of heating of the hydrocarbon fluid passing through the first and second groups. This rate of heating is lower than the rate of heating of the first group for the reason that there is a second row of roof tubes behind the third group as will be presently described.

The heated hydrocarbon fluid leaves the third group of tubes and passes through a fourth group of tubes which comprises part of the exposed row of roof tubes. The third and fourth groups of tubes are in the same horizontal plane and form the exposed row of roof tubes. These tubes in the fourth group are closer together than those in the third group and are spaced at about the same distance from each other as the tubes in the second group of tubes above described. In the fourth group the hydrocarbon fluid is further heated but at a slower rate than the rate of heating of the hydrocarbon fluid passing through the third group for the reason that the heater tubes in the fourth group are spaced closer together and there is also a shielded row of roof tubes behind this fourth group of heater tubes.

The hydrocarbon fluid after passing through the fourth group of tubes is passed to a fifth group of tubes which comprises a shielded row of roof tubes arranged behind the roof tubes forming the third group above described. The heater tubes in the fifth group are spaced apart at about the same distances as the heater tubes in the third group but as they are shielded they receive less heat per unit of heating surface than the hydrocarbon fluid passing through the ex-

posed row of tubes in the third group. In passing through the fifth group the hydrocarbon fluid has its temperature further raised a small amount.

The heated hydrocarbon fluid then passes through a sixth group of heater tubes which forms part of the shielded second row of roof tubes. The heater tubes in the sixth group are spaced closer together than the tubes in the fifth group and are spaced at about the same distances from each other as the tubes in the fourth group. In addition the heater tubes in the sixth group are placed or positioned closer to the exposed row of roof tubes comprising the fourth group and farther from the roof of the furnace than the fifth group of tubes. Due to the positioning in the sixth group the amount of heat per unit of heating surface added to the hydrocarbon fluid passing through these heater tubes is reduced and the hydrocarbon fluid is maintained at substantially the same temperature during its passage through the sixth group of heater tubes. The sixth group of heater tubes comprises a soaker section in which conversion of the hydrocarbon fluid is mainly carried out.

In the drawing the figure represents a transverse vertical cross section taken through a heating apparatus embodying one form of my invention.

Referring now to the drawing the reference character **10** designates a furnace or heating apparatus including radiant heating section **12**, radiant heating section **14** and a convection heating section **16**. The radiant heating sections are each separately fired by means of burners **20** which burn fuel, such as gas, to supply radiant heat to the radiant heating sections. The burners are preferably arranged in the lower portion of each radiant heating section. The radiant heating sections communicate at their one end and the products of combustion from each radiant heating section pass upwardly through the common convection heating section **16** which is positioned above the central portion of the furnace and which communicates with the radiant heating sections at their communicating ends. If desired, the convection heating section may be arranged in other positions, for example, it may be arranged between the radiant heating sections or at an end of the furnace.

While I have shown a furnace provided with two radiant heating sections and a common convection section I do not wish to be restricted in this respect as my invention may be employed with other types of furnaces and may be used in a heating apparatus including a single radiant heating section and preferably a convection heating section.

The heating apparatus shown in the drawing is a box-type furnace in which each radiant heating section has a roof **22**, side walls **24**, floor **26** and end walls **28**. The burners in each radiant heating section preferably extend through opposite end walls **28** of the furnace so that the flames from opposite burners are directed toward each other. Or the burners in one end wall may be offset with respect to the burners in the opposite end wall.

In describing my invention reference will be made to one radiant heating section as the radiant heating sections are substantial duplicates when separate streams of hydrocarbon fluids of substantially the same composition are to be treated and the description of one radiant heating section will suffice for both sections. The heater tubes in each radiant heating section are horizontally arranged in vertical and horizontal rows adjacent the boundary surfaces of the radiant heating section and the heater tubes extend longitudinally of the furnace. The ends of the tubes are connected by suitable headers (not shown) which are positioned in header boxes (not shown) so as to provide a heating coil for the hydrocarbon fluid to be heated.

The convection heating section **16** is provided with two groups of heater tubes **32** and **34** for preheating separate streams of hydrocarbon fluid, one stream passing to one radiant heating section **12** and the other stream passing to the other radiant heating section **14**.

The heating of one stream of hydrocarbon fluid will now be described. When it is desired to convert hydrocarbons such as gas oils to lower boiling hydrocarbons such as motor fuels and with burners having a known capacity, my invention may be used to so arrange and space the heater tubes to effect controlled heating of the hydrocarbons without danger of overheating and consequent deposition of carbon in the tubes. The tubes are so arranged in groups that the hydrocarbons are first subjected to rapid heating and then the rate of heating is decreased until at the end of the conversion operation only sufficient heat is added to the hydrocarbons to effect the desired extent of conversion. I accomplish these results by proper spacing and grouping of the tubes in single and double rows. In the specific form of the invention six different rates of heating are utilized to heat and convert hydrocarbons.

Hydrocarbon fluid to be heated is passed through line **38** by pump **39** and through the heater tubes **34** in the convection heating section **16** where the hydrocarbon fluid is preheated. The preheated hydrocarbon fluid is then passed through line **40** and introduced into the lowest tube **42** of the first group of wall heater tubes designated as I in the drawing. The hydrocarbon fluid passes through tubes in group I which begins with tube **42** and ends with tube **43**.

In this form of the invention there is a single row of wall heater tubes which are substantially equidistantly spaced at relatively large distances whereby the hydrocarbon fluid passing through these tubes is rapidly raised in temperature. As the tubes are relatively far apart, the areas of the boundary surface between the tubes become heated and reradiate heat to the tubes.

The heated stream of hydrocarbon fluid is then passed through a second group of heater tubes designated as II on the drawing. This second group of tubes includes wall heater tubes **44**, **46**, **48**, **50** and **52** which are positioned adjacent the side wall **24** of the radiant heating section **12** and in the upper portion of the radiant heating section **12**. Group II also includes roof tubes **54** and **56** adjacent an upper corner of the radiant heating section **12** which form a single row of roof tubes and which are spaced apart at about the same distances as the wall heater tubes **44**, **46**, **48**, **50** and **52** of the second group. In the heater tubes of group II the hydrocarbon fluid is further heated but the rate of heating is reduced for the reason that the heater tubes are spaced closer together than the heater tubes in the group I. The heater tubes in group II are substantially equidistantly spaced.

The stream of hydrocarbon fluid is then passed

through groups of roof tubes which are arranged in a double row and is further heated. The heated stream of hydrocarbon fluid first passes through certain tubes in an exposed row of roof tubes forming a group designated as III on the drawing in which the individual roof tubes are substantially equidistantly spaced apart about the same distances as those in group I. However, due to the fact that there is a second row of roof tubes behind the exposed row of roof tubes the amount of heat per unit of heating surface added to the hydrocarbon fluid passing through tubes in group III is less than that added to the hydrocarbon fluid passing through tubes in group I. The first tube in group III is 60 and the last tube is 62.

The heated hydrocarbon fluid is then passed through another group of tubes comprising the remaining exposed roof tubes and which is designated as group IV in the drawing. The first tube in group IV is 64 and the last tube is 66. In group IV the last tube 66 is adjacent the convection heating section 16. In the specific form of the invention there are more tubes in group IV than in the previous groups above described.

The tubes in this group are substantially equidistantly spaced but they are spaced closer together than the tubes in group III. The heater tubes in groups III and IV form the exposed row of roof tubes and the tubes are substantially in the same horizontal plane and in alinement. Due to the closer spacing of the heater tubes and due to the presence of a row of tubes behind the heater tubes in group IV the rate of heating of the hydrocarbon fluid passing through these tubes is further decreased.

The heated hydrocarbon fluid leaving group IV of heater tubes is then passed through line 68 and is introduced into the first tube 70 of the shielded row of roof tubes designated as group V in the drawing and passes through these tubes. The last tube in this group is tube 72. The first tube 70 in group V is arranged in the upper portion of radiant heating section 12 adjacent the corner distant from the convection heating section 16. The heater tubes in group V are positioned behind the heater tubes in group III previously described. The heater tubes in group V are substantially equidistantly spaced at about the same distances apart as the heater tubes in group III but the tubes are staggered with respect to the tubes in group V. It is to be noted that the first or shielded roof tube 70 of group V is positioned at some distance from the side wall 24 so that the roof tubes 54 and 56 forming part of group II above described do not have a shielded row of roof tubes behind them.

After being heated in the heater tubes in group V the hydrocarbon fluid is passed through the second shielded row of roof tubes indicated as group VI on the drawing. Group VI starts with roof tube 74 and ends with roof tube 76. End tube 76 is positioned to the rear of tube 66 in group IV and is adjacent the convection heating section 16. The heater tubes in group VI are substantially equidistantly spaced but they are arranged closer together than the heater tubes in group V and in the specific form of the invention the heater tubes in group VI are also arranged closer to the exposed row of roof tubes IV and farther from the roof 22 than the tubes in group V.

Also the number of tubes in group VI is larger than the number of tubes in each of groups I, II, III and V but the same as the number of tubes in group IV. Group VI is arranged behind group IV and the tubes of each group are in staggered relation. With this arrangement and number of tubes the rate of heating of the hydrocarbon fluid passing through the heater tubes in group VI is further reduced. The heater tubes forming group VI comprise a soaking section in which less heat is supplied to the hydrocarbon fluid being converted and the temperature of the hydrocarbon fluid is maintained substantially constant to effect the desired extent of conversion without objectionable coking and without changing the firing of the burners. The products of conversion leave the last heater tube 76 in the group VI and pass through line 78 from the furnace. From the above it will be seen that the hydrocarbon is heated in groups of tubes in one radiant heating section and the control of heating is obtained by arranging and spacing the tubes.

In the heating of the hydrocarbon fluid as it passes through radiant heating section 12, the hydrocarbon fluid passes generally upwardly through tubes in groups I and II, then generally from left to the right through groups III and IV as viewed in the figure and then generally from left to right through groups V and VI as viewed in the figure.

A specific example of heating a hydrocarbon fluid and the arrangement of the heater tubes will now be given. All the heater tubes are about 5 inches in outside diameter and about 4 inches in inside diameter. About 750 barrels per hour of a Mid-Continent gas oil under a pressure of about 1000 pounds per sq. in. and at a temperature of about 660° F. are passed through line 38 and through the one set of convection heating tubes 34 to preheat the hydrocarbon fluid to about 785° F. While I have given specific temperatures and pressures in the specific example, it is to be understood that these are by way of illustration only and the temperatures and pressures may be varied for the same stock or for different stocks. Higher or lower temperatures and higher or lower pressures may be used.

The heated hydrocarbon fluid is then passed through line 40 and upwardly through group I of wall heater tubes wherein it is subjected to drastic heating and the temperature of the hydrocarbon fluid is raised to about 831° F. In the particular form of the invention shown in the drawing the bottom wall heater tube 42 is spaced about 6" from the floor 26 of the furnace. The wall heater tubes in group I are about 13⅞" apart, center to center, and are spaced about 5½" from the side wall 24. The heat density or rate of heat transfer to group I of heater tubes is about 22,050 B. t. u./hr./sq. ft.

The hydrocarbon fluid after passing through the heater tubes in group I is passed through the heater tubes forming group II wherein the temperature is raised to about 865° F. The wall heater tubes indicated as 44, 46, 48, 50 and 52 on the drawing are spaced apart about 9¼", center to center, and the vertical row of these tubes is spaced about 5½" from the side wall 24. In group II there are also included roof tubes 54 and 56 which are spaced apart about 9¼", center to center, and about 18" from the roof 22. Tube 52 is also spaced about 9¼", center to center, from roof tube 54 and about 18" from roof 22. It is to be noted that there are no roof tubes directly behind roof tubes 54 and 56. Due to the closer spacing of the heater tubes in group II the rate of heating of the hydrocarbon fluid in the heater tubes is reduced. The heat density or rate of

heat transfer to the tubes of group II is about 17,820 B. t. u./hr./sq. ft.

The hydrocarbon fluid after leaving the heater tubes in group II is passed through the exposed row of roof tubes in group III and the temperature of the hydrocarbon fluid is raised to about 895° F. The heater tubes in group III are about 13⅞" apart, center to center, and the rate of heat transfer or heat density is about 16,600 B. t. u./hr./sq. ft. The heater tubes in group III are about 18" from the roof **22** and about 12" from the shielded row of roof tubes forming group V.

The heated hydrocarbon fluid is then passed through the heater tubes in group IV which are spaced apart about 9¼", center to center, and the hydrocarbon fluid is heated to about 926° F. The heat density or rate of heat transfer to this group of tubes is about 14,130 B. t. u./hr./sq. ft. The heater tubes in group IV are about 18" from the roof **22** and about 8" from the shielded row of roof tubes forming group VI.

The heated hydrocarbon fluid leaves group IV of tubes through line **68** and is then passed through group V comprising the shielded row of roof tubes. Group V is positioned behind group III. The tubes in group V are about 13⅞" apart, center to center, and are about 6" from the roof **22** of the furnace and about 12" from the exposed row of roof tubes forming group III. The heat density or rate of heat transfer to the shielded row of roof tubes forming group V is about 10,950 B. t. u./hr./sq. ft.

The hydrocarbon fluid after being heated to about 939° F. in the heater tubes in group V is passed through the shielded row of roof tubes forming group VI wherein the temperature of the hydrocarbon fluid is maintained substantially constant. The heater tubes in group VI are arranged closer together than the tubes in group V. The tubes in group VI are about 9¼" apart, center to center, and the heat density or rate of heat transfer is about 5,300 B. t. u./hr./sq. ft. The heater tubes in group VI are arranged closer to the exposed row of roof tubes than the tubes in group V. The heater tubes in group VI are about 8" away from the exposed row of roof tubes in group IV and about 10" away from the roof **22**.

In the specific form of the invention shown in the drawing the distance between tube **43** of group I and tube **44** in group II is about 16". The distance between tube **56** of group II and tube **60** of group III and the distance between tube **62** of group III and tube **64** of group IV are about the same, namely 13⅞". The distance between tube **72** in group V and tube **74** in group VI is about 14½". The heated hydrocarbon fluid leaves the heater tubes in group VI through line **78** at a temperature of about 940° F. and under a pressure of about 750 pounds per sq. in. From this it will be seen that the heater tubes in group VI form a soaking section wherein the temperature of the hydrocarbon fluid being heated is maintained substantially constant but a relatively small amount of heat is added to the hydrocarbon fluid in order to carry out the conversion reaction. In the first groups of heater tubes the rate of heating was controlled to rapidly raise the temperature of the hydrocarbon fluid to a conversion temperature. The hydrocarbon fluid at conversion temperature is passed through group VI as a soaking section, and the soaking section is provided to supply sufficient heat to the hydrocarbon fluid to effect the desired extent of conversion without depositing appreciable amounts of carbon or coke in the tubes.

The heater tubes in the second radiant heating section **14** are arranged similarly to the heater tubes in radiant heating section **12** and the description of the heating of hydrocarbon fluid passing through the heater tubes in the convection heating section **16** and radiant heating section **12** also applies to the heating of the other stream passing through the heater tubes **32** in convection heating section **16** and through the groups of wall and roof heater tubes arranged in the other radiant heating section **14**.

While I have shown one form of heating apparatus embodying my invention it is to be understood that this is by way of illustration and various modifications and changes may be made without departing from the spirit of my invention.

I claim:

1. A heating apparatus for heating hydrocarbon fluids to conversion temperature including a radiant heating section, means for supplying radiant heat thereto, groups of heater tubes arranged adjacent boundary surfaces of said radiant heating section, certain of said heater tubes being arranged in a double row comprising an exposed row and a shielded row, means for passing hydrocarbon fluid to be heated through said groups of heater tubes in succession, the first groups of tubes being arranged in a single row, the tubes in each of said first groups being substantially equidistantly spaced and the tubes in said first group being spaced apart at greater distances than the tubes in another group, the remaining groups of tubes forming the double row of tubes, certain groups forming the exposed row and certain other groups forming the shielded row, the tubes in each of the groups of said double row being substantially equidistantly spaced and the tubes in certain groups being spaced at greater distances apart than the tubes in other groups of tubes, to control the rate of heating of the hydrocarbon fluid passing through said tubes, the last group of tubes in said shielded row being spaced further from the boundary surface than the adjacent group of tubes in said shielded row, the last group of tubes in said shielded row forming a soaking section, the rate of heating the hydrocarbon fluid passing through said tubes in the groups decreasing from the first to the last group.

2. A heating apparatus for heating hydrocarbon fluid to conversion temperature including radiant heating sections and a convection heating section adapted to receive combustion products from said radiant heating sections, heater tubes in said convection heating section for preheating streams of hydrocarbon fluid, fuel burning means for supplying radiant heat to said radiant heating sections, heater tubes arranged adjacent boundary surfaces of each of said radiant heating sections, means for passing separate streams of hydrocarbon fluid through said heater tubes, said heater tubes in each radiant section being arranged and spaced to control the rate of heating of the hydrocarbon fluid passing therethrough, said heater tubes in each radiant heating section being arranged in groups with certain of the heater tubes being arranged in a single row and other tubes being arranged in a double row comprising an exposed row and a shielded row, said heater tubes in each of the groups in the single row being substantially equidistantly spaced and the tubes in one group be-

ing spaced differently from the tubes in another group to obtain different heating rates, said heater tubes in the double row in each radiant heating section being in pairs of groups, the groups in one row being behind the groups in the other row, said heater tubes in each pair of groups being substantially equidistantly spaced and the tubes in one pair of groups being differently spaced from the tubes in another pair of groups, one group of tubes in said shielded row in each radiant heating section being arranged further away from its adjacent boundary surface than the other group in said shielded row.

3. A heating apparatus for heating hydrocarbon fluid to conversion temperature including a radiant heating section, means for supplying radiant heat to said radiant heating section, heater tubes arranged adjacent boundary surfaces of said radiant heating section, means for passing hydrocarbon fluid through said heater tubes, said heater tubes being arranged and spaced to control the rate of heating of the hydrocarbon fluid passing therethrough, said heater tubes being arranged in groups with certain of the heater tubes being arranged in a single row and other tubes being arranged in a double row comprising an exposed row and a shielded row, said heater tubes in each of the groups in the single row being substantially equidistantly spaced and the tubes in one group being spaced differently from the tubes in another group to obtain different heating rates, said heater tubes in the double row being in pairs of groups, the groups in one row being behind the groups in the other row, said heater tubes in each pair of groups being substantially equidistantly spaced and the tubes in one pair of groups being differently spaced from the tubes in another pair of groups, one group of tubes in said shielded row being arranged further away from its adjacent boundary surface than the other group in said shielded row.

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