

June 1, 1937.

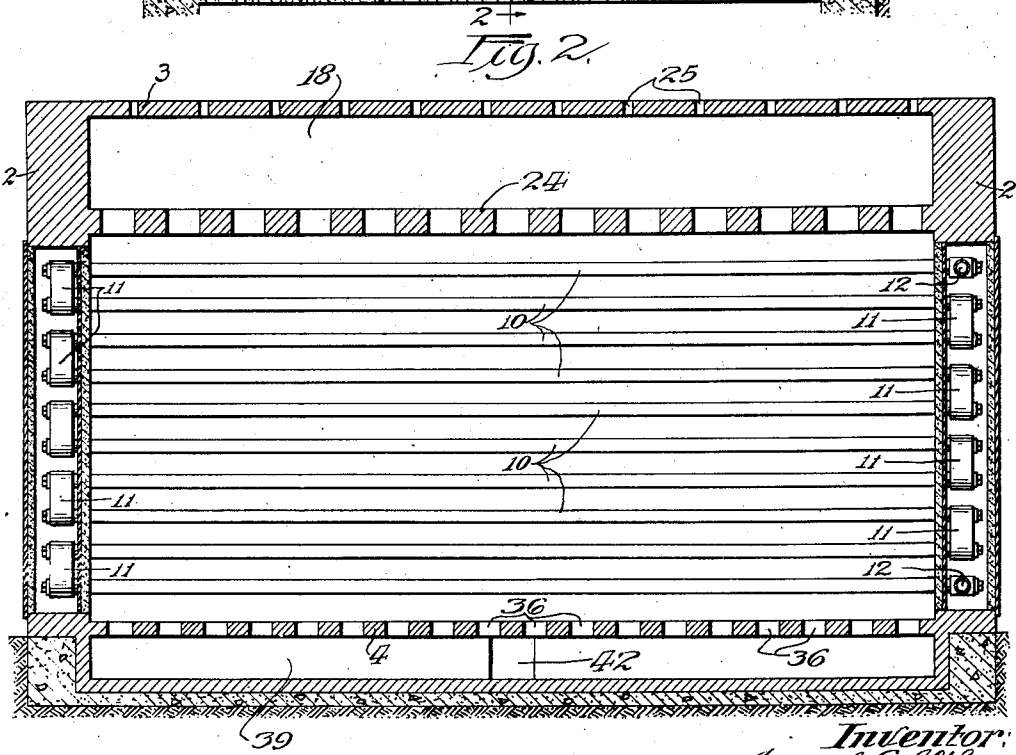
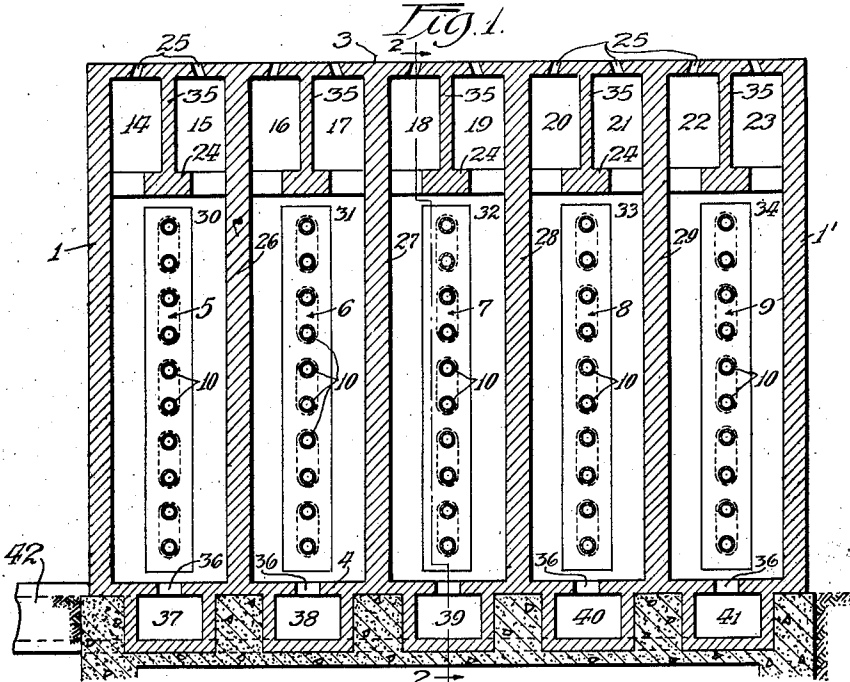
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2,081,973

METHOD OF HEATING FLUIDS

Original Filed June 4, 1932

3 Sheets-Sheet 1



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Fig. 3.

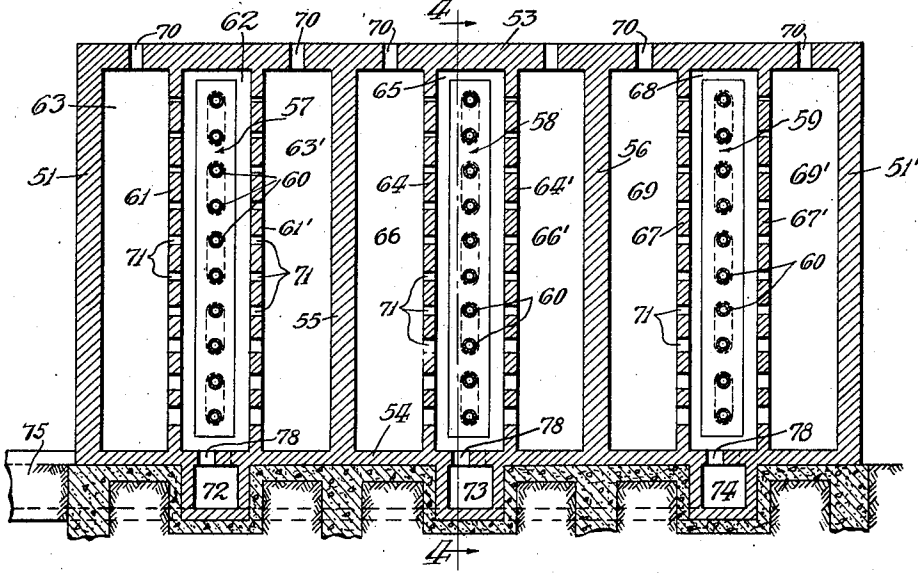
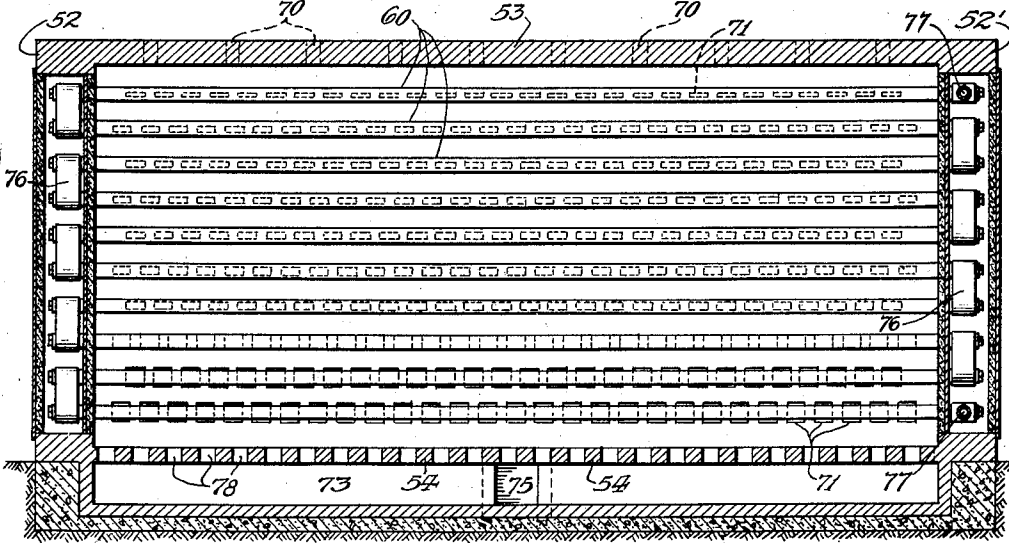


Fig. 4.



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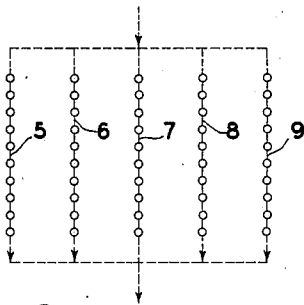


FIG. 5

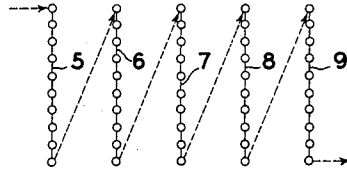


FIG. 6

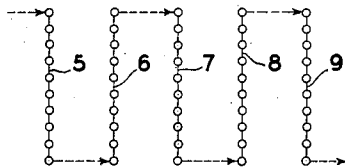


FIG. 7

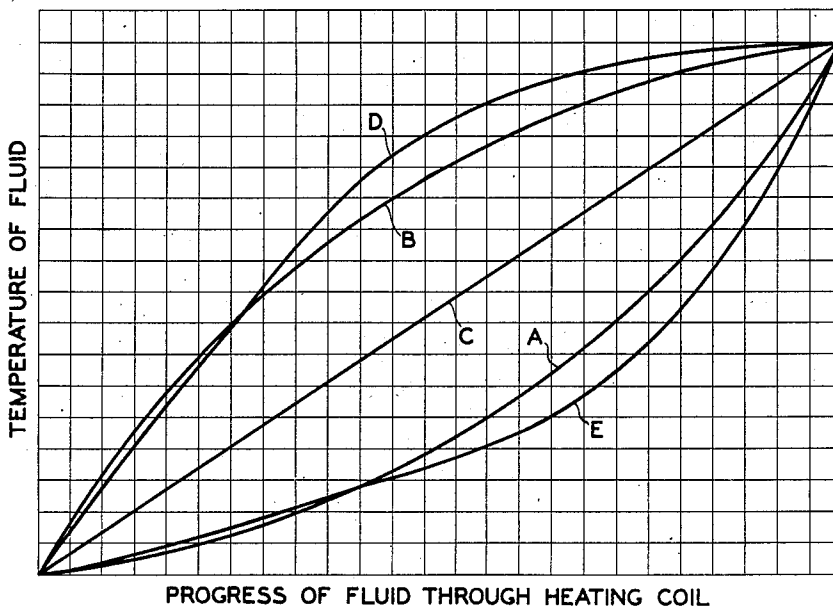


FIG. 8

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METHOD OF HEATING FLUIDS

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7 Claims. (Cl. 122—356)

This invention particularly refers to an improved method and means of heating fluids during their passage through a fluid conduit, which comprises subjecting the maximum surface of a fluid conduit to high rates of heating in order to obtain a high average rate of heat input over the entire surface of the conduit.

More particularly the invention relates to a method and means of heating fluids by subjecting the surfaces of the fluid conduit to radiant and convection heat so as to obtain the maximum average rate of heat input over the entire surface of the said fluid conduit.

While the invention may be applied to the heating of fluids generally, its preferred use is in the heating of hydrocarbon oils, and it is especially applicable to the cracking of hydrocarbon oils.

Among the advantages of the present invention may be mentioned: (a) The control of velocity, pressure drop and turbulence in the fluid conduit irrespective of the total quantity of oil undergoing treatment at one time; (b) high average heat input over the entire surface of the fluid conduit and uniform application of heat to opposite sides of the conduit; (c) flexibility of control of heat application to obtain any desired rate of heat input by direct control of the firing conditions and direct control of heat distribution around each section of the coil to obtain any desired heating curve for the material in the heating coil; (d) high tube efficiency. Maximum capacity for a fluid conduit of given size or, vice versa, minimum tube surface for a given capacity; (e) quick heating of the oil and vapors to relatively high temperatures with minimum time which, as applied to the conversion of hydrocarbon oils, reduces over-cracking with a consequent reduction in coke formation and deposition in the fluid conduit and in gas production and with an increase in gasoline yield and octane number or knock rating of the same. The use of the invention also reduces installation, operation and maintenance cost and improves the safety factor. By the application of the invention a large quantity of oil may receive the same heat treatment as a small quantity of oil with all of the resulting advantages.

Modern heaters employing both radiant and convection heat provide for the application of direct or nascent radiant heat energy from a source of heat to the fluid conduit or heating tubes from one direction only, the opposite sides of the tubes ordinarily receiving indirect radiant heat from adjacent reflecting surfaces, while the

distribution of convection heat around the tubes is uncontrolled and varies with different furnace structures and tube arrangements as well as with variations in the draft and other firing conditions in the furnace. Obviously this method gives unequal heating around the tube or fluid conduit, the side exposed to direct radiation from the source of heat usually receiving heat at an average rate approximately twice as great as the average rate of heating on the opposite surface of the tube, which is exposed to reflected radiant heat, thus greatly decreasing the average rate of heat input over the entire surface of the tube, below the maximum rate. Due to unequal heat intensity, at different points around the circumference of the tube, the walls of the tube are subjected to unequal expansion stresses and, in the heating of hydrocarbon oils to the high temperatures required for their conversion, often causes local overheating of a portion of the oil and the resulting formation of excessive quantities of coke and gas. Also as the capacity of the furnace is increased, usually involving an increase in the length of the fluid conduit, the velocity and pressure drop are correspondingly increased, also, turbulence, heat transfer and other conditions are changed, all of which factors may result in overcracking, coke deposition and reduced yield of gasoline and a poorer quality of the same. These disadvantages are overcome in the present invention.

The present invention embodies a furnace in which the fluid conduit is heated from opposite sides by both radiant and convection heat in such a manner that the maximum surface of each tube of the fluid conduit is subjected to the maximum rate of heat input under the existing conditions and uniform heating conditions are obtained on opposite sides of the tube. In this manner the average rate of heating over the entire tube surface may be greatly increased over that obtainable by other methods without increasing the maximum rate of heating. Thus a much higher tube efficiency is obtainable and the fluid undergoing heating may be heated to the desired temperature in a minimum of time. The simplicity and compactness of the furnace structure of the present invention, as well as the decreased amount of tube surface required for a given capacity, are obvious advantages. Also, due to uniform heating of the tube, unequal expansion stresses are minimized, permitting higher maximum rates of heating than may be safely employed when unequal expansion stresses are present in the tube walls. Uniform heating also elim-

inates local overheating of the fluid passing through the tube and results in the production of less gas and coke and in a motor fuel product of increased antiknock value, as applied to the conversion of hydrocarbon oil.

As a further feature of the invention, the fluid conduit may be divided into a plurality of tube banks each of which is independently heated from opposite sides. The various tube banks may be connected either in series or in parallel. When connected in series, the arrangement provides a method and means of obtaining a close control over the intensity of heating in each section of the entire fluid conduit independent of that in any other section so that the rate of heat input may be varied in different sections of the fluid conduit to suit requirements or be maintained substantially uniform in the various sections of the heating coil or fluid conduit. This makes it possible to obtain any desired type of heating curve and permits changing the heating curve at will by simply changing the firing conditions affecting the different sections of the coil without any change in the furnace structure or in the flow through the heating coil.

With parallel flow through the various sections of the heating coil, the features of the present invention permit increasing the capacity of the furnace by the simple addition of unit sections without changing any of the heating characteristics. For example: given a furnace with a fluid conduit comprising two banks of heating tubes, the tubes of each bank being connected in series and the two banks being connected in parallel, the capacity of the furnace may be doubled by the addition of two similar unit sections having two similar banks of tubes, without increasing the pressure drop through the total fluid conduit, which now comprises the four tube banks connected in parallel, without changing the velocity of the fluid flowing through the heating coil and without otherwise changing the heating conditions such as the intensity of heating in each unit section and each portion of the various unit sections of the furnace and without changing the type of heating curve.

A multiple-unit furnace of the type provided by the features of the present invention may also be utilized to special advantage as applied to the conversion of hydrocarbon oils when it is desirable to subject two or more different types of oil to independently controlled heating conditions in the same cracking system. In this connection, any number of unit sections of the same furnace may be employed for any number of different oils, one or more sections being utilized for each type of oil with independently controlled heating conditions in each unit section.

Figures 1 and 2 of the attached diagrammatic drawings illustrate a simple furnace structure comprising one specific form of apparatus embodying the features of the present invention.

Referring to the drawings, Figure 1 is a sectional end view of the furnace and Figure 2 is a sectional elevation of the same structure. The main furnace structure comprises side walls 1 and 1', end walls 2 and 2', a roof 3 and a floor 4. The fluid conduit comprises a multiplicity of vertical tube banks 5, 6, 7, 8 and 9, each consisting of a number of horizontally disposed tubes 10 extending between the end walls 2 and 2' of the furnace. The tubes of each vertical row or bank are connected in series by means of suitable headers or return bends 11. Inlet and outlet ports 12 are provided at opposite ends of each bank of tubes,

each of which may be utilized as either the inlet or outlet port so that the flow of oil or other fluid to be heated may be either upward or downward through any individual bank of tubes, as desired.

In the particular form of furnace here illustrated, firing and combustion tunnels 14, 15, 16, 17, 18, 19, 20, 21, 22 and 23 are provided beneath the roof 3 and above the sub-roof 24 of the furnace, one tunnel being provided on each side of each vertical bank or row of tubes. Firing ports 25 are provided for each firing tunnel through which fuel of any desired form is supplied by means of suitable burners, not shown in the drawings.

Walls 26, 27, 28 and 29, within the main furnace structure, divide the entire furnace here illustrated into five unit sections comprising heating zones 30, 31, 32, 33 and 34 containing the respective tube banks 5, 6, 7, 8 and 9. Firing tunnels 14 and 15 are located on opposite sides of the vertical center line through tube bank 5 and discharge their products on opposite sides of the tubes. In a similar manner pairs of firing tunnels 16 and 17, 18 and 19, 20 and 21, 22 and 23 discharge their products on opposite sides of the tubes in the respective banks 6, 7, 8 and 9. Dividing walls 35 may separate the members of each pair of firing tunnels or this dividing wall may be eliminated, as desired. Also that portion of walls 26, 27, 28 and 29, between the sub-roof 24 and roof 3 of the furnace which separates adjacent firing tunnels of different pairs may, when desired, be eliminated. Combustion gases are removed from each of the heating compartments 31, 32, 33 and 34 through openings 36 and the floor 4 of the furnace into the respective gas passageways 37, 38, 39, 40 and 41 from which they are discharged through a flue 42 to a suitable stack or air preheater section, not shown in the drawings.

Uniform firing conditions are employed in the pair of firing tunnels contained in each unit section of the furnace in order that equalized heating conditions are obtained on opposite sides of each tube bank. In this manner radiant heat from incandescent gases, directed on opposite sides of each tube bank, and convection heat obtained by contact of the hot combustion products, which are directed equally on opposite sides of each bank of tubes, serve to equally heat the opposite sides of each individual tube.

By controlling firing conditions in any pair of firing tunnels and in the heating zone on opposite sides of the corresponding bank of tubes, substantially the same or different heating conditions may be obtained for the various tubes from top to bottom of any bank so that the rate of heating in any unit section of the furnace may be substantially uniform, increasing or decreasing from top to bottom. In a similar manner by controlling the intensity of firing in each unit section of the furnace, substantially equalized or different rates of heating may be obtained in the various unit sections of the furnace so that a uniform, decreasing or increasing rate of heating may be obtained throughout the entire fluid conduit or so that a maximum or minimum rate of heating may be obtained at any desired point in the fluid conduit.

It will be understood that many modifications of the furnace structure illustrated and above described may be employed without departing from the scope of the invention. For example, dividing walls 26, 27, 28 and 29 may be eliminated, when desired, especially when equalized firing

conditions are to be employed in each unit section of the furnace. Also, when desired, the firing tunnels 14 to 23 inclusive may be eliminated, in which case combustion may be accomplished entirely in heating zones 30, 31, 32, 33 and 34, equalized heating conditions, however, being employed on opposite sides of each tube bank so that the opposite sides of each individual tube are heated equally.

Another specific form of furnace structure embodying the features of the present invention is illustrated in Figures 3 and 4 of the attached diagrammatic drawings. Figure 3 is an end view of the furnace shown in cross-section and Figure 4 is a sectional side elevation of the same furnace structure.

Referring to Figures 3 and 4, the main furnace structure comprises side walls 51 and 51', end walls 52 and 52', a roof 53 and a floor 54. The furnace here illustrated is divided into three unit sections by means of separating walls 55 and 56, within the main furnace structure.

Vertical rows or banks of tubes 57, 58 and 59, each comprising a plurality of horizontally disposed tubes 60 extending between end walls 52 and 52' of the furnace, are located one bank within each unit section of the furnace. The tubes of each vertical row or bank are connected in series by means of suitable headers or return bends 76. Inlet and outlet ports 77 are provided at opposite ends of each tube bank, each of which may be utilized as either the inlet or outlet port so that the flow of oil or other fluid to be heated may be either upward or downward through any individual bank of tubes, as desired.

Perforated walls 61 and 61' separate heating zone 62 containing tube bank 57 from combustion zones 63 and 63' respectively. In a similar manner, perforated walls 64 and 64', respectively, separate heating zone 65 containing tube bank 58 from combustion zones 66 and 66' and perforated walls 68 and 67', respectively, separate heating zone 68 containing tube bank 59 from combustion zones 69 and 69'.

It is evident from the drawings and the above description that the furnace structure is symmetrical on opposite sides of the vertical center line through each tube bank, as viewed from the end of the furnace, as in Figure 3. Due to this symmetry of structure on opposite sides of each bank of tubes and by employing equalized firing conditions between the firing compartments in each unit section of the furnace, equal heating is obtained on opposite sides of each individual tube in the entire fluid conduit.

Each firing compartment is supplied with any suitable form of fuel through burner ports 70, located in the roof of the furnace, by means of any suitable type of burner, not illustrated. Combustion products pass through openings 71 in each of the walls 61, 61', 64, 64', 67 and 67' into contact with opposite sides of the tubes 60 in the heating compartments 62, 65 and 68, imparting heat thereto by convection. Radiant heat is supplied to opposite sides of the tubes in each heating zone by direct radiation from the flame through openings 71 in the distributing walls 61, 61', 64, 64', 67 and 67' and preferably these walls are constructed of a refractory material of high thermal conductivity such as fused or molded alumina or silica, artificial or natural mullite, etc., capable of assuming incandescence upon heating in order that they will transmit radiant heat to opposite sides of each tube bank. Combustion products pass from the heating compartments 62,

65 and 68 through openings 76 in the floor of the furnace into the respective gas passageways 72, 73 and 74 and thence through flue 75 to a suitable stack, not shown.

Conditions may be so controlled in the combustion zones in any unit section of the furnace that the several tubes in each bank will be heated equally or different intensities of heating may be employed in different sections of the same tube bank. The drawings illustrate how the openings 71 and the distributing walls may be graduated in size so that a greater quantity of combustion gases will pass into the lower section of each heating zone than into the upper section. This is one means of supplying additional heating by convection in the lower section of the tube bank to compensate for the normally greater amount of radiant heat received by the upper section of the same tube bank. However, by varying the size and spacing of openings 71 and/or by properly regulating the firing conditions in the combustion zones, such as changing the length of flame by increasing or decreasing the quantity of excess air admitted to the combustion zone, any desired heating condition may be obtained in the tube bank of each unit section of the furnace. Also by regulating the intensity of firing in each unit section of the furnace, the rate of heating in each tube bank may be regulated so that oil or other fluid to be heated may be subjected to an increasing, decreasing or a substantially uniform rate of heating during its flow through the entire fluid conduit or so that a maximum or minimum rate of heating may be obtained at any desired point in the fluid conduit.

Figures 5, 6 and 7 of the attached drawings illustrate diagrammatically the two general types of flow through the heating coil which may be employed in either form of furnace structure above illustrated and described. Figure 5 illustrates parallel flow and Figure 6 illustrates series flow through the heating coil. Figure 7 illustrates a somewhat modified form of series flow arrangement. It will be understood that many modifications of the two general forms may be employed without departing from the scope of the invention.

The numerical designation given to the tube banks in Figures 5, 6 and 7 are the same as those in Figures 1 and 2, although the flow illustrated in Figures 5, 6 and 7 also apply to the furnace structure illustrated in Figures 3 and 4.

Figure 8 of the attached drawings illustrates five general types of heating curves obtainable with the improved furnace of the present invention. Curve A illustrates a constantly increasing rate of temperature rise through the entire heating coil; curve B illustrates a constantly decreasing rate of temperature rise; curve C illustrates a uniform rate of temperature rise; curve D illustrates a heating curve with a maximum rate of temperature rise in the first stages of the heating coil and curve E illustrates a heating curve with the maximum rate of temperature rise in the latter stages of the coil.

Any of the type of heating curves illustrated in Figure 8 may be obtained with either of the furnace structures illustrated and above described and with either parallel or series flow of fluid through the heating coil. For example, when a constantly increasing rate of temperature rise, such as indicated by curve A in Figure 8, is desired with parallel flow through the heating coil, as illustrated in Figure 5, firing conditions are

equalized in the several sections of the furnace so that equal heating is obtained in every bank of tubes and the rate of heating is progressively increased from top to bottom of every vertical tube row. When this same type of heating curve is desired with series flow, as illustrated in Figure 6, progressively more severe heating conditions are employed from top to bottom of each tube bank and progressively more severe heating conditions are employed in the unit sections of the furnace from left to right. With a flow, such as illustrated by Figure 7, the same type of heating curve may be obtained by employing progressively more severe firing conditions in the unit sections of the furnace from left to right and by alternating the firing conditions around adjacent tube banks, progressively increasing heat intensities being employed from top to bottom of the first tube bank, progressively increasing heat intensities being employed from bottom to top of the second tube bank and so on through any number of tube banks in the fluid conduit. In a similar manner, by suitable regulation of the firing conditions, curves of the type illustrated by curves B, C, D and E in Figure 8 may be obtained with flows through the fluid conduit such as illustrated in any of the Figures 5, 6 and 7 or in any modification of the flows illustrated.

As a specific example of the increased efficiency of a furnace such as illustrated and above described, as compared with the usual type of radiant and convection heaters, we will assume two cases. In the first case wherein the features of the present invention are not utilized, a single row of radiant roof and wall tubes is employed in the radiant heating section of the furnace and additional heat is recovered by convection from the hot combustion gases before they pass from the furnace by means of a separate bank of convection tubes. In the second case wherein the features of the present invention are utilized, the furnace structure is of the type above illustrated and both radiant and convection heating is accomplished in the same tube bank. The size and spacing of the tubes in the second case is the same as the size and spacing of the tubes in the radiant bank of the first case and the firing conditions are so regulated that in each case about 30,000 B. t. u. of radiant energy per square foot of equivalent heat absorbing surface is available, theoretically, for absorption by the tubes. In the first case approximately 66 percent of this total is absorbed by that half of the surface of the tubes exposed to direct radiation and about 22 percent is absorbed by the other half of the tube surface, making a total of approximately 26,400 B. t. u. absorbed in the radiant bank, per projected square foot of tubing or about 8,300 B. t. u. per circumferential square foot of tubing. In addition about 6,000 B. t. u. per circumferential square foot of tubing are absorbed by convection in the radiant bank and the convection bank receives an average of about 5,000 B. t. u. per circumferential square foot of tubing. With about 70 percent of the total tube surface located in the radiant section of the furnace and about 30 percent in the convection section, the average rate of heat input for the total fluid conduit is about 11,500 B. t. u. per hour, per circumferential square foot.

In the second case, due to the application of direct radiant heat to opposite sides of each tube of the fluid conduit, about 66 percent of the 30,000 B. t. u. available, per square foot of projected tube surface, is absorbed on each half of the tube, giving a total of approximately 39,600 B. t. u.,

per projected square foot of tube surface, as compared with 26,400 B. t. u. in the first case or 12,600 B. t. u. per circumferential square foot in the second case as compared with 8,300 in the first. Assuming that about 30 percent of the total heat input in the second case is by convection, in order to make it comparable to the first case, an additional 5,400 B. t. u., or thereabouts, per square foot of circumferential tube surface is absorbed by convection. This gives a total average heat input of approximately 18,000 B. t. u. per hour, per circumferential square foot of tubing in the second case as compared with about 11,500, as above shown in the first case, which is an increase of approximately 52 percent in favor of the improved method of heating of the present invention.

With firing conditions such that a greater proportion of radiant to convection heating is employed, a still greater percentage increase in the rate of heat input may be accomplished by use of the features of the present invention.

I claim as my invention:

1. In a process for heating fluid in a plurality of banks of fluid conduits comprising connected elongated passageways vertically super-imposed in a heating zone and equi-spaced from the adjacent side walls of the heating zone, the improvement which comprises subjecting the exterior portions of said side walls to heat of sufficient intensity whereby the opposite surfaces thereof radiate heat simultaneously to opposite sides of each passageway, causing hot products of combustion to pass through openings in said walls and bringing same into contact with opposite sides of each passageway.

2. A process such as is claimed in claim 1, wherein the radiant heat is generated by direct impingement of the flame on the outside of said walls and the gases of combustion generated by said flame constitute the products of combustion passing through said openings.

3. A method for heating fluid which comprises passing the fluid in a restricted stream through a plurality of parallel heating tubes disposed in a common plane between a pair of heat radiant walls parallel to the plane of the tubes, maintaining said walls at heat radiating temperature by combustion of fuel as free flame on the sides thereof opposite the tubes, transmitting radiant heat from said walls to opposite sides of each of the tubes, and passing combustion gases through said walls into contact with the opposite sides of the tubes.

4. A method for heating fluid which comprises passing the fluid in a restricted stream through a plurality of parallel heating tubes disposed in a common plane between a pair of heat radiant walls parallel to the plane of the tubes, maintaining said walls at heat radiating temperature by independent combustion of fuel as free flame outside the plane of the tubes and adjacent each of the walls, the flame being directed angularly away from the tubes, thereby generating combustion gases, and heating the opposite sides of the tubes by radiation from the walls, by radiation from the flames and by convection from the combustion gases.

5. A method for heating fluid which comprises passing the fluid in a restricted stream through a plurality of superimposed horizontal heating tubes disposed between a pair of vertical heat radiant walls spaced from the tubes, maintaining said walls at heat radiating temperature by independent combustion of fuel as free flame outside

5 the plane of the tubes and adjacent each of the walls, the flame being directed angularly away from the tubes, thereby generating combustion gases, and heating the opposite sides of the tubes by radiation from the walls, by radiation from the flames and by convection from the combustion gases.

6. The method as defined in claim 5 further characterized in that the fuel is burned adjacent the sides of said walls facing the tubes.

7. The method as defined in claim 5 further characterized in that the flames are impinged 5 against said walls.

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