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[54] **HEATING SYSTEM PROVIDING CONTROLLED CONVECTIVE HEATING**

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[58] **Field of Search** ..... 122/23, 235 R, 356; 110/49 R

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[57] **ABSTRACT**

A special heater design and arrangement utilizes remote burners to provide for the convective heating of fluid streams which are sensitive to overheating. The remote burners together with means to recirculate a portion of the stack gas to admix with the hot combustion gases from the burners provide for the regulation of the temperature of the hot convection gases being passed from the combustion zone to a separate tube heating section. A preferred design and construction of the system utilizes small diameter tubes in the heat transfer section so as to permit thinner wall tubing and also, from safety aspects, will minimize the quantity of a combustible fluid which could be released into a heating chamber in the event of a tube rupture.

8 Claims, 2 Drawing Figures

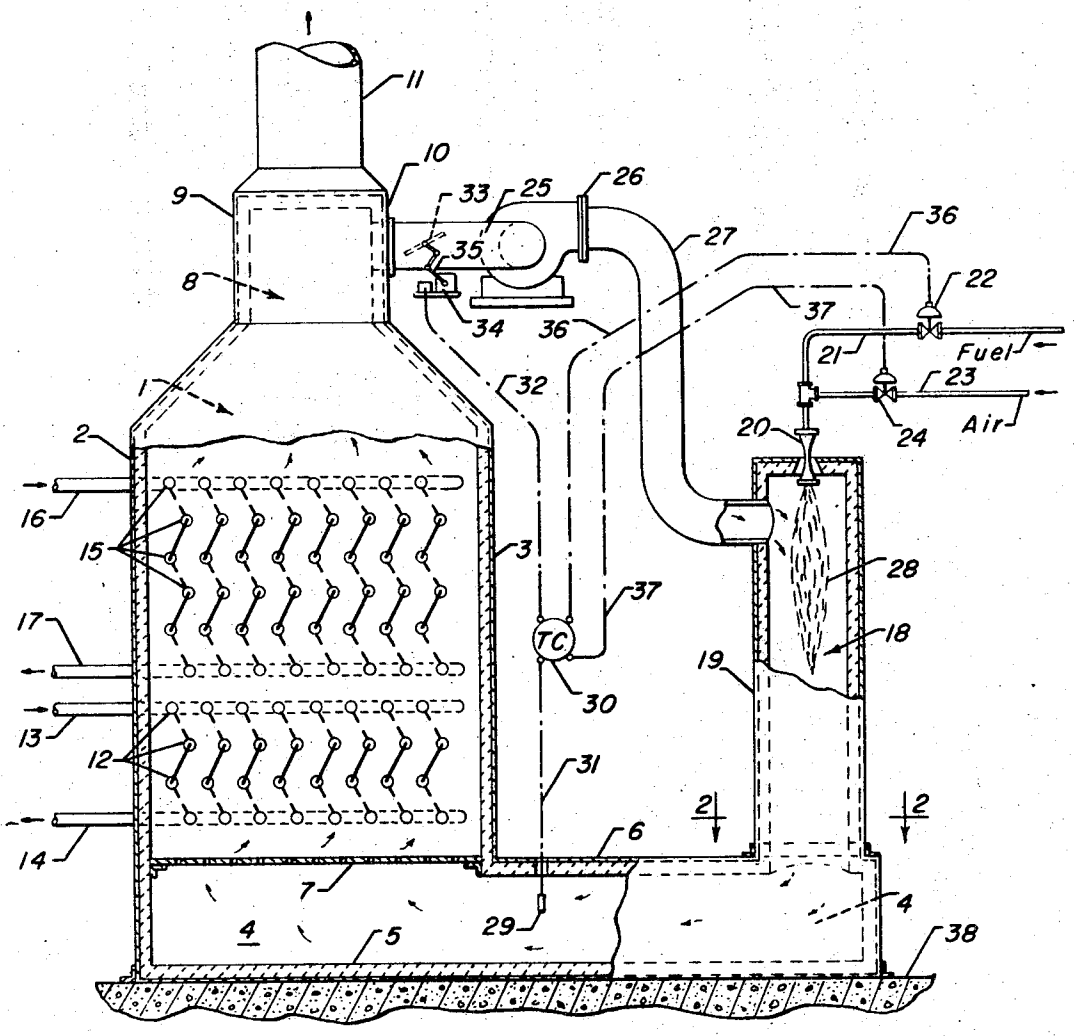


Figure 1

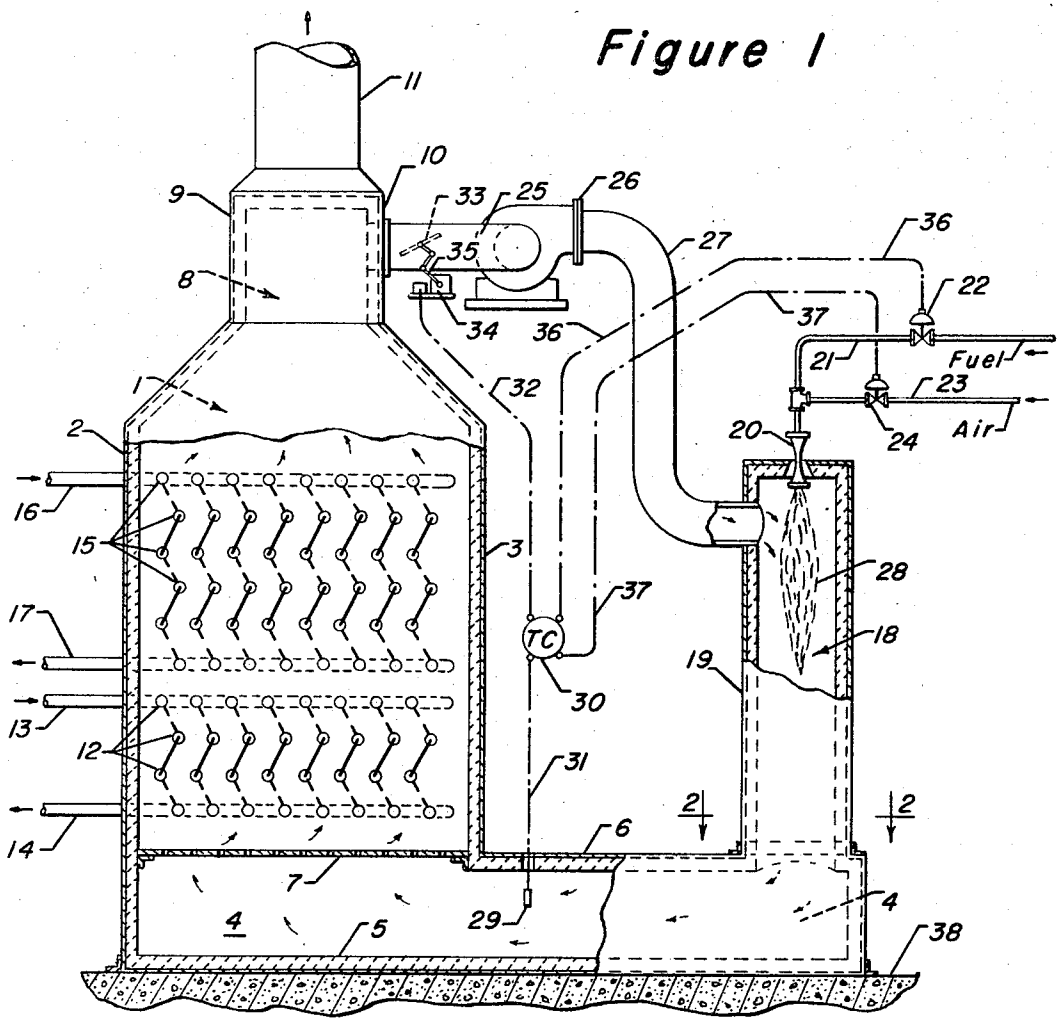
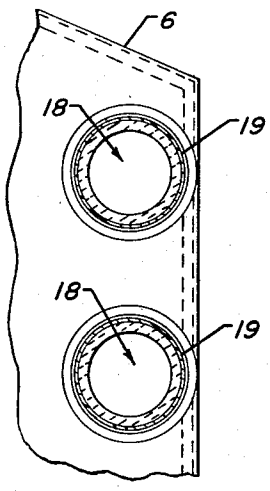


Figure 2



HEATING SYSTEM PROVIDING CONTROLLED CONVECTIVE HEATING

The present invention is directed to a special heating system which is designed and operated to provide controlled convective heating to the plurality of tubes maintained in the heat transfer section of the system.

In a more specific aspect, the present heater system provides for burner means in one or more combustion sections which are remote from the fluid heating section and also provides for the regulated admixing of a recycle portion of the flue gas stream into the hot burner gases to assist in obtaining a controlled temperature hot gas convective heating stream flow to the tube heating section of the system.

Although convection heating is widely used for buildings and space heating problems, it is the more prevelant practice to heat fluid streams with high temperature radiant heating means. For example, most petroleum heaters in refinery processes, or most heaters for reactant streams in chemical processing plants, will utilize fluid containing conduits and tubes in various types of tube banks and flow arrangements which will receive high temperature radiant heat. Typical high temperature heaters for fluids actually provide both radiant and convection heating sections so that optimum heating is obtained, with low temperature fluid heating and/or preheating of a fluid stream being effected in a convection heating zone of the heater, downstream from a radiant heating zone.

It should also be pointed out that certain types of fluid streams are sensitive to overheating and tube wall temperatures cannot be so high as to permit excessive heating of the fluid film which travels along the inside wall of a fluid conduit in a heater. By way of a specific example, where a liquid hydrocarbon stream is to undergo hydrocracking in the presence of a suitable subdivided catalyst, and also in the presence of hydrogen at a relatively high superatmospheric pressure, it is desirable to heat the hydrocarbonaceous stream to a temperature of the order of 800° F. without causing the outer film of the stream to preliminarily have undesired conversion or a decomposition with resulting coke forming on the tube walls.

Thus, it may be considered a principal object of the present invention to provide for controlled uniform convective heating in a fluid heating system so as to minimize any overheating of fluid films in the heat transfer tubing.

It may also be considered to be an object of this improved heating system to provide for a large number of small diameter tubes, in lieu of larger tubes in conventional heaters, such that a high pressure operation can be accommodated while at the same time minimizing the fluid flow rate in the event that a heater tube would get a hot spot and rupture. The provision of small diameter tubes is also desirable in that thin wall tubings may be used to, in turn, assist in obtaining uniform heating to the fluid stream while precluding tube wall temperature differentials and high wall stresses.

In still another aspect, it is an object of the present improved heating system to have temperature measurement and control means such that the convective heating stream may be limited as to high temperature, as well as receive temperature regulation, at least in part, from the quantity of flue gas being recycled and admixed with the hot burner gases to provide the total convective heating stream.

In a broad embodiment, the present invention provides a heating system for heat sensitive fluids to provide uniform heating for the tube banks therein and preclude excessive fluid film temperatures for the fluids passing through the individual tubes, which comprises in combination, a confined tube heating section, a plurality of interconnected small diameter tubular members positioned in said section to provide at least one tube bank therein, inlet and outlet means to the latter to provide for the flow of at least one fluid stream therethrough, at least one combustion section with burner and fuel supply means connective therewith to provide for the introduction of hot combustion gases into the interior of such section, duct means connecting between said combustion section and the lower end of said heating section to provide for the flow of a hot gas convective heating stream to said tubular members therein, waste gas outlet means from the top of said heating section, gas recycle duct means connective between said gas outlet means and said combustion section to provide for waste gas stream mixing with the hot combustion gases therein, gas stream blower means connective with said gas recycle duct means to provide for the pressurized introduction of the recycled waste gas stream into said combustion section and a pressurized convective heating gas flow to said heating section, temperature sensing means in the heating gas stream path to said heating section, and control means connecting with said sensing means and with a flow regulating means in turn connecting with at least one temperature controlling stream being supplied to said combustion section, whereby to regulate temperature for the hot gas convective heating stream being passed to the tube heating section.

In a specific arrangement, the temperature sensing means and the connecting control means will, in turn, connect with flow control valve means in the one or more gas recycle duct means such that there is regulation of the tempering aspects of the recycle gas being admixed into the hot combustion gases from the burner means. In other words, where it is desired to have a slightly lower temperature in the tube heating section then additional flue gas will be permitted to recycle into the combustion zone and temper the resulting heating gas stream carrying to the convective heating zone, or conversely, less recycle gas will be permitted to mix with the hot burner gases.

In another embodiment, the temperature sensing means and the control means will, in turn, connect with valve control means for supply lines to the burner means so as to regulate fuel or otherwise control the operation of the burners to in turn regulate the hot combustion gas output temperature from the combustion zone. Where additional heat is desired, there will be an opening of the fuel and combustion air supply lines to increase the hot gas output in the combustion zone or, alternatively, there can be a reduction in fuel input to the burner means to reduce the temperature of the hot gas stream flowing to the heat transfer zone of the unit.

As still another feature of the present invention, there will be utilized a plurality of small diameter tubes for accommodating the one or more fluid streams in the heat transfer section, with the tubes being in the 1½ inches diameter, or smaller, range. As heretofore

noted, for high pressure fluid streams, the smaller diameter tubes are of particular advantage from a safety aspect in that there will be a lower rate of fluid release in the event of a possible tube rupture and the prevention of a catastrophic fire within a heater system. It should also be reiterated that the present form of convection heating system provides greater uniformity of heat transfer to the fluid stream within each individual tube or conduit and there is a lessening of the chance for coke formation along the inside wall of a tube which, in turn, can lead to a hot spot on a tube which may then become weakened to the extent that there will be a tube rupture and the undesired loss of combustible fluids into the heater.

As still another advantage for small diameter tubes, there is the ability to use thinner wall tubing for any predetermined pressure by reason of a lower hoop stress in the tubing. In other words, with the circumferential stress in pressure containing tubing being proportional to the diameter of the tube, then smaller diameters can permit thinner walls and still maintain the metal stresses within allowable limits. The thinner wall tubes are also of advantage in that they can provide a reduced differential across the thickness of the tubing, from their exterior walls to the interior walls. Also, it should be noted that in the use of thick wall large diameter tubes there can be more warpage or curvature of the individual tubes by reason of uneven heating conditions, particularly where there is radiant heating, in that uneven stresses in various longitudinal portions of each tube will cause a temporary or continuous warpage of the tubings. Conversely, uniform convective heating as provided by the present heating system will result in relatively uniform heating to all sides of all the tubular members such that warpage is minimized.

Reference to the accompanying drawing and the following description thereof will serve to set forth the improved safety features of the present form of fluid heating system as well as operational advantages which may be obtained from the special design and arrangement being embodied in such system.

FIG. 1 of the drawing is a diagrammatic sectional elevational view showing one embodiment of the present convection heating system.

FIG. 2 of the drawing is a partial plan view through the combustion section of the system, as indicated by the line 2—2 in FIG. 1.

Referring now particularly to the drawing, there is indicated a tube heating section 1 which in this instance is of a generally rectangular form defined by side walls 2 and 3 as well as by suitable end walls. The lower portion of the tube heating section 1 is open to a hot combustion gas transfer passageway 4 defined by insulated lower floor 5 and a top cover means 6. Also, where desired, there may be suitable gas distributing means, such as perforated plate 7, that will extend across the area between passageway 4 and the tube containing section 1. The upper portion of the heating section is provided with a flue gas collection section 8 that is defined between the side walls 9 and 10 and is also superposed with an outlet stack 11.

Various fluid conduit arrangements, or tube bank means, may be provided within the heat transfer section 1; however, in the present embodiment, there is indicated a lower tube bank having a multiplicity of spaced tubular members 12 which extend between inlet header means 13 and outlet header means 14. Suitable return bends, not shown, can be provided at the ends of the plurality of tubular members 12 to effect a desired serpentine and/or parallel flow of fluids transversely across the heat transfer section 1 and between the respective headers 13 and 14. There is also indicated a second tube bank utilizing a multiplicity of tubular members 15 which extend between return bends and are connective with inlet header means 16 and outlet header means 17. It is not intended to limit the present invention to any one tube system or tube bank arrangement; however, in accordance with the present form of improved convective heating system for high pressure fluid heating, there shall be utilized a multiplicity of small diameter tubular members, preferably of 1½ inches in diameter, or less, such that there will be relatively thin wall members and rapid heat transfer through the tubular walls with a minimum of temperature differential therethrough. The tubes and tube banks can accommodate liquid streams, gaseous streams, or mixed phase streams; however, it is generally desirable in certain operations to provide separate gas heating and liquid stream heating. Thus, tube bank 12 might well accommodate a gaseous stream, such as hydrogen, to be utilized in a hydrogen consuming hydrocarbon processing operation, while the upper tube bank 15 will accommodate a primarily liquid hydrocarbonaceous fluid stream and the resulting heated streams would subsequently be intermixed in a suitable reactor chamber in the presence of a catalyst, or under thermal conversion conditions.

Although not shown in the drawing, it is to be realized that suitable tube support means extending from the walls of the heater structure can be provided at spaced longitudinal distances in order to adequately support the weight of the heated tubes and their fluid contents for the high temperature heating conditions being encountered.

Along side of, and extending parallel with, the tube heating section 1 there can be a plurality of separate combustion zones 18 defined by insulated walls 19 or, alternatively, there may be a single, elongated combustion section which will feed resulting hot combustion gases downward into the passageway 4 to, in turn, provide an upward flow of convective heating gases through the tube heating zone 1. In accordance with the present invention, the combustion section, or zones, 18 will have spaced burner means 20 to in turn receive fuel by way of lines 21 having control means 22, as well as receive air from lines 23 having valve means 24, such that there is the downward introduction of hot burner gases through the combustion section(s) to be admixed with recycle air from the stack or outlet portion of the heating zone.

In the present instance, recycle flue gas is withdrawn from one or more areas along the plenum section 8 by means of duct means 25, fan means 26, and further duct means 27. The latter discharges into the upper portion of the one or more combustion sections 18 such that there is the desired admixture of recycle flue gas into hot combustion gases 28 in order to provide a desired control of temperature for the heating gas stream through passageway 4 into the lower portion of heat transfer zone 1. Obviously, the recycle gas from the upper portion of the heating section at 8 will be of lower temperature than the hot burner gases such that there is a regulating and tempering of such gases to a

desired inlet temperature for the tube heating section.

In order that there will be careful temperature regulation for the present convective heating system, the present invention provides for temperature sensing means at the heat transfer section or in the hot gas passageway means and suitable accompanying control means such that there is close regulation of temperature in the hot heating gas stream leaving the one or more combustion sections **18.** As one embodiment, the present drawing provides that a temperature sensing means **29** connects with temperature control means **30** through line **31** and that control means **30** will connect through line **32** to a movable valve means **33** in the recycle duct means **25,** with actual adjustment being provided by a valve movement means **34** and linkage means **35.** It is to be realized that the adjuster means **34** and **35** connecting to the valve means **33** is merely diagrammatic and that various types of electric, hydraulic or pneumatic motor means can provide a desired adjustment for the flow regulating means within the one or more ducts **25.**

There is further indicated in the present embodiment that temperature controller **30** can connect through lines **36** and **37** to the respective fuel valve means **22** and air valve means **24** such that there may be variations in the operation of burner means **20** and the hot combustion gas output therefrom responsive to the temperature sensing means **29** positioned in the hot convection heating gas stream of passageway **4.** In other words, where the temperature level appears to be excessive or reaches a predetermined top limit, there will be a suitable reduction in fuel input to the burner means **20** and a cutting back of hot combustion output from the one or more burner means. Optionally, or in conjunction with the burner operation, there may be the opening of valve **33** in duct **25** so as to effect a greater recycle flue gas flow into admixture with the hot combustion gases in the one or more combustion zones **18** such that there is a resulting tempering of the hot combustion gas flow to the tube heating valve **1.**

Although not illustrated, in another embodiment, the temperature control means **30** may be provided to entirely shut down the process fluid flow(s) through the tube heating section. This is in direct contrast to a radiant heating system where a process flow stoppage could permit tube metal temperatures to rapidly reach the theoretical flame temperature for those conduits that are in the radiant heating section of such unit.

The present drawing is, of course, diagrammatic in that no columns, beams, girts, etc., have been indicated for supporting the various walls and roof structures to the various sections of the heater system; however, suitable structural support means will, of course, be embodied in an actual heater structure. A foundation **38** is indicated as supporting the floor insulation **5** and the various side end and wall portions of heat transfer section **1** as well as for the combustion section **18.** Variations in design and arrangement are also within the scope of the present invention, as for example, the combustion section(s) **18** may be placed quite closely adjacent to the heat transfer section **1** whereby there is a minimum passageway **4** and a direct U-turn flow arrangement in effecting the transfer of the hot combustion gases into the convection heating section of the system. Also, other duct arrangements and configurations may well be utilized in effecting the desired transfer of flue gas from the plenum section **8** into the upper portions of the plurality of combustion section **18.**

In still another aspect, there may be the elimination of flow stream distributor **7** below the tube heating section **1** or, optionally, the utilization of directional baffling rather than a single perforate flow distributing member such as indicated by **7.** With regard to the tubular members themselves, it should be noted that all, or a portion of the tubes, may be provided with fins or stud means to increase surface area and enhance the transfer of conducted heat into the fluid streams. The fins may be longitudinal, circular or spiral, and it is not intended to be limited to any one form of extended surface area.

We claim as our invention:

1. A heating system for heat sensitive fluids to provide uniform heating for the tube banks therein and preclude excessive fluid film temperatures for the fluids passing through the individual tubes, which comprises in combination, a confined tube heating section, a plurality of interconnected small diameter tubular members positioned in said section to provide at least one tube bank therein, inlet and outlet means to the latter to provide for the flow of at least one fluid stream therethrough, at least one combustion section with burner and fuel supply means connective therewith to provide for the introduction of hot combustion gases into the interior of such section, duct means connecting between said combustion section and the lower end of said heating section to provide for a hot gas convective heating stream to said tubular members therein, waste gas outlet means from the top of said heating section, gas recycle duct means connective between said gas outlet means and said combustion section to provide for waste gas stream mixing with the hot combustion gases therein, gas stream blower means connective with said gas recycle duct means to provide for the pressurized introduction of the recycled waste gas stream into said combustion section and a pressurized convective heating gas flow to said heating section, temperature sensing means in the heating gas stream path to said heating section, and control means connecting with said sensing means and with a flow regulating means in turn connecting with at least one temperature controlling stream being supplied to said combustion section, whereby to regulate temperature for the hot gas convective heating stream being passed to the tube heating section.

2. The heating system of claim **1** further characterized in that said burner means connect with said combustion section to provide a downflow of hot combustion gases therefrom into said duct means connective with said heating section to provide an elongated U-flow path and an upward convective heating gas flow through said tube heating section.

3. The heating system of claim **1** further characterized in that gas flow valve means is provided in said gas rcycle duct means and control means connects to said valve means and to said temperature control means, whereby recycle gas flow may be regulated responsive to said temperature sensing means and said control means.

4. The heating system of claim **1** further characterized in that said control means is connective with valve means in the fuel supply means to said burner means, whereby said temperature sensing means and the tem-

perature control means may regulate said burner means.

5. The heating system of claim **1** further characterized in that said plurality of interconnected small diameter tube members and said heating section are less than about 1½ inches in diameter, whereby to provide small quantities of fluid flow through each of the tube members.

6. The heating system of claim **1** further characterized in that said plurality of small diameter tubular members are horizontally positioned in said tube heating section whereby to provide flow of fluid therethrough in directions transverse to the direction of the convective heating gas flow in said heating section.

7. The heating system of claim **1** further characterized in that at least a portion of the plurality of tube members have fin means on their outer surfaces to increase surface area in contact with the convective heating gas flow.

8. The heating system of claim **1** further characterized in that gas stream flow distributing means is provided transversely across the lower portion of said tube heating section to provide uniform hot gas stream convective heating flow into the inlet end of such section.

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