June 3, 1952 M. W. BARNES 2,598,879

HEATING APPARATUS

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Fig. 1.

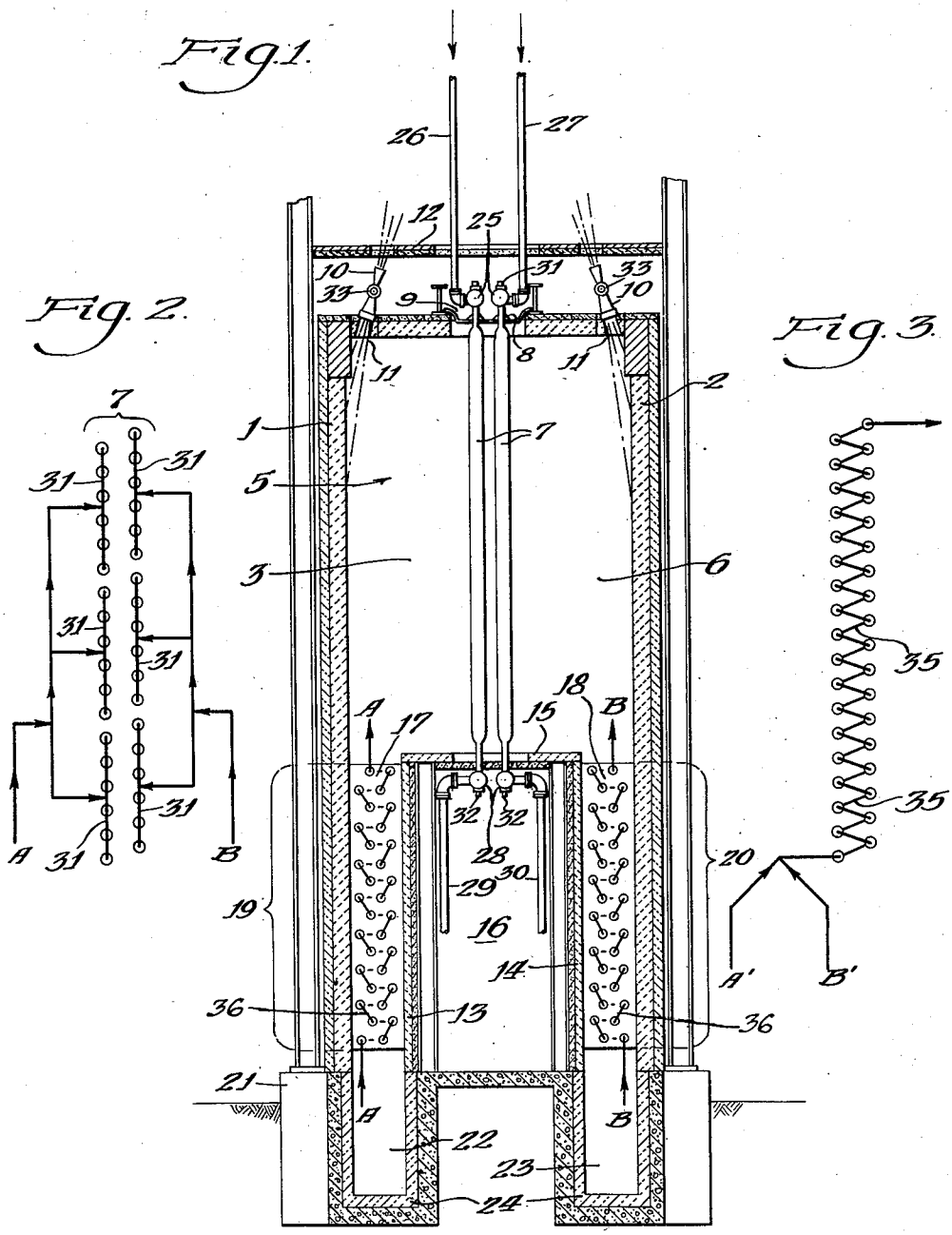


Fig. 2.

Fig. 3.

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HEATING APPARATUS

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3 Claims. (Cl. 122—356)

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This invention relates to a modified form of a heater of the type now generally known as the downdraft equiflux heater, and may comprise one or more individual cells. More specifically, the present modification provides a heater having vertically disposed fluid conduits in the radiant heating section and a header compartment in the lower portion of the heating cell, which divides the convection section into two portions.

The usual equiflux heater is down-fired and has horizontal tubes or fluid conduits in both the radiant and convection heating sections, with only a single convection bank of tubes in a single convection section positioned at the lower portion of the heating cell. The fluid conduits in the radiant heating section are positioned in a staggered formation or other manner providing substantially equal heating from each of the heated side walls of the cell and the side walls of the heater are swept with flame and hot combustion gases from burners placed along the roof of the heating cell. A separate row of burners being provided along the roof of the cell at each side wall, such that a sheet of flame sweeps substantially vertically downward along each wall and so that each wall in turn may provide radiant heating to the tubes positioned centrally within the radiant heating section.

It is a principal object and advantage of the present invention to provide means for maintaining a plurality of vertically suspended tubes within the central portion of the radiant heating section of the heater, with the tubes being suspended from the roof of the heater and projecting downwardly into a lower header compartment, and at the same time placed in a staggered formation or other arrangement permitting substantially uniform radiant heating to each tube from each of the side walls of the heating cell.

The vertical positioning of the tubes in the radiant section has a particular advantage permitting the use of a solid particulated material, such as a catalyst, to be placed within each of the conduits and be contacted by a fluid medium passing therethrough. For example, in the catalytic conversion of a hydrocarbon stream, a catalyst suitable to promote a particular conversion of the reactant stream may be placed within each of the tubes in the heated cell and the reactant stream passed through the tubes in contact with the catalyst while under controlled conditions of heating as provided by the flame from the burners heating the side walls of the cell.

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It is also a feature of the present invention to provide means for rotating or adjusting the position of the burners which supply the flame and hot combustion gases to the radiant walls of the heating cell, such that the flame from the burners may be directed to a controlled spot or elevation along each of the side walls, whereby the radiant heat therefrom may be controlled to provide a varying temperature gradient to the vertically disposed tubes in the center portion of the cell. For instance, if high temperature is desired at the top portion of the vertical tubes, the burners may be directed to impinge flame and hot gases against the upper portion of the side walls, such that they in turn provide the greatest amount of radiant heat to the upper portion of each of the vertical tubes. While on the other hand, if it is desired to more uniformly heat the tubes or to maintain a high temperature at the lower portion of the vertical tubes, each of the burners in each row along the top of the heater may be rotated to direct the flame and hot combustion gases therefrom to an intermediate or lower portion of the side walls such that the radiant heating therefrom provides a high temperature along the lower portion of the vertical tubes. This flexibility in the control of the temperature gradient throughout the vertical height or length of each of the tubes is of particular importance in certain catalytic conversion operations. Where the radiant tubes are filled with a suitable reforming catalyst and a hydrocarbon stream to be catalytically reformed is passed downwardly through each of the conduits, it has been found particularly desirable to maintain a closely controlled temperature gradient throughout the length of the tubes, with a higher temperature being required at the upper inlet ends of the tubes. In other words, the reaction at the inlet end of the tube is highly endothermic and requires a greater supply of heat to that portion of the tube than is necessary in the intermediate or lower portions of the tube where the endothermic heat requirements of the reaction are much less.

While the improved embodiment of this inven-

tion is particularly adaptable to catalytic operations wherein the radiant heating tubes serve as catalyst containing conduits, it is not intended to limit the present apparatus to catalytic operations only. The vertical fluid conduits may well be utilized in this embodiment for thermal processes and the flow through the heating cell may be varied to suit desired processing conditions. Normally, the lower portion of this heater cell, which is divided into two convection sections, is arranged such that substantially equal sized tubes or similar tube banks may be placed within each portion thereof, with each tube bank comprising a plurality of horizontal tubes. The tube banks in the lower portion of the heater are referred to as convection tube banks, since the hot combustion gases resulting from the burners at the top of the cell pass generally downward along the side walls and through each of the more restricted passageways, referred to as convection heating sections, and from the latter pass into flue gas ducts which in turn carry the resulting gases from the heating cell to a suitable stack.

The construction and arrangement of the heating cell of this invention, as well as further advantages, will be more clearly understood by reference to the accompanying drawing and the following description thereof.

Figure 1 of the drawing is a cross-sectional elevation view of the modified equiflux heater, providing vertical radiant tubes and the two convection sections.

Figure 2 of the drawing is a diagrammatic plan view of the vertically disposed radiant tubes and one means for providing parallel flow through the plurality of tubes.

Figure 3 of the drawing is another diagrammatic plan view of vertically disposed radiant tubes, and means for providing a series flow through the plurality of tubes.

Referring now to Figure 1 of the drawing, there is shown a single equiflux cell of the improved and modified construction, comprising substantially vertical refractory side walls **1** and **2**, refractory end walls, one of which is designated as **3**, and a refractory roof **4**. Each of the outer walls are indicated as having an insulating layer on the exterior thereof, such as mineral wool block, or the like, which will cut down heat losses from the interior of the heating cell. In addition, a metal sheeting or other sheathing material may be placed outside of the insulating layer in order that a weather-proof type of construction is furnished.

The upper section of the heater comprises radiant heating zone comprising sections **5** and **6**, between which there is disposed an equiflux tube bank **7**, comprising in this embodiment, two rows of vertically disposed tubes or fluid conduits, with the tubes in each row being arranged in a staggered formation such that each tube receives radiant heat from each of the side walls **1** and **2**. The vertical tubes of the bank **7** are supported from suitable plates or lugs **8**, which in turn rest on framing **9** at the roof section.

Heat is supplied to the interior of the heating cell by means of a plurality of burners **10** which are spaced uniformly along each side wall above the refractory roof **4**. Below each of the burners **10** is a suitable burner port **11**, such that flame and hot combustion gases may be directed from each of the burners **10** downwardly along the side walls **1** and **2**. Positioned above the refractory roof **4** of the heating cell is shown a suitable firing floor **12**, which in this embodiment provides means for furnishing easy access to the various burners **10** and the upper ends of the tubes in bank **7**.

In the lower portion of the heater, there are inner vertical side walls **13** and **14** and a horizontal wall **15**, connecting between the upper ends of the walls **13** and **14**, such that there is thus formed by the walls a header compartment **16**, into which projects the lower ends of the tubes of the bank **7**. As with the outer walls of the heater, the inner walls **13**, **14** and **15** are preferably insulated with a suitable material to prevent the loss of heat from the cell, as well as to provide in this embodiment, a zone or passageway into which plant operators may enter to gain access to the lower ends of the tubes or headers which connect with the tube bank **7**. The construction of the preferred embodiment, with the tubes supported from the roof is also desirable to permit the longitudinal expansion of each tube downwardly through the partition **15** into the header compartment. The outer side wall **1** and the inner wall **13** form therebetween a convection heating zone **17**, while similarly the outer wall **2** and the inner wall **14** form another convection heating zone **18**. Each of the convection heating zones **17** and **18** is adapted to maintain a bank of horizontal tubes, which in this embodiment, are indicated as tube banks **19** and **20**.

Below the framing and walls of the heater is a suitable foundation **21**, which not only provides suitable support for the heater, but in addition, provides flue gas passageways **22** and **23** below each of the convection heating sections **17** and **18**, whereby resulting combustion and flue gases may be transferred to a stack. The flue gas passageways **22** and **23** are preferably lined with an insulating cement or other insulating layer such that high temperature gases do not adversely effect the concrete foundation.

The burners **10** are spaced a short distance apart along the top of the heating cell, such that a continuous sheet of flame and hot combustion gases impinges against the upper portion of each of the side walls **1** and **2**. The refractory side walls thus become heated to a high temperature by the flame and gases, and in turn provide radiant heating to the vertically disposed tubes in bank **7**. The hot combustion gases along each of the side walls then sweeps downwardly, along each side of the cell, and through the respective convection heating sections **17** and **18**, whereby hot gases provide convection heating to each of the tubes in the respective tube banks **19** and **20**. After passage through the convection heating zones **17** and **18**, the relatively cool flue gases pass through the outlet passageways **22** and **23** to a suitable stack (which is not shown on this drawing).

In the embodiment shown, each of the vertically disposed tubes of bank **7** are supplied with a fluid reactant stream by means of horizontal distributing headers **25** extending above the roof **4**, with each of the headers being supplied in turn by means of lines **26** and **27**. Similarly, in the lower header compartment **16**, the outlet headers **28** receive the heated reactant stream from each of the row of tubes in bank **7**, and the outlet headers in turn discharge through outlet lines **29** and **30**. There is thus indicated a parallel flow of fluid reactants downwardly through each of the tubes in the bank **7** with the fluid stream entering the top of the heating cell and being discharged from the lower ends of the tubes below the radiant section.

As has been noted hereinabove, it is also a feature of the present invention to provide means for placing a solid catalyst material within each of the tubular members of the bank 7 and there is thus provided suitable removable caps or plugs 31 within the upper heads 25 for placing a particulated solid material. Suitable outlet plugs 32 are also provided in the lower headers 28, such that the catalyst or other solid material may be withdrawn from the vertical tubes, when such may be desired.

It is also a particular feature of the present embodiment to provide means for rotating or adjusting the angle of each of the plurality of burners 10 such that the impingement of the flame and hot combustion gases from each of the burners may be adjusted with respect to each of the side walls 1 and 2. Suitable pivoting means 33 may be attached to each of the burners 10, or alternatively, suitably adjustable supporting legs or the like may be provided in order to adjust the angle of the burner with respect to the refractory side walls. This feature is of particular advantage in providing a control of the temperature gradient and heat supplied throughout the length of each of the vertical tubes in the bank 7 and thus provide a more closely controlled conversion operation, where such is necessary to provide an efficient processing unit.

As has been noted hereinabove, the improved modification of this invention is adapted to not only effect the controlled thermal conversion of a reactant stream, but is particularly adapted to provide means for furnishing endothermic heat for a catalytic operation, with a suitable catalyst being deposited and maintained within each of the vertical fluid conduits of the bank 7 in the radiant heating section. For example, the present arrangement is particularly desirable for a catalytic reforming operation, wherein a hydrocarbon distillate stream is catalytically reformed and upgraded in the presence of a suitable reforming catalyst which is deposited in each of the vertical tubes. In other words, the tubes in the bank 7 serve as a plurality of reactor tubes, through which the reactant stream flows downwardly under controlled temperature conditions. It has been found that with certain catalytic reforming catalyst, being maintained in a fixed bed manner within a tubular reactor, that the inlet portion of the tube is highly endothermic as compared to the intermediate or lower portions of the tubular zone. Thus, it is desirable to supply a greater amount of heat externally to the upper portions, or alternately inlet portions of the reactor tubes such that a more efficient operation may be obtained. By means of the adjustable burners 10, in this heating cell, the burners may be directed to impinge the flame and hot combustion gases along the very upper portion of the refractory side walls, and result in the highest radiant heating temperature along the upper portions of the vertical tubes.

It is of course, not intended to limit the present construction and arrangement of this heating cell to only one conversion operation or to a downflow through the vertical tubes. In certain conversion operations, it may be found desirable to supply the reactant stream to the lower end of the tubes, in which case, the lower headers 28 serve as inlet or distributing headers to each of the vertical fluid conduits and the reactant stream flows upwardly to be discharged from the upper headers 25 and the lines 26 and 27 become outlet lines. Still further, it is not intended to limit the flow through the vertical conduits in bank 7 to parallel flow of reactant streams, for if desired, suitable headers or return bends may be placed at each end of the tube bank to provide a series flow through the heater from one end to the other. Normally, each of the convection heating sections will be at a substantially equal temperature and will maintain similar types of horizontal tube banks. Thus, it will generally be desirable to supply separate reactant streams to each of the banks 19 and 20 in order to heat the streams and if desired, the separate streams may be combined into a single preheated reactant stream and subsequently passed to the radiant heated tube or alternately, to other equipment. While in a parallel flow, the preheated streams from each of the convection heating sections may be maintained separately and passed in a parallel flow through each of the vertical rows of tubes in the bank 7. The present heater is not limited to any number of tubes in the convection heating zones, nor to similar reactant streams being introduced through each of the banks 19 and 20. However, normally, the convection heating sections are used for preheating the reactant stream and an upward series flow through each of the tubular elements of each of the banks will be maintained in a heater of this type, with the horizontal tubes or conduits being connected by suitable U-shaped return headers or return bend fittings 36, as indicated in the drawing. The present embodiment indicates a stream A passing in a series flow upwardly through the tube bank 19, while a reactant stream B passes upwardly in a series flow through the tube bank 20.

Referring now to Figure 2 of the drawing, there is indicated in plan view and diagrammatically, a plurality of tubes of a vertical tube bank, such as 7 within the radiant heating section of the heater. There is further indicated a parallel downward flow through each of the tubes of the bank, by means of utilizing more than one horizontal header along the tops of the tubes. In other words, three inlet headers 31 are used along the tops of each of the rows forming the tube bank 7 and the preheated stream A is in turn distributed to each of the headers 31 in the left-hand row, while the preheated reactant stream B is distributed to each of the three headers above the right-hand row of the tube bank. By splitting the headers and the vertical tubes into smaller banks of six tubes each, as indicated by this particular drawing, a more equal and uniform distribution of the reactant stream is obtained to each of the individual tubular conduits. It is however, not intended to limit the heater to any set number of vertical tubes nor to any particular number of distributing header or means for effecting the flow and distribution to each of the tubes. Parallel flow through the tubes may be obtained by any number of distributing systems, or alternately, as has been mentioned hereinabove, the fluid distributing system may be maintained such that an upward flow results through each of the vertical tubular members.

In Figure 3 of the drawing, there is shown diagrammatically a plan view of the vertical conduits of a tube bank and there is indicated a series flow through each of the plurality of tubes in each of the two rows of radiantly heated tubes. The series flow being obtained by suitable return bends or end fittings 35, suitable to connect one tube to another and provide a continuous single stream throughout the length of the heater. The diagram also indicates the preheated streams A'

and B' combining to form a single reactant stream which undergoes radiant heating in the tube bank. A series flow would normally not be utilized in connection with a catalyst operation, wherein catalyst is maintained within the vertical tubes, however, a flow arrangement of this type may be of particular advantage in connection with thermal operations such as in the high temperature cracking, or reforming of refractory hydrocarbon stocks, or alternately, thermal operations wherein a soaking period is desirable.

While Figure 1 of the drawing indicates a single heating cell, it is within the scope of the present invention to utilize two or more similar heating cells within a common structure, each of the cells being in a side by side relationship. It is further contemplated that in a multiple cell heater of the equiflux type, that all of the cells need not be constructed exactly alike. In other words, an accompanying cell may have a somewhat different tube arrangement, or may be of a more conventional construction, having a single convection section at the lower portion of the cell, as well as the burner arrangement or firing controlled differently to provide different heating conditions.

I claim as my invention:

1. A heater for fluids comprising in combination, refractory side and end walls and a refractory roof defining a radiant heating section and convection heating sections, a pair of vertical partitioning walls extending upwardly from a foundation for said heater and spaced between the lower portions of said side walls and forming with the latter two separated convection heating sections, a horizontal partition extending between the upper extremities of said vertical partitioning walls forming a longitudinal header compartment and access passageway below the central portion of said radiant heating section and coextensive with said convection heating sections, a plurality of vertically disposed fluid conduits positioned in parallel rows and in a staggered arrangement between said end walls within the center portion of said radiant heating section, each of said plurality of vertically disposed conduits being supported from said roof and extending downwardly through said horizontal partition into the upper portion of said longitudinal header compartment, header means connecting with the upper ends of said vertical conduits above said roof and separate header means connecting with the lower ends of said vertical conduits in said header compartment, separate rows of burners above said roof and adjacent each of said side walls, with adjustable supporting and positioning means at each of said burners for adjustably directing flames and hot combustion gases against each of said side walls of said heater within said radiant heating section and thereby controlling the temperature gradient for the entire height of each of said plurality of vertical fluid conduits, a bank of horizontally disposed fluid conduits in each of said convection heating sections, and gas passageways below each of said convection sections suitable for collecting and discharging flue gases from said heater.

2. A heater for fluids comprising in combination, refractory side and end walls and a refractory roof defining a radiant heating section and convection heating sections, a pair of vertical partitioning walls extending upwardly from a foundation for said heater and spaced between the lower portions of said side walls and forming with the latter two separated convection heating sections, a horizontal partition extending between the upper extremities of said vertical partitioning walls forming a longitudinal header compartment and access passageway below the central portion of said radiant heating section and coextensive with said convection heating sections, a plurality of vertically disposed fluid conduits positioned in parallel rows and in a staggered arrangement between said end walls within the center portion of said radiant heating section, each of said plurality of vertically disposed conduits being supported from said roof and extending through said horizontal partition into the upper portion of said longitudinal header compartment, separate fluid distributing and collecting headers positioned respectively above and below said vertically disposed fluid conduits and connecting therewith providing parallel fluid flow through said vertically disposed conduits, separate rows of burners above said roof and adjacent each of said side walls, with adjustable positioning means at each of said burners for adjustably directing flames and hot combustion gases against each of said side walls of said heater within said radiant heating section and thereby controlling the temperature gradient for the entire height of each of said plurality of vertical fluid conduits, a bank of horizontally disposed fluid conduits in each of said convection heating sections, return headers connecting said plurality of horizontal tubes in each of said banks of said convection heating sections in series flow, whereby a fluid stream may pass upwardly through each of said tube banks, a conduit connecting one horizontally disposed tube bank with the fluid distributing header of one of the rows of vertically disposed tubes and a second conduit connecting the other of said horizontal bank tubes with the fluid distributing header of the other of said rows of vertically disposed tubes, and gas passageways below said convection heating sections suitable for collecting and discharging flue gases passing downwardly through said radiant heating section and convection heating sections of said heater.

3. A heater for fluids comprising in combination, refractory side and end walls and a refractory roof defining a radiant heating section and convection heating sections, a pair of vertical partitioning walls extending upwardly from a foundation for said heater and spaced between the lower portions of said side walls and forming with the latter two separated convection heating sections, a horizontal partition extending between the upper extremities of said vertical partitioning walls forming a longitudinal header compartment and access passageway below the central portion of said radiant heating section and coextensive with said convection heating sections, a plurality of vertically disposed fluid conduits positioned in parallel rows and in a staggered arrangement between said end walls within the center portion of said radiant heating section, each of said plurality of vertically disposed conduits being supported from said roof and extending through said horizontal partition into the upper portion of said longitudinal header compartment, return bends connecting with the upper and lower ends of each of said vertically disposed conduits providing a series fluid flow therethrough, separate rows of burners above said roof and adjacent each of said side walls, with adjustable positioning means at each of said burners for adjustably directing flames and hot combustion gases against each of said side walls of said heater within said radiant heating section and thereby

controlling the temperature gradient for the entire height of each of said plurality of vertical fluid conduits, a bank of horizontally disposed fluid conduits in each of said convection heating sections, with return bends connecting each of the horizontal conduits within each of said convection heating sections to effect series fluid flow upwardly through each of said tube banks, conduits from each of said banks of horizontal tubes combining together and connecting with said series connected plurality of vertically disposed conduits within said radiant heating section, and gas passageways below said convection heating sections suitable for collecting and discharging flue gases passing downwardly through said radiant heating section and through each of said convection heating sections of said heater.

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