TUBULAR HEATER AND METHOD OF CONTROLLING RADIATION EFFECTS THEREIN

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This invention pertains to the art of heating fluids in tubes, and especially to tubular heaters employing upright banks of vertical, horizontal or inclined tubes disposed within and along an enclosing wall defining a heating space containing a burner which is adapted to heat the tubes by radiation at least at a level near the burner. The invention is, more particularly, concerned with heating heaters of such classes by providing means for admitting into the space between the burner and the tubes a current of shielding gas which is semi-opaque to thermal radiation for selectively shielding different portions of the tube bank from flame radiation, e.g., selectively shielding certain tubes or groups of tubes, or selectively shielding certain parts of the tubes as against other parts of the same tubes. The invention is further concerned with a method of controlling or equalizing the heating of the tubes by radiation through the use of such currents of shielding gas.

The heater and method according to the invention are particularly useful in applying heat to process fluids for carrying out chemical reactions or for preheating hydrocarbon fluids near the point of decomposition, where a good control and even heat input to the several tubes are of more importance than in the ordinary preheating of oil for viscosity corrections or simple process preheating. A few specific examples of the operations in which a heater of the type herein considered is useful are: the conversion of ethylene dichloride to form vinyl chloride, which is an endothermic reaction taking place at about 960°F, the dehydrogenation of alcohols or of gaseous hydrocarbons, which takes place at about 1000°F; and the cracking or catalytic dehydrogenation of hydrocarbon oils.

Tubular heaters of the known types, often known as refinery heaters, commonly are constructed with vertical, cylindrical enclosing walls forming of either a circular or polygonal cross section, and a single bank of vertical or horizontal radiant tubes disposed symmetrically along the wall. They have one or more oil or gas burners at one vertical end of the combustion space, either at the top or at the bottom, and a flue outlet at the other end. The area of the tube bank which can “see” the burner, i.e., the portion of the vertical tubes near to the burner or the horizontal tubes which are near to the burner, are heated predominantly by radiant heat, while the area of the tube bank toward the flue outlet which is wholly or partly shielded from radiation by the opaque combustion products or by wall structures are heated predominantly by convection.

In heating the more heat-sensitive stocks, such as cracked hydrocarbon distillates or the process fluids previously enumerated, difficulty is frequently experienced in regulating the flow of heat to the tubes. Considering heaters wherein the main burners are located at a vertical end of the combustion space and the combustion gases ascend or descend, two problems are encountered: (1) Different tubes or parts of the same tubes which lie in different horizontal directions from the flame do not absorb heat at equal rates. This difficulty is particularly encountered at the level wherein radiant heating predominates. (2) Difficulty is encountered in controlling the intensity of heating in the radiant section while supplying a desired rate of heat to the convection section. Thus, it is not feasible with most heaters to effectively provide an independent control of the heat supplied to the radiant and convection sections. Because care must be taken to avoid overheating of the tubes in the radiant section when heating such heat-sensitive stocks it is not usually feasible to permit direct radiation between the main flame and the tubes, and a solid baffle or shield is usually interposed.

The foregoing difficulties may be illustrated by considering specifically a heater with vertical tubes arranged in a circle within a circular wall and having a burner at the center of the floor, and a flue at the top. Despite symmetrical disposition of the tubes, walls and burner, it is not easy to attain even distribution of heat by radiation directly from the burner or burner flame to the individual tubes, and the tubes are apt to become overheated if exposed directly to the intense heat of the flame, resulting in undesired decomposition and carbonization of the process fluid therein. It has, therefore been attempted to mount a metallic baffle shielding a portion of the radiant section of the tubes from direct exposure to the flame and acting as a radiator to supply radiant heat to the shielded portions. Such baffles are in the form of cylinders or upwardly divergent cones arranged immediately around the flame. This arrangement has not been sufficiently satisfactory because the metallic baffles often became overheated and underwent deformation or became partly dislocated due to the weakening of their supporting structures when subjected to the high temperature of the immediate combustion products of the burner. This deviation of the baffle from its symmetrical position or other fortuitous irregularities, such as unsymmetrical flow of combustion gases caused by deposition of obstructing deposits in the flue and resulting in deflection of the flame, has caused uneven circumferential distribution of radiant heat and has resulted in overheating and decomposition or carbonization of the process fluid in some of the tubes and partial obstruction of such tubes. This caused a reduced rate of flow of fluid through these tubes which should have been heated at a correspondingly reduced
2,603,195

rate. It is evident that since these tubes were instead absorbing heat at an unduly large rate, the overheating was rapidly aggravated, and often lead to complete plugging of certain tubes.

Moreover, the amount of heat radiated by the baffle to the tubes is dependent in part upon the design of the baffle, and after installation of the baffle the relative amounts of radiant heat absorbed by different portions of the radiant section cannot be varied because the height of the baffle is fixed, and the portion of the radiant section of the tubes shielded from the flame cannot be varied. Further, the rate of total radiant heating can be varied only by adjusting the burner, which inherently varies also the amount of convection heating in other levels of the heater. Independent control of the distribution of heat between radiant and heating sections has therefore not been practical in heaters of this type.

It is an object of the invention to provide an improved tubular heater and method of heating fluids flowing through tubes arranged in a vertical bank having a radiant section extending horizontally and vertically with respect to a burner in which the tubes are heated predominantly by radiant heating, wherein radiant heat of substantially uniform or controllable intensity is distributed among the different tube surfaces at different horizontal locations of the tube bank, e.g., wherein such heat is controllably distributed among the several vertical tubes or to different parts of horizontal tubes, by means of a protective wall of shielding gas the radiant opacity of which is adjusted in different horizontal directions.

Another object is to provide an improved tubular heater and method of heating fluids flowing through tubes arranged in a vertical bank having a radiant section in which the tubes are heated predominantly by radiant heating, wherein the flow of radiant heat to different levels of the radiant section is adjustable during operation of the heater by means of a protective wall of shielding gas which is semi-opaque toward radiant heat the height of which is adjusted to shield the radiant section of the bank to varying heights.

Another object is to provide an improved tubular heater and heating method of the type indicated in the foregoing object wherein the radiant heating can be controlled more or less independently of the convection heating.

Still another object is to provide a tubular heater having a vertical bank of tubes, disposed either horizontally or vertically, along enclosing walls, such as cylindrical which may be circular, polygonal or rectangular, having a main burner at one vertical end of the combustion space and means for supplying a current of semi-opaque shielding gas which ascends or descends between the main burner and the bank of tubes. Ancillary thereto, it is an object to control the distribution of radiant heat by controlling the temperature and/or rate of flow of the shielding gas at different parts of the current. Another ancillary object is to control the total amount of radiant heating by varying the velocity of the shielding gas so as to vary the height of the shield formed thereby.

It is a further object to simplify the construction of the heaters of the type described by replacing the radiant baffle or metallic shield with a sheath of gases admitted as an annular current surrounding the burner or burners, and to provide an improved method of heating which may be applied to already existing heaters not equipped with the features of the invention by a comparatively simple alteration to such installations where overheating of tubes or excessive carbonization of the process fluids has occurred.

It is known that many gases, such as carbon dioxide, steam, sulfur dioxide, methane, ammonia, and hydrogen chloride are semi-opaque to heat rays and restrict the radiation between surfaces of solids and radiating solids or vapors, such as flames, while a few gases, particularly the homopolymers in nitrogen, oxygen, hydrogen, and chlorine, are largely diathermanous or transparent to heat rays. (See McAdams, Heat Transmission, first ed., 1933, chapter III.) It is also known to admit such semi-opaque gases into the fire box of a still horizontally beneath the horizontal tubes to reduce the radiant heating of the tubes from the flame. (See U. S. 1,821,326.) No heater, however, is known for effecting selective or adjustable control of radiation to different parts of the heating of tubes arranged in vertical banks in accordance with the foregoing objects.

Now, according to the present invention, the heater has an upright bank of tubes disposed either vertically or horizontally or inclined along an enclosing wall and exposed to one or more burners, such as oil or gas burners, in a radiation zone providing a source of radiations, such as flame or an incandescent glowing body. Radiation from the source of radiations to different parts of the tube bank is controlled by flowing a current of shielding gas which is semi-opaque toward heat rays, such gases formed by an auxiliary burner or burners or by recirculation of flue gas, or steam, from a linear source substantially vertically into the space between the source of radiation and the tube bank in the same direction as the combustion gases from the radiating burner, to form a protective wall of vertically moving gas and controlling the radiation-transmitting characteristics of the wall at different parts of the tube bank to control radiation to the tube bank. The characteristics of the wall are controlled by changing the vertical extent of the protective wall and/or the opacity of the protective wall at different parts along its length. The shielding gas is preferably heated but only to a temperature considerably below that of the flame of the radiating burner. The shielding gas may, prior to admission into the heater, be heated to above the temperature of the tubes in the radiant section to permit effective heating of the tubes, but this is not in every case essential because they may be brought to the requisite temperature by absorbing radiant heat from the radiating burner. This shielding gas commingles with the main combustion gas some distance away from the burner and the combined gases pass out of the heater through the flue at the other end.

The protective or cylindrical wall of semi-opaque shielding gas is admitted from a suitably extended source at the same end of the combustion space as the main burner, and the linear source may take the form of a slit or a series of openings in one end of the heater. The linear source may be straight or curved, e.g., circular, and may be supplied with gas from nozzles or jets or from a vertical tube supplied by gas at adjustable pressure. In the preferred embodiment air is passed through the
wind box and is heated by a series of auxiliary, individually adjustable burners, and mixed with the combustion gases of these burners, whereby the air is made semi-opaque and the temperature of the fuel gases is raised, and a portion of the line source can be adjusted independently for varying the shielding effect. According to another embodiment a heated gas, such as steam or recirculated flue gas is used, and the rate of admission of the gas to different parts of the line wall is varied to control the shielding effect. In both embodiments the height of the shielding wall is adjusted and the shifting of heat absorption between the radiant and connection sections made possible by controlling the pressure of the shielding gas, whereby the effective height of the protective wall and hence, the total amount of radiant heating of the tubes at the end of the space near the main burner can be controlled, it being evident that when less heat is radiated to the tubes in the radiant section a correspondingly greater (although not necessarily equal) portion of heat is transferred thereto in the convection section if the fuel supply to the main burner is not altered.

The term “semi-opaque” as used in this specification, has reference to the property of restricting the radiation of heat through the gas.

The invention will be described in greater detail with reference to the accompanying drawings forming a part of this specification and showing certain preferred embodiments thereof by way of illustration, wherein:

Figure 1 is a vertical sectional view of a heater with vertical tubes showing a preferred embodiment of the invention, parts being shown in elevation;

Figure 2 is a horizontal sectional view taken on line 2—2 of Figure 1;

Figure 3 is an enlarged vertical sectional view of one of the auxiliary burners;

Figure 4 is a bottom plan view of the auxiliary burner of Fig. 3;

Figure 5 is a vertical sectional view of a modified heater with horizontal tubes taken on line 4—4 of Figure 5; and

Figure 6 is a horizontal sectional view taken on line 5—5 of Figure 6.

Referring to Figures 1–3 in detail, the heater consists of a vertical cylindrical enclosure wall 1 of circular cross section and built according to standard design of refractory and heat-insulating materials. It is supported by a structural steel frame 2 extending sufficiently high above the ground to permit access to the burners and the wind-box from beneath. The steel frame extends into a frusto-conical steel hood 3 supporting a stack 4. The floor 5 of the combustion space defined by the wall 1 is provided with a plurality of burners 6 arranged in a circle through which the heater tubes 8 extend vertically. The floor also has a large center opening for the main burner 7 and a second, concentric ring of smaller holes for upwardly directed nozzles 8 suitable for burning gas and forming auxiliary or semi-opaque gas. The wind-box 8 is fitted beneath the floor opposite the holes for the burners 8 and supplied secondary combustion and excess air to the auxiliary heaters. The circle of holes for the burners 8 form a linear source for shielding gas, the line being in the form of a circle and discontinuous. Each auxiliary burner is provided with an adjustable cock 10 to control the amount of fuel admitted thereto. Primary combustion air is admitted to the auxiliary burners through adjustable air registers 11. The main burner 7 is provided with an adjustable cock 12; primary air is admitted through an adjustable air register 13 and secondary combustion air is admitted through another adjustable air register 14.

The lower part 15 of the space within the wall constitutes the radiant section, which extends upwardly to an annular convection section 16 defined by the upper part of the wall 1 and a cylinder 17. This cylinder may optionally have a cone 18 and is suspended from the header box 19 at the top of the cylindrical structure. Flue gases from the annular convection section 16 pass through holes below the header box into the steel hood 3 and out through the stack 4. A platform 20 surrounding the top of the structure provides accessibility to the header box. The tubes 6 are suspended near their top flanges 21 by collars 22 which rest on an annular support 23; they extend downwardly through split rings 24 near their bottom flanges 25. The tubes are interconnected by annular manifolds (not shown) at their upper and lower ends for passage of process fluid in a plurality of parallel streams.

Air or recirculated flue gas is supplied under pressure to the wind-box 9 through a pressurized gas duct 26 from a blower 27 which may be operated at a variable speed to admit air or flue gas into the wind-box at a controllable rate. A damper 28 may be provided in duct 25. The blower 27 may be supplied with fresh air from inlet 29 or with flue gas via a duct 30 or with a mixture by adjustment of the damper 31.

In operation, the fluid to be heated is usually admitted to the upper ends of the tubes 6 and flows downwardly. Fuel gas is supplied through valve 12 to the main burner 7 to supply the predominant part of the heat, resulting in a flame which heats the tubes 6. It is evident that the combustion of gas in the main burner 7 is produced by inspiration of air through the register 13 and holes 14 by the action of the burner itself, although it is within the scope of the invention to premix gas and combustion air ahead of the burner in mixing devices at gas-air ratios near the theoretical mixture for maintaining a higher thermal efficiency.

In order to spread the concentrated radiant effect from near the burner and at the same time throw a protective shield in between the flame and the tubes, a cylindrical wall of cooler, semi-opaque gas is ejected upwardly through the openings surrounding the auxiliary burners 8 by operation of the blower 27. The auxiliary burners 8 are charged with fuel gas to heat the ejected gas; when air is ejected all or part of it may be consumed in combustion, or an excess of air may be admitted to lower the temperature of the protective wall. The ejected gas and any gas heated to a temperature below that of the flame of the main burner 7 and will form an annular wall which rises to a height dependent upon the velocity of the gas which is, in turn, governed by the pressure in the wind-box 9. The latter can be controlled by changing the speed and pressure of the blower 27 or adjusting the damper 28. When recirculated flue gas of a sufficiently high temperature is recirculated the operation of the auxiliary burners 8 may at times be unnecessary.

The supply of shielding gas serves a double purpose:

Firstly, the protective wall or cylinder of semi-opaque gas will reduce radiation from the flame of the main burner to the lower portions of the
tubes, thereby lessening the danger of overheating them; it therefore performs the function of a solidifying barrier in the prior art. After rising to above the level of the high radiant effect of the main burner flame the protective wall of shielding gas will break up or diffuse toward the center of the space 18 and the gas becomes mingled with the hot combustion gases from the central burner so that the shielding gas becomes heated and radiation of heat from the gases to the tubes can occur above the break-up level. The effective height of the protective wall can be controlled by varying the rate of gas flow from the wind-box. It is thereby possible to regulate the radiation of heat to different levels of the bank of tubes. Aside from regulating the distribution of radiant heat, this affects some control over the relative amounts of radiant and convection heating, it being evident that when a protective wall which is more opaque to heat rays is used the total amount of radiant heat adsorbed by the tubes is reduced for a given heat output of the main burner; a large part of the heat which would otherwise be absorbed as radiant heat is then adsorbed in the convection section 18.

Secondly, by the individual control and setting of the several burner cocks 10 of the auxiliary burners the temperature and the composition of the shielding gas can be controlled at different circumferential points of the heater. It is thereby possible to apply a correction for uneven heating among the tubes which is often encountered even when the heater walls, tube and walls, are arranged in perfect symmetry about the vertical axis. Thus, the temperatures of the individual tubes or of groups of tubes in different sectors can be determined by thermocouples applied, for example, in wells indicated at 32, and local overheating of certain tubes can be prevented by lowering the rate of fuel gas admission to the corresponding auxiliary burners and lowering the temperature of the shielding gas in that sector.

The effect of supplying gas of a lower temperature may be understood by considering the effect of the semi-opaque gas. Some of the radiating heat from the flame of the main burner and its immediate combustion products will pass through the protective gas wall depending upon its degree of opacity to the radiant heat passage. Another part of the radiated heat will act on the surface of this wall and will be in part reflected and, in part, absorbed by it; some of this is again radiated to the tubes.

When the auxiliary burners 8 are turned down, two effects occur: the reduced temperature of the gas increases the opacity and the radiation from the gas to the tubes is decreased. The opacity can be further increased by adding steam or water vapor in the form of humid air to the atmosphere of the gas wall, e.g., by spraying into the wind-box.

The invention is not limited to the use of diluted combustion gas as a protective means against excessive radiation. The same arrangement can be utilized for other gases; thus, it is possible to supply steam through the cocks 10 and utilize the burners 8 as nozzles instead of as burners. Air or recirculated flue gas may be fed through the wind-box 9 in addition to the steam, or steam may be employed alone. The same controls over radiation effects as were previously considered are possible in this case: The opacity of the shielding gas can be varied by varying the relative amounts of steam and air, while the height of the protective wall can be varied by varying the upward velocity. Control of tubes in different sectors can be achieved by control of the individual cocks 10 to admit more or less steam to different sectors, thereby changing the temperature and/or the composition and opacity of the gas in different sectors. It should be noted that the use of the wind-box 9 is optional when steam is used and that sufficient air can be admitted by the inspirating effect of the steam to the water tubes and nozzles which act to assist the natural draft of the heater.

As was noted above, the invention may also be applied to other forms of heaters, such as those having horizontal tubes extending along straight walls. Such a heater is shown in Figures 4 and 5 wherein 33 denotes the heater walls which are supported on a framework as was described for Figures 1–3 and along which are disposed vertical banks of horizontal radiant heater tubes 34 which may be connected in any suitable manner, e.g., for parallel flow of several streams of process fluid or in series. Connection tubes 35 are mounted in the upper, constricted part of the heater, below the upwardly convergent steel hood 38 and stack 31. There may be a plurality of stacks along the length of the hood 38 to cater to one stack not being used in most cases. A series of main burners 38 are mounted in a row and extend through holes in the lower floor 39.

For preventing excessive radiation from the burner a pair of wind-boxes 40 are mounted beneath the lower floor. Each box communicates with the space above through a slit 41. The slit is a straight, continuous linear source of shielding gas. The wind-box is fed by a pressurized gas duct 42 connected to a blower 43 which may be operated at adjusted speed and which takes suction either from the atmosphere through an inlet 44 or from the hood 38 through a duct 45, depending upon the setting of the damper 46. A damper 47 may be produced in the duct. A plurality of auxiliary burners 48 extend through the wind-box and through enlargements in the slits 41 to provide jet flames at points along the slits 41. These burners are supplied with fuel gas or steam from a pipe 49. Individual cocks 50 are provided to permit the heat release of the several auxiliary burners to be adjusted.

The operation and control of the heater according to Figures 4 and 5 are the same as those previously described, with the difference that the protective wall of semi-opaque gas is flat instead of annular.

I claim as my invention:

1. Method of heating fluids sensitive to excessive temperatures comprising flowing said fluid through a plurality of vertical tubes disposed as an annulus about an enclosed space forming a radiant section of a heater; supplying heat to said tubes by operating a burner emitting radiant heat which is located centrally within and near to the lower end of said radiant section to generate combustion products; withdrawing said combustion products from the space; shielding the lower portions of said tubes against excessive radiant heating from said burner by distributing circumferentially a portion of said withdrawn combustion products as a shielding gas that is semi-opaque to heat rays and ejecting said gas generally upwardly into the space between the burner and the tubes to form a substantially vertical, annular protective wall of continuously ascending shielding gas that is separate from the immediate combustion products of the main burner at least at the lower portions said
tubes; and adjusting the relative radiation-transmitting characteristics of different portions of said protective wall to control the radiation from said burner to different portions of said tubes by commingling said shielding gas at a plurality of circumferentially distributed points thereof with another fluid by controlling the rate of admission of said other fluid independently at said plurality of points.

2. The method according to claim 1 wherein the said other fluid is hot combustion gases generated by operating a plurality of auxiliary burners at said plurality of points and the composition and rates of admission of said hot combustion gases are controlled independently by admitting varying amounts of combustion air to said auxiliary burners and regulating the supply of fuel thereto.

3. A tubular heater comprising an enclosing wall; a vertical bank of tubes disposed along said wall; a flue outlet at a vertical end of the heater; an end wall opposite to said flue outlet; a burner adapted to emit heat radiations directly to said tubes and spaced vertically from said flue outlet within said heat and opposite said bank; a duct for pressurized gas on the outside of said end wall; one or more openings through said end wall establishing communication between said duct and the interior of the heater and extending along a line, said openings being disposed to direct pressurized gas into the space between the bank of tubes and the burner to form a current of said gas that is initially separate from the combustion products of the main burner; means for supplying to said duct under pressure a gas that is semi-opaque to heat rays; a plurality of nozzles located at the end wall and distributed along said line for admitting fluid into corresponding portions of the gas admitted from said duct at different points along said line to become a part of said current; means separate from said duct for supplying a fluid other than said gas to said nozzles; and means for regulating the rates of admission of fluid to said nozzles independently of one another, whereby the characteristics of the parts of the current flowing at different points along said line can be varied independently of one another.

4. A tubular heater comprising an enclosing wall; a vertical bank of tubes disposed along said wall; a flue outlet at a vertical end of the heater; an end wall opposite to said flue outlet; a main burner adapted to emit heat radiations directly to said tubes and spaced vertically from said flue outlet within said heat and opposite said bank; a duct for pressurized gas on the outside of said end wall; one or more openings through said end wall establishing communication between said duct and the interior of the heater and extending along a line, said openings being disposed to direct pressurized gas into the space between the bank of tubes and the main burner to form a current of said gas that is initially separate from the combustion products of the main burner; means for supplying to said duct under pressure a gas that is semi-opaque to heat rays; a plurality of auxiliary burners located at the end wall and distributed along said line so as to discharge combustion products therefrom into said semi-opaque gas directed from said openings for heating corresponding portions of said gas admitted at different points along said line; and means for regulating the heat outputs of said auxiliary heaters independently of one another, whereby the temperature of the gas admitted at different points along said line can be varied independently of one another.

5. In combination with the heater according to claim 4, a flue duct interconnecting the flue outlet with the said means for supplying gas to said duct for pressurized gas, the latter means being a blower for recirculating flue gas into the last-mentioned duct.

6. A tubular heater comprising a cylindrical wall of circular cross-section enclosing a vertical chamber; a plurality of vertical heating tubes disposed along said wall as a circular ring of tubes; a flue outlet at the top of the chamber; a burner located centrally near the bottom of the chamber and adapted to emit heat radiations directly to the lower parts of said tubes; a wind-box beneath said chamber; means for supplying gas under pressure to said wind-box; one or more passageways between the wind-box and said chamber and communicating with the latter along a circular line also near the bottom and disposed to direct pressurized gas into the space as a substantially cylindrical current that is separate from the combustion products of said burner and flows upwardly into the space between said burner and the ring of tubes; a plurality of nozzles arranged substantially along said circular line for admitting a fluid upwardly into said current; means separate from said wind-box for supplying a fluid other than said gas to said nozzles; and means for regulating the rates of admission of fluid to said nozzles independently of one another, whereby the characteristics of the parts of the current flowing at different points along said line can be varied independently of one another.

7. The heater according to claim 6 wherein the said nozzles are burners and the fluid admitted thereto is a fuel, said burners being provided with air registers for admitting primary combustion air.

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