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COMPLETE SPECIFICATION

Fired Heater for Process Fluids, Particularly Hydrocarbons

We, PULLMAN INCORPORATED, a Corporation organized under the laws of the State of Delaware, United States of America, of 200 South Michigan Avenue, Chicago, State of Illinois, United States of America, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to an improved apparatus for the fired heating of process fluids. Process fluid furnaces generally consist of a refractory lined enclosure containing heat resistant metal alloy tubes through which process fluids are passed. The tubes are heated by burners which combust a suitable fuel within the refractory enclosure to provide a heat source. Most furnace designs utilize direct radiant heating of a portion of the process tubing and convection preheating by the combustion gases of a preheat section of the process tubing. A process furnace may have the function of increasing the temperature of a process fluid without effecting a change in state or causing chemical reactions to occur, or the process fluid may be heated to the extent of causing physical and/or chemical changes to take place. The apparatus of the invention is particularly adapted to carry out high temperature heating of process fluids to bring about chemical reactions in the fluid, such as is particularly required, for example, in modern hydrocarbon pyrolysis techniques whereby hydrocarbon feedstocks such as ethane propane, naphtha or gas oil may be thermally cracked to produce less saturated products such as acetylene, ethylene, propylene, butadiene, etc., and other products depending on the nature of the feedstock and the specific cracking conditions chosen.

It is well known that the "severity" of thermal cracking of hydrcarbons, i.e., the process fluid reaction temperature attained and the residence time of the fluid at the reaction temperature, profoundly affect the kind and amount of the various products obtained, as does the total pressure at which the heating is carried out. It is convenient to visualize the thermal cracking process as a graphic plot of temperature of the process fluid versus residence time within the (heated) process tubes; the curve obtained being referred to as the "time-temperature profile". Maintaining the time-temperature profile within narrow selected limits is of prime importance since even relatively small deviations from the planned profile will vary the amount and relative proportion of products from that which is sought. It is thus apparent that an efficient pyrolysis furnace must be capable of providing close control over the process variables of process fluid residence time and temperature.

In the case of pyrolysis of more saturated hydrocarbons to obtain ethylene, other olefins and other products, fluid temperatures at the furnace outlet of from about 1400°F. to 1600°F, depending on the type of hydrocarbon being cracked, are typical of modern, high severity cracking. In view of this high temperature requirement, the temperature resistance of materials of construction of such a furnace, especially the reaction tubes through the walls of which the high heat flux must pass, is a matter of prime consideration. Further, subjecting hydrocarbons to such high temperatures also inevitably results in small portions of the process fluid being over heated and degraded to gummy polymeric substances and carbon, usually collectively referred to as "coke". Coke formation within the tubes cuts down the heat transfer to the process fluid thereby increasing the temperature of the tube walls, and also increases the pressure drop of the fluid. Thus, coke formation is a serious cause of

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furnace downtime and maintenance as the tubes of the furnace must be periodically cleaned, i.e., "de-coked", to remove accumulated coke.

Another factor in process furnace design is the length of reaction tubing which must be provided to permit the entire volume of fluid passing therethrough to be heated to the requisite temperature. In order to obtain high furnace capacity the process tubes are usually of three to five inch inside diameter; a relatively long fired tube (about 150 to 400 feet) is required to heat a three to five inch diameter fluid mass to the required temperature and the prior art furnaces thus require a coiled or serpentine tube configuration to fit the required length of tubing into the confines of a reasonably sized furnace refractory enclosure. The problem of coke formation and pressure drop across the furnace tubes are aggravated by the multiple turns of a coiled process tube configuration.

In order to fix the product composition by halting the reactions of the heated products as they emerge from the reaction tubes, the process fluid must be cooled quickly to a temperature below reaction temperature. This is usually accomplished by cooling the fluid either directly or indirectly, or both, with a coolant liquid, usually water in the case of indirect cooling, and water or refractory oil or a combination of water and oil in the case of direct cooling. Rapid cooling and minimizing the transition period, during which undesirable side reactions, occur, is necessary in order to "freeze" the chemical composition of the fluid at the composition attained at the positively controlled temperature of the reaction zone outlet.

Whereas it may be relatively simple to attain specified conditions of temperature, residence time and pressure drop in laboratory or pilot plant equipment, reproducing these conditions consistently throughout the entire mass of fluid to be treated in a commercial installation is a difficult and complex problem. For this reason the "scaling up" of laboratory and pilot plant data relating to products and yields obtained in small scale equipment to predict the performance of a commercial installation in an uncertain and risky business. Since, as aforesaid, a typical process furnace for the pyrolysis of hydrocarbons utilizes a reaction coil of 3—5 inches inside diameter and a length of 150 to 400 feet, it is obviously impractical to utilize an actual coil in laboratory or pilot plant work, and scaled-down version must be used with all the uncertainty of "scale-up" calculations being of necessity incorporated in the final result.

The fired heater of the invention comprehends a heater employing a plurality of essentially straight, single pass reaction tubes located within a refractory enclosure and situated so as to be heated by burners adapted to combust a fuel to provide the heat source. The description "single pass tube" is meant to indicate that the straight tubes are not interconnected in series to course the process fluid several times within the refractory enclosure, but rather the fluid passes but once through the refractory enclosure by means of straight tubes connected in parallel. Each of the straight reaction tubes is connected to a quench tube located outside the refractory enclosure, within which quench tubes the process fluid is cooled. The diameter of the reaction tubes is small enough so that the mass of fluid contained therein may be heated to the required temperature within a length of straight tubing which can be enclosed within a refractory chamber of reasonable size.

In the case of a process fluid to be heated to a temperature at which a cracking reaction occurs, the process fluid is passed through the straight reaction tubes and heated therein by heat supplied from the burners. The process fluid may have been preheated to less than reaction temperatures in a preheating coil. (The preheating coil may advantageously be heated by fuel gases exhausted from the refractory chamber). Upon attaining the reaction temperature the desired reactions occur and the fluid is maintained within the reaction temperature zone for the required period of time, which may be as short as a small fraction of a second or longer, depending on the type of reaction being carried out with the product mix desired. Residence time within any segment of the reaction tubes is of course simply controlled by controlling the linear velocity of the fluid. The reacted products pass through the portion of the tubes within the refractory enclosure, i.e., the reaction tubes, and into the quench tubes wherein they are cooled and the cooled products are then withdrawn from the quench tubes. The provision of individual quench tubes directly connected to each process fluid tube greatly simplifies the difficult design problem of collecting hot, cracked product gas at high velocity from a plurality of reaction tubes and diverting them into a separate quench boiler. It likewise drastically reduces the time lag between the time the fluid leaves the reaction tube and the time it enters the quench tube, thereby precluding degradation or decomposition of the valuable products by undesirable side reactions (which occur, as aforesaid, during the interval between the heated reaction tubes and the cooled quench tubes).

Inasmuch as the reaction tubes are straight and contain no loops or coils, the length of reaction tube necessary to heat the fluid to the required temperature sets the minimum size of the combustion chamber. In order to limit this size to a practical and economical dimension, considering structural require-

ments and sound engineering practices, the diameter of the reaction tube must be limited so that the volume of fluid passing therethrough can be sufficiently heated during its residence time by the available heat input, which in turn is limited by the maximum allowable wall temperature and heat flux capacity of the tubes. Since the volume of liquid passing through the tube at a given linear velocity is proportional to the square of the tube inside diameter, a furnace designed in accordance with the prior art with, for example, a 160 feet long, 4" inside diameter tube (coiled to fit within a reasonable sized furnace) would have the same fluid capacity as a furnace designed in accordance with the present invention which is equipped with sixteen one-inch inside diameter tubes forty feet in length, i.e., the cross-sectional area of the single four-inch inside diameter tube is the same as the sum of the cross sectional area of the sixteen one-inch inside diameter tubes. Since each one-inch tube is carrying but one-sixteenth the fluid carried in the four-inch tube, yet has one-fourth as much heated surface area per unit length, only about one-fourth the total heated length is required to impart an equivalent amount of heat to the fluid. Therefore, a furnace in accordance with the present invention with sixteen one-inch tubes, forty feet in length (one-fourth of 160) provides about the same furnace capacity, both in terms of fluid throughput and heat input, as a prior art furnace with a single four-inch tube, 160 feet long.

In the case of furnaces designed to carry out hydrocarbon pyrolysis to obtain primarity ethylene as well as other products, for example, current engineering feasibiity limit the size of the furnace refractory enclosure to about 60 feet, more or less. Accordingly, the length of the single pass reaction tubes is likewise limited to about 60 feet, and consequently, the mass of fluid being heated in the reaction tubes must be limited to enable the fluid to attain the required pyrolysis temperature within the short residence time required for satisfactory ethylene yield and within the limitation of the maximum sustainable tube wall temperature. It has been found that with a tube length of not more than about 60 feet, the required temperature for pyrolysis of hydrocarbon feedstocks in the service described above, can be attained in the hydrocarbon fluid mass if the hydrocarbon fluid mass does not exceed about two inches in diameter, i.e., if the reaction tube has a maximum inside diameter of about two inches. To state it differently, it has been found that in this particular service, a ratio of tube inside diameter to reaction tube length of not more than about 1:360 (2 inches/60 Feet= 1/360) will permit efficient operation. A greater inside diameter-to-length ratio would preclude sufficient heat being imparted to the fluid within the residence time and tube wall temperature limitations and result in failure to attain the desired degree and extent of thermally-induced chemical reactions. It is preferred that the reaction tubes have an inside diameter not more than about one-two hundred fortieth (1/240th) of the length of said reaction tubes. It is apparent that if a fixed tube length, maximum allowable tube wall temperature, and fixed residence time are stipulated the amount of heat which can be imparted to the fluid mass decreases as the diameter of the fluid mass increases.

Of course, the ratio between the maximum permissible tube inside diameter and the tube length will depend upon the type of service required and the feedstock to be treated in the furnace. A greater or lesser furnace dimension may be feasible in other services thus permitting a greater or lesser tube length and corresponding tube diameter. In most cases, the maximum permissible tube inside diameter will not be greater than about three inches. The residence time and temperature and heat input requirements will likewise vary depending on the service in which a furnace is employed. It is apparent that it is within the ordinary abilities of one skilled in the art, given the disclosure of the present invention, to determine the particular requirements of the service in which the furnace is to be used and to size the furnace and the tubes for a particular service so as to obtain an efficient furnace designed in accordance with the present invention and particularly adapted to the service in which it is to be used. It is further apparent that such fired heaters are contemplated by the present invention.

It is thus apparent that a furnace designed in accordance with the present invention prosides significant advantages over furnaces designed in accordance with the prior art. For example, the short reaction tube length permits extremely short residence times in the process tubes which has the important process advantage in producing ethylene and other olefins by hydrocarbon pyrolysis, of increasing the yield of ethylene from the feed. Shortened residence times in the quench tubes and in the transition between the reaction and quency tubes are also attained. The straight-tube design reduces pressure drop significantly as compared to coiled or serpentine process tubes. The straight reaction and quench tubes permit efficient and highly effective decoking by means of high pressure steam or other fluid lancing shutdown or on-stream decoking and, during operation of the furnace, enhances, the scouring effect of loose coke and polymer particles being carried with the process fluid. During operation of the furnace, a large quantity of fluid (preferably steam) may be injected into any individual reaction tube

by means of valved, flexible fluid, (steam) injection hoses which can be connected to any of the furnace reaction tubes. The flexible hose connections are located downstream of metering orifices located in the process fluid inlet end of each reaction tube. The metering orifices are high pressure drop orifices which provide uniform distribution of process fluid into each of the reaction tubes. Injection of a large quantity of decoking, e.g., steam into the reaction tube downstream of the metering orifice during furnace operation provides the tube with a large "slug" of steam in addition to process fluid; as a result heat is absorbed at a faster rate by the combined volume of steam and process fluid and the tube being decoked is cooled sufficiently to cause it to contract and thereby spall off coke particles from the tube inside surface. When the steam injection is stopped, the tube heats up and expands, providing an additional spalling effect. Decoking may be accomplished by injecting other fluids than steam, such as for example, water. The spalled coke particles pass with naturally occurring particles in the process fluid to the furnace outlet and are removed in the usual scrubbing and fractionating steps practiced on the furnace effluent. Because of the enhanced scouring effect and the elimination of turns in the tubing, steam or other fluid lancing, either alone or with the addition of scouring granules, quickly and efficiently cleans the tubes so that an individual tube may be efficiently decoked while the rest of the unit stays in service. It will be appreciated that the feature of on-stream decoking is an extremely advantageous one which will greatly reduce the number and length of expensive shutdowns of the entire furnace.

A small diameter reaction tube has the advantage of having smaller mechanical forces acting on it from the pressure of the process fluid than does a large diameter tube. Therefore, the tube wall thickness necessary to contain the process fluid mass within the tube need not be as great in a small diameter tube as in a large diameter tube. This permits a considerable reduction in the quantity of expensive heat resistant alloys required for the tubes as compared with an equivalent, large diameter tube furnace. Another significant advantage of the furnace of the invention resides in the fact that the relatively large number of small diameter tubes (as compared to the small number of large diameter tubes of furnaces designed in accordance with the prior art) means that any given tube carries a much smaller percentage of the total furnace throughput (tube capacity varies with the square of the diameter). Accordingly, the failure of a tube does not seriously affect the total furnace throughput and the failed tube may be isolated by valves and the furnace kept on stream. With furnaces operated at or near the metallurgical limits of available materials of tube construction, it will be appreciated that ready isolation of failed reaction tubes with but small diminution of furnace capacity is a valuable feature of the invention.

Yet another advantage of the straight-tube, relatively small diameter furnace is that a pilot plant installation may conveniently consist of a single tube from a commercial unit so that data obtained in the pilot unit can be exactly reproduced in commercial scale; the commercial unit consists merely of a large number of fluid tubes identical to those used in the pilot unit. For example, if a typical furnace coil of the prior art contains a given number of serpentine coils of 160 feet of reaction tube linear length and 4 inch inside diameter, an equivalent furnace designed in accordance with the present invention would contain the same given number of groups of sixteen reaction tubes of one-inch inside diameter and forty feet of reaction tube length. It is obviously not feasible to construct a pilot unit with a 160 foot, 4 inch inside diameter tube coil, while it is entirely feasible to construct a pilot unit containing a single forty foot, one-inch tube; furthermore, the use of the one-inch pilot tube would require diversion and disposal of but one-sixteenth the amount of test fluid as would be required in the four inch tube. It is apparent that for a furnace tube designed in accordance with the prior art, the pilot unit must be a scaled-down version of the commercial unit and this will require complex calculations and empirical assumptions in converting the pilot plant data to predict commercial performance; whereas a pilot unit for a furnace tube designed in accordance with the present invention consists of one or more tubes identical to those which will form the commercial unit and the data obtained therefrom directly establishes the performance of the commercial unit. The assumptions and calculations involved in scaling-up data, which cast grave doubt on the validity of scaled-up data and often require that a commercial unit be over-designed to ensure meeting its specifications are thus entirely avoided by the present invention.

The invention will be more clearly understood from the following description with reference to the accompanying drawings of preferred embodiments of the invention which are illustrative of fired heaters designed in accordance with the invention.

Figures 1, 2 and 3 of the drawings show, respectively, a side elevation, an end elevation and an isometric view, all in partial section, of a preferred embodiment of the invention.

Figure 4 is a schematic representation of a preferred embodiment of a zoned furnace

constructed in accordance with the invention.

Figure 5 is a schematic representation of the arrangement of an alternative preferred embodiment of the invention.

Referring now to Figures 1, 2 and 3 which illustrate a preferred embodiment of the invention, and particularly to Figure 3, a refractory enclosure 10 encloses reaction tubes 12 which extend past the enclosure as quench tubes 14. Reaction tubes 12 and quench tubes 14 are coaxially aligned and connected in flow communication with each other. Support for the entire structure is provided by steel framework 1. Each of quench tubes 14 is jacketed by cooling jackets to constitute quench coolers 16. As best shown in Figure 2 a coolant liquid (preferably water) header 18 provides coolant to the quench coolers 16 via coolant connectors 20. Vapour (steam) is generated within the quench coolers by absorbing heat from the quench tubes and the vaper and recirculating liquid passes through vapour connectors 22 into vapour drum 24. Make-up liquid (water) is introduced through line 26 into vapour drum 24 thence to coolant header 18 via downcomer lines 30. Uncondensed vapour (steam) is taken off via line 28.

Process fluid is introduced to the furnace via line 40, preheated in preheat coil 42 (Figure 1) and the preheated fluid is passed via lines 44A and 44B to process fluid headers 46, thence via flexible process fluid connectors 48 into reaction tubes 12 wherein the fluid is heated to the temperature required to have the desired chemical reaction and/or change of state take place. Metering orifices 49 are located in each fluid connector 48 for the purpose of distributing the process fluid uniformly to the reaction tubes by maintaining a high pressure drop (in relation to the pressure drop through the furnace) across the orifices 49. The reacted fluids pass directly into quench tubes 14 wherein they are cooled sufficiently to halt the reaction and "freeze" the composition of the product mix. Quenched, reacted products then pass through products connectors 50 to product header 52 from whence where quenched product is removed via line 54.

Heat is provided to the furnace by the combustion of a suitable fuel in burners 56 (Figure 2). Fuel and air is supplied to the burners via lines 58 through suitable connections (not shown). Flames from burner 56 provide direct radiant heating for reaction tubes 12. Hot combustion gases, which are withdrawn from enclosure 10 via flue 60, are used to preheat the process fluid in preheat coil 42, after which further heat may be recovered from the gases in coil heater 43 (Figure 1) for example, by superheating steam which is introduced into heater 43 via line 45 and withdrawn via line 47. The cooled gases are then withdrawn from the furnace.

Steam for decoking the process fluid tubes is provided from decoking steam header 32 to valved connection 34 which provides connection via flexible steam hose 36 to a number, about eight, of tubes 12, which can be serviced by each valved connection 34. Removable coupling 38 and steam inlet valves 39 permit steam hoses 36 to be readily connected and disconnected between the several tubes serviced by each of the plurality of steam hoses. By the present arrangement, decoking steam may be injected into the individual reaction tubes in need of decoking while the furnace stays on stream. While the furnace is shutdown for regular maintenance, high pressure steam or water lances may be introduced through steam inlet valves 39 to permit additional cleaning of the tubes. Suitable drainage plugs 62 are provided at the bottom of each process fluid tube to drain off decoking steam or water and coke removed from the inside surface of the tubes during such shutdown cleaning. During onstream decoking, the decoking steam and removed coke particles merely pass out of the furnace with the furnace effluent.

Details of the arrangement of the feed inlet and onstream decoking connections, burners and tube supports are shown in end view in Figure 2 and in isometric view in Figure 3. In order to simplify the drawing only representative elements are shown; the close spacing of the elements would needlessly complicate the drawing if each element were portrayed. Each tube is flexibly supported by tube support cables 64 strung over pulleys 66a and 66b and held by counterweights 68. Each tube is thus flexibly supported to allow for thermal expansions during operation of the furnace. The various connections and supports are sheltered from the elements by shed enclosure 70.

In another preferred embodiment of the invention the design may be adapted to a zoned furnace, i.e., a furnace in which sections of the reaction tubes are physically isolated from one another and provided with individual sets of burners. In this manner, by firing the burners at different rates, the heat input to each section of the reaction tubes can be controlled to provide a further refinement of control over the time-temperature profile.

Figure 4 shows in schematic partial elevation a preferred embodiment of a zoned furnace designed in accordance with the present invention in which a steel supporting framework 100 supports the refractory enclosure 101 which contains inward sloping walls 102 which divide the refractory enclosure into an upper radiant section 104A and a lower radiant section 104B. The lower radiant section 104B is fired by floor burners 106 which heat the lower portion of reaction tubes 108.

Combustion gases from burners 106 flow upwardly and are channeled by sloping walls 102 into flue gas duct 110 within which is disposed convection pre-heating coil 112. The combustion gases are withdrawn from the furnace via duct 110.

In like manner, roof burners 114 fire upper radiant section 104A and heat the upper portion of reaction tubes 108. The combustion gases are withdrawn through flue gas duct 110 in which they are comingled with the combustion gases from floor burners 106.

Process fluid is introduced via line 116, preheated by convection, heating in coil 112, the preheated fluid is passed via line 118 to process fluid header 120, thence through metering orifices 121, thence through reaction tubes 108 serially through lower radiant section 104B and upper radiant section 104A of the refractory enclosure, which sections may be fired at different rates, thence into quench tubes 120. The hot reacted gases are cooled within quench tubes 120 by a cooling medium, usually water, introduced from coolant header 122 via coolant connectors 124 and through quench coolers 126. The cooling medium is vaporized and the vapor withdrawn through vapor connectors 128 into boiler outlet header 130, thence to a vapor drum (not shown). The reacted, quenched process fluid is removed via product connectors 132 and product header 134.

On-stream decoking of individual tubes 108 is accomplished by introducing decoking steam from decoking steam header 136 via flexible hose 138 into reaction tubes 108 downstream of metering orifice 121. For shutdown cleaning of the tubes, high pressure steam or water lances may be connected at the upper end 109 of tubes 108 and fluid and coke removed via drainage plugs 140.

Each reaction tube is flexibly supported to allow for thermal expansion during operation by means of support spring 142 and yoke 144.

Yet another preferred embodiment of the present invention is the use of straight relatively small diameter reaction tubes utilizing a U-connection to the quench tubes so that the total furnace dimensions (height in this case) is set by the required length of the reaction tubes only, and not by the combined length of reaction and quench tubing. This embodiment thus reduces the overall furnace height, but at the expense of the added pressure drop, cost and inconvenience of introducing a U-turn into the tubes. Figure 5 shows in schematic partial elevation such a preferred embodiment of a furnace in accordance with the present invention consisting of a steel framework 200 supporting refractory enclosure 202 which encloses burners 204 and reaction tubes 206. U-connectors 208 connect reaction tubes 206 to quench tubes 210 which are encased by quench coolers 212. Cooling medium is introduced into the quench coolers via lines 214A and 214B, partially vaporized in quench coolers 212 and the vaporized and recirculating coolant is withdrawn via vapor connectors 216 to vapour drum 218 from whence vapours are withdrawn via line 219.

Process fluid is preheated, preferably in a convection preheat coil (not shown) by combustion gases from the furnace, and is passed via line 220 into process fluid header 222 thence through orifice meters 223, thence into reaction tubes 206. The heated reacted products through U-connections 208 are cooled in quench tubes 210 and withdrawn via product header 224 and line 226.

On-stream decoking of individual reaction and quench tubes is accomplished by introducing decoking steam from decoking steam header 228 via flexible steam hose 230 and valved connections 231. The steam is introduced downstream of orifice meters 223. For shutdown decoking, high pressure steam or water is introduced through Y-connectors 209 and drainage is provided by drainage plugs 232 which service reaction tubes 206 and quench tubes 210. Tube supports and other structural elements are omitted from the drawing of Figure 5 to simplify the drawing.

In the above description and the attached drawings numerous valves, pump, meter, etc. necessary or useful in operating the fired heaters described have been omitted for the sake of clarity; such items and their use are well known to those skilled in the art.

WHAT WE CLAIM IS:—

1. A fired heater for process fluids, particularly for pyrolyzing normally gaseous or normally liquid hydrocarbon feedstocks to obtain olefins and other products which comprises a refractory furnace enclosure having a plurality of reaction tubes contained therein, said tubes communicating with a quench section through which said fluids pass after being heated, said reaction tubes being essentially straight and making a single pass through the refractory enclosure and being in flow communication with a plurality of essentially straight quench tubes in the quench section.

2. A fired heater according to claim 1, in which the quench tubes are coaxially aligned with corresponding reaction tubes.

3. A fired heater according to claim 1, in which the quench and reaction tubes are connected in flow communication by means of a U-shaped connection so that the connected reaction and quench tubes are aligned in planes essentially parallel to and spaced one from the other.

4. A fired heater according to any one of the preceding claims, in which the reaction

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On-stream decoking of individual reaction and quench tubes is accomplished by introducing decoking steam from decoking steam header 228 via flexible steam hose 230 and valved connections 231. The steam is introduced downstream of orifice meters 223. For shutdown decoking, high pressure steam or water is introduced through Y-connectors 209 and drainage is provided by drainage plugs 232 which service reaction tubes 206 and quench tubes 210. Tube supports and other structural elements are omitted from the drawing of Figure 5 to simplify the drawing.

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2. A fired heater according to claim 1, in which the quench tubes are coaxially aligned with corresponding reaction tubes.

3. A fired heater according to claim 1, in which the quench and reaction tubes are connected in flow communication by means of a U-shaped connection so that the connected reaction and quench tubes are aligned in planes essentially parallel to and spaced one from the other.

4. A fired heater according to any one of the preceding claims, in which the reaction

* C L M S *

tubes are of an inside diameter not greater than about three inches.

5. A fired heater according to any one of the preceding claims in which the reaction tubes have an inside diameter not more than about one-hundred fortieth (1/240th) of the length of said reaction tubes.

6. A fired heater according to any one of the preceding claims, in which each quench tube is enclosed by a cooling jacket adapted to course coolant over the external surface of said quench tubes.

7. A fired heater according to any one of the preceding claims, in which the enclosure is subdivided into at least two zones, said reaction tubes pass through said at least two zones said reaction tubes pass through said zones, and each of said zones is independently heated.

8. A fired heater according to any one of the preceding claims, which comprises means to inject decoking fluid into any reaction tube while said heater remains in service.

9. A fired heater according to any one of the preceding claims, in which the reaction tubes are vertically disposed in the furnace enclosure, which has burners therein.

10. A fired heater for process fluids, substantially as herein described with reference to the accompanying drawings.

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