

June 20, 1972

B. A. WALLACE
CRACKING FURNACE HAVING THIN STRAIGHT SINGLE
PASS REACTION TUBES

3,671,198

Filed June 15, 1970

5 Sheets-Sheet 1

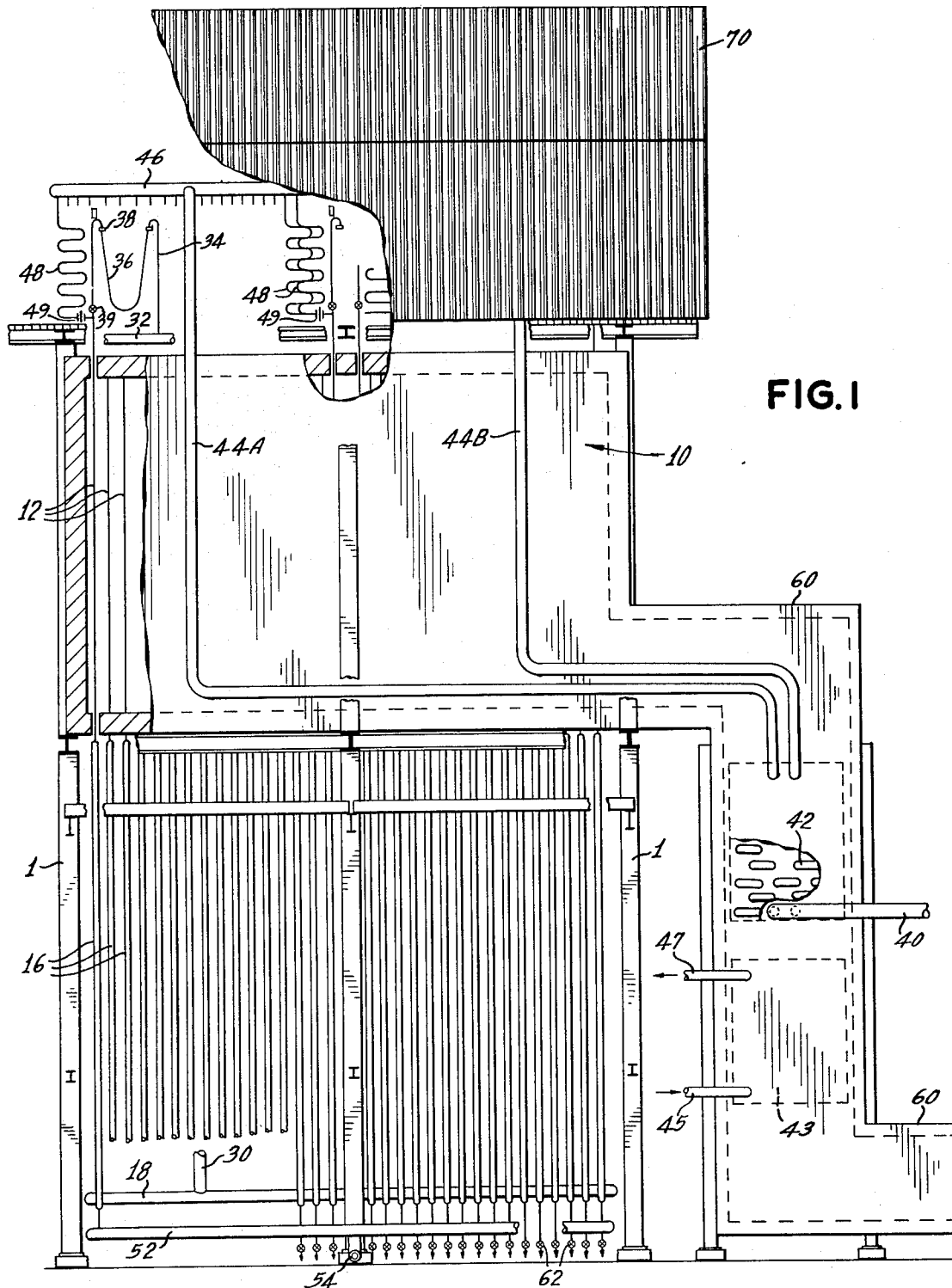


FIG. 1

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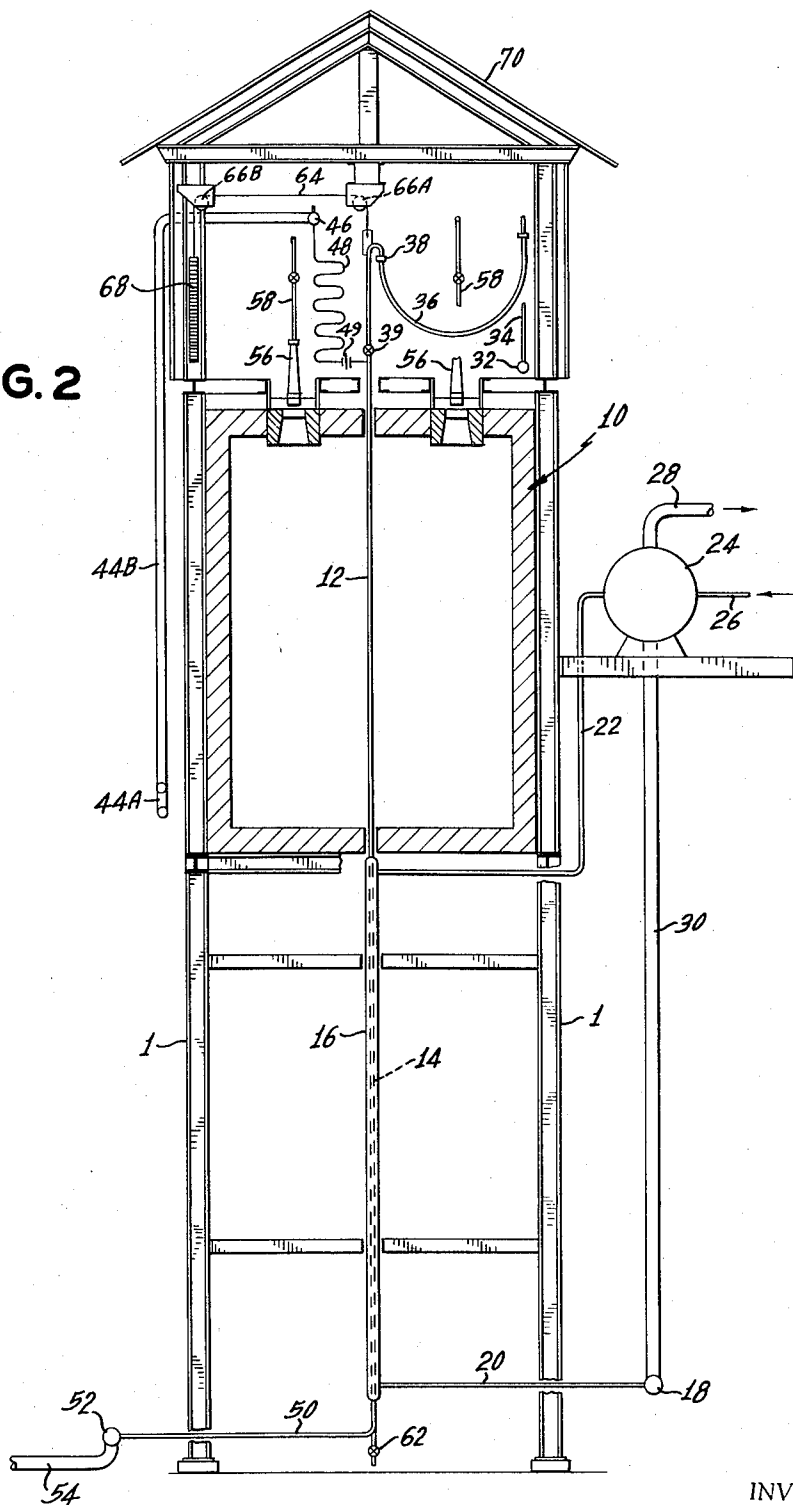
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FIG. 2



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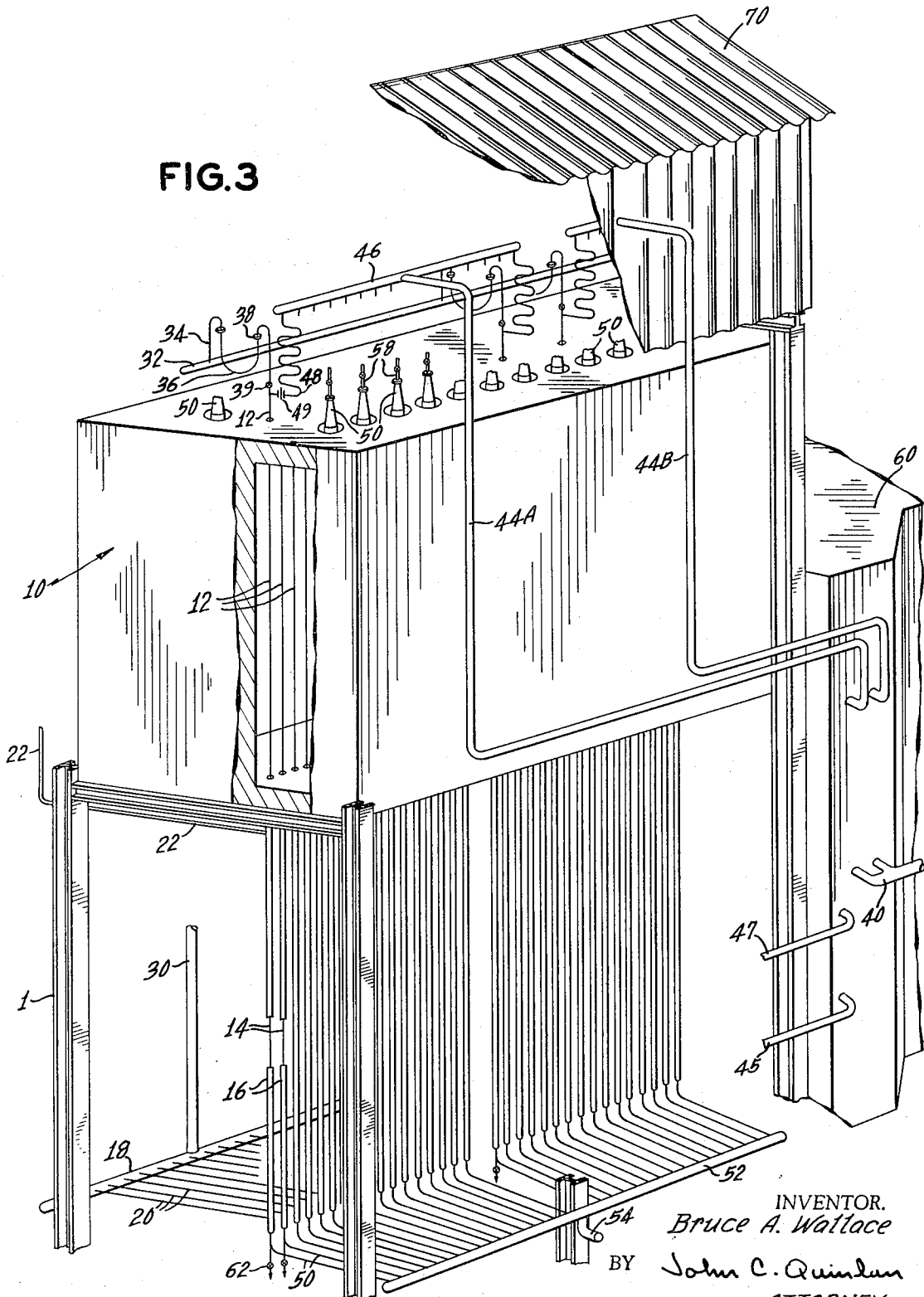
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FIG. 3



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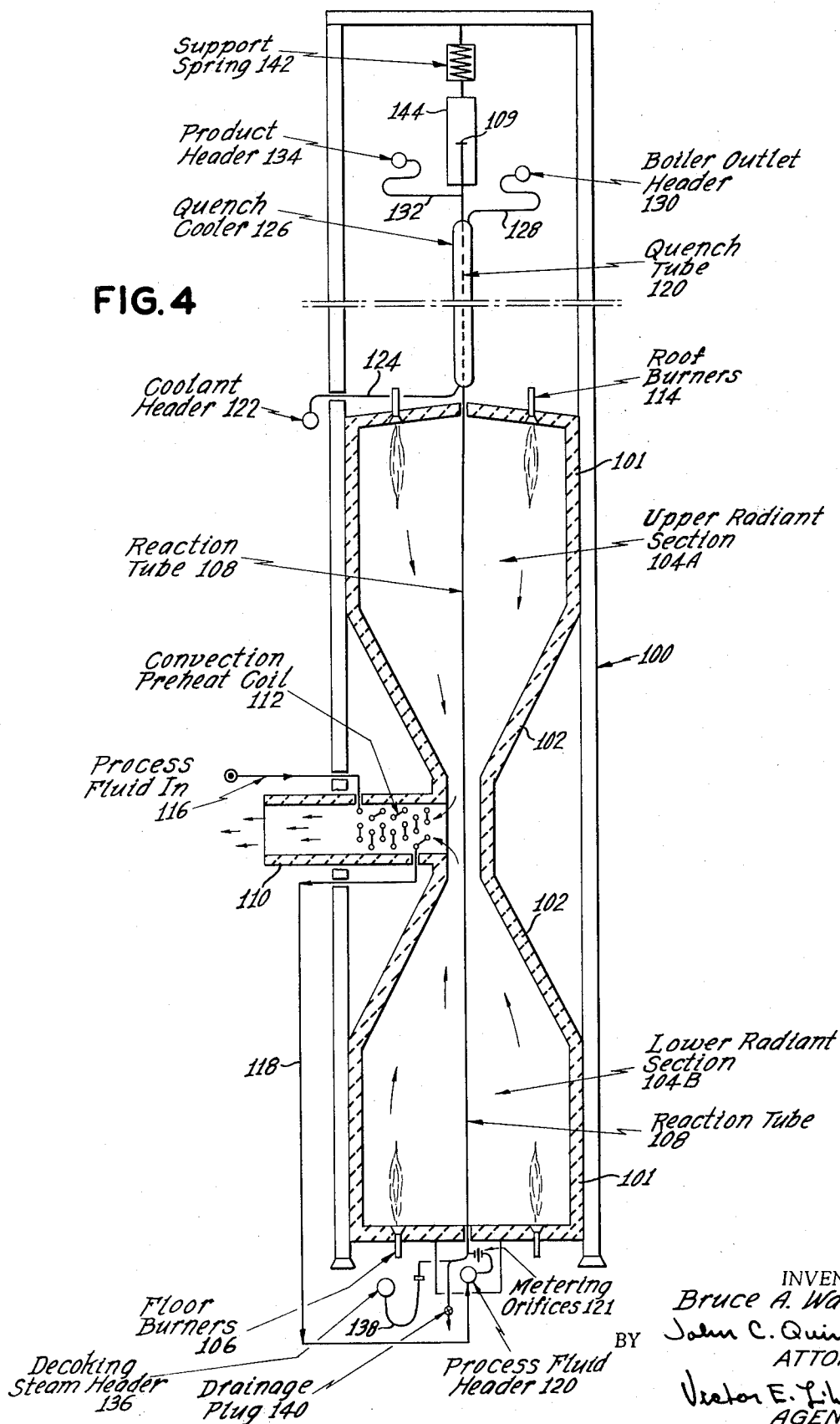
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FIG. 4



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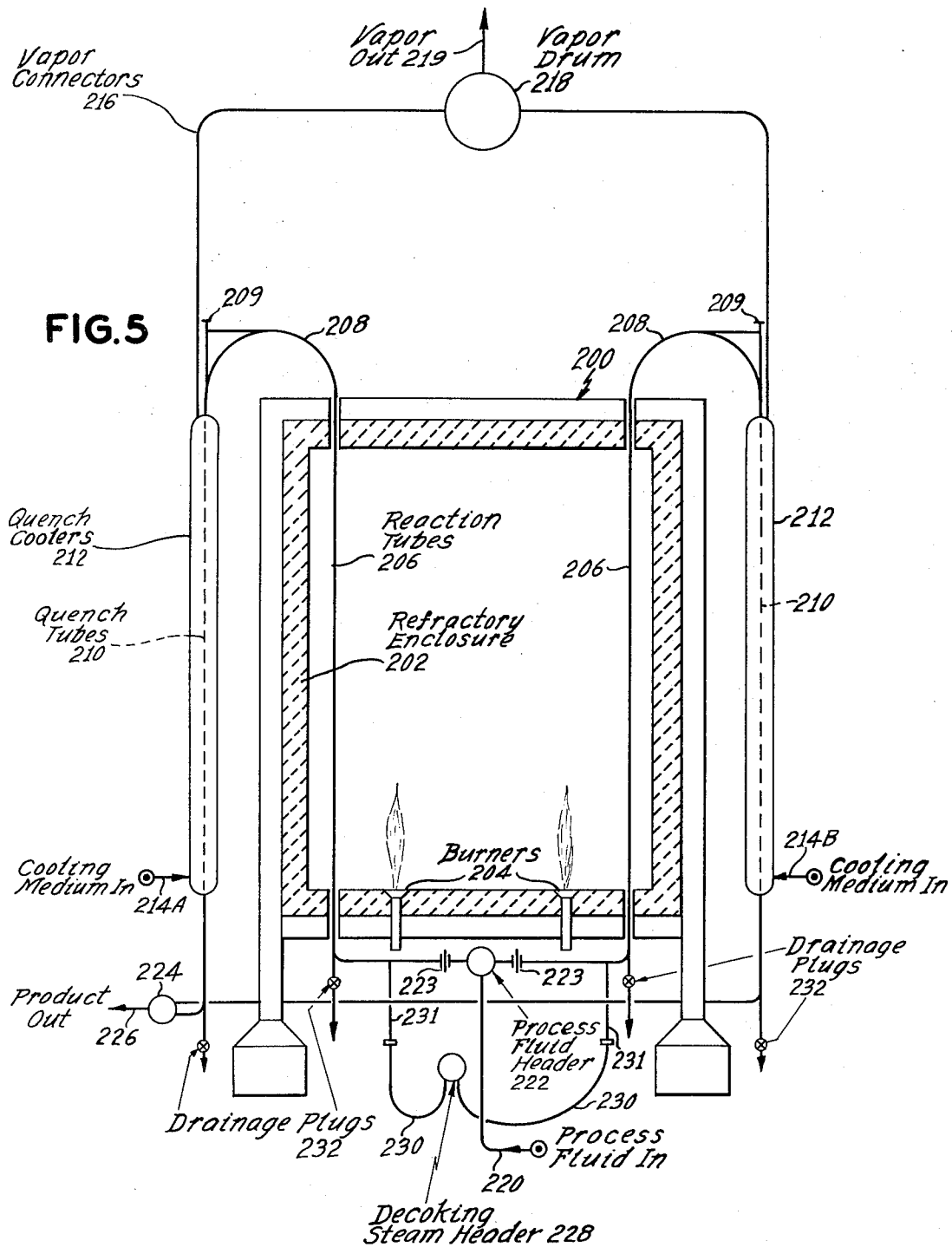
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3,671,198

CRACKING FURNACE HAVING THIN, STRAIGHT SINGLE PASS REACTION TUBES

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Continuation-in-part of application Ser. No. 683,703, Nov. 16, 1967. This application June 15, 1970, Ser. No. 46,043

Int. Cl. B01j 3/00; C10b 1/04; C10g 9/04

U.S. Cl. 23—277

10 Claims

ABSTRACT OF THE DISCLOSURE

The present invention concerns a method and apparatus for treating a hydrocarbonaceous process fluid by indirectly heating such fluid to high temperatures in extremely short periods of time and then rapidly cooling. The process fluid is passed into the straight single pass reaction tubes of the novel heater of this invention, such reaction tubes being contained in a refractory enclosure. The tubes are each connected to an individual quench tube wherein the process fluid may be rapidly cooled either by a coolant flowing through a plurality of jackets each surrounding each individual quench tube or, in another embodiment, the process fluid may be cooled by having the quench tubes immersed in a liquid bath. In another embodiment of this invention a method and apparatus is provided for carrying out the aforementioned method while simultaneously decoking individual reaction tubes.

This application is a continuation-in-part of copending application Ser. No. 683,703, filed Nov. 16, 1967 and now abandoned.

The present invention relates to an improved method and apparatus for treating hydrocarbonaceous process fluids. The method and apparatus of the invention is particularly adapted to carrying out rapid high temperature heating of process fluids, such as is required in modern hydrocarbon pyrolysis 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 such product mix depending, for example, on the nature of the feedstock.

Heretofore, prior processes for pyrolyzing hydrocarbons by indirect heating have been limited by the process fluid effluent temperature attainable. In the extreme, in indirect heating processes, the process fluid has been heated to temperatures as high as 1650° F. It was found that if such hydrocarbonaceous process fluids were subjected to higher temperatures for the residence times heretofore employed in such processes, i.e., 0.1 or more seconds, portions of the process fluid would be degraded to gummy polymeric substances and carbon, usually collectively referred to as "coke." Coke formation within indirectly heated 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. Further, it was discovered that the combination of high temperatures and long residence times drastically increased the quantity of light, saturated hydrocarbons produced. The presence of large quantities of such products substantially increased the difficulties in recovering the desired olefin products from the pyrolysis effluent and further, reduced the yield of olefins for a given quantity of process fluid charged to the heater.

Another factor limiting effluent temperature in prior processes 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.

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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 problems of coke formation and pressure drop across the furnace tubes are aggravated by the multiple turns of a coiled process tube configuration. Inasmuch as the total number of mols of gaseous material increases during the pyrolysis of hydrocarbons to ethylene and other olefins, this particular process is carried out at about atmospheric pressure since elevated pressures would tend to reduce the extent of reaction and adversely affect the product yield. Other processes such as, for example, steam re-forming are advantageously carried out at elevated pressures. Therefore, it is desirable in cases where low or atmospheric pressure operation is desired, to minimize the pressure drop through the furnace, since overcoming a high pressure drop will require a correspondingly high effective pressure in the furnace tubes. In addition to the pressure-drop problem they pose, maintenance and construction costs of serpentine coils are also higher than would be the case of straight run tubes, but, as mentioned above, the coiled tubes are necessary to limit the size of the furnace enclosure to reasonable proportions. Accordingly, prior processes have been limited to the aforementioned temperatures when heating the process fluid indirectly.

Other processes have been suggested which provide means for heating the process fluid to temperatures higher than those heretofore attained by indirect heating in tubes. These processes generally comprise combusting a fuel in the presence of an oxygen containing gas and then intermixing the resulting hot products of combustion with the hydrocarbonaceous process fluid to be treated. High temperatures are attainable in relatively short periods of time and the problems normally associated with the resultant coking, e.g., decrease in heat transfer and clogging of indirectly heated tubes are generally not applicable to processes of this type which eliminate the need for such indirect heating in tubes. A major drawback, however, is that the products of combustion leave the reactor in admixture with the desired product and add to the difficulty of recovering such products.

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 a refractory oil or a combination of water and oil in the case of direct cooling. Because of the high temperature of the reactants, high pressure steam can be readily generated from the coolant water. The thermal stresses of sudden cooling and the diversion of high velocity, extremely hot reactant streams from the tube exits into the indirect cooling exchangers (usually referred to as quench boilers) entails severe stresses on the material of the tube exits and the quench boilers themselves, and concomitant design problems. The problem is complicated by the necessity of holding the transition period, i.e., the time period from the time the fluid leaves the cracking zone of the reaction tubes and until it reaches the cooling zone of the quench boiler, to a minimum so as to minimize the amount of reaction during the transition period. 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 at-

tained at the positively controlled temperature of the reaction zone outlet.

It is therefore an object of this invention to provide a method for treating hydrocarbonaceous fluids by heating them to high temperatures without the drawbacks heretofore encountered in prior processes.

It is another object of this invention to accomplish the above object and to provide a method for rapidly cooling the heated fluid below reaction temperature thereby fixing the effluent product composition.

It is a further object of this invention to provide a simple, efficient and relatively inexpensive furnace capable of carrying out the foregoing method with minimum downtime for maintenance.

These and other objects of the invention will be apparent from the following description and accompanying drawings.

The method of the invention comprises passing a hydrocarbonaceous process fluid through a plurality of essentially straight reaction tubes contained in a refractory enclosure. Heat is transferred, by radiation and convection to the outside walls of such reaction tubes, by conduction through the tube walls, and by convection to the process fluid. Such heat is supplied by burners which combust a suitable fuel. The process fluid is heated in this manner to a temperature which may range from about 1550 to about 1850 degrees Fahrenheit. Such heating may be accomplished in a residence time of about 0.2 to about 0.01 second. The heated process fluid is then passed through a plurality of quench tubes each connected in flow communication with a corresponding reaction tube and is rapidly cooled therein. Such cooling may be accomplished by indirectly exchanging heat with a coolant coursing through a jacket surrounding each individual quench tube. Alternately, such cooling may be accomplished by passing the heated fluid through the individual quench tubes which may be partially submerged in a liquid bath common to all the quench tubes. In this manner the heated fluid passes through the tubes and is first partially cooled by exchanging heat indirectly with the bath through the walls of the tubes. Then the partially cooled fluid is further cooled directly by passing out of the quench tubes and through the liquid bath. Preferably, the liquid bath comprises molten lead. Other substances may be used to achieve lower melting point or vapor pressure characteristics.

In the case of the pyrolysis of a hydrocarbonaceous process fluid, the process fluid is passed through the straight reaction tubes and heated therein by heat supplied from the burners to temperatures ranging from 1550 to 1850° F., and preferably from 1650 to 1750° F. The process fluid may have been preheated to less than reaction temperatures in a preheating coil. (The preheating coil may advantageously be heated by flue 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 residence time which is about 0.1 to about 0.01 second and preferably about 0.10 to about 0.02 second. Residence time within any segment of the reaction tubes is of course simply controlled by controlling the linear velocity of the fluid.

It has been discovered that by limiting the residence time within the above described ranges, the process fluid may be heated to the high aforementioned effluent temperatures without substantial degradation to coke. Further, it has been discovered that by heating within the short residence times prescribed by this invention, a low production of light, saturated hydrocarbons result, the high effluent temperatures notwithstanding.

Still another advantage accrues by using the method of this invention. It has been found that by operating within the prescribed ranges, a substantially larger proportion of the feed is converted into olefins. In particular there is a

substantial increase in the yield of olefins heavier than ethylene.

As aforementioned, it is necessary to rapidly cool the furnace effluents in order to arrest the reaction and fix the product composition. Accordingly 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 tube 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 requirements 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 fluid 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 foot long, 4" inside diameter tube (coiled to fit within a reasonable size 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 primarily ethylene as well as other products, for example, current engineering feasibility limits 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 more or less, 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= $\frac{1}{360}$) will

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permit efficient operation. A significantly 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 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. Generally, the ratio of inside diameter to length should not exceed $\frac{1}{240}$. The residence time and temperature and heat input requirements will likewise vary, within the ranges specified herein, 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 provides 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 quench 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 during shutdown or on-stream decoking and, 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 fluid, 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

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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-steam 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 or other shutoff devices 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 insure meeting its specifications, are thus entirely avoided by the present invention.

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

FIGS. 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.

FIG. 4 is a schematic representation of a preferred embodiment of a zoned furnace constructed in accordance with the invention.

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

Referring now to FIGS. 1, 2 and 3 which illustrate a preferred embodiment of the invention, and particularly to FIG. 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 FIG. 2 a coolant liquid (preferably water) header 18 provides coolant to the quench coolers 16 via coolant connectors 20. Vapor (steam) is generated within the quench coolers by absorbing heat from the quench tubes and the vapor and recirculating liquid passes through vapor connectors 22 into vapor drum 24. Make-up liquid (water) is introduced through line 26 into vapor drum 24 thence to coolant header 18 via downcomer lines 30. Uncondensed vapor (steam) is taken off via line 28.

Process fluid is introduced to the furnace via line 40, preheated in preheat coil 42 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 product connectors 50 to product header 52 from whence quenched product is removed via line 54.

Heat is provided to the furnace by the combustion of a suitable fuel in burners 56. Fuel and air is supplied to the burners via lines 58 through suitable connections (not shown). Flames from burner 58 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 (FIG. 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. When the furnace is shut down 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 on-stream 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 on-

stream decoking connections, burners and tube supports are shown in end view in FIG. 2 and in isometric view in FIG. 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 expansion 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.

FIG. 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 steam hose 138 into reaction tubes 108 downstream of metering orifices 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 dimension (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. FIG. 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 vapor drum 218 from whence vapors 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 pass 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 hoses 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 FIG. 5 to simplify the drawing.

To further illustrate the methods of this invention the following example is given.

A gas oil feed is first combined with steam and then passed through straight, small diameter, indirectly heated tubes. The steam to oil ratio and the outlet temperature are held substantially constant for two runs; however, the residence time is varied from a relatively slow time to the time prescribed by this invention. The table below illustrates the operating conditions and the results.

TABLE

Run Number	1	2
Steam/oil, lbs./lbs.	1.00	1.05
Residence time, seconds	0.233	0.066
Temp. outlet, ° F	1,700	1,702
Weight percent yields per pass:		
H ₂	0.99	0.95
CH ₄	14.8	9.47
C ₂ H ₂	0.69	1.24
C ₂ H ₄	22.5	22.7
C ₂ H ₆	2.19	0.86
C ₃ H ₄	1.15	1.06
C ₃ H ₆	6.89	7.91
C ₃ H ₈	0.12	0.38
C ₄ H ₆	2.74	3.80
C ₄ H ₈	0.94	3.02
C ₄ H ₁₀	0.05	0.21
C ₅ +	46.2	48.5
Total olefins	34.9	39.7

Examination of the table reveals the advantages of operating in accordance with the methods of this invention. Run 2, wherein the residence time was 0.066 second in contrast to a 0.233 second residence time for run 1, results in superior feedstock utilization while maintaining the ethylene production at substantially a fixed level. There is a markedly decreased "tail gas" production, i.e., the weight percent yield per pass of hydrogen, methane and acetylene has been reduced from 16.48 percent to 11.66 for runs 1 and 2, respectively. Moreover, increased propylene and butadiene and butene yields are realized.

In the above description and the attached drawings numerous valves, pumps, meters, 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. The invention is not intended to be limited by the preferred embodiments de-

scribed in detail and it will be apparent to those skilled in the art that numerous modifications to the embodiments described are possible without departing from the scope of the invention.

What is claimed is:

1. A fired heater comprising:

- a refractory enclosure of limited length;
- a plurality of essentially straight pass reaction tubes contained within said limited length refractory enclosure and each having a length of up to about 60 feet and an inside diameter of not more than one two hundred and fortieth ($\frac{1}{240}$) of the length of the respective reaction tube;
- means to heat said reaction tubes;
- a plurality of quench tubes, connected in flow communication with said reaction tubes;
- means adapted to course a process fluid through said reaction and quench tubes; and
- means adapted to cool said process fluid after leaving said reaction tubes.

2. The fired heater of claim 1 wherein each reaction tube is connected in flow communication with a quench tube and the means adapted to cool the process fluid comprise a plurality of cooling jackets each adapted to course coolant over the external surface of each of said quench tubes.

3. The fired heater of claim 1 wherein the means adapted to cool the process fluid comprise a liquid bath adapted to surround each of the quench tubes.

4. A fired heater comprising:

- a refractory enclosure of limited length;
- a plurality of essentially straight single pass reaction tubes contained within the refractory enclosure and each having a length of up to about 60 feet and an inside diameter of not more than one two hundred and fortieth ($\frac{1}{240}$) of the length of the respective reaction tube;
- means adapted to heat said reaction tubes;
- a plurality of essentially straight quench tubes connected in flow communication with said reaction tubes;
- means adapted to course a process fluid through said reaction and quench tubes;
- means adapted to cool said process fluid after leaving said reaction tubes; and
- means to inject decoking fluid into any reaction tube while said heater remains in service.

5. The fired heater of claim 4 wherein the length of said refractory enclosure of limited length is less than sixty feet.

6. The fired heater of claim 4 wherein each reaction tube is connected in flow communication with a quench tube and the means adapted to cool the process fluid comprise a plurality of cooling jackets, each adapted to course coolant over the external surface of each of said quench tubes.

7. The fired heater of claim 4 wherein the means adapted to cool the process fluid comprise a liquid bath adapted to surround each of the quench tubes, each quench tube being at least partially immersed in said bath so as to have the cooling process fluid effluent end of said quench tube below the liquid level of the bath.

8. A fired heater for pyrolyzing normally gaseous or normally liquid aromatic and/or aliphatic hydrocarbon feedstocks to obtain olefins and other products comprising:

- a plurality of essentially straight, vertical, single pass reaction tubes each having an inside diameter not greater than 3 inches and a length between 40 and 60 feet.
- a refractory enclosure containing said tubes and fitted with burner means to heat said tubes;
- a plurality of quench tubes connected in flow communication with said reaction tubes;

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- (d) means adapted to course process fluid through each paired reaction and quench tubes; and
 (e) means to inject decoking fluid into any reaction tube while said heater remains in service.
9. A fired heater comprising:
- (a) a refractory enclosure of limited length; 5
 - (b) a plurality of essentially straight single pass reaction tubes contained within said refractory enclosure, each of said reaction tubes having a length of up to about 60 feet and an inside diameter of not more than one two hundred and fortieth ($\frac{1}{240}$) of the length of its respective reaction tube; 10
 - (c) a chamber containing quenching fluid; and
 - (d) a plurality of quench tubes connected in flow communication with the reaction tubes adapted to transfer process fluid from said reaction tubes to said quench chamber containing quench fluid. 15
10. The process of claim 8 wherein the quench tubes are adapted to eject the process fluid into a body of cool-

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ant liquid so as to quench the process fluid by direct heat exchanger with said coolant.

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