A furnace having horizontally disposed single pass tubes. The tubes of the furnace extend horizontally from the furnace inlet to the furnace outlet. Fluid passing through the horizontally disposed tubes is exposed to heat from the individual furnace burners only once.

8 Claims, 4 Drawing Figures
HORIZONTAL HIGH SEVERITY FURNACE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a furnace apparatus and a method for heating fluid material in the furnace apparatus. More particularly, the invention relates to an apparatus and process for carrying out hydrocarbon conversion processes which include heating hydrocarbon feed to a high temperature and maintaining the feed at a high temperature for a short reaction time.

A specific purpose to which the process and apparatus of the present invention is directed is the cracking of hydrocarbon under conditions of short residence time, high temperature, high severity and low hydrocarbon partial pressure. The furnace is particularly suitable for selective cracking to afford high olefin production, particularly ethylene, and high ratios of olefin yield to saturates, such as methane, ethane, and propane. The process and apparatus of the invention can achieve high ethylene yield from a wide range of hydrocarbon feeds including ethane and crude oil.

2. Description of the Prior Art

The present invention comprehends a furnace design directed to affording efficient temperature profile control of the furnace tubes. Control of the temperature profile in a furnace provides maximum flexibility. In general, furnaces used to heat fluids are limited in amount of heat that can be fired in the firebox by the temperature which the tubes can withstand. Where uniform firebox temperature is maintained, the tubes conveying fluid to be heated will show a temperature gradient from the fluid inlet to the fluid outlet. With a uniform firebox temperature, the tube metal temperature will be highest at the furnace outlet since the fluid in the tubes will be higher than at any other point in the furnace. Consequently, the temperature for the entire firebox must be set to maintain the tube metal temperature at the furnace outlet within acceptable limits. Thus, the tube metal temperature and heat flux or rate of heat input to the fluid at the furnace inlet will be lower than necessary. It is particularly inefficient to heat the fluid at the inlet at a rate corresponding to less than the maximum temperature which the tube metal can withstand.

Heat flux is a measure of heat exchange in that it is the number of BTU's/hr./sq. ft. that the fluid passing through the furnace tubes will absorb from the heat energy generated by the furnace burners. As a general rule, the greater the temperature difference between the burner combustion gases and the fluid in the furnace conduit, the greater the heat flux.

With a means for controlling the furnace temperature profile, the tube metal can be heated to the maximum allowable temperature at all points and the heat flux at the furnace inlet can be maximized. As a result, the fluid will be heated to the design temperature more rapidly, thus allowing a furnace design having fewer burners, shorter over-all tubes and less structural material. In addition, floor mounted oil fired flame burners often can be used exclusively rather than the more expensive radiant heat burners.

Several attempts have been made achieving temperature profile control in furnaces. For example, a furnace employing horizontally disposed tubes having serpentine coils is disclosed in U.S. Pat. No. 2,638,879 (Hess; May 19, 1953). However, the serpentine coils which make several passes over the same vertical plane require a plurality of radiant heaters arranged in very close spaced relationship to provide any sort of profile control. Since the fluid in the tubes passes through the same vertical plane several times, the fluid passing through the later or downstream portion of the tubes will be at a much higher temperature than the fluid initially heated by the same burners in the upstream portion of the tubes. Therefore, varying the heat output of the individual burners will not vary the heat of the tube metal at the upstream section relative to the downstream section. Both the upstream and downstream sections will necessarily be varied.

Conversely, another furnace design directed in part to temperature profile control is depicted in U.S. Pat. No. 3,062,197 (Fleischer; Nov. 6, 1962). Radiant burners located along a single-pass vertically disposed tube which passes through the heating section is disclosed. The flow of fluid is from the top of the tubes to the bottom of the tubes, while the heat initially radiated will flow countercurrently to the fluid in the tubes thereby heating a large portion of the tubes rather than a localized area.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a furnace design wherein high capacity floor burners can be used in a furnace to provide efficient temperature profile control.

It is a particular object of the present invention to provide a furnace design wherein the tube metal temperature throughout is at essentially the same temperature.

It is a still further object of the present invention to provide a furnace which transfers a maximum amount of heat to the fluid passing through the tubes or conduit at the inlet section.

To this end, a horizontally disposed furnace comprised of a plurality of single-pass coils arranged in a vertical plane is provided. The furnace is preferably U-shaped but can extend in a straight line. The furnace is fired by a plurality of high-capacity burners located in the floor of the furnace. However, radiant wall burners can also be used to fire the furnace. Either a single stack of tubes or a plurality of stacks of tubes can be provided. The flue gas opening is arranged directly above the furnace firebox to facilitate vertical flow of the combustion gases from the burners. Any draft regulation means can be used to increase or decrease the flow rate of the combustion gases passing over the tubes. Quench means such as a single transfer line heat exchanger common to all or a plurality of the tube outlets or an effluent quencher for each tube outlet is provided to rapidly cool the cracked gas issuing from the furnace.

DESCRIPTION OF THE DRAWINGS

The invention will be better understood and its advantages and specific objects will become more clearly apparent by reference to the accompanying drawings wherein;

FIG. 1 is a cross-sectional side elevational view of the furnace embodying the invention;

FIG. 2 is a cross-sectional plan view taken along the line 2—2 of FIG. 1:
FIG. 3 is a vertical cross-sectional front elevational view taken along the line 3—3 of FIG. 2; and FIG. 4 is a cross-sectional plan view of a modified embodiment of the furnace of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention comprehends a furnace 1 for heating fluid. The furnace uses a tube or tubes 10 to convey fluid through a firebox 2. Essentially, the furnace tubes 10 are horizontally disposed and make a single pass through the furnace firebox 2. Since a single pass of the tubes 10 is required, the furnace 1 can be elongated in configuration with straight tubes 10 extending from an inlet at one lateral wall to an outlet at the opposite lateral wall. Alternatively, the furnace 1 can be configured to form a U or any similar shape with the only limitation being that the tubes follow the furnace shape from inlet to outlet without passing through any vertical plane more than once.

As seen in FIGS. 1–3, the basic furnace design of the preferred embodiment includes an essentially rectangularly shaped furnace firebox 2 to be formed of a floor 32, outer laterally extending walls 3, 3a and 4, outer longitudinally extending walls 5 and 6, centrally disposed walls 5a and 6a and bridging wall 7. Each of the walls is constructed of refractory material typically used in furnace environments and is provided with conventional structural members used in the construction of furnaces.

The furnace shown in FIGS. 1–3 is essentially comprised of two sections which can be characterized as an upstream section 8 and a downstream section 9. The upstream section 8 extends from the lateral wall 3 to the lateral wall 4 and is defined by the longitudinal wall 5 and the centrally disposed wall 5a. The downstream section extends from the lateral wall 4 to the lateral wall 3a and is defined by the longitudinal wall 6 and the centrally disposed wall 6a. An intermediate section 22 connects the upstream section 8 and downstream section 9.

A lower roof 46 extends between the top of the centrally disposed walls 5a and 6a and upper roofs 47 and 47a are provided for the radiant section 8 and 9 respectively.

Furnace tubes 10 are arranged to extend from the inlet end of the upstream section 8 to the outlet end of the downstream section 9. An inlet manifold or header 11 is provided to facilitate delivery of fluid to the furnace tubes 10. The inlet manifold 11 can be located outside the firebox 2, as seen in FIGS. 1 and 2, or inside the firebox. In either case, the inlet header 11 is connected directly to an inlet tube 12 through which hydrocarbon feed passes to enter the header 11. Restricting orifices (not shown) are provided for each tube 10 and are normally inserted between flanges located just downstream of the header 11. The holes in the orifice plates are sized to give pressure drops large compared to those through the tubes 10, thus assuring uniform flow through the tubes 10. An outlet header 13 is provided to facilitate delivery of heated furnace effluent to cooling apparatus, such as a single transfer line heat exchanger 24. In the embodiment depicted, the outlet header 13, seen in FIG. 2, is located within the furnace 1 and a single line 25 is employed to facilitate delivery of the furnace effluent from the header 13 to the transfer line heat exchanger 24. Alternatively, each of the tubes 10 can be adapted to pass through the wall 3a and connect directly to separate transfer line heat exchangers. A transfer line heat exchanger which is particularly suitable for either design is shown in U.S. Letters Pat. No. 3,583,476 (Woebecke et al.) issued June 8, 1971.

As seen in FIGS. 1 and 3, the furnace is provided with a stack 19 having draft regulation means such as a variable louver damper 20. Convection coils 18 or similar heat recovery apparatus are adapted to be arranged in the stack 19 to make maximum use of the heat passing therethrough. The stack 19 is located above the lower roof 46 and extends upwardly from the inner ends of the upper roofs 47 and 47a. A horizontal passage 48 provides communication between the furnace sections 8 and 9 and the stack 19.

The tubes 10 are adapted to be arranged on supports 21. Since the temperature of all the tubes 10 at all the positions will be similar, there will be essentially identical thermal growth experienced by all tubes 10 as the furnace goes from the cold to the hot condition. In practice, it has been found that a growth of 2–6 inches in the tubes 10 can be expected as the transition is made from the cold to hot condition with all of the tubes experiencing the same thermal growth. The supports depicted in the U.S. Letters Pat. No. 3,554,168 (Woebecke) issued Jan. 12, 1971, are particularly suited to serve as the supports 21 for the tubes 10. However, with all of the tubes 10 experiencing identical thermal growth, any of the presently known supports can be used.

The furnace is fired by a plurality of symmetrically disposed floor fired burners 14 and radiant wall burners 23 which can be regulated to provide variable heat from the various parts of the furnace. Effectively, the floor fired burners 14 heat a localized area. The heat emanating from each burner 14 flows vertically rather than horizontally. In practice, it has been found desirable to arrange the floor fired burners 14 in a series of aligned pairs, each burner 14 of the pair being in proximity to a wall of the furnace.

As best seen in FIG. 1, fuel manifolds 15 are provided to supply fuel, preferably oil, to the floor fired burners 14 through individual conduits 16 associated with each respective burner 14. Each conduit 16 has a regulator valve 17 which can be adjusted manually or automatically as a function of the temperature profile in the furnace to vary the amount of fuel being fed to each burner 14. Similarly, each manifold 15 is provided with a valve 26 to regulate the flow of fuel to the conduits 16. The fluid passing through the tubes 10 passes by each burner 14 only once. Consequently, temperature control of each localized section of an individual tube 10 can be realized by regulating the amount of heat emanating from the particular burners 14 in that section independently of the other burners.

The radiant wall burners 23 are located in walls 5, 5a, 6 and 6a.

As best seen in FIG. 2, four fuel manifolds 28, provided with valves 27 are arranged to supply fuel, either gaseous or liquid, to the radiant wall burners 23 in each of the respective walls 5, 5a, 6 and 6a. Fuel is supplied to the radiant wall burners 23 from the manifolds 28 through individual conduits 29 associated with each radiant wall burner 23. Each conduit 29 has a regulator valve 30 which can be adjusted manually or automatically as a function of the temperature profile in the fur-
nace to vary the amount of fuel being fed to each burner 23. Individual control of the radiant wall burners 23 affords the means for varying the heat input to the furnace at each specific location as a function of the temperature profile of the furnace. Therefore, the temperature of each localized section of the furnace tubes 10 can be controlled.

The furnace of FIGS. 1, 2 and 3 can be modified to be fired exclusively by radiant wall burners 23. If this modification is chosen and the floor burners 14 are eliminated, the radiant wall burners 23 need only be strategically located to provide heat over the entire length of each tube 10.

Depending on the number of tubes 10 employed, the uppermost tube may be located close enough to the floor fired burners 14 so that it will be provided with essentially the same heat exposure as the lowest tube, i.e., the tube nearest the floor fired burner. Hence, the result is to provide a condition of equal heating throughout a vertical plane rather than a temperature gradient from the bottom to the top of the tube bundles, in which case radiant wall burners 23 are unnecessary.

The embodiment of the present invention depicted in FIG. 4 illustrates a furnace 31 which need not employ radiant wall burners. As a consequence, the radiant wall burners are omitted and the centrally disposed walls 5a, 6a and the bridging wall 7, seen in FIG. 2, are replaced by a single central wall 37 since access to inner radiant wall burners is not required. Except for these differences, the furnace of FIG. 4 is essentially the same as the furnace of FIG. 1.

The furnace of FIG. 4 is comprised of lateral furnace walls 33, 34 longitudinal furnace walls 35, 36 and a single centrally disposed inner wall 37. The outer wall 35 and the center wall 37 define the upstream section 38 and the outer wall 36 and the center wall 37 define the downstream section 39. Intermediate section 52 connects the upstream section 38 with the downstream section 39. The furnace tubes 40 are arranged in vertical alignment, are supported by supports 51 and extend from the inlet end of the upstream section 38 to the outlet end of downstream section 39. An inlet manifold 41 serves to convey furnace feed from an inlet tube 42 to the furnace tubes 40 and an outlet header 43 serves to facilitate delivery of the cracked effluent from the tubes 40 to a line 55 and ultimately to quench means such as a transfer line heat exchanger 54.

The furnace 31 is provided with heat solely by floor burners 44 which are provided with fuel by a delivery system identical to that shown in FIG. 1. Manifolds 45 and the valves 56 therefor are shown as illustrative of the system.

The operation of the furnace of the present invention will be considered by reference to the furnace 1 of FIGS. 1, 2 and 3. In operation, the furnace 1 is designed to be fired to provide a greater heat concentration in the area of the inlet than in the area of the outlet since the fluid at the inlet is necessarily at a lower temperature than the fluid at any point downstream in the tubes 10. At various times the temperature profile of the tubes 10 is read. The reading indicates the areas of the tubes 10 which should be supplied with a greater amount of heat than those which necessarily must be subjected to less heat. Preferably, the furnace is fired to heat the fluid within the tubes 10 at such a rate that the tube metal temperature will be the same from the inlet to the outlet of the tube. To achieve this effect, the furnace can be provided with appropriate probes and/or gauges such as recording optical pyrometers to sense the temperature of the tubes 10 at each burner location and automatically signal the need for more or less heat at the location. Alternatively, the readings can be obtained manually by an operator and the heat provided by each burner can be regulated manually.

The furnace of the present invention is designed to use the tubes of virtually any size and can have any number of tubes 10 in a stack. Typically, tube sizes will range from 2 inches to 5 inches I.D., tube lengths will be 70 to 120 feet and stacks of tubes can include from 8 to 40 tubes, but preferably 10 to 20 tubes. In addition, a plurality of stacks can be arranged in the furnace. If more than a single stack of tubes 10 is used, the respective tubes in the adjacent stacks should not be at the same elevation, but should be staggered. Staggering of the tubes minimizes heat shielding of one side of the individual tubes. Also, the number of floor fired burners 14 can vary as a function of the tube size, tube length, number of tubes and tube spacing used in the furnace.

An example of a furnace of the present invention which provides particularly good service is a U-shaped furnace designed in accordance with the furnace shown in FIG. 4.

The furnace is provided with a single stack of 16 horizontally disposed tubes 40. The tubes are 2½ inches I.D. and 90 feet long. Ten to sixteen floor fired burners 44 are arranged symmetrically in the upstream section 38 and 8 to 14 burners are arranged symmetrically in the downstream section 39. The floor fired burners 44 have a capacity of 2–10 million BTU/hr. and are spaced apart at intervals of 2 to 10 feet. Burners generally need not be provided in the intermediate section 52 which connects the upstream section 8 with the downstream section 9.

The entire firebox is 50 feet long, 15 feet wide and 10 feet high.

In operation, the furnace is fired at a rate to supply a maximum heat flux to the fluid in the tubes 40 consistent with maintaining the tube metal temperature at 1,800°C to 2,100°F. The maximum heat flux occurs at the tube inlet area and is about 60,000 BTU/hr./ft.². The inlet temperature of the hydrocarbon being cracked in the tubes 40 is 1,000°C to 1,300°F, while the outlet temperature is 1,500°C to 1,700°F. The feed rate is such that the mass velocity of the feed through the furnace tubes 40 is 20 to 40 lb./sec./ft.².

The residence time of the feed in the furnace is from 0.15 to 0.50 second. As a result of heating the furnace tubes 40 to the maximum allowable temperature along their entire length, the residence time is minimized.

The following table compares the pertinent features of the horizontal furnace of this invention, as described in the example, when operated to give uniform and maximum metal temperature along the entire tube length compared to a conventional serpentine coil furnace operated at essentially constant firebox temperature and the same process conditions:
The furnace of the present invention affords relatively precise control of the temperature at a plurality of localized areas along the length of the furnace tubes. Consequently, the furnace can be fired to heat the furnace tubes along their entire length of the maximum metal temperature consistent with the metallurgy. This design affords a relatively high heat flux at the inlet and a relatively low heat flux at the outlet. Obviously, as the tube metals are refined and improved to withstand higher temperatures, the furnace of the present invention will continue to provide the benefits which attend temperature profile control.

In addition, the effective temperature profile control affords a shorter tube length which results in both a material saving and reduced residence time. Also, the pressure drop through the furnace is reduced thereby providing a more efficient over-all operation since less downstream equipment will be required to compensate for pressure losses in the upstream furnace section.

The furnace of the present invention facilitates the use of a single transfer line heat exchanger rather than the plurality of heat exchangers frequently required. The specific operating conditions of the furnace of this invention are dependent on the characteristics of the feed stock and the desired products.

What I claim is:

1. A furnace comprised of:
   a plurality of U-shaped single pass horizontally disposed furnace tubes arranged in a vertically aligned stack for the passage of fluid therethrough arranged to extend in a direct line following the contour of the furnace firebox from a location outside the end wall at the inlet end of the upstream section to a location outside the end wall at the outlet end of the downstream section;
   floor fired burners for providing variable amounts of heat to localized sections of the horizontally disposed tubes and fluid passing therethrough;
   a furnace stack centrally disposed above the furnace tubes; and
   means to support the tubes,
   whereby the fluid in the furnace tube only once passes by each floor fired burner.

2. A furnace as in claim 1 further comprising:
   an inlet header common to all of the tubes, which inlet header is adapted to communicate with a feed supply source;
   heat exchange means for cooling the furnace effluent; and
   an outlet header adapted to communicate with the heat exchange means.

3. A furnace as in claim 2 wherein the length of the firebox is 35–70 feet, the width is 10–20 feet and the height of the coil stack is 8–15 feet.

4. A furnace as in claim 3 wherein the number of horizontally disposed tubes is 10–24.

5. A furnace as in claim 4 wherein the tubes are 2–4 inches I.D.; the floor burners are 2–10 million BTU/hr. capacity and are symmetrically disposed in pairs in the upstream and downstream sections of the firebox at intervals of 2–10 feet.

6. A furnace as in claim 1 further comprising means to regulate the flow through the furnace of combustion gas from the furnace burners and means to regulate the flow of fuel to each burner.

7. A furnace as in claim 2 wherein the heat exchange means for cooling the furnace effluent is a single transfer line heat exchanger in the outlet line.

8. A furnace as in claim 2 further comprising means to regulate the flow through the furnace of combustion gas from the furnace burners, means to regulate the flow of fuel to each burner and wherein the heat exchange means for cooling the furnace effluent is a single transfer line heat exchanger in the outlet line.