

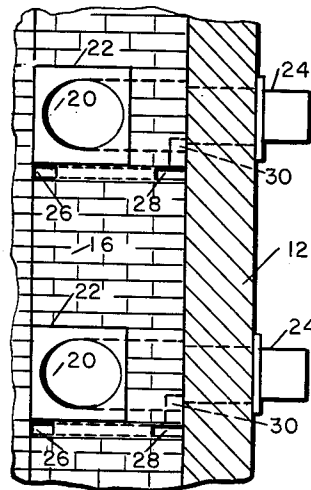
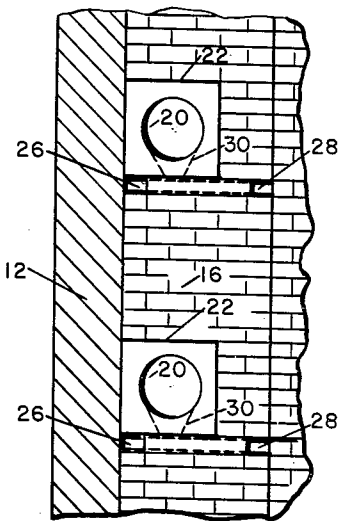
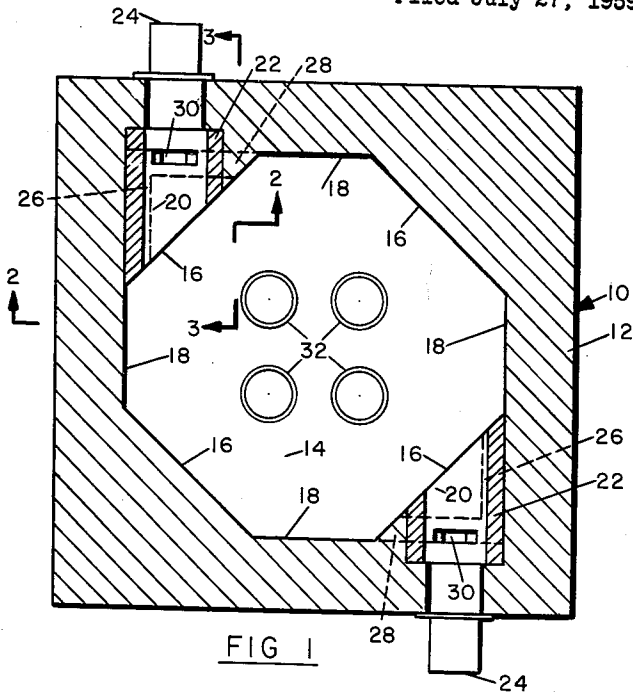
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TUBULAR FURNACE

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TUBULAR FURNACE

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This invention relates to tubular furnaces and more particularly to improved apparatus and method for more efficient and economical treatment of fluid reactants in tubular furnaces.

In recent years the tube type furnaces, wherein thin walled metallic reaction tubes are passed through a refractory heating chamber and externally heated by means of combustion gases, have become very popular particularly in the production of hydrogen and various olefins from fluid hydrocarbons. Despite the wide use of such furnaces and a great deal of development directed to their improvement, these furnaces are still characterized by several disadvantages, the obviating of which would be most beneficial, particularly to the hydrocarbon reforming or cracking art.

Reaction tubes employed in tubular furnaces are generally elongated alloy tubes such as 310 metal ranging from 4 to 10 inches in diameter and having a tube wall thickness in the neighborhood of $\frac{3}{16}$ to $\frac{3}{8}$ inch. In the currently employed furnaces larger heating chambers are employed than would be desirable from the standpoint of economy in construction.

Many furnaces are fired with gaseous fuels rather than liquid fuels even in geographic locations where the liquid fuels are cheaper. In locations where gaseous fuels are prohibitively expensive, the installation of tubular furnaces has been retarded by fear of detrimental effects on metal tubes when operated at the high temperature generated by liquid fuels. While problems exist in tubular furnaces employing gaseous fuels when attempt is made to attain the full potential of high metal temperatures, these problems are greatly increased when liquid fuels are employed. Liquid fuel has been employed in tubular furnaces in both the United States and Europe but these installations are still lacking in the attainment of advantages which have been long sought in the tubular furnace art.

Criticism has been leveled at the tube-type furnace to the effect that it is difficult to obtain a high heat input to the tubes because, to avoid physical damage to the metal, temperatures must be below 1600° F. Actually, this criticism is completely unjustified and it has been demonstrated, particularly with gas firing, that with proper furnacing techniques considerably higher temperatures may be employed. Nevertheless, even those skilled in this advanced state of tubular furnacing realize that there exists a large field of improvement still to be obtained which would greatly broaden the scope of use of tubular furnaces and constitute great improvement over the present state of development in this field. For example, it would be highly desirable to obtain one or more of the following improvements: gain in capacity per unit of investment which would approach current refinery capacities in terms of barrels per day; use in high temperature reactions generally thought to be out of the field of tubular furnace practice; a marked reduction in the quantity of catalyst necessary per unit of output from a catalytic process; an increased use of heavy liquid as process feedstock; and broader use of pressures above atmospheric and particularly above 100 p.s.i. In the path of obtaining such desired results, however, stand one or more of the following hindrances which are applicable to both the use of gaseous or liquid fuel in the firing of the present tubular furnaces; difficulty in attaining and controlling combustion

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tion in furnacing to give short flame length (i.e., about one foot for gaseous fuels and about three feet for the heavier liquid fuels); the lack of appreciation of the advantages of short flames and their relationship to physical factors important to economical operation; the damage to tube metal due to impingement of flame or extremely hot combustion gases; the intermittent detrimental breaking and reforming of metal oxide films on reaction tubes by presence of atmospheres alternately oxidizing and reducing, and the lowering of the strength of such films; the improper interference of combustion gas from two burners which promotes tube hot spots; the appearance of spots and deposits on reaction tubes from the impingement of combustion gas streams from oil fired burners, partly related to vanadium in the oil and low fusion point ash; uneven tube temperatures at points 180° apart on the tube causing permanent tube deterioration; damage to the internal form of the metal and structure; tube blistering and bloating; difficulty of control of luminous flames; and improper application and control of tube tension.

In present tubular designs, one of the most popular of which is disclosed in U.S. Reissue 21,521, one or more reaction tubes are suspended through the central portion of a heating chamber and gases of combustion are introduced into the chamber to transfer heat by convection and radiation to both the tubes and the refractory furnace walls. The furnace chamber walls then radiate the heat thus received to the tubes. The burners spaced vertically introduce combustion envelopes or streams between the tubes and the adjacent furnace wall or else between rows of tubes according to the number and spacing of the tubes in the particular furnace cell. It has theretofore been found necessary to leave a considerable space between the tubes and furnace wall and/or between the rows of tubes where firing is performed between the tubes, thereby necessitating an undesirably large firing chamber. Although this particular arrangement has been used on a worldwide basis and has been considered a very satisfactory furnace, inadequacies are nonetheless present when it is desired to increase tube capacity, to employ larger tubes, to use tubes under pressure, to employ intensified and more critical reaction zone conditions and in general to pass into improved fields of operation (particularly with liquid hydrocarbon firing) and to the use of liquid feedstock or highly unsaturated feedstock instead of the usual gaseous, paraffinic feedstock.

In prior art tubular furnaces the walls of the heating chamber have had the sole purpose of forming a refractory walled enclosure in the simplest and least expensive manner consistent with the necessary structural strength. The furnace walls have been of uniform thickness, the actual thickness being varied according to well-known tables of heat loss to prevent external radiation insofar as it is economically feasible. The furnaces have been rectangular or round and have been about 25 feet high between arch and hearth. The burners in such furnaces have been mounted in burner blocks and while the burner nozzles have not been aimed directly at the tubes in the better designs, the incompletely oxidized gas envelopes have extended into the chambers to produce fluctuating reducing and oxidizing atmospheres highly conducive to tube damage.

The problem of economically introducing heat into reaction tubes is further complicated by the current belief in the art that the reaction tubes must be widely spaced from each other in order to effect high percentage absorption of radiant heat and to allow sufficient circulation of combustion gases therebetween to prevent uneven tube temperature. Such uneven heating on opposite sides of the tube may cause cracking. Moreover, such cracks cause pressurized streams of burning reactants

to jet into the combustion chamber and damage closely adjacent tubes. Thus, the chambers of tubular furnaces currently employed have been further enlarged due to this wide tube spacing and the necessity for spacing the outermost tubes far enough from the furnace chamber wall to prevent detrimental flame impingement.

The supporting of the reaction tubes in the tubular furnace has also presented many difficult problems to the art. Some of the shortcomings of tubular furnaces in some high temperature reactions are due to the effect on tube metal of the temperatures necessary to the desired reactions. Metal temperatures within the apparatus, particularly in the production of hydrogen either by reforming methane or by cracking of liquid hydrocarbons, may range from a black heat at the furnace arch to as high as 2000° to 2400° F. at the furnace hearth. Within this range, and particularly at temperatures between 1100° to 1700° F., serious weakening effects arise during service due to carbide precipitation inherent in the otherwise desirable stainless steels. Moreover, these highly heated reaction tubes, generally employed in lengths of 20 to 30 feet, undergo expansion of as much as 5 to 7 inches when heated to these high metal temperatures. In most furnace designs the tubes normally pass through both the arch and the hearth and are subject to binding stresses caused by temperature effects. In addition to elongation, there is a tendency for the tubes to bloat due to internal pressure during operation and to low creep strengths at high temperature. The weakening effects caused by these changes have in the past been partially offset by supporting the reaction tubes from above in order that the weight of the tube, together with the weight of manifolding below the furnace hearth, plus the weight of the catalyst, will exert a downward pull on the tube wall, thus placing the tubes under axial tension. Such an arrangement constitutes a considerable improvement over prior practices where the tubes were anchored below the furnace and where the effluent was removed from the top of the tubes rather than from base points below the furnace. However, the use of downwardly applied tension in suspended tubes has in turn worked a very undesirable temperature limitation since, as the tension is increased for a given tube of given wall thickness, the upper limit of temperature which can be employed must be correspondingly decreased to prevent structural failure of the tube itself. This difficulty can be readily appreciated when it is realized that a reaction tube made of type 310 metal, 30 feet in length and 8 inches in diameter with a wall thickness of about $\frac{1}{4}$ inch will normally weight about 800 pounds. Depending upon the specific catalytic reaction being conducted, this tube may contain from about 600 to 1200 pounds of catalyst. Thus, when the weight of the manifolding below the furnace is added to the weight of tube and catalyst, it will be seen that a force of about 2000 pounds is being directed downwardly along the tube. In addition there will be a downward thrust on the bottom of the tube enclosure related to the pressure within the tube. These various effects result in a tube tension which is normally highest at the bottom of the tube where the greatest temperatures will normally be applied and therefore where the tube will have its lowest creep strength. Thus, the temperature must be lowered to a point corresponding to the strength of the tube at a sacrifice of reaction efficiencies throughout or both.

Further, in multiple tube furnaces with tubes joined in a common manifold at their base below the hearth, the separate tubes undergo unequal expansion. This unequal expansion creates a condition wherein the floating position of the manifold is determined by tubes in a different state of tension, the tube of highest temperature normally being in the state of least downward tension.

In fact, under extreme conditions a tube might approach zero downward tension and actually expand up-

wardly in a state of compression. Thus, it is common in current industrial practice to have manifold tubes suspended by means of springs from above the furnace arch in states of downward tension substantially less than that of a fully suspended tube in downward tension under its own weight. In practice, however, these spring mounts have been found to be inadequate in many ways. Primarily there is insufficient control of tension on the individual tube and warping has resulted. Moreover, the creep of the tube is not under positive control and excessive changes in length occur. Tube life is thereby shortened.

In accordance with my copending application Ser. No. 476,201, now Patent No. 2,914,386, it has been discovered that one or more of the difficulties above discussed may be obviated by a new furnace design whereby a new and greatly broadened scope of use is opened up to tubular furnaces.

According to my new furnace design there is provided a tubular reaction furnace having in combination a shell comprising a refractory walled heating chamber having spaced portions of greater thickness than the intermediate portions, vertically disposed metallic reaction tubes passing through the heating chamber and spaced from the chamber walls, and fluid hydrocarbon burners to furnish hot combustion gas to the heating chamber mounted in elongated tunnels formed in the thicker portions of the chamber walls, said tunnels being located at a plurality of vertical levels and so disposed in the chamber wall that the extension of a straight line drawn from the burner nozzle to a point on the end of the innermost wall of the tunnel in the horizontal axial plane will pass between the reaction tubes and the adjacent chamber wall. Although the shell may have any desired outer configuration, it will preferably be substantially rectilinear in cross-sectional exterior configuration.

In such apparatus the thickness of the portion of the chamber walls containing the burner tunnels will be controlled by the particular reaction for which the furnace is constructed and the type of fuel employed. It is desired to retain as much as possible of the combustion envelope from the burners in the burner tunnels. By use of the burner tunnel, the hot combustion gas streams into the heating chamber and out of direct contact with the tubes to prevent detrimental flame impingement and to protect the tube from damage due to fluctuating conditions. Even when employing gas as a fuel, it is a difficult matter to consistently retain the entire combustion flame within a tunnel. When employing oil as a fuel, it is impossible to retain all of the flame within a tunnel of any practical length. However, with either fuel the flame which does emit into the heating chamber is directionalized and controlled. With either gas or oil firing, therefore, the reaction tubes may be disposed closer to the chamber walls and in a chamber of the same size more reaction tubes can be employed than in furnace designs heretofore employed, thus greatly increasing the efficiency and economy of the furnacing operation.

Now in accordance with the present invention, it has been discovered that additional improvement is obtained by a recirculation of combustion gas from the combustion chamber to at least one burner tunnel through at least one duct tunnel positioned in the wall of the combustion chamber. With this arrangement in which a portion of the hot combustion gas is introduced into a cooler zone of a newly fired burner stream, it has been found that many advantages accrue. For example, because of the intermixing of the recirculating combustion gas with the newly fired burner stream, there is the introduction of oxygen contained in the recirculating combustion gas into the firing stream which causes a quicker ignition and a more complete combustion of the fresh fuel contributed to by the higher temperature recirculating gas on the

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initially lower temperature fresh stream burner combustion. The combined effects result in a shorter flame and a more favorable completion of combustion prior to formation of the combustion envelope within the furnace proper. When oil is the fuel, the duct tunnel recirculation of gas causes the oil to gasify and mix faster with oxygen within the burner tunnel, thereby accelerating combustion within said tunnel. Furthermore, a principal advantage of a multiple fired furnace resides in its control to maintain a desired temperature gradient. The gradient is, of course, established by control at the firing "points." Ideally, a smooth controlled transition to establish the gradient is most desirable rather than a gradient established by multiple firing "points." The present invention tends to establish such a smooth controlled transition since there is produced a mixing cycle between the combustion chamber gas at lower temperature and the combustion gas which upon completion of combustion is at higher temperature which to an extent produces a moderate tempering of the combustion gas before it issues from the burner tunnel into the combustion chamber.

More explicitly, the present invention comprises a tubular reaction furnace having in combination a heating chamber the walls thereof having spaced portions of greater thickness than the intermediate portions, at least one vertically disposed reaction tube passing through the heating chamber and spaced from the chamber walls, a plurality of vertically spaced burners to supply hot combustion gas to the heating chamber each of which is disposed in an elongated burner tunnel within the spaced portions of greater thickness of the chamber walls, and at least one duct tunnel disposed subjacent to at least one burner tunnel having its ingress opening in communication with the interior of the heating chamber and having its egress opening in communication with the interior of said burner tunnel. The present invention also comprises a method of treating fluid reactants in a tubular reaction furnace heated by introducing hot combustion gas into the furnace from a plurality of vertically spaced burner streams, the improvement which comprises withdrawing a portion of the combustion gas as such and introducing it into a cooler zone of a newly fired burner stream.

As indicated, the furnace itself will preferably be square or rectangular in cross-sectional external configuration. The internal cross-sectional configuration of the heating chamber will preferably be either elliptical, octagonal or circular. Thus, the portions of the chamber wall adjacent the furnace corners will be thicker than the intermediate portions. In this manner thickened portions may be economically provided adjacent the corners for the disposition of the burner tunnels without the necessity of providing Dutch oven type effects and without the necessity of providing a furnace wall of a uniform thickness sufficient to accommodate adequate burner tunnels. Moreover, due to the thickness of the corner portions of the structure, regions of higher heat capacity are provided which add to the use and performance of the furnace.

In one preferred embodiment of the invention the tubes will be spaced from each other on centers of from $1\frac{1}{2}$ to $2\frac{1}{2}$ tube diameters. It has been discovered that when care is taken to avoid detrimental flame impingement, and particularly in the improved furnace design of the invention utilizing the duct tunnels, adequate heat input to the tubes can be obtained with this relatively close tube spacing which has heretofore been deemed undesirable by the art. Thus, in a chamber of given size, the closer spacing of tubes provides more space between the tubes and the chamber walls and further enhances the controlled protective combustion gas flow and reintroduction thereof to the newly fired burner stream characterizing the invention. Alternatively, where this additional protection is unnecessary, chamber size can be reduced with corresponding economies.

In accordance with another preferred embodiment of the invention, the reaction tubes will be anchored below

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the furnace hearth to support members, manifolding, a quench tank, a secondary furnace or other process equipment and tension will be applied in the upward direction by means disposed above the furnace arch. Such means may be manually or automatically controlled to exert the desired amount of tension on the tubes and thus permit the use of higher temperatures which in turn will derive the highest efficiencies from the metals employed. Thus, where a tensile force of as much as 2000 pounds has been employed in prior art designs where the tubes are suspended even though it is only necessary to employ, for instance, a 200 pound tension to minimize binding, bloating, or warping, it is possible in accordance with the present invention to apply exactly the amount of tension desirable and thus remove undesirable temperature limitations.

In terms of process, the invention relates to a process for applying heat to vertically disposed metallic reaction tubes passing through the refractory walled heating chamber of a tubular furnace which comprises, at a plurality of vertical levels introducing streams of newly fired gas into the heating chamber along paths obliquely disposed to the surfaces through which the streams emit and which paths direct the streams between the tubes and the adjacent refractory wall, maintaining said streams out of contact with the tube until substantially complete combustion of the gas has occurred, continuously maintaining a blanket of the fully oxidized gas around the tubes to provide a continuous oxidizing atmosphere for the tubes and reintroducing a portion of this oxidized gas into the initially fired burner mixture, said blanket diluting the streams of gas entering the chamber at the interfaces formed between the blanket and streams and said blanket being continuously replenished from said diluted portion, and leading the combustion gases in the path between the tubes and chamber wall and in the blanket through the chamber in substantially parallel relationship to heat the tubes by convection and radiation from the gas and by radiation from the refractory wall. Preferably the combustion gases in their ultimate path will be led upward to exit adjacent the top of the furnace structure.

In employing the apparatus of the invention, new and beneficial heat relationships are set up within the furnace chamber. As the furnace operation is initiated, hot combustion gases are introduced into the chamber from the burner tunnels and flow along the chamber wall between the wall and the nearest tubes. As this gas comes from the burner and begins to burn, reducing conditions are present and continue to be present until complete combustion is achieved. Then the gas, contains water and from about $\frac{1}{2}$ to about 9% oxygen depending on firing conditions and location. Generally, the combustion gas entering the duct tunnel or duct tunnels will be within the temperature range of about 2600° F. maximum and a minimum temperature of about 1200° F. The quantity of recirculating gas per duct tunnel will be related to the inspiration and convection effect which in turn are related respectively to the position, size and shape of duct tunnel openings and to the temperature difference between the intake of the duct tunnel and the point where the combustion gas and burner tunnel gas mix. In the invention, it is desirable to effect as nearly complete combustion in the burner tunnels as possible. In any event, even if complete combustion has not occurred in the tunnel, the directionalized flow along the wall allows complete combustion to take place before tube contact. This gas, now an oxidizing gas, proceeds upwardly around the chamber wall, with a portion diffusing inwardly into the center of the chamber and circulating about the tubes and with a portion circulating outwardly and passing through the duct tunnels for reentry with the newly fired burner streams. As operations continue, this centrally disposed body of oxidizing gas continues to surround and bathe the tubes in a continuously oxidizing atmosphere. As the relatively hotter

fresh burner gas emits from the tunnels, usually at a temperature of about 3500° F., it flows peripherally around the outer portion of the chamber. Even when combustion is not complete at the mouth of the tunnel and reducing conditions exist at that point, the tubes are protected by the inner body of oxidizing gas. The inner fringe of the gas stream emitting from the tunnels and circling around the chamber is constantly diluted by the relatively cooler oxidizing gas and recycle thereof through the duct tunnels and diffuses inwardly to become part of the inner protective columnar body, a corresponding portion of which exits from the flue with the other gas.

In a single cell furnace it is preferred that the combustion gas streams all flow into the chamber in the same direction. In this manner, smoothest flow of gas is obtained and the stream from each burner joins the unidirectional flow. However, this arrangement is not always practical, especially in some multiple cell furnaces where it may be desirable to fire from only two faces. In multiple cell furnaces, for example, it may be desirable to fire from two faces at each level with gas flow being in opposite directions at each level. While such flow causes turbulence and some reduction in efficiency of the duct tunnels, the gas stream from each burner becomes completely oxidized in its travel from the burner tunnel to the far side of the chamber and the turbulence and minor reduction in efficiency is not detrimental.

The use of burner tunnels and duct tunnels, the controlled peripheral flow and the presence of the inner protective body of relatively cooler oxidizing gas results in great advantages particularly in terms of metal tube life and permissible temperatures. Not only is detrimental flame impingement eliminated, but of equal importance, the tubes in the furnace are not exposed to the metal damaging fluctuation between oxidizing and reducing conditions which is present in the prior art apparatus. Therefore, the tubes are immediately coated with a thin, permanent, protective film of metal oxide which is smooth, ductile and elastic. This film is fluid impervious and prevents or minimizes detrimental tube damage resulting from vanadium and low fusing alkali sulfates present in fuel oil. In prior furnaces, tube metal was liable to attack of varying degree of frequency first by an oxidizing atmosphere and later by a reducing atmosphere due to insufficient latitude against mechanical and human failure in control with the resulting scaling of metal causing decreased tube life.

Moreover, the method of heating in the apparatus of the invention keeps the hottest gas close to the refractory wall thus more efficiently heating the primary source of radiant heat to the tubes. If desired, oxygen or oxygen enriched air can be employed together with the hydrocarbon feed to generate hotter flame and hotter gases of combustion due to the new protection afforded to the tubes. Thus, substantially greater heat input can be obtained without tube damage.

The introduction of gas into the chamber along a path disposed obliquely to the furnace face from which the gas emits adds considerably to the efficiency of the furnace. Each portion of the longer, outer wall of the burner tunnels which extends beyond the end of the shorter inner wall of the tunnel becomes a highly heated radiating surface which would otherwise be lost if the tunnel walls were of equal length.

A preferred embodiment of the invention has been chosen for purposes of illustration and description and is shown in the accompanying drawing wherein reference symbols refer to like parts wherever they occur:

FIG. 1 is a sectional plan view of a single cell tubular furnace employing the principle of my invention;

FIG. 2 is a fragmentary elevational view taken along line 2—2 of FIG. 1; and

FIG. 3 is a fragmentary elevational view taken along line 3—3 of FIG. 1.

With reference to the drawing, the furnace 10 illus-

trated has a refractory wall 12. The external cross-sectional plan configuration of the furnace is substantially square while the internal cross-sectional plan configuration of the heating chamber 14 is substantially octagonal.

Four of the sides or thickened portions 16 of the octagon forming the walls of the heating chamber 14 are of substantial thickness while the other four intermediate sides or thinner portions 18 are of conventional thickness. Elongated burner tunnels 20 with refractory housings 22 are disposed in the thickened portions 16 and a fluid hydrocarbon burner 24 is located at each of the burner tunnels and fires therein. A duct tunnel 26 and a duct tunnel 28 is disposed subadjacent to each of the burner tunnels 20. These duct tunnels have their ingress openings in juxtaposition with the transition intersection of the thickened wall portions 16 and the thinner wall portions 18 of the combustion chamber and have a common divergent egress opening 30 in direct communication with the interior of the burner tunnel 20 with the egress opening entering the burner tunnel in the vicinity of the hot flame area of the burner. A plurality of reaction tubes 32 pass vertically downwardly through the chamber 14 and are spaced from each other on centers of approximately 1½ tube diameters. In the structure shown, two burners are disposed at each horizontal level, however, one, two, three or four burners per level may be employed as desired. In operation of the furnace, fluid hydrocarbon is introduced into the burners and ignited. The combustion gas streams are directionalized by the walls of the tunnel, so that the hot gases will pass between the tubes and the wall of the furnace without detrimental flame impingement on the tubes. The gases which diffuse inwardly are completely oxidized and heat the tubes by convection and radiation. The refractory furnace walls are highly heated by the peripheral flow of hot gas from the tunnels and radiate heat to the tubes. Due to the oblique surfaces involved, the gases from the burners are conducted smoothly around the tubes in a spiral path. The gases diffusing inwardly to form the protective blanket of fully oxidized gas also move generally spirally about and between the tubes and continuously bathe the tubes in an oxidizing atmosphere. Additionally, a portion of the oxidized gas passes into and through the duct tunnels and into the burner tunnel where it intermixes with the newly fired burner stream combustion products. As pointed out previously, this recirculation assists in a quicker ignition and more complete combustion of the fresh fuel which in combination results in a shorter flame which, of course, is a highly desirable object of the invention. The total spent gases are withdrawn from a flue, not shown, at the top of the chamber and thus progress in an ascending path around the tubes. The eight angular internal surfaces add to the efficiency of the radiation from the refractory walls of the furnace to the reaction tubes. In addition to these eight walls the portions of the burner tunnel walls which are obliquely extended also furnish radiation surfaces for the heating of the tubes.

More specifically, in accordance with the furnace design of this invention, with vertical disposition of burners in the sidewalls thereof, there is an upward gradient of refractory temperature and of combustion gases within the furnace. The amount of the gradient is flexible and related to the conditions of operation of the furnace, said conditions being related to the performance taking place within the tubes being heated. For example, in practicing the invention there is a draft gradient vertically within the furnace varying from about 0.75 inch water to substantially zero. Within the furnace therefore, and vertically disposed therein, temperature differences as well as draft differences between levels exist. Accordingly, the temperature difference and the pressure difference are employed in the natural circulation of the combustion gas from within the heating chamber to the burner tunnels, all of which is carried out within the walls of the furnace itself. Here it will be appreciated that an additional objective of the present invention is to employ combustion

gases from more than one burner and at a substantial combustion envelope travel distance from the exit of the burner tunnel whereby great assurance exists that the combustion gas will be of an analysis which is a composite result from the multiplicity of burners which normally assures the presence of oxygen as furnaces are customarily fired. Furthermore, and with reference to the drawing, the entrance point of the duct tunnel into the burner tunnel is from the under side whereby natural circulation is independent and separate from the inspiration effect of the burner nozzle.

In designing a furnace in accordance with the invention, it is preferred that the wall thickness at the thinnest point be of conventional thickness, that is, normally no less than about 12 to 14 inches in order to obtain the desired heat capacity. It is at once apparent that burner tunnels of sufficient length cannot be had in a wall of this thickness. However, by employing the preferred octagonal, circular, or elliptical internal configuration of the chamber, the corner portions of the furnace become thick enough for the formation of burner tunnels, desirably about three feet in length and duct tunnels, from about two to about twelve feet in total length, with the vertical riser of the duct tunnel from about one to about ten feet. If desired, impingement devices or baffles may be employed within the burner tunnels to promote more rapid combustion.

As indicated, in a furnace composed of a single cell as illustrated, firing may be effected from a single face, from two, from three or from all four furnace faces. Where two or more adjacent cells form the furnace, firing will desirably be effected from two or three faces per cell. If four cells are employed to compose the furnace, firing will advantageously occur from two faces of each cell. However, despite the number of cells or the number of faces from which the furnace is fired, advantage is gained due to the relative freedom from flame or hot gas impingement as described.

While it is necessary that the inner boundary of the gas streams or envelopes emitting from the tunnels do not cut the cross-sectional area of any of the tubes, the contacting of the wall of the furnace directly adjacent the mouth of the tunnel is desirable to highly heat the primary radiating surfaces.

As previously indicated, the angular or curved faces of the furnace opposite the mouth of the burner tunnels act as deflecting faces and direct the extended ends of the combustion envelopes or streams around the periphery of the chamber. Thus, where the burners are all aimed in a similar clockwise or counter-clockwise direction, the gas will flow smoothly about the furnace in a direction parallel to the walls and also into the duct tunnels. This arrangement provides for minimum flow around individual tubes and is preferred. As indicated, however, if turbulence is desired it can be produced by opposed gas flow from burners aimed in opposite directions. While the burner tunnels shown are substantially horizontal, such disposition is not essential and the burners may be aimed upwardly or downwardly as desired to obtain the desired gas behavior and temperature control within the chamber. In general, it is desired that the angle of flare of the burner tunnel be between about 20° and about 30° for best results, although for specific purposes greater or less flare may be desirable. The use of tunnels in general not only provides for directionalization but broadens the group of fuels which can be employed. For example, residues from thermal cracking of oils, asphaltics and the like may be employed.

With regard to tube spacing, it is not essential that each tube be spaced from the adjacent tube by the same distance. Any desired tube arrangement may be employed, such as parallel rows, on rectangular centers, in

hollow squares or rectangles or in single or concentric circles and the like. The discovery that it is possible to obtain completely satisfactory results by the closer spacing of the reaction tubes in accordance with the invention makes it possible to obtain the same throughput with a smaller, less expensive furnace or to obtain greater throughput with a furnace of the size currently employed but having more tubes.

As indicated, the apparatus and method of furnacing may be employed for any desired reaction which lends itself to tubular processing. However, greatest utility will be found in the hydrocarbon field and particularly in the manufacture of hydrogen, and olefins and refining products. All of the normally employed feedstocks ranging from methane through crude oils may be employed. In like manner the reforming and cracking catalyst employed by the art may be used in the catalytic reactions.

Since many modifications of the invention as disclosed will be apparent to those skilled in the tubular furnace art, it is intended that the invention shall be limited only by the scope of the appended claims.

This application is a continuation-in-part of my copending application, Serial No. 476,201, filed December 20, 1954, now Patent No. 2,914,386, patented November 24, 1959.

What I claim and desire to protect by Letters Patent is:

1. In a tubular reaction furnace having a heating chamber, the walls thereof having spaced refractory wall portions of greater thickness than the intermediate portions, and having reaction tubes passing through the heating chamber and spaced from the chamber walls, and having a plurality of vertically spaced burners to supply hot combustion gas to the heating chamber, each of which is disposed in an elongated burner tunnel within the spaced refractory wall portions of greater thickness to avoid direct impingement of the hot combustion gas from the burners with the reaction tubes; the improvement comprising:

- (a) two duct tunnels horizontally disposed subjacent to each elongated burner tunnel and spaced therefrom and disposed within the spaced refractory wall portion of a greater thickness,
- (b) an ingress opening for each duct tunnel horizontally spaced apart and in communication with the interior of the heating chamber, and
- (c) each said duct tunnel extending from its ingress opening to a common egress opening extending upwardly into the interior of each said elongated burner tunnel to provide mixing means between the lower temperature combustion gas from the heating chamber and the higher temperature combustion gas within the burner tunnel to accelerate complete combustion of the latter gas and to produce tempering of the gases issuing from the burner tunnel.

2. The tubular reaction furnace according to claim 1 in which the common egress opening is divergent with the maximum opening in direct communication with the interior of said burner tunnel.

3. The tubular reaction furnace according to claim 1 in which the duct tunnels are in close vertical proximity to each burner tunnel.

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