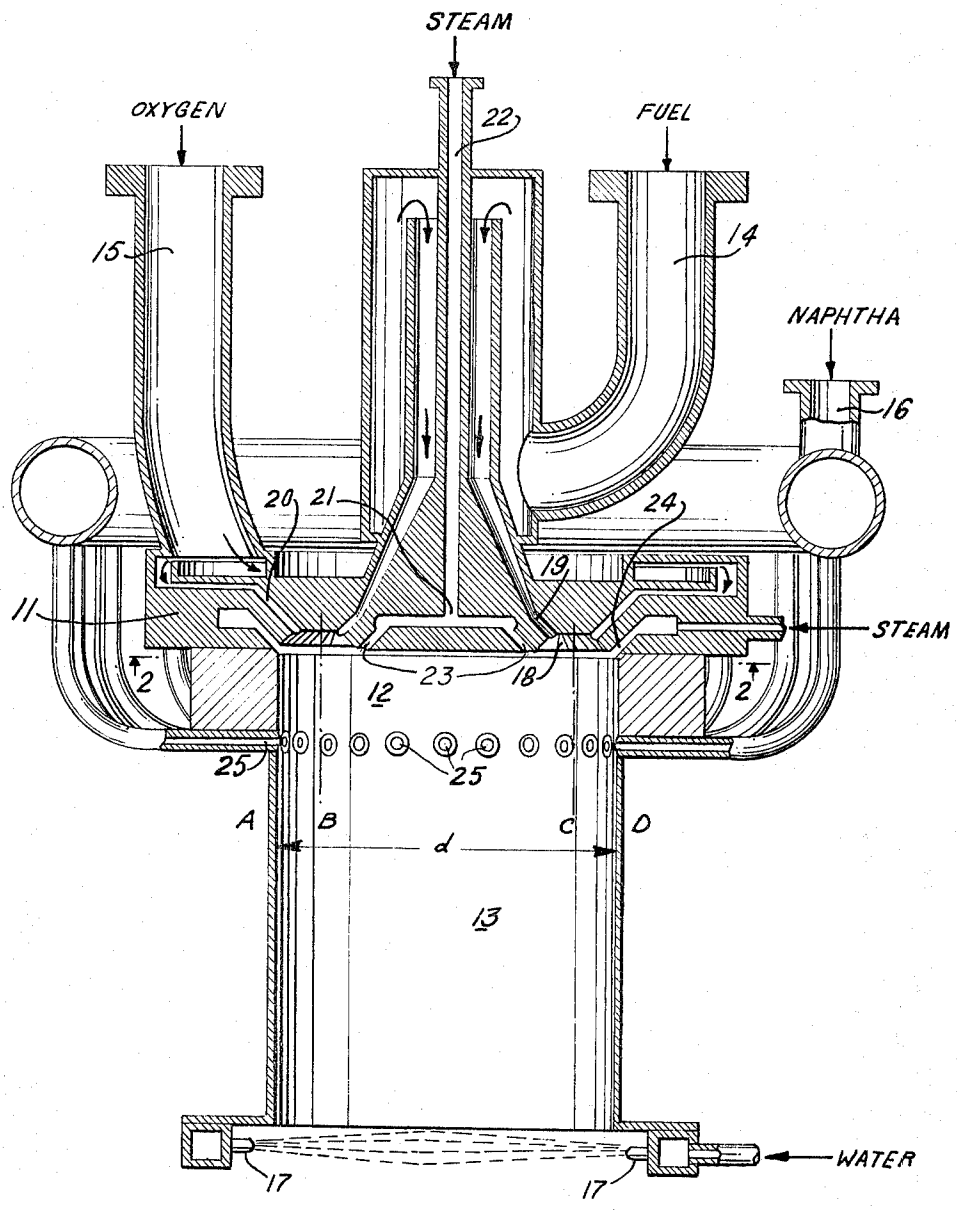
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APPARATUS FOR THERMAL DECOMPOSITION OF HYDROCARBONS

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FIG. 1




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FIG. 2

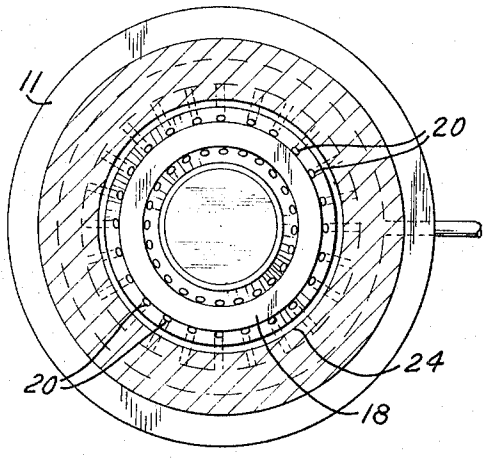



FIG. 5

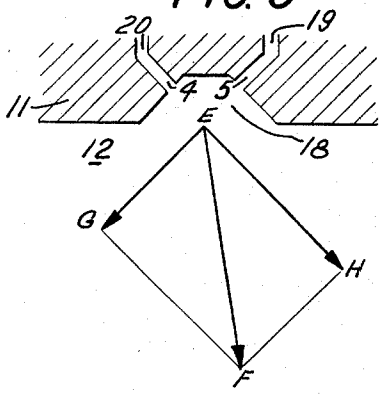



FIG. 3

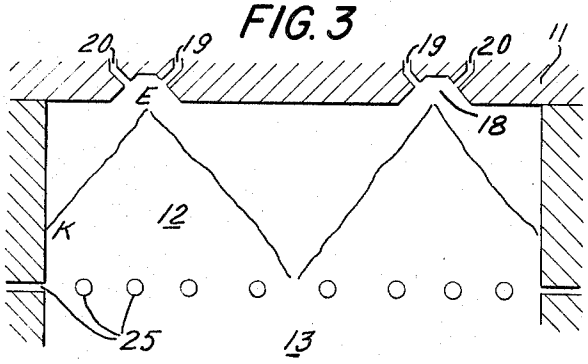



FIG. 6

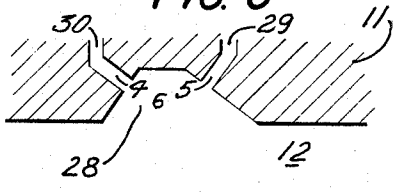
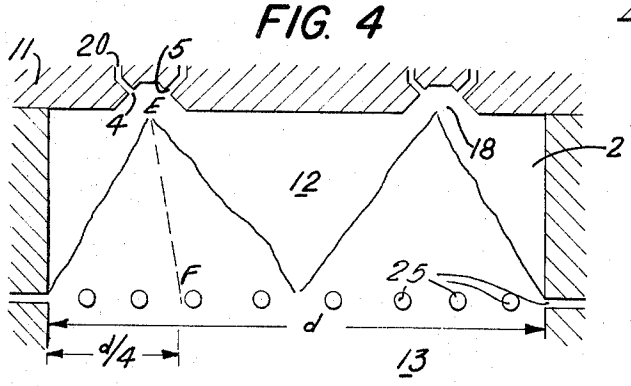



FIG. 4




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3,284,168

# APPARATUS FOR THERMAL DECOMPOSITION OF HYDROCARBONS

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4 Claims. (Cl. 23—277)

This invention relates to the thermal decomposition of hydrocarbons such as acteylene and ethylene and, more hydrocarbons such as acteylene and ethylene and, more particularly, to methods and apparatus for accomplishing such pyrolysis reactions under commercial production conditions of enhanced efficiency and, especially, with larger capacity apparatus.

As now well understood, pyrolysis or thermal decomposition reactions are conveniently utilized to decompose saturated hydrocarbons into less saturated hydrocarbons, particularly acetylene. Two general types of such processes may be recognized as (a) those in which a saturated hydrocarbon such as methane is partially burned and pyrolyzed to an acetylene, and (b) others in which a fuel gas of some sort is burned with oxygen to produce heat and hot gases into which saturated hydrocarbons such as naphtha are injected for pyrolysis into a mixture of acteylene and ethylene. Pyrolysis reactions of the latter type are generally of the character to which this invention relates and, more particularly, as disclosed in applicant's prior Patents Nos. 3,019,271 and 3,055,957.

As noted in such prior teachings, a generally cylindrical furnace is provided and streams of a fuel gas and a comburent gas such as oxygen are fed through ports in the top of the furnace. The ports are arranged on concentric rings and the axes of each pair of oxygen and fuel ports are at an angle of about 90°. Thus, with the oxygen and fuel fed into the furnace at substantially equal momenta, a ring of flames is established within the combustion zone to provide the hot gases into which the hydrocarbon to be pyrolyzed is later injected. As noted in such prior teachings, an important consideration of the technique includes providing the extremely rapid heating of the gas to be pyrolyzed to decomposition temperatures and, most preferably, in the absence of free oxygen which, if present, would readily react with the hydrocarbon to be pyrolyzed to give unwanted secondary products which would decrease the ultimate conversion yield of the hydrocarbon into the desired unsaturated products.

To this end the combustion conditions are carefully controlled, including the particular manner of injection of the fuel gas and oxygen to form a uniform ring of flames, each directed substantially parallel to the axis of the combustion chamber and pyrolysis zone. Similarly, for efficiency and uniformity of results, it is desired to have the hot combustion gases extend substantially uniformly all across the pyrolysis chamber, particularly at the point therein where there is injected the hydrocarbon to be pyrolyzed. Yet this total filling of the chamber with hot combustion gases is preferably obtained without direct impingement of the intensely hot flames on the inner walls of the combustion chamber in order to avoid wasting heat efficiency merely to heat the combustion chamber walls and in order to lengthen the life of the refractory or other materials from which the chamber is constructed.

The foregoing results are satisfactorily accomplished in the prior teachings noted above provided only that the combustion chamber and the pyrolysis reaction zone which joins it do not have diameters larger than permit uniformly covering the entire cross sectional area of the



chamber with flames from the ring of flames noted without having to expand the flames so greatly as to cause them directly to impinge upon the combustion chamber walls, in a manner described in more detail below. That is, particularly satisfactory results are achieved according to the noted prior teachings when the ring of heat-producing flames is concentric with the cylindrical combustion chamber and has a diameter approximately one-half that of the combustion chamber.

For a variety of reasons, and particularly as the size and capacity of the combustion chamber is increased, it may be desired to locate the fuel and oxygen flame ports on a circle having a diameter somewhat larger than one-half the diameter of the combustion chamber. In such an event, expanding the flame area sufficiently to cover the entire central portion of the combustion chamber means that a substantial portion of the flame impinges directly against the wall of the combustion chamber, provided that above noted teachings are followed in the construction and the operation of the burner itself.

According to this invention, on the other hand, the advantages of arrangements generally similar to those disclosed in the above mentioned prior patents are retained even with larger pyrolysis apparatus constructions and/or those in which the diameter of the flame ring is greater than half the diameter of the combustion chamber, by providing for altering the axis of flame propagation away from a direction exactly parallel to the axis of the combustion chamber; and such provision is accomplished in accordance herewith in a variety of ways which include feeding the fuel and comburent gases through the ports separately and at high speed but with different momenta and/or by arranging the ports or the separate gas streams in the flame ring to be each disposed at an angle other than 45° with respect to the axis of the combustion chamber, etc.

With the foregoing and additional objects in view, this invention will now be more particularly described, and other objects and advantages thereof will be apparent from the following description, the accompanying drawings, and the appended claims.

In the drawings:

FIG. 1 is a somewhat diagrammatic view in axial section of a pyrolysis furnace embodying and for practicing this invention;

FIG. 2 is a transverse section of the apparatus of FIG. 1 taken along the line 2—2 thereof;

FIG. 3 is a purely diagrammatic showing indicating undesired operation of the furnace with injection of fuel and comburent gas evenly at equal momenta;

FIG. 4 is a diagram like FIG. 3 but indicating operation of the furnace as embodying and for practicing this invention;

FIG. 5 is a vector diagram indicating desired operation of a furnace in accordance herewith; and

FIG. 6 is a detail of one side of fuel and comburent gas ports modified as a means for providing satisfactory operation in accordance herewith with the gases injected at substantially equal momenta.

Referring to the drawings, in which like reference characters refer to like parts throughout the several views thereof, there is shown a form of pyrolysis furnace apparatus embodying and for practicing this invention, although purely as illustrative for explanation here. Thus, a vertically disposed cylindrical combustion chamber 12 is shown above and in unrestricted flow communication with a pyrolysis chamber 13, with a distributor manifold 11 preposed to combustion chamber 12 and pyrolysis chamber 13. Conduits 14 and 15, respectively, feed fuel and a comburent gas such as oxygen to distributor 11, while conduit 16 feeds the hydrocarbon to be pyrolyzed,

such as naphtha, to pyrolysis chamber 13 as described below. A quenching device, such as a ring of water sprays or jets indicated at 17, is also provided in known manner for quenching the pyrolysis gases as they exit from pyrolysis chamber 13.

That side of the distributor 11 which faces combustion chamber 12 includes a circular notch or groove 18, of trapezoidal cross section, which circular groove is disposed concentric to the longitudinal axis of the pyrolysis furnace. A ring of ports or feed jets 19, in flow communication with conduit 14, and a second concentric ring of ports or jets 20, in flow communication with conduit 15, feed fuel gas and oxygen, respectively, into chamber 12. Ports 19 and 20 are disposed, as indicated, in the inclined annular side walls of groove 18, substantially perpendicularly to these walls (in the apparatus of FIGS. 1 and 2), with the axes of ports 19 and 20 being inclined perpendicularly to each other and at angles of about 45° with the longitudinal axis of combustion chamber 12. Ports 19 and 20 are symmetrically distributed around groove 18 with a fuel port 19 being adjacent each oxygen port 20, and satisfactory results have been achieved in accordance herewith with each of the ports 19 and 20 dimensioned to give a high jet nozzle velocity, for example of about 100–200 m. per second, to the oxygen and fuel gas injected therethrough into combustion chamber 12.

In operation, hydrogen or a hydrogen-rich fuel gas and oxygen are introduced into combustion chamber 12 through conduits 14 and 15 and the rings of ports 19 and 20 connected thereto. The gaseous reagents, which may be preheated, meet at an angle of approximately 90° on issuing from ports 19 and 20 with high linear velocity. This results in an efficient and rapid local mixing, with a formation of a ring of short flames extending generally longitudinally of combustion chamber 12. In this manner, in the particular form of apparatus illustrated in FIGS. 1 and 2, the actual flame may be established at the juncture of the gas streams from ports 19 and 20 and, thus, spaced slightly from actual intense flame heating contact with the bottom surface of distributor 11. As noted in more detail below, the combustion thus effected is intended to produce a relatively uniform front of hot gases at the upper end of the pyrolysis chamber 13, as defined by the ring of injection ports 25 through which hydrocarbon to be pyrolyzed is introduced, also as noted below.

In the particular form of apparatus illustrated in FIGS. 1 and 2, there is also provided for optionally introducing a curtain of steam around the primary combustion ring of flames as an aid to maintaining distributor 11 at a fairly low temperature and for providing a steam curtain around the inside of the combustion chamber walls as some further protection against intense heating. As illustrated, such steam curtain means include a steam chamber 21 centrally of distributor 11, and steam inlet 22. Steam introduced through conduit 22 may be utilized (and as indicated by the flow arrows in FIG. 1) to preheat some of the fuel gas introduced through conduit 14, and the steam is injected from chamber 21 into combustion chamber 12 through an annular slit 23 inclined at an angle of about 35° to 50° with respect to the longitudinal furnace axis. A second annular slit 24 around the periphery of the combustion chamber 12, and also inclined at an angle of about 35° to 50°, injects another steam jet stream or curtain around the inner walls of the combustion chamber.

As will be understood from the foregoing, a ring of flames is established around groove 18 and with such intensity or quantity of heat and fuel to provide a substantially uniform hot gas layer at the level of the apparatus where hydrocarbon injection jets 25 are located so that the hydrocarbon to be pyrolyzed can be injected through jets 25 for almost instantaneous and uniform mixing with a uniform hot gas layer at that level in the apparatus. Thereupon, the hydrocarbon is pyrolzed into the desired components (such as, primarily, acetylene and ethylene when a hydrocarbon such as naphtha is utilized), and the resulting reactions and decompositions are quenched as the gases proceed down through pyrolysis zone 13 by water sprays 17. For particularly enhanced efficiency, and in view of the substantially instantaneous nature of pyrolysis reactions and the gas flow rates through the apparatus, it is desired that the hot combustion gases at the level of nozzles 25 be formed with maximum temperature and substantially free of molecular oxygen (which might combine disadvantageously with the hydrocarbons to be pyrolyzed producing undesired waste or secondary products), and under conditions as adiabatic as possible. Because of the high temperature and intense flames desired, the distributor 11 and the walls of combustion chamber 12 are inevitably subjected to extremely high temperatures, and, while it is perfectly possible to utilize materials for the apparatus which can adequately withstand such temperatures, it is more desirable to arrange matters so that the direct flame heating of the walls of the combustion chamber is minimized as much as possible, both from the standpoint of prolonging the life of whatever refractory metals or other materials are used and from the realization that any quantity of heat utilized merely to impinge directly on the walls of the combustion chamber or any other portions of the apparatus is essentially wasted.

Assuming, thus, that the flames or intense heating of the ring of flames in groove 18 is desired to be such as will form a complete layer of maximum temperature fully combusted gases at the level of injection ports 25, one may note that an arrangement in which the diameter of the ring of flames (i.e., the diameter of the circle defined by the center of groove 18) is about one-half the diameter of combustion chamber 12, the ring of flames will be disposed midway between the walls of combustion chamber 12 and the center thereof so that the flames may be regulated to produce expanding gases to form a uniform hot gas mixture at the level of injection ports 25 without directly impinging upon the walls of the combustion chamber. That is, with notch 18 disposed inwardly from the walls of combustion chamber 12 by a distance corresponding to one-fourth the diameter *d* thereof, the circular areas indicated on FIG. 1 as BC and AB–CD will be substantially equal.

If, on the other hand, it should be desired to arrange the furnace with the diameter of the circle defined by groove 18 as being greater than one-half the diameter of combustion chamber 12 (as may be desirable for a variety of reasons, especially as the total size and capacity of the apparatus is increased), the same situation does not obtain. Thus, with the fuel and comburent being injected through ports 19 and 20 with substantially equal momenta, and with such momenta selected so as to produce a flame front or uniform hot gas layer completely filling the combustion chamber 12 at the level of injection ports 25, a situation as diagrammed in FIG. 3 may result. That is, as indicated by the line EK, if the fuel and oxygen feed is increased through ports 19 and 20 (with substantially equal momenta) to expand the heating front to include the whole area of the burner, there is wasted a substantial portion of the direct flame heat in direct impingement thereof on the side walls of the combustion chamber 12 as indicated by the distance of the letter K above the level of injection ports 25, with the disadvantageous effects noted above.

In accordance with this invention, on the other hand, a preferred form of operation is as diagrammed, in substantially the same manner, in FIG. 4 and, more particularly, in the diagram of FIG. 5, which diagrams or indicates a manner of operation under the foregoing circumstances (where the specific disposition of ports 19 and 20 may be indicated or dictated by other mechanical or operating considerations) while avoiding the direct im-

pingement of intense heating on the side walls of combustion chamber **12** (to avoid unnecessary thermal degradation of the refractory materials thereof) while also producing a uniform hot gas or heat level at the plane of injection nozzles **25**. Thus, even in the convenient situation where the axes of ports **19** and **20** are perpendicular to each other and are also each disposed at an angle of 45° with the longitudinal vertical axis of combustion chamber **12**, the injection momenta of the fuel and comburent gas streams injected through ports **19** and **20** is specifically altered and controlled so as to form a resultant flow vector moment EF disposed at such an angle to the axis of combustion chamber **12** that such vector reaches the point F at the level of injection nozzles **25** on a circle inwardly spaced from the combustion chamber walls by an amount equivalent to about one-fourth the diameter *d* of combustion chamber **12**.

Thus, the flame or hot combustion gas propagation direction is influenced by the relative momenta with which the fuel and comburent streams meet each other after being injected into combustion chamber **12** through ports **19** and **20**. As diagrammed in FIG. 5, the individual fuel and comburent gas streams being injected through ports **19** and **20** meet at point E, and are represented by vectors EG and EH, having a resultant vector EF, depending upon the relative momenta of the separate gas streams. If these momenta are substantially equal, resultant vector EF will be substantially parallel to the axis of combustion chamber **12**, and the undesired or inefficient results depicted in FIG. 3 are obtained. If the particular momenta of injection of the separate fuel gas and the comburent gas streams are selected to be approximately of the relative order of magnitude indicated by vectors EG and EH, then resultant vector EF will lie at an angle to the axis of combustion chamber **12**, and, in accordance herewith, such relative momenta are selected so that the resultant vector EF is inclined at such an angle to the axis of combustion chamber **12** as will dispose vector EF at a point in combustion chamber **12** approximately *d*/4 from the outer walls thereof at the level therein defined by the ring of hydrocarbon injection ports **25**.

If such operating conditions are maintained, as will be apparent from the foregoing and with particular regard to a comparison of FIGS. 3 and 4, the propagation direction of intense heating flames and the hot gases is diverted inside the combustion chamber and toward the center thereof, but controllably diverted to concentrate such heating uniformly across the entire transverse area of the combustion chamber at the level therein defined by inlet port **25** while avoiding direct and wasteful or undesired impingement of such heating directly on the walls of the combustion chamber. In addition to providing that the actual wall of combustion chamber **12** is not directly exposed to any intensely hot gases prior to the point where the heat from the gases is immediately utilized for pyrolyzing the hydrocarbon injected through ports **25**, the foregoing operation also provides for a more uniform and desirable mixture of the hot combustion gases specifically at the effective level where hydrocarbon to be pyrolyzed is injected thereinto through injection ports **25**.

As a further example of apparatus and operating techniques with which satisfactory results have been achieved in accordance with this invention, one may note the utilization of a pyrolysis furnace as illustrated in FIGS. 1 and 2 (and as described in more detail in Patent 3,019,271) suitable for the production of six tons per day of acetylene along with 12 tons per day of ethylene from the pyrolysis of petroleum naphtha and operated in a manner indicated in FIG. 4. The diameter *d* of combustion chamber **12** of such apparatus was approximately 260 mm. Because of the high capacity of such apparatus, a very large number of fuel and comburent gas ports **19** and **20** is required—so much so that optimum results are difficult or impossible to obtain if this large number of ports is attempted to be arranged in a groove **18** having a diameter of no more than one-half the 260 mm. diameter of combustion chamber **12**. Accordingly, for mechanical and other reasons and for the efficient operation of the furnace under the desired conditions, the groove **18** had a diameter of about 190 mm., with this larger diameter thus satisfactorily accommodating 40 fuel gas ports **19** and 40 corresponding oxygen ports 20, each disposed in pairs in groove **18** with the axes of ports **19** and **20** being perpendicular to each other and being inclined at an angle of 45° with the axis of combustion chamber **12**.

To avoid the undesired situation diagrammed in FIG. 3, the oxygen and fuel gas were injected with controlled and different momenta (as diagrammed in FIG. 5) so that the resultant vector EF was inclined at an angle providing the point F being inwardly spaced by a distance of about 65 mm. (i.e., *d*/4) inwardly from the wall of combustion chamber **12**. To achieve the situation, the various reactants were introduced at comparative rates of 900 m.$^3$/hr. oxygen mixed with 700 kg. steam at 650° C., thus representing a total mass of 1,987 kg. through ports **20**, having an effective area of 88 mm.$^2$. At the same time, 630 m.$^3$/hr. fuel gas mixed with 400 kg. steam at 650° C., representing a total mass of 940 kg., were injected through ports **19**, which had an effective area of 44.5 mm.$^2$. As will be apparent, under these conditions, the ratio between the momenta of the comburent and fuel gases was about 1.77, thus resulting in the desired radially inward deflection of the flame or heat front propagation to the desired point of about *d*/4 at the level of combustion chamber **12** defined by hydrocarbon injection ports **25**.

Although completely satisfactory results are achieved by the operating control of the respective momenta of the injected fuel and comburent gas streams through ports **19** and **20** disposed with the axes thereof meeting at substantially 90°, satisfactory results have also been achieved in accordance with this invention by modifying the distributor **11** as indicated in FIG. 6. That is, instead of having the axes of ports **19** and **20** meet each other perpendicularly and each at an angle of about 45° to the axis of combustion chamber **12**, the disposition of the injection ports may be altered to provide the desired radially inward deflection of vector EF even when the fuel and comburent gases are injected therethrough at equal momenta. As noted in FIG. 6, for example, the distributor **11** is provided with a groove **28** having a trapezoidal cross section of other than isosceles configuration and, accordingly, with the axes of fuel gas ports **29** and comburent gas ports **30** disposed so that the streams injected into combustion chamber **12** therefrom meet each other at an angle other than 90°, and with the axes of the ports **29** and **30** disposed at different angles with respect to the longitudinal axis of combustion chamber **12**.

In this manner, the inward deflection of vector EF is obtained, even when the injection of the gases is accomplished at equal momenta and by varying the angles of the streams thereof. As will be apparent from the foregoing, of course, satisfactory results are also achieved in accordance herewith by any of a variety of combinations of the non-identical disposition of ports **29** and **30** (as indicated in FIG. 6) with a control or altering of the separate gas stream feeds at non-identical momenta to produce the desired inward deflection of the heat propagation direction resultant vector EF to the desired extent of radial deflection for achieving a substantially complete and uniform heat front at the level of hydrocarbon injection without direct impingement of intense flame or hot gas heating on the wall of the combustion chamber **12**.

Thus, in accordance herewith, there are provided apparatus and operating techniques for achieving maximum efficiency in a pyrolysis furnace of the character to which this invention relates, not withstanding the fact that various mechanical and design criteria may indicate that the

diameter of groove **18** should advantageously be larger than would permit the desired combustion conditions readily achievable when flames forming the ring of flames around groove **18** are are parallel to the longitudinal axis of the combustion chamber and disposed at a radially inward position equivalent to ¼ the diameter of the combustion chamber. Similarly, the advantages of this invention are satisfactorily achieved either by modifying and controlling the feed speed velocities of the separate streams of fuel and comburent gases to provide unequal momenta thereof specifically to achieve the inward deflection of the resultant vector EF or by so forming the inlet ports themselves at other than perpendicular arrangement, or by combinations of the foregoing means and techniques.

While the methods and forms of apparatus herein described represent preferred embodiments of this invention, this invention is not limited to these precise methods and forms of apparatus, and changes may be made therein without departing from the scope of this invention which is defined in the appended claims.

What is claimed is:

**1.** In a pyrolysis reactor for pyrolyzing hydrocarbons into less saturated hydrocarbons by injection thereof into hot combustion gases in said reactor, the combination which comprises a cylindrical combustion chamber for producing said hot combustion gases by combustion of a fuel gas and a comburent gas therein, a pyrolyzed chamber in direct flow communication with said combustion chamber and into which said hydrocarbons to be pyrolyzed are injected, said pyrolysis chamber being downstream of said combustion chamber in the line of flow of said hot combustion gases, a distributor at the upstream end of said combustion chamber consisting essentially of a plurality of injection ports in said distributor arranged in pairs with the center point of both ports of each pair lying on a common radius of said combustion chamber for injecting a plurality of separate streams of said fuel and comburent gases for admixture and combustion in said combustion chamber, said plurality of pairs of ports being disposed in said distributor in only two circles with one each of each said pair being in each circle and with the circles being coaxial with each other and with said cylindrical combustion chamber and having a diameter greater than one-half that of said combustion chamber, one of said circles having a diameter larger than the other and forming the radially outer circle and the smaller one forming the radially inner circle of ports, the axis of each of said ports being downwardly inclined with respect to the axis of said combustion chamber and with the axis of each respective fuel and comburent gas port intersecting for admixture of said gases at said intersections to form a ring of flames, and the angle between the axis of the radially outer port of each said pair and the axis of said combustion chamber being greater than the angle between the axis of the radially inner port of each said pair and the axis of said combustion chamber for deflecting radially inwardly said flames formed at said intersections avoiding direct impingement of said flames on periphery walls of said combustion chamber upstream of said hydrocarbon injection.

**2.** A pyrolysis reactor as recited in claim **1** which also includes an annular groove in said distributor having a diameter more than half the diameter of said combustion chamber and coaxial therewith, and in which said fuel and comburent gas ports are disposed in opposite sides of said annular groove.

**3.** A pyrolysis reactor as recited in claim **1** in which the radially outer port of each said pair of ports is connected to a source of comburent gas and is a comburent gas port while the radially inner port of each said pair of ports is connected to a source of fuel gas and is a fuel gas port.

**4.** A pyrolysis reactor as recited in claim **1** in which the axis of said outer port with an angle of inclination to the axis of said combustion chamber greater than said inner port is positioned to deflect said flames radially inwardly by about one-fourth the diameter of said combustion chamber at the axial position of said hydrocarbon injection.

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