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J. E. LOEFFLER, JR., ETAL
HEAT EXCHANGER FOR APPARATUS FOR COMBUSTION
OF GASES WITH OXYGEN

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2 Sheets-Sheet 1

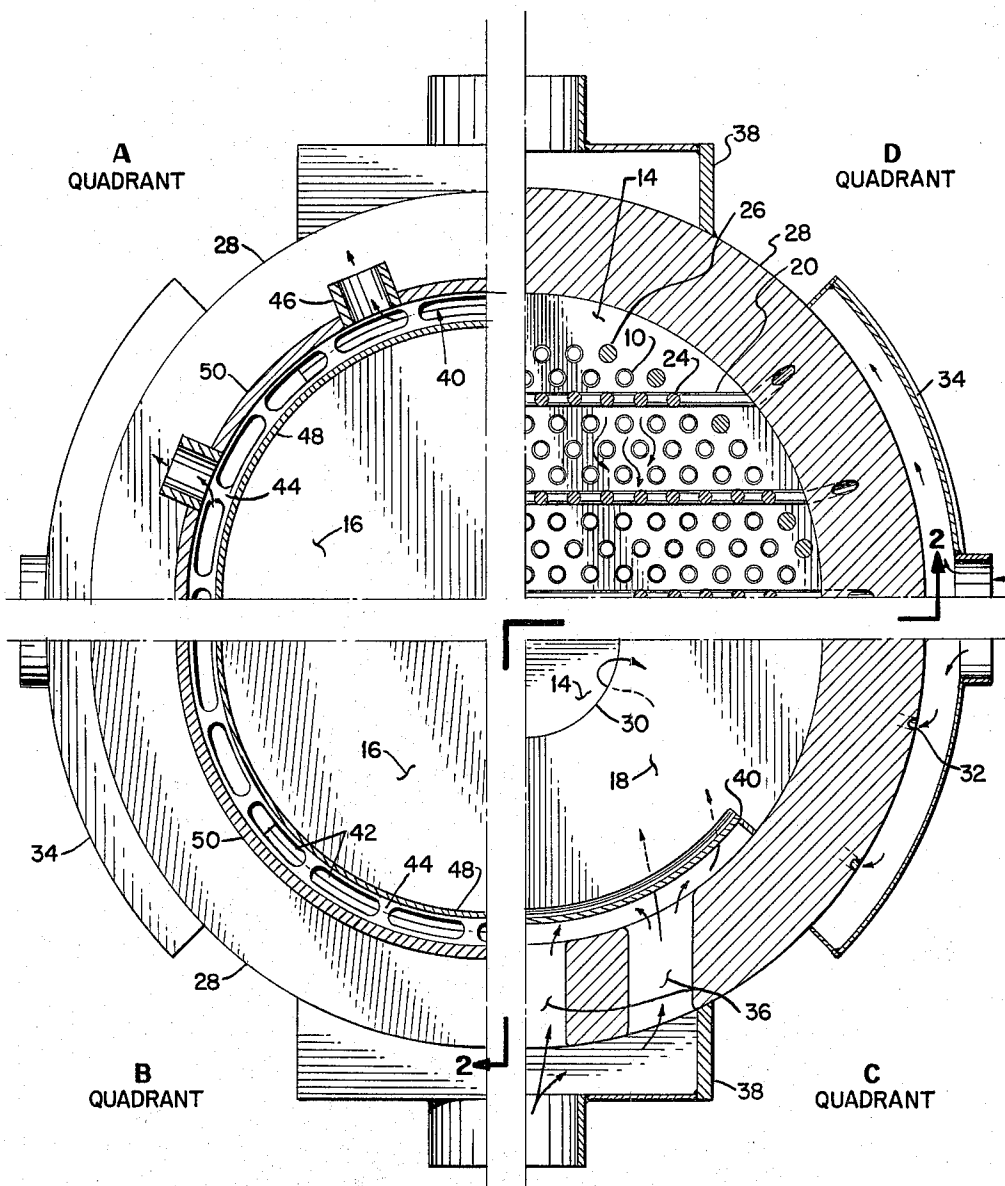


Fig. 1

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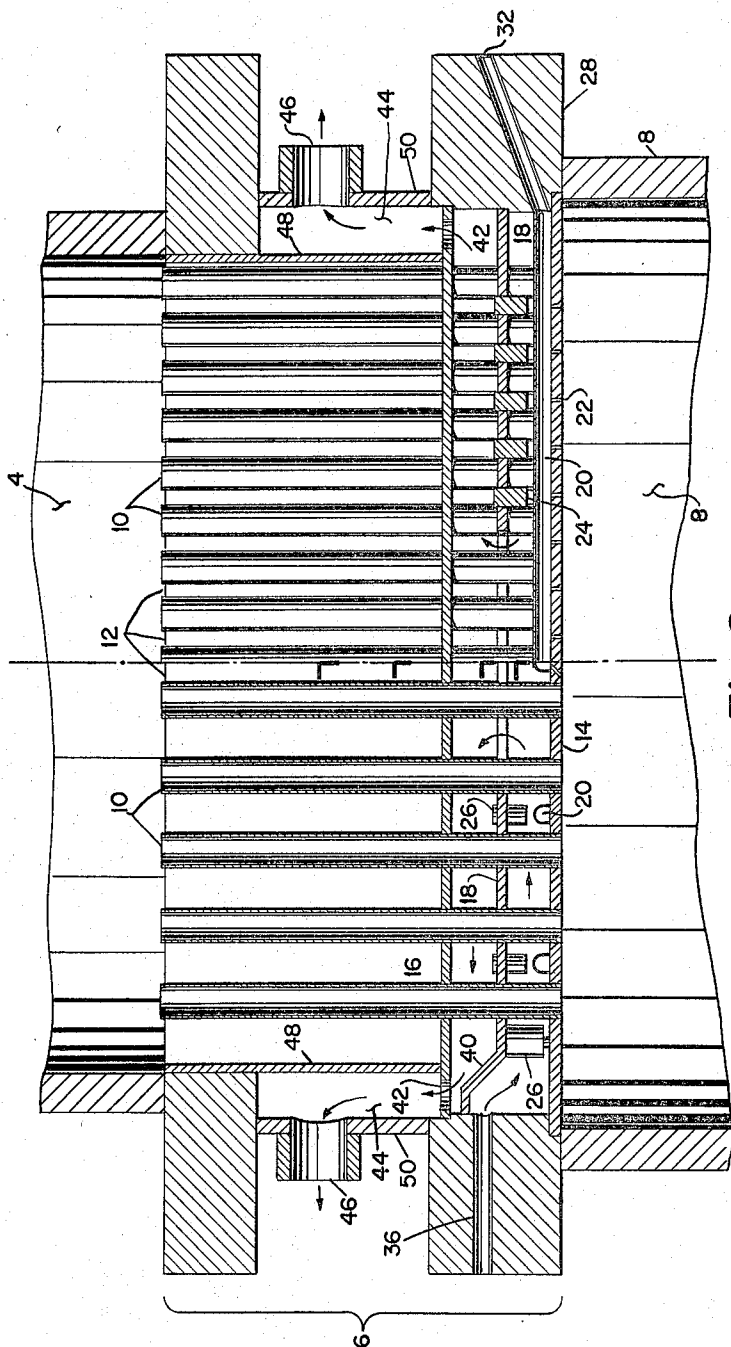


Fig. 2

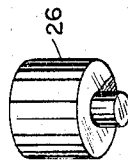


Fig. 4

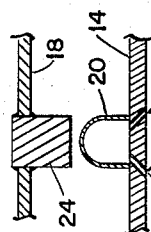


Fig. 3

A —
B —
C —
D —

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HEAT EXCHANGER FOR APPARATUS FOR COMBUSTION OF GASES WITH OXYGEN

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3 Claims. (Cl. 23—277)

This invention relates to improvements in apparatus for the production of unsaturated hydrocarbons by the incomplete oxidation of more saturated hydrocarbons, with oxygen, in a flame reaction, and more particularly relates to improvements in the type of apparatus for the production of such unsaturated hydrocarbons wherein the apparatus includes a mixing chamber for preheated streams of gaseous hydrocarbons and oxygen, a flame chamber into which a plurality of auxiliary streams of oxygen are introduced in order to stabilize the flame which is a source of energy for the reaction, and an intermediate section which may be regarded as a gas-distributor, flame-arrester, connecting the flame chamber and the mixing chamber. Still more particularly the invention relates to improvements in apparatus of the above-described type wherein there is provided in the gas-distributor, flame-arrester, section a plurality of regularly spaced groups of symmetrically arranged tubular channels opening into the mixing chamber and the flame chamber.

According to methods well known in the art, unsaturated hydrocarbons may be produced by the incomplete oxidation of more saturated hydrocarbons, with oxygen, in a flame reaction, the most notable of which is the production of acetylene from methane or higher hydrocarbons. Probably the most widely used method involves the incomplete oxidation of methane with oxygen, by separately preheating methane and oxygen, mixing them as quickly and completely as possible in a suitable mixing chamber, the amount of oxygen used ordinarily being about one-third the stoichiometric amount for complete combustions to carbon dioxide and water, and passing the gas mixture through a gas-distributor, flame-arrester, section leading from the mixing chamber into the flame chamber. The gas-distributor, flame-arrester, section is customarily constituted by a ceramic burner block in which there are regularly spaced, symmetrically-arranged, tubular channels through which the gas mixture passes from the mixing chamber to the flame chamber at a speed generally in excess of that at which flame propagation of the mixture of the hydrocarbon and oxygen will take place.

However, such an arrangement for the incomplete combustion of a hydrocarbon, and particularly methane, with oxygen, has two rather serious drawbacks, the first of which is the formation of relatively large amounts of carbon which are deposited upon the surface of the gas distributor, flame-arrester, section facing the flame chamber, as well as other adjacent surfaces, thus not only diminishing the yield of acetylene, but when formed under the conditions existing in the flame chamber, such deposits adhere very firmly, and must be removed by mechanical means. In such circumstance the face of the gas distributor, flame-arrester, section is sometimes badly damaged and often becomes unfit for further use.

The second of these drawbacks is the matter of providing a stable flame in the flame chamber, i.e., a flame which retains its position in the flame chamber without undue fluctuation either away from or back toward the gas-distributor, flame-arrester, section.

It has been proposed to overcome both difficulties by

the introduction of auxiliary streams of oxygen sufficient to maintain the flame in a relatively fixed position in the flame chamber, such introduction of auxiliary oxygen being made at the periphery of the flame chamber and immediately downstream from the openings of the gas-distributor, flame-arrester, tubes into the flame chamber, and by having that part of the gas-distributor, flame-arrester, section facing the flame chamber in the form of metal conduits surrounding the ends of the tubular channels, in which conduits cooling fluid is circulated, thereby forming a single pass heat exchanger.

While the flame in the flame chamber may be stabilized to some extent in the manner, our experience with such arrangement has demonstrated that there is insufficient stabilization of the flame to provide the desired degree of control of the acetylene-forming reaction.

It has also been proposed to stabilize the flame in the flame chamber by providing a multiplicity of small-bore oxygen ports (orifices) in the metal wall of the heat exchanger facing the flame chamber, the ports being directed at an angle from the vertical such that the streams of oxygen impinge upon some of the streams of the gaseous mixture of oxygen and methane entering the flame chamber through the tubular members. In this proposed arrangement the oxygen supplied to the ports is by way of conduits arranged between groups of the tubular members passing through the cooling chamber of the gas-distributor, flame-arrester, section.

While the flame in the flame chamber may also be stabilized in this manner, and the formation of carbon lessened, we have found that the introduction of auxiliary oxygen provides small localized flame cones of high heat radiation which considerably increases the radiant heat flux in the flame chamber, which radiant heat must be absorbed and dissipated if the flame side of the gas-distributor, flame-arrester, section is to remain intact for any appreciable length of time during operation of the apparatus, whether fabricated of ceramic material or metal. Also, and particularly from the standpoint of commercial production of acetylene from methane and oxygen, we have found that the combination of the use of auxiliary oxygen to stabilize the flame in the flame chamber with the added provision of simple fluid circulating metal conduits surrounding the ends of the tubular channels is totally unsatisfactory because of the very high heat fluxes encountered, which seriously affect the metal surfaces facing the flame chamber, and maintaining the apparatus in satisfactory working condition for any substantial period of time becomes nearly impossible.

During the course of our investigations in the manufacture of unsaturated hydrocarbons, such as acetylene, from gaseous hydrocarbons, such as methane, with oxygen in a flame chamber, and employing a multiplicity of small-bore oxygen ports as described above as a means for providing an auxiliary supply of oxygen to the flame chamber in order to stabilize the flame therein, it was discovered that flame temperatures and radiant heat fluxes were considerably in excess of those heretofore considered normal in the design of apparatus heretofore customarily employed for the purpose. In fact, it was found that heat fluxes of the order of 1,180,000 B.t.u./sq. ft./hr., or about 20 times that accepted as practical in engineering design work, were to be dealt with. In such circumstance, when the surface of the gas-distributor, flame-arrester, section facing the flame chamber is fabricated from a high heat-resistant metal alloy, and is water-cooled, the heat radiated to such metallic surface by the main flame and the auxiliary flames in the flame chamber is not transferred to the water sufficiently rapidly, because of the poor heat conductivity and required thickness of such metals. The result is that there is a large temperature gradient through

the metal and thus high internal stresses are generated within the metal, accompanied by comparatively rapid failure, due to cracking at the metal surface adjacent the flame chamber. Accordingly, it is apparent that, if the surface of the gas-distributor, flame-arrester, section facing the flame chamber is of metallic material, either the metal face must be very thin if fabricated from high temperature-resistant alloys, or the face must be made of a highly heat-conductive metal. However, in order to have a high temperature-resistant alloy conduct the amount of heat encountered, the thickness would necessarily be considerably less than practicable for the standard fabrication techniques and the mechanical stresses involved.

On the other hand, in such environment, it is apparent that metals having much greater heat conductivity than those metals resistant to high temperatures would by ordinary standards be considered as out of the question as materials of construction, since it would be expected that such metals would quickly be destroyed by the high heat flux by virtue of the fact that, due to the amount of heat to be transferred by the metal, a coolant such as water circulated in the heat exchanger would be vaporized and little or no liquid would remain in contact with the metallic surface at the face of the gas distributor, whereby transfer of heat from the metal to the liquid would not take place, but rather the heat transfer would be from metal through vapor to liquid and the good heat-conductive metals would be expected to be very rapidly destroyed.

With the knowledge of the heat flux (q/A) involved in the combustion of methane with oxygen to produce acetylene and with the further knowledge that good heat conductivity would be mandatory for the face of the gas-distributor, flame-arrester, section facing the flame chamber, the problem then faced is one of transferring this large amount of heat through the metal surfaces of the gas-distributor, flame-arrester, section facing the flame chamber, to the metal surfaces internally of the heat exchanger to the coolant.

While it is known that a maximum heat flux for a system operating under atmospheric pressure and natural convection velocity is about 380,000 B.t.u./sq. ft./hr., this is still far short of the heat flux involved in the type of apparatus to which the present invention is directed. It was found that in order to absorb a much greater heat flux and still have the temperature gradient through the metal wall facing the flame chamber at a sufficiently low level for practical commercial operation, three factors were critical at any given pressure under which the coolant is circulated in the heat exchanger; the first is the velocity of the body of coolant across the metal surfaces internally of the heat exchanger, the second, subcooling of the coolant (the temperature below the boiling point of the coolant at the pressure at which it is introduced into the heat exchanger), and third, the geometry of the cooling chamber, which necessarily bears a relationship to the velocity of coolant travelling within the cooling chamber of the heat exchanger.

Of the three factors involved, the subcooling of the coolant is the most easily controlled, and it was found during the course of our investigation that in addition to the gas-distributor tubes passing through the heat exchanger, which tubes necessarily act as deflectors for the coolant material, as do the conduits supplying auxiliary oxygen to the oxygen ports, further coolant deflecting members mounted within the cooling chamber were required and their placement was found to be critical in the sense that such additional coolant deflecting members should form, with the gas distributor tubes and the auxiliary oxygen supply conduits, a plurality of labyrinthine passageways of substantially equal length extending across the cooling chamber from the outer reaches of the cooling chamber to the central portion from which the coolant material is discharged. For example, where the cooling chamber is circular in cross-section, it should be

as nearly radially symmetrical as practicable. By designing the apparatus in such a way that these three conditions are met, it was found that the phenomenon of "nucleate" boiling could be assured in the cooling chamber of the heat exchanger, and that the heat fluxes involved were readily accommodated. In this regard, the term "nucleate" boiling refers to boiling which is initiated at nuclei or tiny centers of active boiling on a metal surface, such nuclei being induced by minute surface cracks or pits or similar imperfections in the metal surface, with the further provision that the minute bubbles of coolant vapor forming at such nuclei are immediately swept away and condensed in the body of coolant, and thereby prevented from coalescing and forming a blanket of vapor in the immediate vicinity in which boiling is taking place.

One of the objects of the present invention is to provide a suitable design of heat exchanger for the absorption and removal of large amounts of radiant heat through nucleate boiling of a coolant in an apparatus for the production of unsaturated hydrocarbons by the incomplete oxidation of more saturated hydrocarbons with oxygen in a flame reaction.

It is a further object of the present invention to provide efficient heat exchange means in such an apparatus where the apparatus makes provision for introducing a plurality of auxiliary streams of oxygen into the flame chamber to stabilize the flame.

These and other objects of the invention will be apparent to those skilled in the art from the description which follows hereinafter, and particularly with respect to the accompanying drawings attached hereto and made a part hereof.

Pursuant to the above objects, the present invention is directed to an improvement in apparatus for the production of unsaturated hydrocarbons by incomplete oxidation of more saturated hydrocarbons with oxygen in a flame reaction, where such apparatus provides for a mixing chamber for said hydrocarbons and oxygen, a flame chamber into which a plurality of auxiliary oxygen streams are introduced to stabilize the position of said flame, and having a gas-distributor, flame-arrester, section interconnecting said chambers, with provision for a plurality of parallel rows of tubular channels opening into said mixing chamber and said flame chamber, such improvement including a double pass shell-and-tube heat exchanger interposed between said mixing chamber and said flame chamber, said heat exchanger having (a) a first metal tube sheet forming one boundary of said flame chamber, (b) an intermediate baffle substantially co-extensive with said first tube sheet and spaced apart therefrom, said baffle having a centrally located perforation therethrough, and (c) a second metal tube sheet spaced apart from said baffle so as to form adjacent fluidly connected cooling chambers, the tubes of said heat exchanger constituting at least a portion of said channels interconnecting said mixing chamber and said flame chamber, (d) means for introducing coolant into one of said cooling chambers, means for withdrawing coolant from the other of said cooling chambers, (e) a plurality of metal conduits mounted on said first tube sheet within the cooling chamber between adjacent rows of said tubular channels, said first tube sheet having orifices therein directed toward the space between the openings of adjacent tubular channels into said flame chamber, said orifices fluidly communicating with said conduits, (f) means for introducing oxygen through said conduits to said orifices, (g) coolant deflecting metallic members mounted within the cooling chamber formed by said first tube sheet and said baffle, so as to form with said tubular channels a plurality of labyrinthine passageways of substantially equal length extending across said cooling chamber to said centrally located perforation in said baffle.

Referring now to the drawings:

FIG. 1 is a composite of sectional plan views of successive quadrants of the cylindrical gas-distributor, flame-arrester, and the metal shell-and-tube heat exchanger, the quadrants being observed at progressively lower levels and indicated by A, B, C, and D, respectively; with the tubular channels removed, for clarity, in quadrants A-C, inclusive;

FIG. 2 is an elevation of two vertical sections made from the geometrical center of FIG. 1 to the lines 2-2 of FIG. 1 and viewed in the direction indicated by the arrows;

FIG. 3 is a vertical section in detail of an oxygen supply conduit and one form of coolant deflecting member above said conduit; and

FIG. 4 is a perspective view of a coolant deflecting member placed between the first tube sheet and the baffle in such a way as to form the labyrinthine passageways.

In the apparatus of the present invention, as shown in detail on the drawings, 4 is the mixing chamber wherein a hydrocarbon and oxygen are mixed together, after being preheated, the gaseous mixture then passing into the gas-distributor, and flame-arrester, section 6 through distributor tubes 10 to flame chamber 8. Tubes 10 through a portion of their length may be surrounded by suitable insulating or refractory material in the spaces 12. The lower portion of the tubes 10 also form a shell-and-tube heat exchanger with member 28, which acts as the shell, lower tube sheet 14, and upper tube sheet 16 which may also act as support for the insulating or refractory material in spaces 12. At least the lower tube sheet of the heat exchanger should be formed of metal having heat transfer properties, preferably in the range from that of ordinary steel to that of copper. A baffle plate 18 is interposed between the upper and lower tube sheets thereby forming a double pass shell-and-tube heat exchanger. Mounted upon the lower tube sheet are metal conduits 20 for carrying the auxiliary supply of oxygen to the orifices 22 which pass through the lower tube sheet 14 and open into conduits 20 and flame chamber 8.

The tubes 10 are preferably arranged in parallel rows in such a manner that their centers fall on a line parallel to a diameter of the heat exchanger, and on a line at an angle of 60° to such diameter, and arranged in groups of three rows of tubes paralleling a diameter of the heat exchanger section, thus providing triangular pitch arrangement to each group of tubes. The oxygen conduits 20 preferably have mounted thereabove metallic coolant deflecting members 24 which are preferably also of good heat conducting metal such as ordinary steel, and positioned so as to be substantially in register with the symmetrical arrangement of the tubular channels 10. In addition, there are provided other metallic coolant deflecting members 26 mounted upon the lower tube sheet 14 and arranged so as to fill out the symmetry of the groups of tubular channels in the outer reaches thereof near the inner wall of shell member 28 of the heat exchanger. By such an arrangement of the coolant deflecting members 24 and 26 in the lower cooling chamber between the tube sheet 14 and the baffle 18, coolant material circulating in the lower cooling chamber is thereby afforded a plurality of generally equidistant labyrinthine paths across the cooling chamber, and uniform flow of coolant material from the periphery of the cooling chamber to the centrally located perforation 30 in baffle plate 18 is assured.

Oxygen is supplied to conduits 20 through tubes 32 passing through shell member 28 from oxygen header 34, shown in FIG. 1. In a preferred embodiment of the apparatus of the present invention the conduits 20 are arranged between adjacent groups of three rows of tubular members 10 with the orifices 22 in lower tube sheet 14 directing streams of oxygen toward the space between adjacent pairs of gas-distributor tubes 10 of

the rows of tubes immediately adjacent the oxygen conduits 20.

Water, which is the preferred coolant, may be introduced into the cooling chamber formed by the lower tube sheet 14, and baffle 18 through water conduits 36, of which there is preferably more than one, the water being supplied through header 38, as shown on FIG. 1, and after passing through conduit 36 a portion 40 of baffle plate 18 may be provided to deflect the water stream downwardly into the lower cooling chamber, or the opening 36 may be so placed in the shell 28 as to be substantially on the same level as the mid-portion of the lower cooling chamber in which case the baffle plate 18 would simply be extended horizontally to the shell of the heat exchanger. After passing through the lower cooling chamber, the cooling water moves upwardly through the perforation 30 centrally located in baffle plate 18 and thence around the tubes 10, through the upper cooling chamber formed by the upper tube sheet 16 and baffle 18, and outwardly through a plurality of ports 42, passageway 44, having an inner wall 48 and outer wall 50, and then through a second series of ports 46 to a collection chamber (not shown), all as indicated by the arrows in FIG. 2.

In the operation of the apparatus of the present invention to produce acetylene from methane and oxygen, initially the coolant material, preferably water, for the shell-and-tube heat exchanger, is introduced through header 38 to openings 36, and thus into the lower cooling chamber of the heat exchanger toward the centrally located opening 30 in baffle 18, and thus into the upper cooling chamber formed between the upper tube sheet 16 and baffle 18, and outwardly through openings 42, passageway 44, and exit ports 46. A preheated mixture of oxygen and methane is introduced into mixing chamber 4, and passes through distributor tubes 10, the rate of flow of the gaseous mixture being such as to be in excess of flame propagation in the flame chamber 8. The mixture passing into flame chamber 8 is ignited by a suitable pilot light (not shown) and oxygen is fed through tubes 32 from header 34, into conduits 20, and through orifices 22 which direct the streams of oxygen between pairs of tubular conduits 10 adjacent the orifices, thus generating auxiliary high-temperature flames in the flame chamber, assuring stabilization of the lower-temperature acetylene-generating flames generated by the mixture of oxygen and methane passing through those distributor tubes not adjacent the auxiliary oxygen orifices 22.

In regard to the coolant material, preferably water, with the heat exchanger having at least the lower tube sheet fabricated of ordinary steel or equally good heat conductive material, the volume rate of flow of the water, and the temperature of the water introduced into the heat exchanger, should be such as to insure substantially uniform nucleate boiling of the water in the lower cooling chamber of the heat exchanger, i.e., the volume rate of flow and the temperature of the water so introduced should be such as to sweep away the minute bubbles of steam as they are formed on the metal surfaces of the heat exchanger, particularly on lower tube sheet 14, and the water should be sufficiently subcooled to insure that the bubbles are absorbed into the body of liquid. In this regard, it has been found specifically that where the gas-distributor, flame-arrester, section is of circular cross-section, the area of the tube sheet exposed to the flames in the chamber is of the order of eight-tenths of one square foot (0.8 sq. ft.), and the water entering the lower cooling chamber is subcooled to a temperature at least 100° F., below its boiling point at the pressure existing in the lower cooling chamber, substantially uniform nucleate boiling is assured if the volume rate of flow is sufficient to provide movement of the body of water at a speed of about 12 to 15 feet per second along the labyrinthine pas-

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sageways formed by the tubes 10, the conduits 20, and deflecting elements 24 and 26 within the lower cooling chamber, as the liquid passes from the outer reaches of the groups of tubes toward the centrally located perforation 30 in baffle plate 18. Further, it has been found that without assuring nucleate boiling substantially uniformly in the lower cooling chamber, by omitting the coolant deflecting members at the periphery of the tube bundle, or otherwise permitting the coolant substantially unequal paths of flow across the lower tube sheet of the cooling chamber, relatively large localized bodies of steam will necessarily be formed, thereby considerably lessening the heat exchange capacity of the lower tube sheet, followed by deterioration of the metal in this portion of the heat exchanger.

It is to be understood that although the invention has been described with specific reference to particular embodiments thereof, it is not to be so limited, since changes and alterations therein may be made which are within the full intended scope of this invention as defined by the appended claims.

What is claimed is:

1. In an apparatus for the production of unsaturated hydrocarbons by incomplete oxidation of more saturated hydrocarbons with oxygen in a flame reaction, such apparatus having a mixing chamber for said hydrocarbons and oxygen, a flame chamber into which a plurality of auxiliary streams of oxygen are introduced to stabilize said flame, and a gas-distributor, flame-arrester, section interconnecting said chambers and having a plurality of regularly spaced groups of symmetrically arranged tubular channels of substantially uniform length and cross-section opening into said mixing chamber and said flame chamber, the improvement which includes:

- (1) a double pass, shell-and-tube heat exchanger interposed between said mixing chamber and said flame chamber, said heat exchanger having a shell surrounding
 - (a) a first metal wall forming one boundary of said flame chamber,
 - (b) an intermediate baffle plate coextensive with said first wall and spaced apart therefrom, said baffle plate having a centrally located perforation therethrough, and
 - (c) a second metal wall spaced apart from said baffle so as to form adjacent fluidly connected cooling chambers, the tubes of said heat exchanger constituting a portion of said tubular channels interconnecting said mixing chamber and said flame chamber,
 - (d) means for introducing coolant into one of cooling chamber means for withdrawing coolant from the other of said chambers,

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(e) a plurality of metal conduits mounted on said first wall of said heat exchanger between adjacent groups of said symmetrically arranged tubular channels, said first wall having orifices therein directed toward the space between the openings of adjacent tubular channels into said flame chamber, said orifices fluidly communicating with said conduits,

(f) means for introducing oxygen through said conduits to said orifices,

(2) coolant deflecting metallic members mounted within the cooling chamber formed by said first wall and said baffle, including

(a) a first group of deflecting members symmetrically positioned above said conduits substantially in register with the symmetrical arrangement of said tubular channels,

(b) and a second group of deflecting members in the chamber bounded by said first wall and said baffle, positioned so as to retain the symmetry of said groups of tubular channels in the outer reaches thereof away from said centrally located perforation in said baffle wall,

whereby coolant circulating in chamber is afforded labyrinthine paths of generally equal length across said chamber.

2. The apparatus of claim 1 wherein said mixing chamber, said flame chamber and said shell-and-tube heat exchanger are coaxially vertically disposed and circular in horizontal cross-section, said tubular channels are arranged in parallel rows such that their centers fall on a line parallel to a diameter of said heat exchanger and on a line at an angle of 60° to such diameter, and said second group of deflecting members are attached to said first wall and said intermediate wall.

3. The apparatus of claim 1 wherein the means for introducing coolant to said heat exchanger comprises two groups of oppositely disposed conduits through said shell opening into the cooling chamber formed by said first wall and said intermediate baffle plate.

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