

Dec. 17, 1957

R. R. GOINS
PRODUCTION OF UNSATURATED HYDROCARBONS
AND APPARATUS THEREFOR

2,816,941

Filed Nov. 27, 1953

3 Sheets-Sheet 1

Fig. 1.

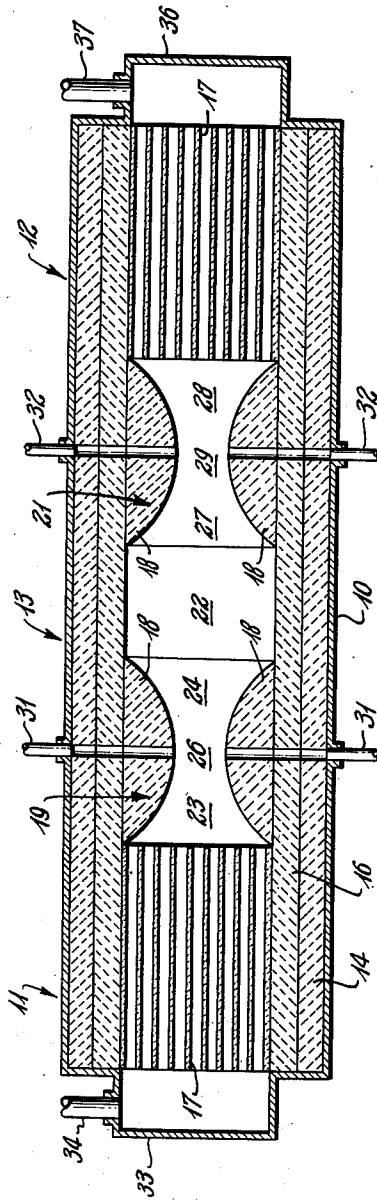
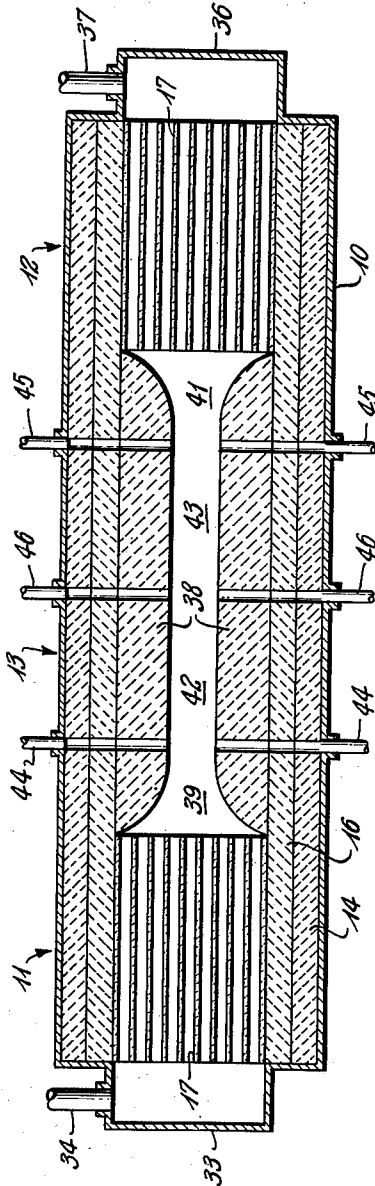


Fig. 2.



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Fig. 3.

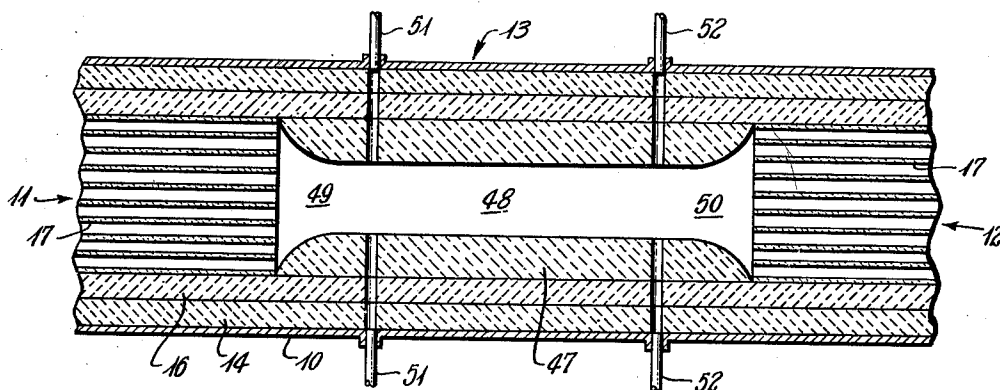
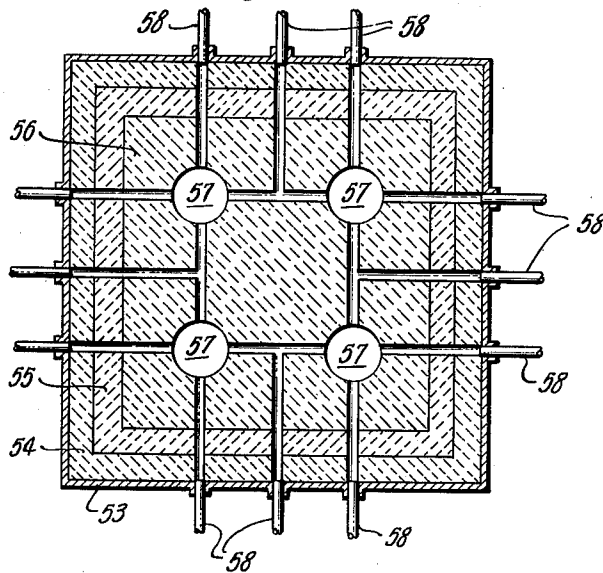


Fig. 4.



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Fig. 5.

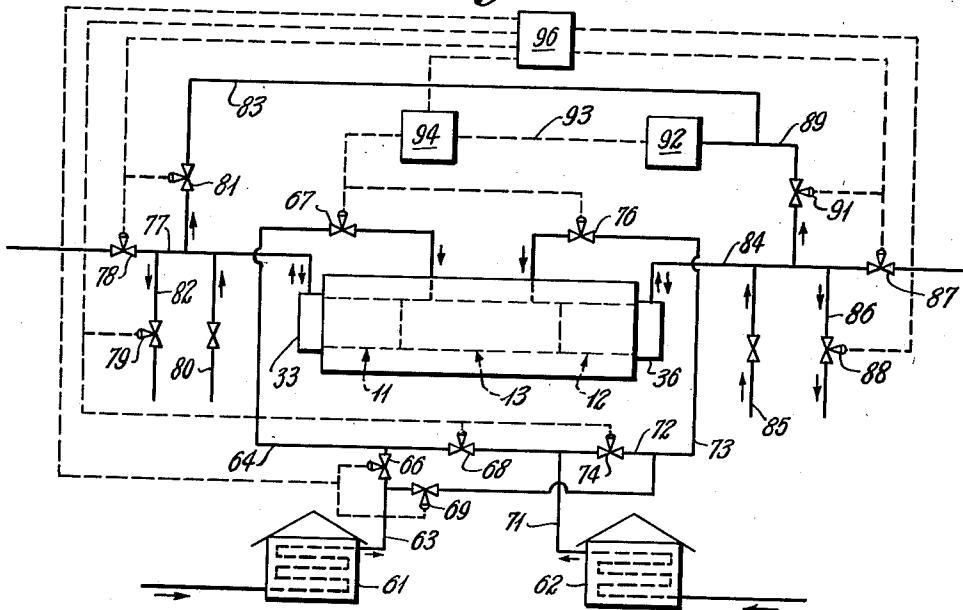
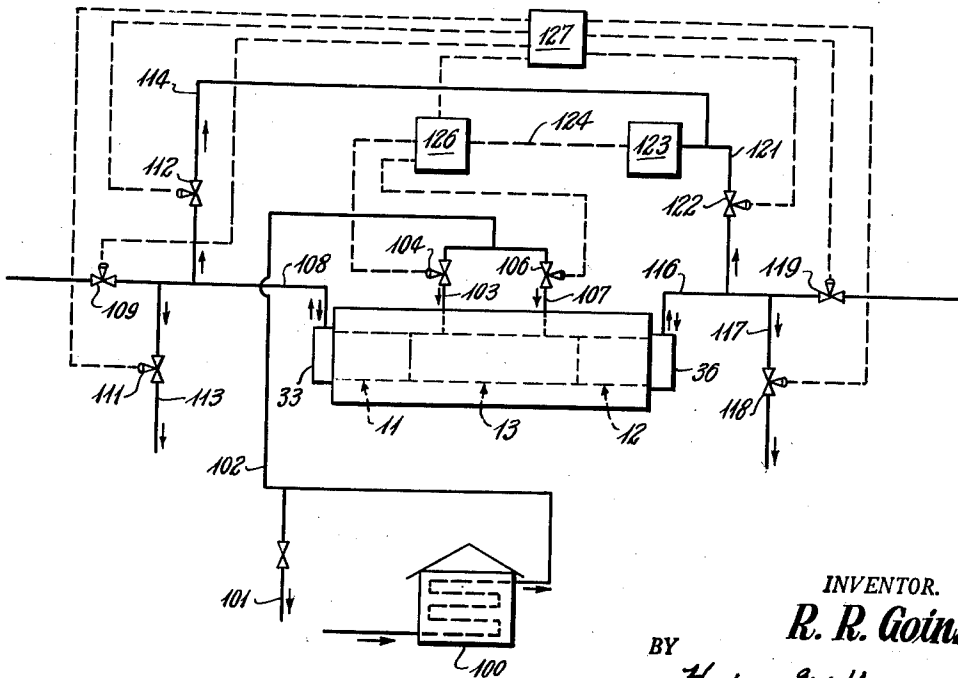


Fig. 6.



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2,816,941

PRODUCTION OF UNSATURATED HYDROCARBONS AND APPARATUS THEREFOR

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Application November 27, 1953, Serial No. 394,686

16 Claims. (Cl. 260—679)

This invention relates to the production of unsaturated hydrocarbons. In one of its more specific aspects, it relates to a process for the production of unsaturated hydrocarbons such as acetylene, ethylene, and mixtures of acetylene and ethylene. In another of its more specific aspects, it relates to a partial oxidation process for the production of unsaturated hydrocarbons. In still another of its more specific aspects, it relates to a precombustion process for the production of unsaturated hydrocarbons. In yet another of its more specific aspects, it relates to novel apparatus adapted for use in the processes of the invention.

During the early years of the petroleum industry, the possibility of producing unsaturated hydrocarbons by the cracking of low boiling hydrocarbons received comparatively little attention. Because of apparatus limitations imposed by the high reaction temperatures involved and the lack of understanding of the best manner of operation, early developments excluded the cracking of low boiling hydrocarbons. Still another deterrent in the development of successful processes was the availability of vast supplies of heavy naphthas which could be cracked by more easily manageable processes to form easily purifiable products in high yield. Recent advancements made in organic chemistry have resulted in such an increased demand for petro-chemical starting materials such as acetylene and ethylene that it is no longer possible to rely on the old sources of supply for these materials. The demand for ethylene has reached such proportions that it cannot be supplied from refinery streams without upsetting the balance in the production of motor and aviation fuels. Furthermore, commercial production of acetylene by reacting calcium carbide with water is too expensive and is limited to amounts far too low to satisfy the demand for acetylene as a chemical synthesis starting material. Accordingly, the development of successful processes for producing unsaturated hydrocarbons by the cracking of low boiling hydrocarbons has in recent years taken on added importance.

Various methods for the pyrolysis of gaseous hydrocarbons have been proposed which involve the use of a variety of heat sources including externally heated tubes, electric heating resistance elements, and spark or electric discharges. The lack of cheap electric power has also drawn attention to other possible methods of heating such as by the combustion of preheated natural gas with preheated compressed air. In such latter processes, the heat may be applied either to the outside of tubes or to a checkerwork heat exchanger in which combustion and pyrolysis take place alternately. It is also well known to the workers in the art that hydrocarbons can be converted into olefins and acetylene by a high temperature heat treatment wherein partial oxidation of the hydrocarbon feed is utilized to supply the endothermic heat of the cracking reactions.

It has been found that the precombustion and partial

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expectations in that the claimed theoretical high product yields are impossible of attainment, or if actual product yields are recorded in a reduction of the process to practice, such yields have been consistently low. The shortcomings of these processes can be attributed at least in part to the improper mixing of the reactants which results in overcracking and undercracking. Improper mixing of the reactant gases also causes a non-uniform heating of the reactant material which results in the development of "hot spots" with consequent failure of the refractory material lining the interior of the reaction chamber. By practicing the processes of this invention in the manner as described hereinafter, it is possible to overcome the aforementioned difficulties while still obtaining a high yield of the desired product.

The following objects will be attained by the various aspects of the invention.

It is an object of the invention to provide an improved precombustion process for the production of unsaturated hydrocarbons.

Another object is to provide an improved partial oxidation process for the production of unsaturated hydrocarbons.

Another object is to provide a process for the production of acetylene.

Another object is to provide a process for the production of ethylene.

Another object is to provide a process for the simultaneous production of both acetylene and ethylene.

Still another object is to provide improved apparatus for use in precombustion and partial oxidation processes for the production of acetylene, ethylene, and mixtures of acetylene and ethylene.

A further object is to provide a dependable method for the control of temperature and reaction time in processes relating to the cracking of low boiling hydrocarbons.

A still further object is to provide apparatus for the production of unsaturated hydrocarbons which is compact, inexpensive to install, and simply and easily constructed.

Still other objects and advantages will be apparent to those skilled in the art from the following description and disclosure.

Broadly speaking, the present invention is concerned with the cracking of low boiling hydrocarbons utilizing apparatus which comprises a pair of regenerative furnaces connected in series by a reactor. The reactor consists essentially of a shell having disposed in a portion thereof a venturi or constricted section or sections. The reactor is further provided with fluid inlet means whereby a gaseous hydrocarbon feed and a fuel, in the case of the precombustion processes, and a gaseous hydrocarbon feed or an oxidant, in the case of the partial oxidation processes, can be introduced thereinto. The regenerative furnaces provide means for preheating the oxidant in the precombustion processes and the hydrocarbon feed or oxidant in the partial oxidation processes, and for quenching the reaction products in both types of processes.

A more complete understanding of the invention may be obtained by reference to the following description and the accompanying drawing, in which:

Figures 1, 2 and 3 are diagrammatic longitudinal sections of different modifications of apparatus for carrying out the invention;

Figure 4 is a cross-sectional view illustrating the employment of multiple reactors;

Figure 5 is a flow diagram of an arrangement of apparatus for controlling the precombustion processes of this invention; and

Figure 6 is a flow diagram of an arrangement of apparatus for controlling the partial oxidation processes of this invention.

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Referring to the drawing and in particular to Figure 1, one modification of the apparatus of the invention is illustrated which comprises a shell 10 having refractory material disposed therein so as to form regenerative furnaces 11 and 12 connected in series by reactor 13. The walls of shell 10 are lined with insulating means including common refractory material 14 and super-refractory material 16. Common refractory materials may include block insulation, insulating firebrick and fire clay brick. Super-refractory materials may include mullite, alumina, zirconia, silicon carbide, magnesium oxide, or any other suitable refractory capable of withstanding the contemplated high temperatures. The regenerative masses 17 within furnaces 11 and 12 may be formed of brick made of super-refractory material and positioned so as to provide passageways therethrough, but in order to reduce the pressure drop through the furnaces, it is preferred to employ refractory material so shaped that a plurality of longitudinal tubes are formed within the furnaces. In the heat exchange sections of the furnaces, i. e., those portions removed from the reactor as contrasted with the hotter parts near the reactor where temperatures are fairly constant, the refractory desirably possesses a high heat conductivity and a low thermal-expansion coefficient in order to avoid cracking and spalling of the refractory which might otherwise result because of the rapid temperature changes occurring during the cycle of operation. A refractory having a high heat conductivity is desirable also in order that the high rate of temperature change which is required during the alternating heating and quenching cycles can be accomplished more efficiently. The alumina tile manufactured by the Aluminum Company of America and the Norton Company exhibit excellent resistance to cracking and spalling, possess the requisite high heat conductivity and low thermal expansion coefficients, and can, therefore, be advantageously used in conjunction with the regenerators.

Reactor 13 has refractory material 18 disposed therein so as to form a pair of constricted or venturi sections 19 and 21 connected by a combustion chamber 22. Super-refractory material similar to that employed in conjunction with regenerative furnaces 11 and 12 can be used to form the constricted or venturi sections 19 and 21. Venturi section 19 comprises substantially truncated conoidal sections 23 and 24 separated by throat section 26 whereas venturi section 21 comprises corresponding truncated conoidal sections 27 and 28 separated by throat section 29. Conoidal sections 23 or 28, respectively, serve as reaction chambers during the reverse or direct cycle of operation, respectively. Fluid inlets 31 and 32 extend through the refractory material and communicate with throat sections 26 and 29 of venturi sections 19 and 21, respectively. The two pairs of fluid inlets provide means for introducing gases laterally into the reactor and are preferably radially-disposed and diametrically-opposed as illustrated. It is also within the scope of the invention to employ a plurality of pairs of opposed inlets disposed around the periphery of shell 10. The fluid inlets can be constructed of refractory material or metal, such as copper or steel, and can be in the nature of jets as disclosed by D. K. MacQueen in copending U. S. application Serial No. 370,296, filed July 27, 1953. A gas introduction and removal means comprising plenum chamber 33 provided with a fluid inlet and outlet conduit 34 is attached to one end of shell 10. The plenum chamber covers the end of regenerative furnace 11 and provides means for evenly distributing the incoming gas over the face of the furnace and assures equal flow of gas throughout the entire furnace. A similar plenum chamber 36 provided with a fluid inlet and outlet conduit 37 is affixed to the other end of shell 10.

Referring to Figure 2, another modification of the apparatus of the invention is shown in which regenerative furnaces 11 and 12 are connected by reactor 13 which is made up of refractory material 38 so as to form an elongated

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gated constricted or venturi section therein. The venturi section comprises two substantially truncated conoidal sections 39 and 41 connected by a throat section, designated by reference numerals 42 and 43. Three sets of fluid inlets 44, 45, and 46 are provided which are of the same construction and disposed similarly to those discussed in conjunction with Figure 1. Fluid inlets 44 and 45 are located at either end of the throat section and at about the beginning of that section while fluid inlets 46 are positioned intermediate the ends of the throat section. In the direct cycle of operation, that portion of the throat section between fluid inlets 44 and 46, designated by reference numeral 42, comprises a combustion chamber while the portion of the throat section designated by reference numeral 43 and conoidal section 41 comprises a reaction chamber. In the reverse cycle of operation, throat section portion 43 is a combustion chamber whereas throat section portion 42 and conoidal section 39 constitute a reaction chamber.

With reference to Figure 3, a further modification of the apparatus of the invention is illustrated which is quite similar to that of Figure 1. Reactor 13 has disposed therein refractory material 47 so as to form an elongated constricted or venturi section comprising a throat section 48 and substantially conoidal sections 49 and 50. Two sets of fluid inlets 51 and 52, similar to those of Figure 1, are provided, inlets 51 being located in throat section 48 downstream, on a direct cycle of operation, from conoidal section 49 while inlets 52 are similarly positioned in the opposite end of the throat section. On a direct cycle of operation, that portion of the throat section between fluid inlets 51 and 52 comprises a combustion chamber while the portion of the throat section downstream from fluid inlets 52 and conoidal section 50 constitute a reaction chamber. The combustion chamber is the same on the reverse cycle while the reaction chamber comprises that portion of the throat section downstream from fluid inlets 51 and conoidal section 49.

Although the apparatus of this invention has been described with reference to a single reactor connecting a pair of regenerative furnaces, it is within the scope of the invention to employ a plurality of such reactors between the regenerators. In Figure 4, which is a cross-sectional view of a multiple arrangement of reactors, shell 53 is lined with insulating means including common refractory material 54 and super-refractory material 55. Super-refractory material 56 is disposed within the shell lining so as to form a plurality of reactors having constricted or venturi sections 57 into which fluid inlets 58 lead. The constricted or venturi sections of the reactors may take the form of any of those previously described in conjunction with Figures 1, 2 and 3. It is evident that multiple arrangements other than the one illustrated can be resorted to which come within the contemplation of the present invention.

The description of the reactors of Figures 1, 2 and 3 as given above applies specifically to their employment in a precombustion process. As will become apparent hereafter, however, the reactors can be adapted for use in partial oxidation processes. Furthermore, while the reactors of Figures 2 and 3 comprise a substantially cylindrical throat section, it is not intended to so limit the invention. Thus, the throat section can take various shapes so as to form, for example, a sinuous or wavy, or a bellows-like passageway through the reactor.

In the practice of the processes of this invention, the placement of the fluid inlets in the reactor constitutes an important aspect of the invention. The reaction temperatures will vary within wide ranges depending upon the specific process involved, and it has been found that the higher the reaction temperature employed in the pyrolysis of gaseous hydrocarbons, the shorter the optimum heating period must be. For example, in the production of acetylene, a very short optimum heating interval is necessary for a maximum yield, and an unduly

extended heating period will result in a low yield of acetylene and the deposition of carbonaceous materials in the reaction chamber. By utilizing the reactor of the present invention, the relationship between reaction temperature and reaction time can be closely correlated. Accordingly, the fluid inlets through which hydrocarbon feed is introduced into the reactor can be positioned therein so that for a given flow rate the hydrocarbon will remain subject to the desired cracking temperature for an optimum interval of time corresponding to that temperature.

In the various processes of this invention, the reaction temperatures will vary from about 1250° to 2700° F. while the reaction times are in the range of about 0.0001 second to about 2 seconds. In general, it can be stated that the reaction times vary inversely with the reaction temperatures, i. e., the higher the reaction temperature the shorter the reaction time. In the case of the production of acetylene, it is important that the reaction be allowed to proceed for only a very short period of time, for otherwise decomposition and polymerization of the acetylene will result with a correspondingly low product yield. Although control over the different processes is accomplished preferably by means other than by temperature control, it is within the scope of the invention to utilize reaction temperatures to control the processes. Accordingly, the temperature ranges required for the various steps of the different processes are discussed hereinafter in order to aid in a better understanding of the invention.

In the practice of the precombustion processes of this invention, the regenerative furnaces are conditioned to preheat the oxidant and quench the effluent gases. Accordingly, on a direct cycle of operation, the inlet refractory temperature of the first regenerative furnace will be initially at a temperature in the approximate range of 250° F. to 650° F. with the oxidant entering at a temperature of about 100° F. During the direct cycle of operation, the inlet refractory temperature of the first regenerator decreases by about 50 to 150° F. Prior to its introduction into the reactor, the fuel can be preheated to above its ignition temperature which will vary in accordance with the specific fuel used. The hydrocarbon feed stock is precracked or preheated to a temperature between about 1000° F. and 1500° F. depending upon the charge stock, the temperature being in the lower end of the range for butane and in the upper end of the range for methane. It is preferred to utilize a precracked hydrocarbon feed in the precombustion processes primarily because of the increased efficiency of operation, resulting from a decrease in the heat requirement for the cracking reaction and the concomitant increase in the amount of feed which can be charged to the reactor. The temperature of the combustion gases resulting from burning the oxidant and fuel is in the approximate range of 2500° F. to 4000° F. Since in the acetylene process the reaction temperature is considerably higher than in either the ethylene process or the process for the production of a mixture of acetylene and ethylene, the combustion gases will generally be at higher temperatures in the acetylene process than in the latter two processes in order to supply the requisite amount of heat for the cracking reaction. By maintaining the ratio of combustion gases to feed stock at a low level, however, combustion gases having temperatures in the upper end of the range can be utilized when producing ethylene or a mixture of acetylene and ethylene.

The reaction temperatures in the precombustion processes of this invention vary in the approximate range of 1250° F. to 2700° F. More specifically, in the acetylene process the reaction temperature is preferably maintained between about 2200° F. and 2700° F., in the process for the production of acetylene and ethylene between about 1700° F. and 2200° F., and in the ethylene process between about 1250° F. and 1700° F. The reaction times for the several processes are in the following approximate

ranges: for acetylene between 0.0001 and 0.2 sec., for a mixture of acetylene and ethylene between 0.01 and 0.2 sec., and for ethylene between 0.01 and 2 sec. The refractory temperatures of the hot ends of the first and second regenerators are from about 100° to 200° F. lower than the corresponding reaction temperature of the particular process being practiced. The quenched gases leave the second regenerator on the direct cycle at a temperature below about 750° F., the refractory temperature at the exit end being initially at a temperature in the approximate range of 200° F. to 500° F. During the direct cycle of operation, the exit refractory temperature of the second regenerator increases by about 50 to 150° F. Substantially the same temperatures are maintained during the reverse cycle of operation as on the direct cycle, it being understood that the function of the first and second regenerative furnaces is now reversed.

In the practice of the partial oxidation processes of this invention, the reaction temperatures and the reaction times for the several processes fall within the temperature and time ranges as specified above with respect to the precombustion processes. Furthermore, the refractory temperatures of the hot and cold ends of the first and second regenerators will be approximately the same as those in the corresponding precombustion process as previously described. When the hydrocarbon feed stock is introduced axially through the regenerator it is not preheated, but for lateral introduction the feed is precracked or preheated to a temperature between about 1100° F. and 1500° F.

In the operation of the apparatus of Figure 1 in a precombustion process for the production of acetylene, during the direct cycle of operation an oxidant is forced by a blower through conduit 34 into plenum chamber 33 from which it passes into and through preheated regenerative furnace 11. The plenum chamber provides for even distribution of the oxidant across the face of the furnace and assures even flow throughout the furnace. It is assumed that the apparatus has been previously brought to operating temperature by utilizing an outside source of preheated gas, and that the hot end of furnace 11 is at a temperature between about 2200° F. and 2700° F.

Oxidants which can be used in the processes of this invention include oxygen, air, oxygen-enriched air, air and steam, oxygen and steam, and oxygen-enriched air and steam. It is also within the contemplation of the invention to utilize hydrogen as a diluent instead of steam. It has been found that the presence of diluents will increase somewhat the percentage conversion of the carbon in the hydrocarbon feed to acetylene, but on the other hand the concentration of acetylene in the effluent will be correspondingly lower because of the diluents. The selection of an oxidant and/or diluent may very well be controlled by the economics of the overall operation. While it may be desirable to utilize oxygen in order to avoid the addition of difficultly separable inert gases, in some cases it may be found to be more economical to separate the product, e. g., acetylene, from the reaction products when using air than to remove oxygen initially from air for use in the process. For an effluent containing the highest concentration of acetylene, oxygen and steam or hydrogen are preferably employed as the oxidant, and in any of the processes of this invention the addition of steam has the benefit of removing any carbon formed on the reactor walls.

The oxidant in passing through regenerator 11 is heated to a temperature at least as high as the ignition temperature of the fuel introduced into throat section 26 of venturi section 19. The heated oxidant thereafter enters venturi section 19 of reactor 13 and passes into throat section 26 thereof. In its passage through the venturi section, the oxidant undergoes a pressure drop with a corresponding increase in linear velocity in this part of the reactor. Simultaneously with the passage of the oxidant axially through venturi section 19, a fuel is introduced laterally into the reactor through fluid inlets 31. As a fuel, which

may be preheated, it is preferred to use hydrogen or a gaseous hydrocarbon having a high hydrogen content. The impingement of oxidant and fuel in the narrow throat area of the venturi section creates a condition of forced turbulence therein, resulting in the rapid and uniform mixing of oxidant and fuel to form a combustible mixture. The combustible mixture so formed passes into combustion chamber 22 where it burns forming combustion products at a temperature in the approximate range of 2500° F. to 4000° F., depending upon the amount of oxidant and the amount of fuel introduced through fluid inlets 31. The combustion products flow from combustion chamber 22 into throat section 29 where they meet the hydrocarbon feed being introduced through fluid inlets 32.

In the practice of the processes of this invention a wide variety of hydrocarbon feed stocks can be used. Those which can be suitably used include methane, ethane, propane, butane and mixtures of these hydrocarbons and/or their corresponding olefins. It is to be understood, however, that any vaporizable or gaseous hydrocarbon can be advantageously employed as the feed.

The impingement of hydrocarbon feed and combustion gases in the narrow throat area of venturi section 21 creates a highly turbulent condition therein, the forced turbulence resulting in a rapid and uniform mixing of the feed and combustion gases, thereby raising the hydrocarbon feed to the desired high reaction temperature. The cracking reaction continues in reaction chamber 28 at a high acetylene-forming temperature in the approximate range of 2200° F. to 2700° F. for a time interval in the range of about 0.2 to .0001 second depending upon the rate of flow of reactants and the length of the reaction chamber as defined by conoidal section 28. The gaseous effluent from the reaction chamber passes immediately into regenerative furnace 12, which has been previously cooled by passage of oxidant therethrough, for rapid quenching to a temperature in the range of about 200° F. to about 600° F. Thereafter, the effluent can be passed from plenum chamber 36 through outlet conduit 37 to quenching means, not shown, for further cooling, and thence to means for recovery of the acetylene as by absorption or fractionation.

When the direct cycle of operation has continued for a period of from about one to two minutes, the flow of oxidant to regenerative furnace 11, the flow of fuel through fluid inlets 31, and the flow of feed through fluid inlets 32 are shut off. The reverse cycle of operation is then commenced by forcing oxidant into plenum chamber 36 and thence through furnace 12 by means of a blower, not shown. Thereafter, the reverse cycle proceeds as described in relation to the direct cycle of operation except that fuel is now introduced through fluid inlets 32 while the hydrocarbon feed is passed into the reactor through fluid inlets 31.

In carrying out the precombustion process for the production of acetylene in the apparatus of Figure 2, the oxidant is heated in its passage through regenerator 11 to a temperature at least as high as the ignition temperature of the fuel being introduced into the reactor through fluid inlets 44. The heated oxidant on entering the throat section of the venturi section encounters the fuel being introduced through fluid inlets 44. The oxidant and fuel meeting in the narrow throat section create a state of high turbulence therein with the result that oxidant and fuel are rapidly and uniformly mixed to form a combustible mixture. The combustible mixture burns in combustion chamber 42, forming products at temperatures in the approximate temperature range of 2500° F. to 4000° F. The combustion gases continue to flow through the throat section at a high velocity and meet the gaseous hydrocarbon feed being introduced through fluid inlets 46. The impingement of hydrocarbon feed and combustion gases in the narrow throat section creates a highly turbulent condition therein, resulting in a rapid and uniform mixing of the reactants and raising the tem-

perature of the feed to the desired high reaction temperature in the approximate range of 2200° F. to 2700° F. Residence time in the reaction chamber comprising throat section 43 and conoidal section 41, as described in conjunction with Figure 1, is in the range of about 0.2 to .0001 second. The gaseous effluents from the reaction chamber are then passed into regenerative furnace 12, and the direct cycle of operation proceeds as described in relation to Figure 1.

When the direct cycle of operation has continued for a period of from about one to two minutes, the flow of oxidant to furnace 11 and the flow of fuel through fluid inlets 44 are terminated. The reverse cycle of operation is then commenced by forcing oxidant through furnace 12. Thereafter, the reverse cycle of operation proceeds as described in conjunction with the direct cycle except that the fuel is now introduced through fluid inlets 45 instead of inlets 44.

In carrying out the acetylene process in the apparatus of Figure 3, the manner of operation except for the introduction of the fuel and feed is substantially the same as that described in relation to Figure 2. During the direct cycle of operation, fuel is introduced into the reactor through fluid inlets 51 while the hydrocarbon feed is passed into the reactor through fluid inlets 52. The burning of the combustible mixture occurs in combustion chamber 48 while the cracking reaction takes place in the venturi section downstream from fluid inlets 52. During the reverse cycle of operation, fuel is injected through inlets 52 while the feed is introduced through inlets 51. The burning of the combustible mixture takes place in the same combustion chamber, but the cracking reaction occurs in the venturi section downstream from inlets 51.

When a multiple arrangement of reactors is employed as illustrated in Figure 4, the conduct of the acetylene process proceeds essentially as described in relation to Figures 1, 2 or 3, depending upon the specific reactor used. By the employment of a multiple arrangement, an increased capacity of operation is obtainable with a minimum outlay in equipment cost.

In carrying out the above described precombustion process for the production of acetylene, it is within the scope of the invention to introduce an excess of oxidant into the reactor. By operating in this manner, a part of the hydrocarbon feed is burned with the result that a combination partial oxidation and precombustion reaction takes place in the reaction zone. The amount of combustion gases required to crack the hydrocarbon feed is thereby cut down which will permit operation at lower temperatures in the combustion zone.

While in the practice of the processes of this invention, the temperatures for the various steps will fall within the ranges as outlined above, it has been found that the measurement of high temperatures in gaseous reactions of short durations are not at all times accurate nor dependable. Accordingly, in the preferred method of control reaction temperatures are not utilized to control the processes, but rather control is based on depth of cracking which is proportional to both reaction temperature and reaction time. As the acetylene process operates at the most difficultly measurable conditions, i. e., extremely high temperatures and extremely low reaction time, and involve all the variables to be encountered in the various processes of this invention, the manner of controlling the precombustion process for the production of acetylene will now be discussed.

Since the first regenerative furnace is at its maximum heat content at the beginning of the direct cycle of operation, the oxidant is heated to a higher temperature at the beginning of the cycle than at the end of the cycle. This condition has the effect of decreasing the temperature of the combustion gases which contact the hydrocarbon. As the cycle progresses, therefore, the cracking reaction will be carried on at progressively lower temper-

atures. Furthermore, as the hot effluent gases contact the refractories of the second regenerative furnace, the refractories are heated, thus allowing the cracking reaction, as the cycle progresses, to progressively creep farther into the furnace. This condition has the effect of increasing the size of the reaction zone and results in a progressive increase in the reaction time during the cycle. While excellent results can be obtained in the acetylene process even with the aforementioned variables operating, for optimum results it is necessary to compensate for the reduced oxidant temperature, for the additional reaction time, and for the decreased reaction temperature, all of which conditions occur as each cycle of operation progresses. Accordingly, in a preferred method of operation, the temperature of the combustion gases is maintained substantially constant by progressively increasing the flow of oxidant and fuel or by the addition of varying amounts of diluents during the cycle of operation. Furthermore, by gradually increasing the feed during the cycle, the tendency of the reaction zone to creep into the regenerator is compensated for because with the resulting lower temperatures a longer reaction time can be tolerated. The increased flow rate also tends to shorten the reaction time which compensates for the unavoidable increase in the size of the reaction zone.

A study of the reaction products of the precombustion process for the production of acetylene indicates that a plot of the acetylene content of the effluent gases at a given temperature against reaction time passes through a maximum reaction time and that a given acetylene content other than the maximum corresponds to two different reaction times. For control purposes, therefore, acetylene content is limited to qualitative indications as to whether or not the process is operating properly. It has been found, however, that other products, which will be designated as key products and which are present in the effluent gases, not only indicate whether or not the process is operating properly but additionally indicate whether the depth of cracking is too deep or too shallow. Accordingly, in the acetylene process, ethylene can serve as the key product since the ethylene content of the effluent indicates the depth of cracking, and in conjunction with acetylene content can be used to control the process.

The acetylene and ethylene content of the reaction products is determined by infra-red spectrometry, mass spectrometry, refractive indexes or other well-known analytical methods. It is preferred to utilize an instrument which produces an electrical current proportional to the concentration of acetylene and ethylene in which case the current can be used to control the operation of the process equipment. Accordingly, if cracking is too shallow as indicated by low acetylene content and high ethylene content in the effluent gases, the hydrocarbon feed can be decreased or the combustion gases can be increased in order to obtain an optimum acetylene yield. If cracking is too deep as indicated by low acetylene content and low ethylene content in the effluent gases, the combustion gases can be decreased, or the feed rate can be increased. In general, however, it is preferred to decrease the feed when cracking is too shallow and to decrease combustion gases if cracking is too deep. By analyzing a portion of the quenched effluent gases so as to determine the concentration of the key product ethylene and the concentration of the desired product acetylene, the amount of oxidant, fuel, and/or hydrocarbon feed introduced into the reactor can be controlled so as to ensure that a high product yield is at all times being obtained.

Figure 5 illustrates diagrammatically an arrangement of apparatus utilizing the reactor of Figure 1 whereby the desired control over the precombustion process for the production of acetylene can be effected. Fuel to the reactor is heated by passing same through heater 61 while heater 62 serves to heat the hydrocarbon feed. It is to

be understood that it is not necessary to preheat the fuel in which case heater 61 can be omitted. On a direct cycle of operation, fuel passes from heater 61 to reactor 12 through lines 63 and 64, valves 66 and 67 being open and valves 68 and 69 being closed. Hydrocarbon feed is passed from heater 62 to reactor 12 through lines 71, 72 and 73, valves 74 and 76 being in an open position. Oxidant is passed into regenerative furnace 11 through line 77, valve 78 being open, valves 79 and 81 in lines 82 and 83, respectively, being closed. Line 80 provides means for introducing a diluent such as steam or hydrogen into the reactor along with the oxidant. The reaction proceeds as described supra, the product containing effluent leaving regenerative furnace 12 through line 84 and thereafter passing to an acetylene recovery system, not shown, through line 86, valve 87 being closed and valve 88 being open.

A sample of the effluent stream is continuously removed through line 89, valve 91 being in an open position, and passed to an infra-red analyzer 92 capable of giving a continuous determination of the concentration of acetylene and a key product such as ethylene. The output of analyzer 92 is passed through electrical leads 93 to controller 94 which is operatively connected to valves 67 and 76. The signals produced by analyzer 92 are indicative of the concentration of acetylene and the key product ethylene, and controller 94 is adapted to control valves 67 or 76 on a direct cycle of operation so as to vary the amount of fuel or hydrocarbon feed entering the reactor. In this manner the amount of fuel and hydrocarbon feed introduced into the reactor is continuously controlled so as to ensure that a predetermined amount of acetylene and the key product ethylene is present in the effluent stream. Furthermore, by controlling the process in this manner the reaction time and temperature required for a high acetylene yield are concomitantly obtained.

The direct cycle of operation continues for a period of from about one to two minutes after which period timer 96 operates to effect the change-over to the reverse cycle of operation. Accordingly, the timer operates to close the valves which were open and to open the valves which were closed on the direct cycle of operation as described above. The fuel now enters the reactor through line 73 while the hydrocarbon feed is introduced through line 64. Oxidant is charged to regenerator 12 through line 84, and the effluent is removed from regenerator 11 through line 77 and passed by line 82 to the acetylene recovery system. A diluent as on the direct cycle of operation can be added to the oxidant through line 85. A sample from the effluent stream is passed to infra-red analyzer 92 through line 83, and the desired control is effected as on the direct cycle of operation. Timer 96 is operatively connected to controller 94 as well as to the several valves in order to reverse the control from valve 67 to valve 76 as the cycle changes, or vice versa depending on whether the fuel or the hydrocarbon feed to the reactor is being varied.

In illustrating and describing the method for controlling the precombustion process for the production of acetylene, means have not been shown for progressively increasing the flow of oxidant, fuel and hydrocarbon feed during a cycle of operation so as to compensate for reduced oxidant temperature, for additional reaction time and for decreased reaction temperature. As previously discussed, excellent results can be obtained even with the aforementioned variables operating, but it is to be understood that additional control means can be provided to compensate for these variables.

The precombustion processes for the production of ethylene and mixtures of acetylene and ethylene are conducted essentially in the same manner utilizing the same steps as described above in conjunction with the preparation of acetylene. Since the reaction temperatures and reaction times, as discussed hereinbefore, are considerably different from those utilized in the acetylene process, it

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becomes necessary to adjust the amount of reactants passed into the reactor so as to control the cracking reaction. In order to obtain longer reaction times, it may be found necessary to vary the operating conditions of the acetylene process by decreasing the rate of flow of the axial gas or by changing the length of the reaction chamber by relocating the position of the fluid inlets.

Control of the precombustion processes for the production of ethylene and mixtures of acetylene and ethylene is effected essentially in the same manner as outlined above for the production of acetylene. Compensation for reduced oxidant temperature, for the additional reaction time and for the decreased reaction temperature can be made as previously described, or the processes can be carried out with good results without taking these variables into account. Overall control is obtained as in the acetylene process by analyzing the effluent gases for a key product and varying the oxidant, fuel, and/or hydrocarbon feed so as to obtain a high product yield. In the case of either process, ethylene can be taken as the key product. The concentration of the ethylene in the effluent gases will indicate the depth of cracking, and the reactants can be automatically and continuously varied in accordance therewith.

In the partial oxidation process for the production of acetylene, the hydrocarbon feed undergoes an incomplete combustion and thereby supplies the heat of reaction for cracking the remainder of the hydrocarbons. It becomes unnecessary, therefore, to make provision for introduction of a fuel into the reactor, and accordingly the conduct of the process is somewhat simplified. In carrying out the partial oxidation process, the apparatus of Figure 3 comprising an elongated venturi section with two sets of fluid inlets can be advantageously employed, and the acetylene process will, therefore, be described in conjunction therewith.

During the direct cycle of operation, the hydrocarbon feed is passed into and through regenerative furnace 11 of Figure 3. It is assumed that the apparatus has been previously brought to operating temperature by utilizing an outside source of preheated gas, and that the hot end of furnace 11 is at a temperature between about 2000° F. to 2500° F. In passing through regenerator 11, the hydrocarbon feed is precracked or heated to a temperature about 100° F. to 200° F. lower than the hot end of furnace 11. The precracked or heated hydrocarbon feed thereafter enters throat section 48 of the venturi section where it encounters the preheated oxidant being introduced through fluid inlets 51. The impingement of oxidant and feed in the narrow throat area of the venturi section creates a condition of extreme turbulence therein with the result that oxidant and feed are rapidly and uniformly mixed. It is also within the contemplation of the invention to introduce the oxidant axially in which case the hydrocarbon feed is precracked or preheated prior to being passed laterally into the reactor. The combustible mixture so formed immediately burns, the hydrocarbon undergoing an incomplete combustion. Since the partial oxidation reaction is exothermic, the temperature of that part of the venturi section downstream from fluid inlets 51, which may be termed the reaction chamber, is rapidly raised to an acetylene forming temperature in the approximate range of 2200° F. to 2700° F. The remainder of the hydrocarbon, not converted in the partial oxidation reaction, undergoes a cracking reaction in the reaction chamber forming acetylene in high yield. The gaseous effluent from the reaction chamber passes immediately into regenerative furnace 12, which has been previously cooled by passage of oxidant therethrough, for rapid quenching to a temperature in the range of about 200° F. to about 600° F. Thereafter, the effluent can be passed to quenching means, not shown, for further cooling, and thence to means for recovery of the acetylene as by absorption or fractionation.

When the direct cycle of operation has continued for

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a period of from about one to two minutes, the flow of hydrocarbon feed to regenerative furnace 11 and the flow of oxidant through fluid inlets 51 are terminated. The reverse cycle of operation is then commenced by passing the hydrocarbon feed into and through furnace 12. Thereafter, the reverse cycle of operation proceeds as described for the direct cycle except that oxidant is now introduced into the reactor through fluid inlets 52.

The partial oxidation processes for the production of ethylene and mixtures of acetylene and ethylene are carried out in the same manner employing the same steps as described in relation to the preparation of acetylene. Since the reaction temperatures and reaction times are considerably different from those utilized in the acetylene process, it becomes necessary to adjust the amount of oxidant passed into the reactor so as to control the cracking reaction. In order to obtain longer reaction times, it may be found necessary to further vary the operating conditions of the acetylene process by decreasing the rate of flow of the oxidant or by increasing the length of the reaction chamber.

In the partial oxidation processes for the production of acetylene, ethylene and mixtures of acetylene and ethylene, the desired control is obtained in essentially the same manner as in the corresponding precombustion processes. In the control of the processes, by varying the ratio of oxidant to feed, more or less of the partial oxidation reaction is brought about which automatically limits the temperature of the cracking process. By analyzing a portion of the quenched effluent gases so as to determine the concentration of a key component such as ethylene, the ratio of oxidant to feed can be controlled so as to ensure that a predetermined amount of the key product is at all times present in the effluent. In this manner sensitive control over the cracking operation can be maintained without resort to reaction temperature and time measurements. It is also within the scope of the present invention to control both the precombustion and partial oxidation processes by varying the amount of diluents, such as steam or hydrogen, supplied to the reactor with the oxidant.

Figure 6 illustrates diagrammatically an arrangement of apparatus utilizing the reactor of Figure 3 whereby the desired control over the partial oxidation process for the production of acetylene can be accomplished. Oxidant to reactor 13 is heated by passing same through heater 100. On a direct cycle of operation, oxidant passes from heater 100 through lines 102 and 103, valve 104 in line 103 being open and valve 106 in line 107 being closed. Line 101 connected to line 102 provides means for introducing a diluent such as steam or hydrogen into the system. Hydrocarbon feed is passed into regenerative furnace 11 through line 108, valve 109 being open and valves 111 and 112 in lines 113 and 114, respectively, being closed. The partial oxidation reaction proceeds as described previously, the product containing effluent leaving regenerative furnace 12 through line 116 and thereafter passing to an acetylene recovery system, not shown, through line 117, valve 118 being open and valve 119 being closed.

A sample of the effluent stream is continuously removed through line 121, valve 122 being in an open position, and passed to infra-red analyzer 123 capable of giving a continuous determination of the concentration of acetylene and a key product such as ethylene. The output signal of analyzer 123 is passed through electrical leads 124 to controller 126 which is operatively connected to valves 104 and 106. The signals produced by analyzer 123 are indicative of the concentration of acetylene and the key product ethylene, and controller 126 is adapted to control valve 104 on a direct cycle of operation so as to vary the amount of oxidant entering reactor 13 through line 103. In this manner the amount of oxidant introduced into the reactor is continuously varied so as to ensure that a predetermined amount of acetylene and the key product

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ethylene is present in the effluent stream. Furthermore, by controlling the process in this manner the reaction time and temperature for a high acetylene yield are concomitantly obtained.

The direct cycle of operation continues for a period of from about one to two minutes after which period timer 126 operates to bring about the change-over to the reverse cycle of operation. Accordingly, the timer functions to close the valves which were open and to open the valves which were closed on the direct cycle of operation. The hydrocarbon feed now enters regenerative furnace 12 through line 116. Oxidant is charged to reactor 13 by line 107, and the effluent is removed from regenerator 11 through line 108 and passed by line 113 to the acetylene recovery system. A sample from the effluent stream is passed to infrared analyzer 123 through line 114, and the desired control is carried out similarly as on the direct cycle of operation through the operation of controller 126 operatively connected to valve 106. Timer 127 is operatively connected to controller 126 as well as to the several valves in order to reverse the control from valve 104 to valve 106 or vice versa as the cycles of operation change.

It is also within the contemplation of the present invention to utilize the described apparatus in a process for the production of aromatics such as benzene and toluene. In such a process, the reactor is operated to obtain an effluent rich in olefins. The gaseous olefins after separation from the reaction product are compressed and introduced into a soaking chamber where they are subjected to a high pressure and temperature. The polymerization products formed in the soaking chamber are thereafter quenched, and the tar removed from the cooled products. The tar-free hydrocarbon is then introduced into a product separation means comprising coolers, separators, distillation equipment, storage tanks, and the like which can be used to effect a separation of the various selected product fractions such as benzene, toluene and/or heavier aromatic hydrocarbon fractions.

It will be apparent that by practicing the various processes of this invention in the manner described, it is possible to control the severity of the cracking reaction within narrow limits. The importance of effective control is emphasized by the fact that overcracking increases the formation of secondary products which form coke and tars. And furthermore, in the case of undercracking, a part of the hydrocarbon feed passes off with the cracked gases, resulting in a low yield per pass. Another advantage of the present invention lies in the variety of feed stocks which can be treated to prepare acetylene or olefins. Also because of the design of the apparatus with a reactor in line with two regenerators, it is possible to obtain high velocity flow rates throughout which result in reaction times measured in milliseconds. This latter feature of the invention becomes important in the production of acetylene where extremely short reaction times are especially desirable. Still again, by utilizing apparatus of the type described, a rapid and uniform mixing of fluids is made possible while at the same time maintaining a high velocity flow of fluids through the reactor. Thus, the possibility of the development of "hot-spots" with resulting apparatus failure is substantially eliminated, and the formation of carbonaceous materials is materially reduced. Furthermore, because of the rapid fluid velocities involved and the rapid mixing of fluids attained, the apparatus of this invention can be of comparatively simple construction and of small size while still having a large fluid throughput capacity.

Except when changing from a direct to a reverse cycle of operation or vice versa, the processes of this invention are continuous, and control devices can be employed and installed to effect the necessary cyclic operation. Furthermore, many additional pieces of equipment, such as valves, pipes, headers, blowers, heat exchangers, absorbers, strippers, and the like, have been omitted from

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the drawing for the sake of clarity and may be installed by anyone skilled in the art.

As will be evident to those skilled in the art, various modifications of this invention can be made or followed without departing from the spirit of the disclosure.

I claim:

1. Apparatus for the production of unsaturated hydrocarbons which comprises, in combination, a reactor having a constricted passageway therethrough the ends of said passageway having a larger cross-sectional area than intermediate portions thereof; a regenerative furnace connected to each end of said passageway; at least two spaced apart sets of fluid inlet means, said means of each set being oppositely positioned in and communicating with said passageway of said reactor and each of said sets of fluid inlet means being independently adjustable; and fluid inlet and withdrawal means attached to the outer end of each of said regenerative furnaces.

2. The apparatus of claim 1 in which each of said fluid inlet and withdrawal means comprises a plenum chamber encompassing the outer end of each of said regenerative furnaces and having a fluid conduit attached thereto.

3. The apparatus of claim 2 in which a plurality of said reactors is positioned between said regenerative furnaces.

4. Apparatus for the production of unsaturated hydrocarbons which comprises, in combination, a first and a second regenerator, each having a plurality of passages therethrough formed of refractory material; a reactor comprising a shell connected between said first regenerator and said second regenerator; a first venturi section in said shell adjacent the inner end of said first regenerator; a second venturi section in said shell adjacent the inner end of said second regenerator; a combustion chamber in said shell between said first and second venturi sections; a plurality of first fluid inlet means positioned in said shell at about the throat of said first venturi section; a plurality of second fluid inlet means positioned in said shell at about the throat of said second venturi section, said first and second inlet means being independently adjustable; and fluid conduit means attached to the outer end of each of said regenerators.

5. Apparatus for the production of unsaturated hydrocarbons which comprises, in combination, a first and a second regenerator, each having a plurality of passages therethrough formed of refractory material; a reactor comprising an elongated shell connected between said first regenerator and said second regenerator; an elongated venturi section in said shell, said section comprising a pair of truncated conoidal sections having their small ends connected by an elongated throat section; a first set of a plurality of radially-disposed, diametrically-opposed fluid inlet means positioned in said shell at about the beginning of one end of said throat section; a second set of a plurality of radially-disposed, diametrically-opposed fluid inlet means positioned in said shell at about the beginning of the opposite end of said throat section, said first and second sets of fluid inlet means being independently adjustable; a third set of a plurality of radially-disposed, diametrically-opposed fluid inlet means positioned in said shell intermediate the ends of said throat section; and fluid conduit means attached to the outer end of each of said regenerators.

6. Apparatus for the production of unsaturated hydrocarbons which comprises, in combination, a first and second regenerator, each having a plurality of passages therethrough formed of refractory material; a reactor comprising an elongated shell connected between said first regenerator and said second regenerator; an elongated venturi section in said shell, said section comprising a pair of truncated conoidal sections having their small ends connected by an elongated throat section; a first set of a plurality of radially-disposed, diametrically-opposed fluid inlet means positioned in said shell at a

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point substantially inwardly from one end of said throat section; a second set of a plurality of radially-disposed, diametrically-opposed fluid inlet means positioned in said shell at a point substantially inwardly from the opposite end of said throat section, said first and second sets of fluid inlet means being independently adjustable; and fluid conduit means attached to the outer end of each of said regenerators.

7. A process for the production of acetylene which comprises heating a stream of oxidant by passing the same through a first regenerator; passing the heated oxidant into an elongated reactor; increasing the velocity of said heated oxidant in said reactor; simultaneously introducing a plurality of lateral streams of fuel into the accelerated stream of oxidant; rapidly and uniformly mixing the oxidant and fuel so as to form a combustible mixture; burning said combustible mixture in a combustion zone; passing a stream of combustion products from said combustion zone into a reaction zone; simultaneously therewith introducing a plurality of lateral streams of a gaseous hydrocarbon feed into said stream of combustion products; rapidly and uniformly mixing said combustion products and said hydrocarbon feed in said reaction zone; utilizing the heat of said combustion products to crack said hydrocarbon feed; measuring the concentration of a key product contained in the product stream removed from said reaction zone; varying the amount of reactants introduced into said reactor so as to maintain the concentration of said key product at a predetermined value, thereby obtaining a high yield of acetylene; passing the resulting reaction products into a second regenerator for rapid quenching to a temperature at which said acetylene is stable; terminating the supply of oxidant to said first regenerator; introducing a stream of oxidant into said second regenerator; and continuing the steps of the process as enumerated hereinabove utilizing said second regenerator to heat said oxidant and said first regenerator to quench said reaction products.

8. A process for the production of ethylene which comprises heating a stream of oxidant by passing the same through a first regenerator; passing the heated oxidant into an elongated reactor; increasing the velocity of said heated oxidant in said reactor; simultaneously introducing a plurality of lateral streams of fuel into the accelerated stream of oxidant; rapidly and uniformly mixing the oxidant and fuel so as to form a combustible mixture; burning said combustible mixture in a combustion zone; passing a stream of combustion products from said combustion zone into a reaction zone; simultaneously therewith introducing a plurality of lateral streams of a gaseous hydrocarbon feed into said stream of combustion products; rapidly and uniformly mixing said combustion products and said hydrocarbon feed in said reaction zone; utilizing the heat of said combustion products to crack said hydrocarbon feed; measuring the concentration of a key product contained in the product stream removed from said reaction zone; varying the amount of reactants introduced into said reactor so as to maintain the concentration of said key product at a predetermined value, thereby obtaining a high yield of ethylene; passing the resulting reaction products into a second regenerator for rapid quenching to a temperature at which said ethylene is stable; terminating the supply of oxidant to said first regenerator; introducing a stream of oxidant into said second regenerator; and continuing the steps of the process as enumerated hereinabove utilizing said second regenerator to heat said oxidant and said first regenerator to quench said reaction products.

9. A process for the production of a mixture of acetylene and ethylene which comprises heating a stream of oxidant by passing same through a first regenerator; passing the heated oxidant into an elongated reactor; increasing the velocity of said heated oxidant in said reactor; simultaneously introducing a plurality of lateral streams of fuel into the accelerated stream of oxidant;

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rapidly and uniformly mixing the oxidant and fuel so as to form a combustible mixture; burning said combustible mixture in a combustion zone; passing a stream of combustion products from said combustion zone into a reaction zone; simultaneously therewith introducing a plurality of lateral streams of a gaseous hydrocarbon feed into said stream of combustion products; rapidly and uniformly mixing said combustion products and said hydrocarbon feed in said reaction zone; utilizing the heat of said combustion products to crack said hydrocarbon feed; measuring the concentration of a key product contained in the product stream removed from said reaction zone; varying the amount of reactants introduced into said reactor so as to maintain the concentration of said key product at a predetermined value, thereby obtaining a high yield of acetylene and ethylene; passing the resulting reaction products into a second regenerator for rapid quenching to a temperature at which the mixture of acetylene and ethylene is stable; terminating the supply of oxidant to said first regenerator; introducing a stream of oxidant into said second regenerator; and continuing the steps of the process as enumerated hereinabove utilizing said second regenerator to heat said oxidant and said first regenerator to quench said reaction products.

10. A process for the production of a mixture of acetylene and ethylene which comprises heating a stream of oxidant by forcing same through a first regenerator; passing the stream of heated oxidant into an elongated reactor; increasing the velocity of said stream of oxidant in said reactor; simultaneously introducing a plurality of lateral streams of fuel into the accelerated stream of oxidant; rapidly and uniformly mixing the oxidant and fuel so as to form a combustible mixture; burning said combustible mixture in a combustion zone; passing a stream of combustion products from said combustion zone to a first reaction zone; simultaneously therewith introducing a plurality of lateral streams of a gaseous hydrocarbon feed into said stream of combustion products; rapidly and uniformly mixing said combustion products and said hydrocarbon feed in said first reaction zone; utilizing the heat of said combustion product to crack said hydrocarbon feed; passing the reaction product from said first reaction zone into a second regenerator for rapid cooling to a temperature at which said mixture of acetylene and ethylene is stable; recovering a product stream containing acetylene and ethylene from said second regenerator; measuring the concentration of a key product contained in the product stream; varying the amount of reactants introduced into said reactor so as to maintain the concentration of said key product at a predetermined value, thereby obtaining a high yield of a mixture of acetylene and ethylene; discontinuing the supply of oxidant to said first regenerator and the supply of fuel and feed to said reactor after a period of operation in the range of between 1 and 2 minutes; forcing a stream of oxidant through said second regenerator; passing the resulting stream of heated oxidant into said reactor; increasing the velocity of said stream of oxidant in said reactor; simultaneously introducing a plurality of lateral streams of fuel into the accelerated stream of oxidant; rapidly and uniformly mixing the oxidant and fuel so as to form a combustible mixture; burning said combustible mixture in said combustion zone; passing a stream of combustion products from said combustion zone into a second reaction zone; simultaneously therewith introducing a plurality of lateral streams of a gaseous hydrocarbon feed into said stream of combustion products; rapidly and uniformly mixing said combustion products and said hydrocarbon feed in said second reaction zone; utilizing the heat of said combustion products to crack said hydrocarbon feed; passing the reaction products from said second reaction zone into said first regenerator for rapidly cooling to a temperature at which said mixture of acetylene and ethylene is stable; recovering a product stream containing acetylene and ethylene from said first

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regenerator; measuring the concentration of a key product contained in the product stream; varying the amount of reactants introduced into said reactor so as to maintain the concentration of said key product at a predetermined value, thereby obtaining a high yield of the mixture of acetylene and ethylene; and continuing to supply oxidant to said first and second regenerators and fuel and feed to said reactor in alternate cycles.

11. A process for the production of a mixture of acetylene and ethylene which comprises heating a stream of gaseous hydrocarbons by forcing same through a first regenerator; passing the stream of heated hydrocarbons into an elongated reactor; increasing the velocity of said stream of hydrocarbons in said reactor; simultaneously introducing a plurality of lateral streams of a preheated oxidant into the accelerated stream of hydrocarbons; rapidly and uniformly mixing the oxidant and hydrocarbons so as to form a combustible mixture; partially burning the resulting mixture in a reaction zone; utilizing the heat given up in the partial oxidation reaction to crack the unreacted hydrocarbons and form a mixture of acetylene and ethylene; passing the reaction products into a second regenerator for rapid cooling to a temperature at which said mixture of acetylene and ethylene is stable; recovering a product stream containing acetylene and ethylene from said second regenerator; measuring the concentration of a key product contained in the product stream; varying the amount of oxidant introduced into said reactor so as to maintain the concentration of said key product at a predetermined value, thereby obtaining a high yield of said mixture of acetylene and ethylene; discontinuing the supply of oxidant to said first regenerator and the supply of hydrocarbon feed to said reactor after a period of operation in the range of between 1 and 2 minutes; forcing a stream of gaseous hydrocarbons through said second regenerator; passing the resulting stream of heated hydrocarbons into said reactor; increasing the velocity of said stream of heated hydrocarbons in said reactor; simultaneously introducing a plurality of lateral streams of a preheated oxidant into the accelerated stream of hydrocarbons; rapidly and uniformly mixing the oxidant and hydrocarbons so as to form a combustible mixture; partially burning the resulting mixture in a second reaction zone; utilizing the heat given up in the partial oxidation reaction to crack the unreacted hydrocarbons and form a mixture of acetylene and ethylene; passing the reaction products into said first regenerator for rapid cooling to a temperature at which said mixture of acetylene and ethylene is stable; recovering a product stream containing acetylene and ethylene from said first regenerator; measuring the concentration of a key product contained in the product stream; varying the amount of oxidant introduced into said reactor so as to maintain the concentration of said key product at a predetermined value, hereby obtaining a high yield of the mixture of acetylene and ethylene; and continuing to supply gaseous hydrocarbons to said first and second regenerators and oxidant to said reactor in alternate cycles.

12. Apparatus for the production of unsaturated hydrocarbons which comprises, in combination, a first and a second regenerator, each having a plurality of passages therethrough formed of refractory material; an elongated shell connected between said first regenerator and said second regenerator; a plurality of reactors formed within said shell, each of said reactors comprising a first venturi section adjacent the inner end of said first regenerator, a second venturi section adjacent the inner end of said second regenerator, and a combustion chamber between said first and second venturi sections; a plurality of first fluid inlet means positioned in said shell and communicating with each of said reactors at about the throat of said first venturi section; a plurality of second fluid inlet means positioned in said shell and communicating with

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each of said reactors at about the throat of said second venturi section, said first and second fluid inlet means being independently adjustable; and fluid conduit means attached to the outer end of each of said regenerators.

13. Apparatus for the production of unsaturated hydrocarbons which comprises, in combination, a first and a second regenerator, each having a plurality of passages therethrough formed of refractory material; an elongated shell connected between said first regenerator and said second regenerator, a plurality of reactors formed within said shell, each of said reactors comprising an elongated venturi section, said section comprising a pair of truncated conoidal sections having their small ends connected by an elongated throat section; a first set of a plurality of radially disposed, diametrically-opposed fluid inlet means positioned in said shell and communicating with each of said reactors at about the beginning of one end of each of said throat sections; a second set of a plurality of radially-disposed, diametrically-opposed fluid inlet means positioned in said shell and communicating with each of said reactors at about the beginning of the opposite end of each of said throat sections; a third set of a plurality of radially-disposed, diametrically-opposed fluid inlet means positioned in said shell and communicating with each of said reactors at a point intermediate the ends of each of said throat sections, said first, second and third sets of fluid inlet means being independently adjustable; and fluid conduit means attached to the outer end of each of said regenerators.

14. Apparatus for the production of unsaturated hydrocarbons which comprises, in combination, a first and a second regenerator, each having a plurality of passages therethrough formed of refractory material; an elongated shell connected between said first regenerator and said second regenerator, a plurality of reactors formed within said shell, each of said reactors comprising an elongated venturi section, said section comprising a pair of truncated conoidal sections having their small ends connected by an elongated throat section; a first set of a plurality of radially disposed, diametrically-opposed fluid inlet means positioned in said shell and communicating with each of said reactors at a point substantially inwardly from one end of each of said throat sections; a second set of a plurality of radially-disposed, diametrically-opposed fluid inlet means positioned in said shell and communicating with each of said reactors at a point substantially inwardly from the other end of each of said throat sections, said first and second sets of fluid inlet means being independently adjustable; and fluid conduit means attached to the outer end of each of said regenerators.

15. A process for the production of unsaturated hydrocarbons which comprises introducing a stream of one of the preheated gaseous reactant materials selected from the group consisting of an oxidant and a gaseous hydrocarbon axially into an elongated reaction zone; increasing the velocity of said preheated reactant material in said reaction zone; simultaneously introducing the other of said gaseous reactant materials laterally into said stream of preheated reactant material of increased velocity; burning at least a portion of the resulting combustible mixture, utilizing the heat of the resulting combustion products to crack said gaseous hydrocarbon and form unsaturated hydrocarbons; rapidly quenching the resulting reaction products to a temperature below the temperature of decomposition of said unsaturated hydrocarbons; recovering a product stream containing unsaturated hydrocarbons; measuring the concentration of a key product contained in said product stream; and varying the amount of one of said preheated reactant materials introduced into said reaction zone so as to maintain the concentration of said key product at a predetermined value and thereby obtain a high yield of unsaturated hydrocarbons.

16. A process for the production of unsaturated hy-

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drocarbons which comprises introducing a stream of preheated oxidant axially into an elongated reactor; increasing the velocity of said stream of oxidant in said reactor; simultaneously introducing a plurality of lateral streams of fuel into the accelerated stream of oxidant; 5 burning the resulting combustible mixture in a combustion zone; passing a stream of the resulting combustion products from said combustion zone into a reaction zone; simultaneously therewith introducing a plurality of lateral streams of a gaseous hydrocarbon feed into said stream of combustion products; utilizing the heat of said combustion products to crack said hydrocarbon feed; recovering a product stream containing unsaturated hydrocarbons; measuring the concentration of a key product contained in said product stream; and varying the amount 15 of reactant materials introduced into said reactor so as to maintain the concentration of said key product at a predetermined value and thereby obtain a high yield of unsaturated hydrocarbons.

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