Sept. 29, 1953 A. L. GLAESER 2,653,859

APPARATUS FOR PYROLYZING REACTANTS

Filed Oct. 26, 1949 2 Sheets-Sheet 1

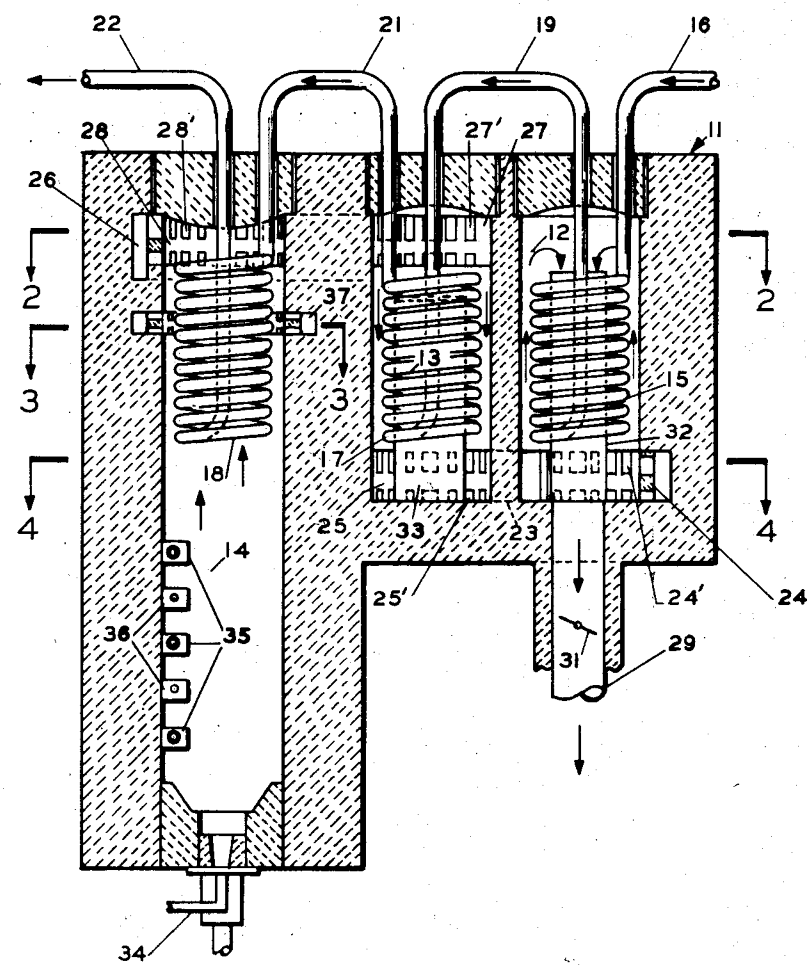

FIG. 1

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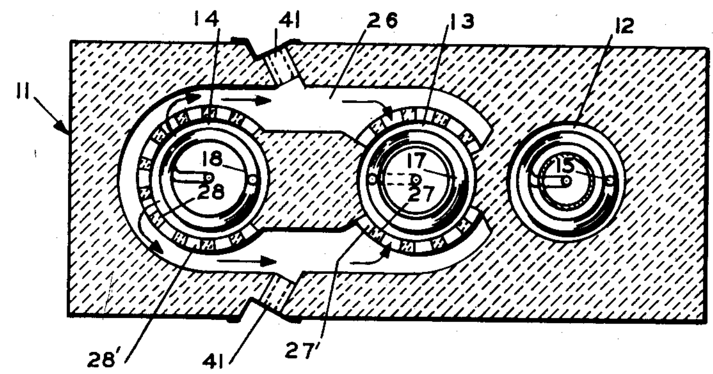

FIG. 2

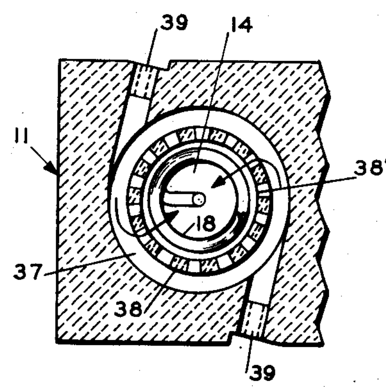

FIG. 3

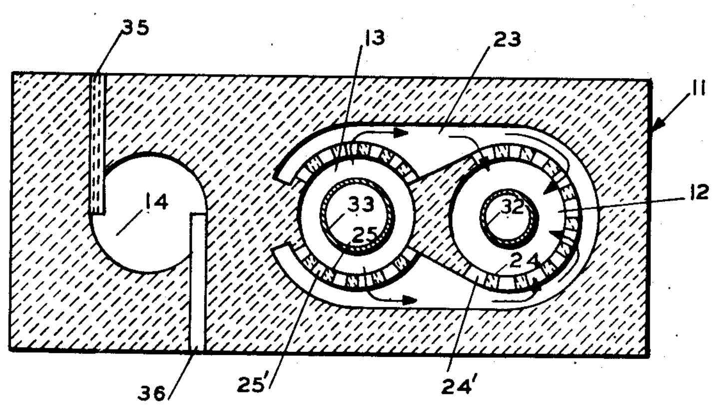

FIG. 4

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APPARATUS FOR PYROLYZING REACTANTS

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Application October 26, 1949, Serial No. 123,690

3 Claims. (Cl. 23—277)

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This invention relates to the pyrolysis of organic compounds and, more particularly, to an improved method and apparatus for pyrolyzing reactants such as the lower aliphatic acids and lower aliphatic ketones in a tubular pyrolysis furnace.

It is well known that pyrolysis reactions involving the decomposition or cracking of organic materials are endothermic and that the reactions are carried out in a heated tube or tubes which must be supplied with considerable heat energy from some outside source. It follows, since such reactions are endothermic, that the rate and efficiency at which the cracking reaction proceeds are functions of the temperature which can be maintained in the reaction mixture, and that this temperature in turn is directly effected by the rate at which the reaction tube can absorb heat from its surroundings.

In order to promote such reactions as efficiently as possible, the reaction tubes usually take the form of elongated tubes or coils having a high ratio of surface to volume. These tubes are housed in a furnace and heated by bringing combustion gases into intimate contact with the tubes containing the material to be cracked. It is obvious that the rate at which a reaction tube can absorb heat from the hot combustion gases will depend on the temperature of the gases, with a higher gas temperature promoting a more rapid input of heat to the tube.

Heretofore, pyrolysis installations for the pyrolysis of lower aliphatic acids and ketones have been limited to the use of a low B. t. u. content fuel such as producer gas which burns to produce a low temperature luminous flame, usually below about 1300° C. High B. t. u. content fuels such as butane or propane which burn to produce a high temperature, nonluminous flame with flame temperatures in the order of 1600° C. or higher have never been successfully used to supply heat for such pyrolysis installations. This fuel limitation has been dictated largely by the fact that excessively high flame temperatures severely reduce the life of reaction tubes by overheating. If the tubes are continuously subjected to temperatures in excess of about 1100° C., they are susceptible to premature failure.

In the commercial production of ketene, acetic acid vapors, for example, in the presence of a catalyst, are passed through tubular reaction coils of heat-resistant alloy disposed in a furnace. The heat input necessary to effect cracking is supplied by bringing combustion gases into intimate contact with the reaction coils containing

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the acetic acid vapors. Heretofore, commercial installations for producing ketene by the pyrolysis of acetic acid have utilized producer gas for supplying pyrolysis heat. Since producer gas inherently burns with a long, lazy, fully luminous type of flame, it has been necessary to design the pyrolysis furnaces to utilize this type of pyrolysis heat. The furnaces themselves have been constructed with a series of chambers separated one from the next by partial partitions or baffle walls. The combustion fuel is fired in a separate combustion chamber in the furnace and the combustion gases are led in a zigzag path around the baffle walls and through the furnace chambers housing the reaction coils. Such an arrangement necessarily means that a marked temperature gradient exists within the reaction zone of the furnace, for the gases are obviously hottest when they first contact the reaction coils and rapidly become cooler as they proceed through the furnace. Since the pyrolysis reaction is highly endothermic, it is apparent that the efficiency of the reaction becomes markedly lower with lower temperatures. In effect, this means that the portion of the reaction coil in which cracking actually occurs is restricted to that portion which is in contact only with the hottest gases.

It is, therefore, an object of the invention to provide a method and apparatus for obtaining an improved distribution of heat to a pyrolysis reaction.

Another object of the invention is to provide a method and apparatus for utilizing a high B. t. u. content fuel which burns with a flame temperature in excess of about 1600° C. to supply heat for a pyrolysis reaction.

Another object of the invention is to provide an improved method and apparatus for regulating the heat input to a pyrolysis reaction.

Other objects of the invention will appear hereinafter, the novel features and combinations being set forth in the appended claims.

Generally described, the method for obtaining an improved distribution of heat input to a pyrolysis reaction in accordance with this invention comprises generating primary hot combustion gases in a primary heating zone, passing the primary hot combustion gases into contact with a reaction tube, generating additional hot combustion gases in at least one other heating zone, passing the additional hot combustion gases into contact with the reaction tube and into the primary hot combustion gases, and passing reactants through the reaction tube. When a high

B. t. u. content fuel such as butane or propane is employed to supply the heat input for the pyrolysis reaction, the method comprises generating a supply of primary hot combustion gases by burning high B. t. u. content fuel in a primary heating zone, regulating the temperature of the primary hot combustion gases in the primary heating zone, bringing the regulating gases into contact with the reaction tube, and supplying additional heat to the pyrolysois reaction by introducing fresh hot combustion gases into the primary combustion gases in the reaction zone. For certain high B. t. u. content fuels, such as, for example, No. 6 fuel oil, it is desirable to regulate the temperature of the fresh hot combustion gases introduced in the reaction zone.

The apparatus for practicing the method of this invention comprises a primary heat zone, a reaction zone in juxtaposition to the primary heat zone, a reaction tube disposed in the reaction zone, primary fuel burning means disposed in the primary heat zone, at least one additional heat zone spaced apart from the primary heat zone and in juxtaposition to the reaction zone, and additional fuel burning means disposed in the additional heat zone or zones. When a high B. t. u. content fuel is employed to supply the heat input for the pyrolysis reaction, the apparatus is provided with means disposed within the primary heat zone for introducing a cooling fluid such as steam into the primary hot combustion gases. The cooling fluid mixes with and controls the temperature of the primary hot combustion gases in the primary heating zone prior to contact with the pyrolysis tube. The apparatus may be provided with means in conjunction with the additional fuel burning means disposed in additional heat zones for introducing cooling fluid into the additional hot combustion gases to regulate them.

A preferred embodiment of the invention has been chosen for purposes of illustration and description and is shown in the accompanying drawings forming a part of the specification wherein reference symbols refer to like parts wherever they occur.

Figure 1 is a vertical sectional view taken along the longitudinal axis of a pyrolysis furnace constructed in accordance with this invention;

Figure 2 is a horizontal sectional view taken along section 2—2 of Figure 1;

Figure 3 is a horizontal sectional view taken along section 3—3 of Figure 1; and

Figure 4 is a horizontal sectional view taken along section 4—4 of Figure 1.

With reference to the drawings, a furnace 11 constructed of refractory material is provided with a preheat chamber 12, a superheat chamber 13, and a cracking chamber 14. The cracking chamber 14 is substantially longer than the preheat and the superheat chambers. A tubular preheat coil 15 with an inlet 16 is disposed in the preheat chamber 12. A tubular superheat coil 17, connected to the preheat coil 15, is disposed in the superheat chamber 13 and a tubular cracking or pyrolysis coil 18, connected to the superheat coil 17, is disposed in the cracking chamber 14. The preheat coil 15 and the superheat coil 17 are connected by a U-shaped conduit 19. Similarly, the superheat coil 17 and the cracking coil 18 are connected by a U-shaped conduit 21. As illustrated, the U-shaped conduits 19 and 21 which connect the coils are disposed externally of the furnace, but the connections can be disposed internally of the furnace if so desired. The cracking coil 18 is provided with an outlet 22. Thus, in combination, the coils 15, 17 and 18, the connecting conduits 19 and 21, and the inlet 16 and the outlet 22 form an elongated reaction zone.

It will be noted that the preheat coil 15 and the superheat coil 17 occupy a substantial portion of the chambers 12 and 13, while the cracking coil 18 is disposed in the upper portion of the cracking chamber 14, leaving the lower portion of the chamber unoccupied for combustion and control purposes hereinafter described.

With reference to Figure 4, the preheat chamber 12 and the superheat chamber 13 are connected at the bottom thereof with a passageway 23 which extends through the furnace wall separating the two chambers. The passageway is further extended to substantially encompass a bottom refractory partition 24 in the preheat chamber 12 and a bottom refractory partition 25 in the superheat chamber 13. The refractory partitions 24 and 25 are provided with a plurality of ports 24′ and 25′, respectively, which permits communication between the chambers 12 and 13 and the passageway 23. With reference to Figure 2, the superheat chamber 13 and the cracking chamber 14 are connected at the top thereof with a passageway 26 which extends through the furnace wall separating the two chambers. The passageway is further extended to substantially encompass a top refractory partition 27 in the superheat chamber 13 and a top refractory partition 28 in the cracking chamber 14. The refractory partitions 27 and 28 are provided with a plurality of ports 27′ and 28′, respectively, which permits communication between the chambers 13 and 14 and the passageway 26.

With reference to the drawings, the chamber 12 is provided with an exit conduit 29 provided with a regulating damper 31. The exit conduit 29 leads to a suitable stack (not shown). The chamber 12 is also provided with a tubular member 32 concentrically disposed in the space encircled by the preheat coil 15. The tubular member 32 forms an extension of the exit conduit 29 to a point approximately flush with the top of the preheat coil 15.

The superheat chamber 13 is provided with a cylindrical member 33 closed at the top and concentrically disposed in the space encircled by the superheat coil 17. The member 33 extends from the bottom of the superheat chamber 13 to approximately the top of the coil. The tubular member 32 and the cylindrical member 33 function as space reducers for the gases entering chambers 12 and 13, respectively.

The chamber 14 is provided at its base with a centrally located adjustable fuel burner 34. A plurality of adjustable fuel burners 35 is disposed vertically in the walls of the chamber 14 in the space below the coil 18. The burners 34 and 35 generate a supply of primary hot combustion gases for furnishing heat input for the pyrolysis reaction. The combustion space in chamber 14 into which burners 34 and 35 extend is termed the primary heat zone. This primary heating zone or primary heat release zone is in juxtaposition with the pyrolysis zone containing the cracking coil 18.

A plurality of adjustable, cooling jets 36 is disposed vertically in the walls of the chamber 14 in alternating relationship with the burners 35. The burners 35 and cooling jets 36 are arranged vertically in two banks (Figure 4) and are adapted, respectively, to burn fuel and inject cooling fluid tangentially in the same rotational direction into the chamber 14. By this arrangement the cooling fluid and primary combustion gases quickly become intimately intermixed and the temperature of the primary combustion gases is thus controlled and regulated in the primary heat zone. In addition, a rotational motion is imparted to the combustion gases as they rise and the hot gases intimately contact the cracking coil 18.

The chamber 14 is provided with an annular gas-fired ring 37 concentrically disposed in the chamber walls at a point approximately intermediate the two ends of the coil 18. The ring 37 has an inner refractory partition 38 which has a plurality of radial ports 38′ extending therethrough opening into the cracking chamber 14 to afford communication between the ring and the chamber 14 (Figure 3). A plurality of adjustable burners 39 is disposed in the furnace wall and tangentially fires into ring 37 in the same rotational direction. The ring 37 through the burners 39 generates a secondary supply of hot combustion gases which pass into the cracking chamber 14 through the ports 38′ and mix with the primary combustion gases in the cracking zone of the furnace to supply additional controlled heat input for the pyrolysis reaction. The combustion space in ring 37 into which secondary burners 39 fire is termed the secondary heat zone or the secondary heating zone. The annular gas-fired ring 37 constitutes an effective means for obtaining an improved distribution of heat input to the pyrolysis reaction and for regulating and controlling the temperature of the combustion gases in the reaction zone of the pyrolysis furnace. The fresh combustion gases in passing into chamber 14 impinge directly on the spirals of the coil adjacent to the ring but direct impingement of the flame gases is prevented by the refractory partition 38. Cooling fluid ducts or jets may be disposed in conjunction with burners 39 for regulating the combustion gases generated therein.

A plurality of adjustable burners 41 disposed in the furnace wall fire obliquely into the passageway 26 in the direction of gas movement through the passageway. These burners generate an additional tertiary supply of hot combustion gases which mix with the primary and secondary combustion gases and supply additional controlled heat input for the pyrolysis reaction. The space in passageway 26 into which tertiary burners 41 fire is termed the tertiary heat zone or the tertiary heating zone. This additional burner capacity firing into passageway 26 constitute an effective means for obtaining an improved distribution of heat input to the pyrolysis reaction, and for regulating and controlling the temperature of the combustion gases in the reaction zone of the pyrolysis furnace. Cooling fluid ducts or jets may be disposed in conjunction with burners 41 for regulating the combustion gases generated therein.

The additional heat input derived from the fresh combustion gases generated in the annular gas-fired ring 37 and in the passageway 26 maintains a nearly constant temperature in the combustion gases throughout a substantial portion of the reaction zone. As a result, there is a greatly improved distribution of heat input to the endothermic reaction. Increased production of cracked products results because a much larger area of the reaction vessel is maintained at optimum cracking temperatures.

In operation, when using a low B. t. u. content fuel such as producer gas, for example, the gas is fired in the primary heat zone and the primary hot combustion gases pass upwardly and contact the cracking coil 18 in the cracking chamber 14. The primary hot combustion gases are supplemented by the secondary hot combustion gases which are generated in the annular gas-fired ring 37. The combined combustion gases then enter the passageway 26 and are further supplemented by the tertiary hot combustion gases generated by the burners 41. The combined combustion gases then enter the superheat chamber 13 where they contact the superheat coil 17. The gases then pass downwardly and through the passageway 23 and into the preheat chamber 12 where they contact the preheat coil 15, and are vented through the tubular member 32 and exit conduit 29. Acetic acid vapors, for example, containing catalyst are introduced into the furnace through inlet 16 and pass successively through the preheating coil 15, the superheat coil 17, and the cracking coil 18 where they are heated to cracking temperature and are cracked to yield ketene and the cracked products are removed at outlet 22.

When operating with a high B. t. u. content fuel such as propane, for example, the propane is fired in the primary heat zone and a cooling fluid such as steam, for example, is introduced into the primary hot combustion gases in the primary heat zone in sufficient quantity to regulate and control the temperature of the combustion gases in the primary heat zone at the desired temperature level. A combustion gas temperature between about 800° C. and about 1100° C. is preferred for the pyrolysis of acetic acid to form ketene. From that point on, optimum operation is conducted in the same manner as operating with a low B. t. u. content fuel such as producer gas, provided, of course, that the secondary and tertiary hot combustion gases may, if desired, be regulated by the introduction of a cooling fluid such as steam.

In the embodiment illustrated in Figure 1, the furnace contains a plurality of chambers disposed horizontally side-by-side, with adjacent chambers connected by passageways and with the reaction coils protected from direct flame impingement by ported refractory walls. Other arrangements may be employed, however. For example, the furnace can be constructed with the several chambers disposed vertically, one above the next, with connecting passageways. The furnace can also be constructed with a single long chamber and therefore not require any connecting passageways. In this embodiment the reaction vessel instead of comprising a plurality of coil sections connected in series can be a single long coil or any other suitable configuration presenting a high ratio of area to volume. Construction of the furnace is conventionally of refractory material such as brick, laid up and lagged on the outside for insulation.

As well known to the art, the reaction vessel is constructed of any suitable material which is resistant to corrosion at cracking temperatures, either by the materials of the reaction or by the hot combustion gases employed.

Any combination of burners may be employed in the primary heat zone to supply primary hot combustion gases. Normally, sufficient burner capacity will be employed to furnish enough heat to maintain a substantial portion of the cracking or pyrolysis coil section at optimum cracking temperature with normal throughput of material.

As indicated previously, the fuel may be a low B. t. u. content fuel such as producer gas or any other fuel which burns with a low temperature flame, usually below 1300° C. In this case, no regulation or control of the temperature of the primary combustion gases in the primary heat zone is necessary before they contact the reaction vessel in the reaction zone.

Preferably the fuel is a high B. t. u. content fuel such as propane, butane, fuel oil or any other fuel which burns with a high temperature flame on the order of 1600° C. or higher. In this case, the primary hot combustion gases must be regulated or controlled in temperature in the primary heat zone before they contact the cracking tube. This is accomplished by introducing sufficient cooling fluid such as steam into the primary hot combustion gases in the primary heat zone to reduce their temperature below about 1300° C. Any combination of cooling fluid jets may be employed to accomplish the desired regulation and control of the temperature of the primary combustion gases within the primary heat zone.

In the embodiment illustrated in Figure 1 and Figure 4, burners and cooling fluid jets are disposed alternately in two vertical banks in the chamber walls to respectively fire and inject cooling fluid tangentially in the same rotational direction into the primary heat zone. This arrangement is quite advantageous, as it insures efficient mixing of the cooling fluid with the primary hot combustion gases in the primary heat zone.

The preferred cooling fluid in accordance with the invention is steam. However, other cooling fluids are satisfactory, such as nitrogen, carbon dioxide, or other inert gaseous materials. Water in liquid form is also suitable. Sufficient cooling fluid is used to bring the temperature of the primary hot combustion gases to a value not in excess of about 1300° C. and to regulate and control the temperature of the primary hot combustion gases substantially at this level within the primary heat zone.

In accordance with the invention, at least one annular gas-fired ring is provided to supply additional and controlled heat input to the pyrolysis reaction. In the embodiment illustrated in Figure 1, the ring is disposed concentrically in the chamber walls at a point approximately midway between the two ends of the cracking coil. However, this annular gas-fired ring can be suitably disposed at other points within or in juxtaposition to the reaction zone of the furnace. Also, additional similar annular gas-fired rings may be disposed at suitable points within or in juxtaposition to the reaction zone. It is contemplated within the scope of this invention that the heat required for the reaction may be supplied entirely by a plurality of suitably disposed annular gas-fired rings. The annular gas-fired rings are preferably constructed of silicon carbide brick which has a high rate of heat conductivity and therefore exposes a high temperature radiating surface for heat input to the spirals of the coil in juxtaposition thereto.

In the embodiment illustrated in Figure 2, a plurality of burners is disposed to fire into the passageway connecting the cracking chamber with the superheat chamber. Instead of this arrangement, the burners may be positioned to fire into the passageway connecting the superheat chamber with the preheat chamber, or alternatively, burners may be positioned to fire into both of the passageways.

Any desired combination of burners in the annular gas-fired ring or rings and burners fired into the passageways can be employed, the only requirement being sufficient burner capacity to maintain and control an even distribution of heat input to the pyrolysis reaction over a substantial proportion of the reaction zone.

For certain types of high B. t. u. content fuel such as, for example, No. 6 fuel oil, it is desirable to provide cooling fluid means disposed in conjunction with each means for generating hot combustion gases within the system in order to properly regulate these gases and insure an even distribution of heat input to the pyrolysis reaction over a substantial proportion of the reaction zone.

The following examples set forth three ways in which the principle of the invention has been practiced. It is to be understood, however, that the examples are purely illustrative and are not to be construed as a limitation of the invention.

In the examples, ketene is produced by the pyrolysis of acetic acid in accordance with the apparatus depicted in the drawings wherein each of the burners **34**, **35**, **39** and **41** has a nominal or rated capacity of 2,700,000 B. t. u., 500,000 B. t. u., 200,000 B. t. u., and 200,000 B. t. u. per hour, respectively, using propane as the fuel. The ketene formed is then reacted with glacial acetic acid in additional apparatus associated with the pyrolysis furnace to produce acetic anhydride.

Example I

Four of the burners **35** were fired with propane gas as fuel to generate a supply of primary hot combustion gases. Steam was introduced through the lowest disposed cooling fluid jet **36** to control and regulate the temperature of the hot combustion gases in the primary heat zone. The regulated gases were brought into contact with the cracking coil **10** and were supplemented by combustion gases generated by the two burners **39** firing into the annular gas-fired ring **37** using propane throughout as fuel. The combustion gases were further supplemented by combustion gases generated by the two burners **41**, using propane as fuel, firing into the passageway **26** which connects the cracking chamber **14** with the superheat chamber **13**. Acetic acid vapors containing catalyst were passed into the inlet **16** at the rate of 1000 lb./hr. The burners and steam jet were adjusted so that the temperature of the gases throughout the cracking chamber and the superheat chamber was maintained between about 850° C. and about 1020° C. and remained so throughout the run, and at a level to promote the pyrolysis reaction at its maximum efficiency. This close temperature control over a substantial proportion of the reaction zone was made possible by regulating the temperature of the primary gases in the primary heat zone and by augmenting the regulated primary combustion gases with additional fresh combustion gases generated in the annular gas-fired ring and in the passageway connecting chambers **13** and **14**. This control was not possible in the absence of the tempering steam and the augmenting additional fresh combustion gases. The total propane consumption was approximately 200 lb./hr. Approximately 3000 lb. of air/hr. was introduced at the burners to burn the propane, and approximately 750 lb. steam/hr. was introduced to regulate the temperature of the primary hot combustion gases. The ketene formed was reacted with glacial acetic acid in additional apparatus associated with the pyrolysis furnace to produce acetic anhydride. A yield of 1 lb. of acetic anhydride for each 1.22 lb. of acetic acid passed through the pyrolysis furnace was obtained whereas the theoretic yield is 1 lb. of acetic anhydride for each 1.178 lb. of acetic acid, thus demonstrating a satisfactory yield of ketene at a high rate of efficiency.

Example II

The burner 34 was fired with propane gas as fuel to generate a supply of primary hot combustion gases. Steam was introduced through the lowest disposed cooling fluid jet 36 to control and regulate the temperature of the hot combustion gases in the primary heat zone. The regulated gases were supplemented in the cracking chamber by combustion gases generated by the two burners 39 firing into the annular gas-fired ring 37, using propane as fuel. The combustion gases were further supplemented by combustion gases generated by the two burners 41, using propane as fuel. These burners fired into the passageway 26 which connects the cracking chamber 14 with the superheat chamber 13. Acetic acid vapors containing catalyst were passed into the inlet 16 at the rate of 1000 lb./hr. The burners and steam jet were adjusted so that the temperature of the gases throughout the cracking chamber and the superheat chamber was maintained between about 850° C. and about 1020° C. and remained so throughout the pyrolysis run, and at a level to promote the pyrolysis reaction at its optimum efficiency. Fuel, air and steam consumption were substantially the same as in Example I, and substantially the same yield of ketene was obtained at substantially the same high rate of efficiency.

Example III

This example was conducted under substantially the same conditions as Example II, but the throughput of acetic acid was increased to 1250 lb./hr. An increased yield of ketene was obtained without loss of efficiency.

The foregoing examples demonstrate the principle of the invention when acetic acid is pyrolyzed to produce ketene. The invention is by no means limited in its application, however, to the pyrolysis of acetic acid. It is equally applicable for the pyrolysis of other organic compounds, including acetone, methyl ethyl ketone, diethyl ketone, propionic acid, and butyric acid.

In the foregoing examples, it is demonstrated that a high B. t. u. content fuel such as propane can be employed satisfactorily as a source of heat input for a pyrolysis reaction. The temperature of the primary hot combustion gases was satisfactorily controlled and regulated in the primary heat zone by the use of steam as a regulating agent. An improved distribution of heat input to the pyrolysis reaction is demonstrated in the examples by the fact that the temperature of the gases throughout the cracking and superheat zones was substantially the same. The advantages of the apparatus and method of the present invention are several. A high B. t. u. content fuel can be employed as the source of heat input for the pyrolysis reaction, thereby eliminating the investment cost of constructing and maintaining, and the cost of operating a producer gas plant. The temperature of the combustion gases employed to supply heat to the pyrolysis reaction is controlled and regulated over a substantial portion of the reaction zone, and a greatly improved distribution of heat input to the pyrolysis reaction is obtained.

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

1. In a pyrolysis furnace, the improvement which comprises a primary heat zone, a pyrolysis zone spaced from the primary heat zone and in direct communication therewith, a pyrolysis coil disposed in the pyrolysis zone, primary fuel burning means and cooling jets disposed in the primary heat zone, a secondary heat zone spaced apart from the primary heat zone and in juxtaposition to the pyrolysis zone, said secondary heat zone being concentrically disposed around a portion of the pyrolysis coil intermediate the ends thereof, secondary fuel burning means disposed in the secondary heat zone, said secondary fuel burning means being an annular gas-fired ring for generation of flame gases without impingement of said flame gases on the pyrolysis coil and for passage of combustion gases from said annular gas-fired ring into direct contact with said pyrolysis coil, a superheat zone in spaced relationship to the pyrolysis zone, a superheat coil disposed in the superheat zone, a chamber connecting the superheat zone with the pyrolysis zone, tertiary fuel burning means disposed in the chamber, a preheat zone in spaced relationship to the superheat zone, a preheat coil disposed in the preheat zone, a chamber connecting the preheat zone with the superheat zone, a space reducer disposed within the superheat coil and a space reducer disposed within the preheat coil, said latter spaced reducer adapted to permit passage of the combustion gases therethrough and from the furnace.

2. In a pyrolysis furnace, the improvement which comprises a primary heat zone, a pyrolysis zone spaced from the primary heat zone and in direct communication therewith, a pyrolysis tube disposed in the pyrolysis zone, primary fuel-burning means and steam jets disposed in the primary heat zone, a secondary heat zone spaced apart from the primary heat zone and in juxtaposition to the pyrolysis zone and being concentrically disposed around a portion of the pyrolysis tube intermediate the ends thereof, and secondary fuel-burning means disposed in the secondary heat zone comprising an annular gas-fired ring with burners disposed therein to produce flame gases within said ring and to prevent impingement of flame gases on the pyrolysis tube, and with ports for passage of combustion gases from said ring into direct contact with the pyrolysis tube.

3. In a pyrolysis furnace, the improvement which comprises a primary heat zone, a pyrolysis zone spaced from the primary heat zone and in direct communication therewith, a pyrolysis coil disposed in the pyrolysis zone, primary fuel-burning means and steam jets disposed in the primary heat zone, a secondary heat zone spaced apart from the primary heat zone and in juxtaposition to the pyrolysis zone and being concentrically disposed around a portion of the pyrolysis coil intermediate the ends thereof, secondary fuel-burning means disposed in the secondary heat zone comprising an annular gas-fired ring with burners disposed therein to produce flame gases within said ring and to prevent impingement of flame gases on the pyrolysis coil and with ports for passage of combustion gases from said ring into direct contact with the pyrolysis coil, a superheat zone in spaced relationship

to the pyrolysis zone, a superheat coil disposed in the superheat zone, a chamber connecting the superheat zone with the pyrolysis zone, tertiary fuel-burning means disposed in the chamber, a preheat zone in spaced relationship to the superheat zone, a preheat coil disposed in the preheat zone, and a chamber connecting the preheat zone with the superheat zone.

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