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CONVERSION OF HYDROCARBONS AT HIGH RATES OF HEAT INPUT

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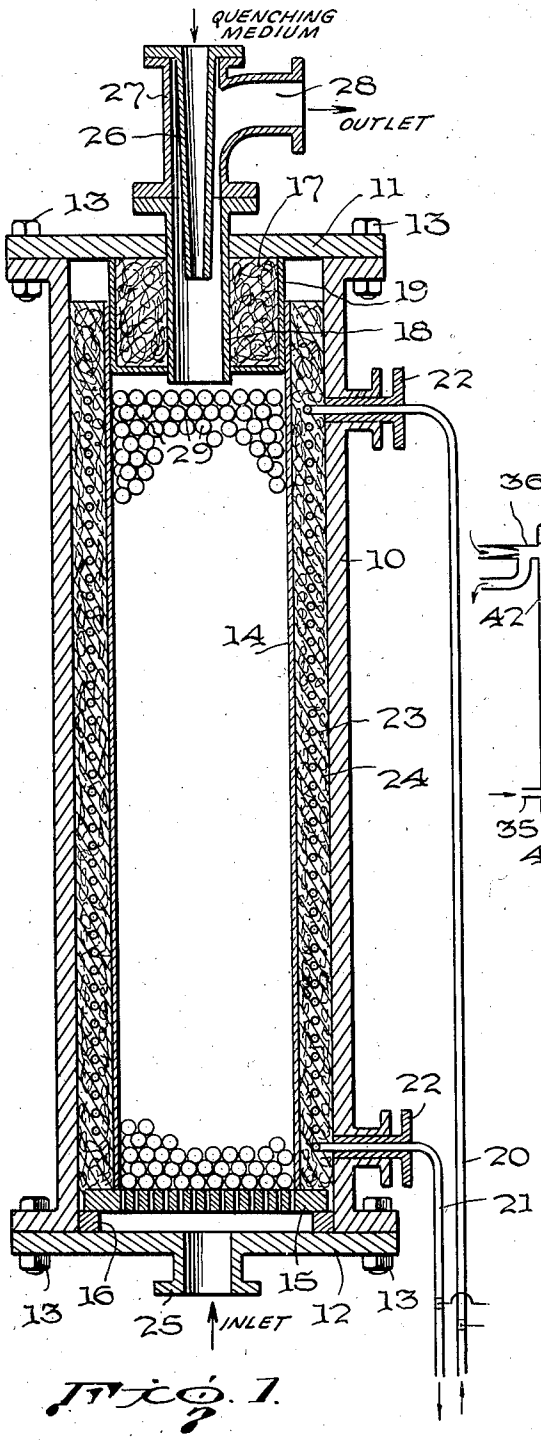



Fig. 1.

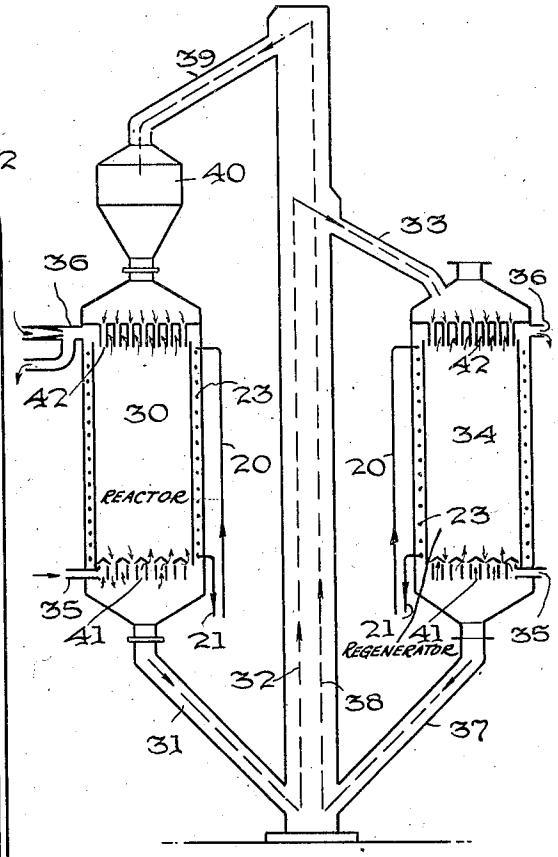



Fig. 2.

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## CONVERSION OF HYDROCARBONS AT HIGH RATES OF HEAT INPUT

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3 Claims. (Cl. 196—52)

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This invention relates to the cracking of hydrocarbons at high rates of heat input by electrical induction heating whereby reaction is accomplished at higher temperature and in shorter time than is possible by conventional practice with an equivalent degree of carbon formation.

More especially, my invention comprises the method and apparatus wherein hydrocarbons are flowed through a reaction chamber which contains a bed of contact material or catalyst, or a mixture of the two, located in a field of changing magnetic flux and heated by electrical currents induced therein. The bed may be either fixed or flowing, if it is granular or of shapes which present numerous interstitial voids, or the inductively heated material may, instead, comprise a pool of molten material maintained in the field of changing flux. In either case the reactant is brought into such intimate contact with the contained material of high ratio of surface area to void volume that the temperature difference between them is reduced by rapid heat transfer, with the result that carbon formation is retarded and favorable conditions are maintained for carrying out reactions at high temperatures and in short reaction times.

The conversion or cracking of hydrocarbons either thermally or catalytically is known to be a function of time, temperature, pressure and nature of charging stock. Of these variables the nature of charging stock and pressure may be arbitrarily adjusted as desired, while the temperature and time are dependent upon the design of the equipment which is employed.

Inasmuch as the depth or extent of conversion is directly proportional to both time and temperature, and as coke formation is the limiting factor in the maximum depth of conversion for successful operation, it follows that neither of these variables may be increased without a proportionate decrease in the other.

Thus, for ordinary thermal cracking processes conducted in conventional tube still heaters which themselves are limited to a maximum rate of heat transfer per unit area of tube surface, the relationship between time and temperature is set by the ratio of area to volume per unit length of tube or, in turn, to the tube diameter. Because of this the requisite tube diameter for conducting reactions in shortened time and corresponding elevated temperature would be impractically small for commercial operations.

In catalytic cracking processes utilizing a catalyst which is circulated through a reaction zone where the rate of heat transfer is limited by the

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oil-catalyst ratio, the relationship between time and temperature is set by the ratio of catalyst circulation to the volume of the reaction zone. Because of this if higher temperatures are desired the rates of catalyst circulation required are impractical for commercial operation. Also, in catalytic cracking processes which utilize a fixed bed catalyst and internal tubular heat transfer, the same limitations are encountered as in thermal processes.

The conversion of hydrocarbons, either thermally or catalytically, involves a progressive series of complex reactions, and for a given depth of conversion, the end products of these reactions are a function of compensating variation in the time and temperature relationship. Thus, it is known that with the same degradation of charge stock, a greater amount of higher octane products are usually made at higher temperatures and shortened reaction times, and these conditions are also favorable to optimum production of many of the desirable specialized products now produced by the conversion of hydrocarbons.

The present invention is especially suitable for the conversion of hydrocarbons to produce an optimum yield of the aforesaid specialized products. Although the hydrocarbons are rapidly brought to severe reaction temperature, the transfer of heat to them from the inductively heated contact material maintains a reduced temperature differential between them throughout the heating range and therefore retards carbon formation; and a more severe reaction at a higher temperature level is made possible without coke formation or for a given rate of coke formation.

Attempts have heretofore been made to alleviate the difficulty by employing diluents such as steam or hydrocarbons in tube still practice, or by employing heat carrying materials such as superheated steam or hydrocarbons, flue gas, molten caustic, or metals, in reaction chambers, or by utilizing refractory or glass bath furnaces. In such processes the problem of separating the diluent has been troublesome and certain disadvantages have been encountered because of unfavorable reaction times, variations in temperature gradient through the reaction zone, the difficulty of operating at high pressures, and mechanical problems which are inherent in commercial operations. The present invention obviates the aforesaid disadvantages and achieves as its principal object the conversion of hydrocarbons at a high rate of heat input by intimate contact with a material which itself is heated by magnetically induced currents, the heat transfer

being effected so rapidly that the temperature difference between the heated contact material and the heat reactant fluid is maintained at a low value, thereby minimizing carbon formation.

Another object of the invention is to provide a process wherein a heat-reactant fluid undergoes conversion in contact with a fixed or flowing bed of material which has the property of high electrical conductivity and which is located in a field of changing magnetic flux, or which flows therethrough, to be heated by magnetic induction.

Another object of the invention is to provide novel apparatus for carrying out the aforesaid process.

Other and further objects will be apparent from the following description and drawing in which

Figure 1 is a vertical sectional view of a magnetic induction heater which constitutes a fixed bed type of reaction chamber.

Figure 2 shows diagrammatically an apparatus wherein the contact material is circulated between the reaction and regeneration chambers.

The induction heating apparatus of Figure 1 comprises an elongated receptacle consisting of an outer shell **10** having end flanges to which heads **11** and **12** are secured by bolts **13**. This receptacle is of any material which is suitable for withstanding operating pressures, as for example quartz, glass, porcelain, Bakelite, or other synthetic resins or polymers, carbon steel, alloy steel, or other metals or their alloys. The shielding effect of the surrounding outer shell, when the same is made of magnetically permeable metals, does not reduce the strength of the field within the confines of the coil.

An inner shell **14** is supported by a perforated distributor plate **15** which rests upon an annulus **16** and is spaced thereby above the lower head **12**. This inner shell **14** extends upwardly in the receptacle and terminates short of its upper end to permit it to expand longitudinally. The inner shell **14** and its support, plate **15** and annulus **16**, is of any material which is suitable for withstanding operating temperatures, as for example quartz, glass, porcelain, Bakelite, or other synthetic resins or polymers, carbon steel, alloy steel or other metals or their alloys. More especially, that portion of the inner shell **14** which resides within the field of changing magnetic flux, should be of materials possessing properties of poor electrical conductance except where the reaction chamber is of relatively small diameter, as shown in the drawing, in which case a thin metal shell inwardly spaced from the induction coil may be employed without unduly absorbing the energy of the magnetic field even though it be to some extent electrically conductive. A plug of insulation **17** which surrounds an outlet conduit **18** is enclosed in a cup-shaped container **19** which has slidable fit in the upper end of the inner shell **14**, such outlet conduit extending through the bottom of the container **19** and communicating with the reaction chamber defined by the inner shell **14**.

Electrical leads **20** and **21** which extend from any conventional source of high frequency alternating current as for example, rotating generators, spark gap converters, or vacuum tube oscillators, enter the space between the inner shell **14** and outer shell **10** through insulating bushings **22** and connect with a coil **23** of silver, copper or other suitable material of low electrical resistivity. The leads and coil may be either solid or tubular, in which latter case connection may conveniently



be made for circulation of a cooling liquid therethrough, as indicated by the arrows.

The coil **23** is embedded in a material **24** which has both thermal and electrical insulating properties, as, for example, spun glass, mica, gypsum, or powdered asbestos, or it may instead be confined between alternate layers of electrical and thermal insulation.

The lower head **12** is formed with a tubular boss **25** through which hydrocarbons or other materials for treatment are introduced into the reaction chamber, the effluent being withdrawn through the discharge conduit **18** which extends through the upper head **11** and the confined plug of insulation **17** into the upper end of the reaction chamber. It will be understood that the inlet and outlet, instead of being arranged as shown in Figure 1, may communicate with the reaction chamber through the side walls of the receptacle in the manner shown diagrammatically in Figure 2.

The discharge conduit **18** is coupled to a Y-fitting which mounts a quenching nozzle **26** in one branch **27**, discharging into the effluent as the same passes from the reaction chamber through the other branch **28**.

A bed **29** of highly conductive contact material is contained in the reaction chamber and supported by plate **15**. It is composed of fragments or shapes which, in bulk, present numerous interstitial voids through which the reactant fluid passes upwardly after being distributed in a plurality of small streams by passing through the perforations in plate **15**. The contact material may be selected according to the requirements of the process in which it is used, as for example, soft iron, alloys, carbon, graphite, or metallic salts or oxides; in fact it may be any material of high electrical conductivity and a high ratio of surface area to voids or free volume, if it comprises solid shapes such as spheres, tubes or irregular bodies, or it may instead be liquids. The conductive material, whether in the form of discrete shapes or a liquid, constitutes a core in which eddy currents are induced by the magnetic flux which penetrates it when high frequency alternating current is supplied to the surrounding coil **23**. The material is then heated and the heat is rapidly transmitted to the hydrocarbons or other fluids passing upwardly through the bed or molten pool. Where the latter is employed conventional modification of the form of apparatus shown in Figure 1 will be required.

The hydrocarbon effluent leaves the conductor bed **29** and enters the quenching unit in the outlet where it is mixed with sufficient quenching fluid to reduce its temperature and prevent further decomposition. The quenching fluid employed is any of those conventionally used for the purpose such as steam, water, hydrocarbon liquids, vapors, etc. If desired, these may be recirculated through the fractionating equipment to which the effluent flows, and returned for further use.

Various modifications of the disclosed reaction chamber suggest themselves and are within the purview of this invention. For example, the character and placement of insulation **24** may be changed. Also the inner shell **14** may be eliminated with certain types of insulation **24** or by mounting the coiled conductor unit **23** and its enveloping insulation **24** on the outside of the outer shell **10**.

Furthermore, the bed **29** of conductive material may be supported by other means than the distributor plate **15**, as will be described with

reference to Figure 2, and in catalytic conversion reactions, wherein the catalyst is not an electrical conductor, the bed may consist of a mixture or alternate layers of catalyst and a suitable conducting material; or if desirable the catalyst may be circulated with the hydrocarbons thru the bed **29**.

In thermal cracking of such severity that coke formation results, or in catalytic cracking the process may be carried on continuously by supplanting the conductive material on which carbon has been deposited by a supply which has been regenerated. An apparatus which is adapted for continuous operation is shown in Figure 2 wherein the conductive material which is contaminated with carbon passes from the reaction chamber **30** downwardly through conduit **31** and onto an elevator **32** which raises and deposits it in conduit **33** from which it passes into a regenerating chamber **34**. In the regenerating chamber steam or air is admitted at **35** and passes in counterflow through the regenerating zone to outlet **36**, the material with which it comes in contact being heated in the meanwhile by electrical induction to the temperature required for the regeneration reaction. The induction coil for the regeneration zone is required only if an endothermic reaction, such as the water-gas reaction with steam, is used for regeneration, and would not be required for combustion regeneration with air.

The regenerated material leaving chamber **34** passes downwardly through conduit **37** and is picked up by elevator **38** which deposits it in the entrance of conduit **39** from which it flows to the bulk storage bin **40** and thence returns to the reaction chamber **30**.

In this form of apparatus headers **41** and **42** are provided at opposite ends of each chamber. The lower header in each instance has transverse flues which are covered by louvered angles so that although the entering fluid at **35** may pass freely through the louvres into the space occupied by the highly conductive contact material and through the chamber, the downwardly flowing material is deflected by the angles and passes between the flues to the hopper-like bottom from which it passes to the conduit **31**. The upper header comprises a plate formed with a multiplicity of openings sufficiently large for passage of the conductive material and depending tubes which terminate slightly below the discharge conduit **36**. Thus, the electrically conductive contact material flowing downwardly into the chamber passes through the several tubes, but the effluent rising around tubes is confined by the header plate and is directed to the outlet **36** which is provided with a quenching unit similar to that shown in detail in Figure 1.

In this form of apparatus, as in that previously described, the conductive material is heated by electrical induction in a zone of changing magnetic flux. To this end leads **20** and **21** connect a coil **23** to a source of high frequency alternating current, thereby to induce a changing magnetic field in the reaction chamber, and if desirable in the regeneration chamber.

From the foregoing it will be apparent that this invention provides a method and apparatus wherein the depth or extent of conversion of hydrocarbons under conditions of high heat input is not restricted by factors which limit the utility of tube stills and other conventional apparatus for thermal or catalytic cracking. It will further be understood that the hydrocarbons under treatment may be either liquid or vapor and may be preheated if desired, and that the effluent may or may not be quenched, as determined by the needs of the process.



What I claim is:

1. An apparatus for the conversion of hydrocarbons at high rates of heat input which comprises an outer shell having ends secured thereto, an inner shell of less length than said outer shell and spaced therefrom, a coil of electrically conductive material mounted in the space between said inner and outer shells and embedded in electrical and thermal insulation, a perforated distributor plate of larger diameter than the inner shell mounted in spaced relation to an inlet at one end of said outer shell and supporting said inner shell and insulation, an outlet conduit extending into the opposite end of said inner shell, a plug of thermal insulation surrounding said outlet conduit and retained by an annulus between said conduit and inner shell, and a bed of highly conductive material within said inner shell and supported upon said distributor plate, the material of said bed being in shapes which afford large surface area for contact with the hydrocarbons undergoing conversion.

2. An apparatus for the continuous conversion of hydrocarbons at high rates of heat input which comprises a reaction chamber, an electrically conductive coil surrounding the same and supplied with electric current of such character as to create therein a magnetic field of changing flux, means for flowing an electrically conductive material through said reaction chamber whereby the same is heated by magnetic induction in traversing such field, means for flowing a heat-reactant fluid through said reaction chamber in intimate contact with said heated conductive material, means for continuously and separately withdrawing hydrocarbon reaction products and inductively heated material, a regeneration chamber and means for circulating the inductively heated material through said regeneration chamber in passage back to the said reaction chamber.

3. The method of cracking hydrocarbons at high rates of heat input while avoiding excessive coke formation, by reason of a low temperature differential between the hydrocarbon and heating medium, and thereby promoting depth of conversion in short reaction time, which comprises passing the hydrocarbon through a thermally insulated reaction chamber in counterflow to a material of high electrical conductivity, heating said material by the induction of electromagnetic currents therein, transferring heat from the material to the hydrocarbon by conduction to effect endothermic reaction and separating the hydrocarbon reaction products from commingled conducting material.

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