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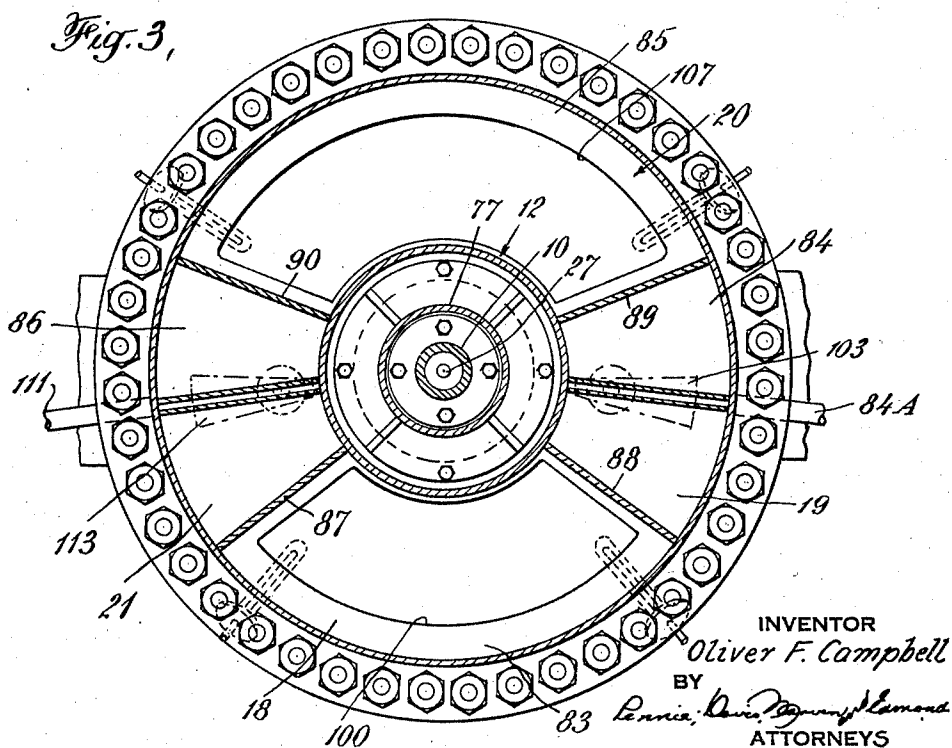
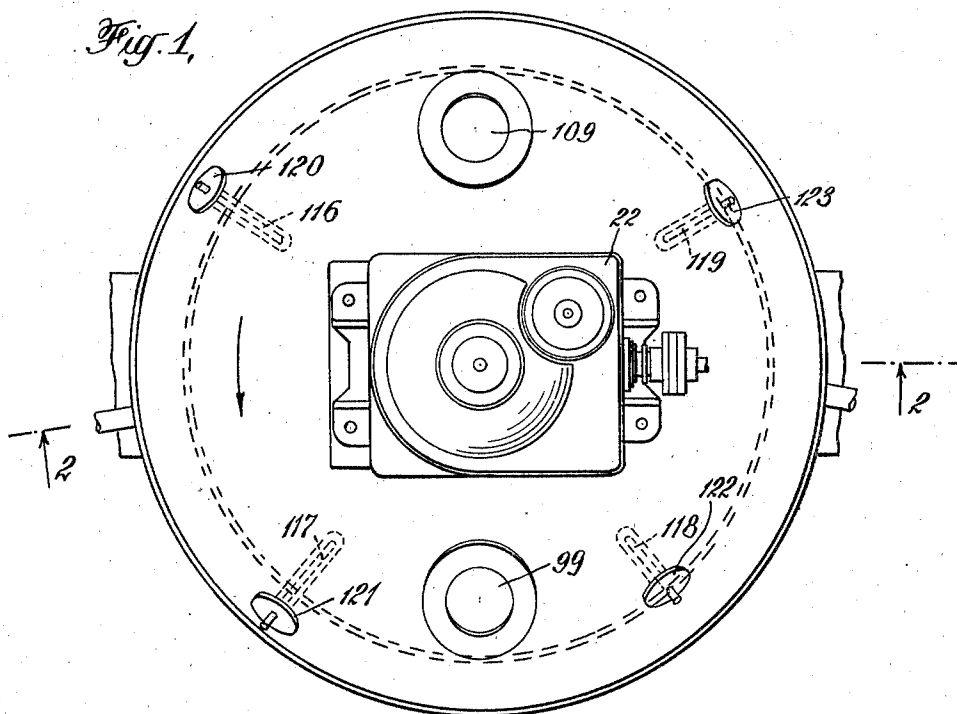
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CATALYTIC CRACKING

Filed Aug. 16, 1939

4 Sheets-Sheet 1



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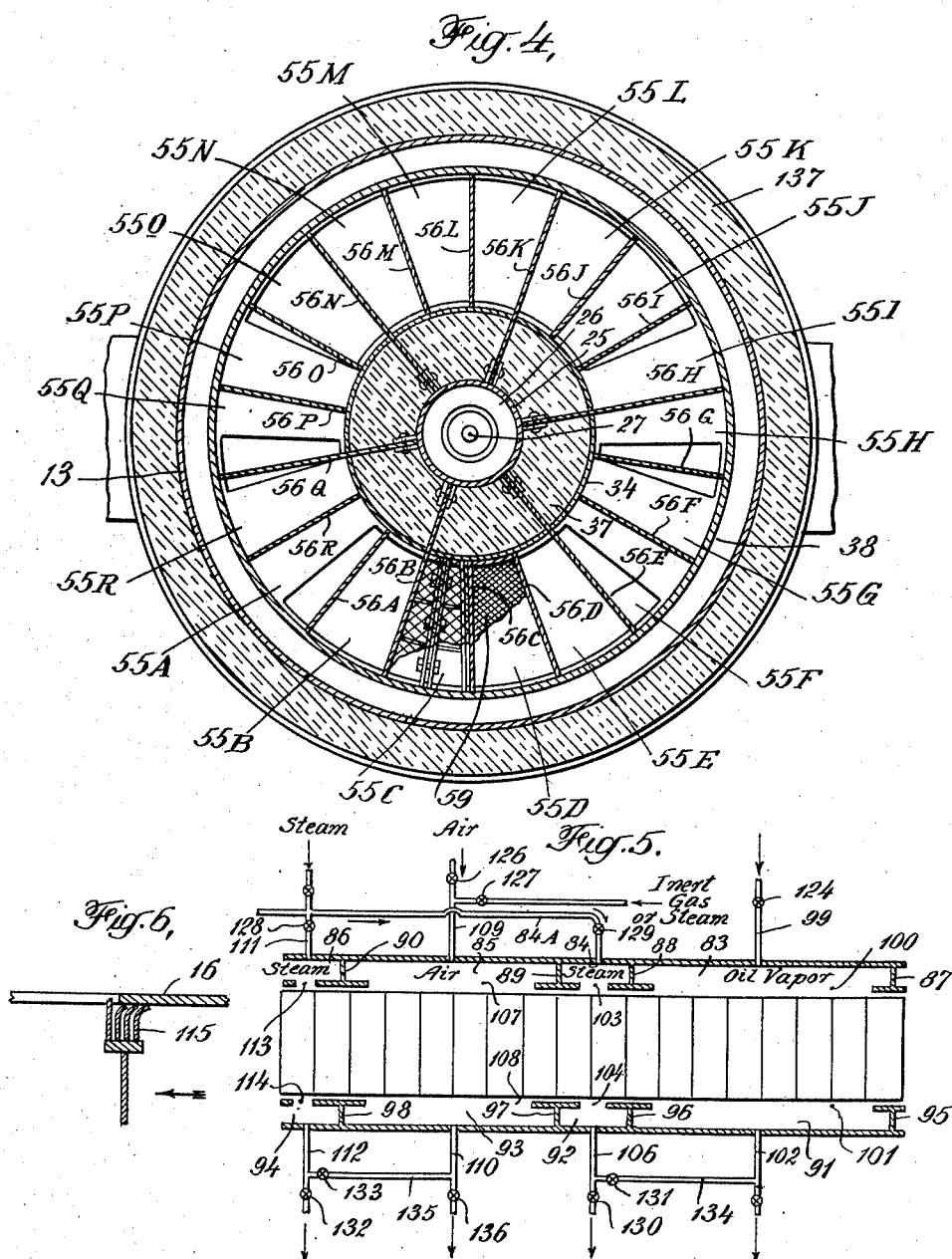
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CATALYTIC CRACKING

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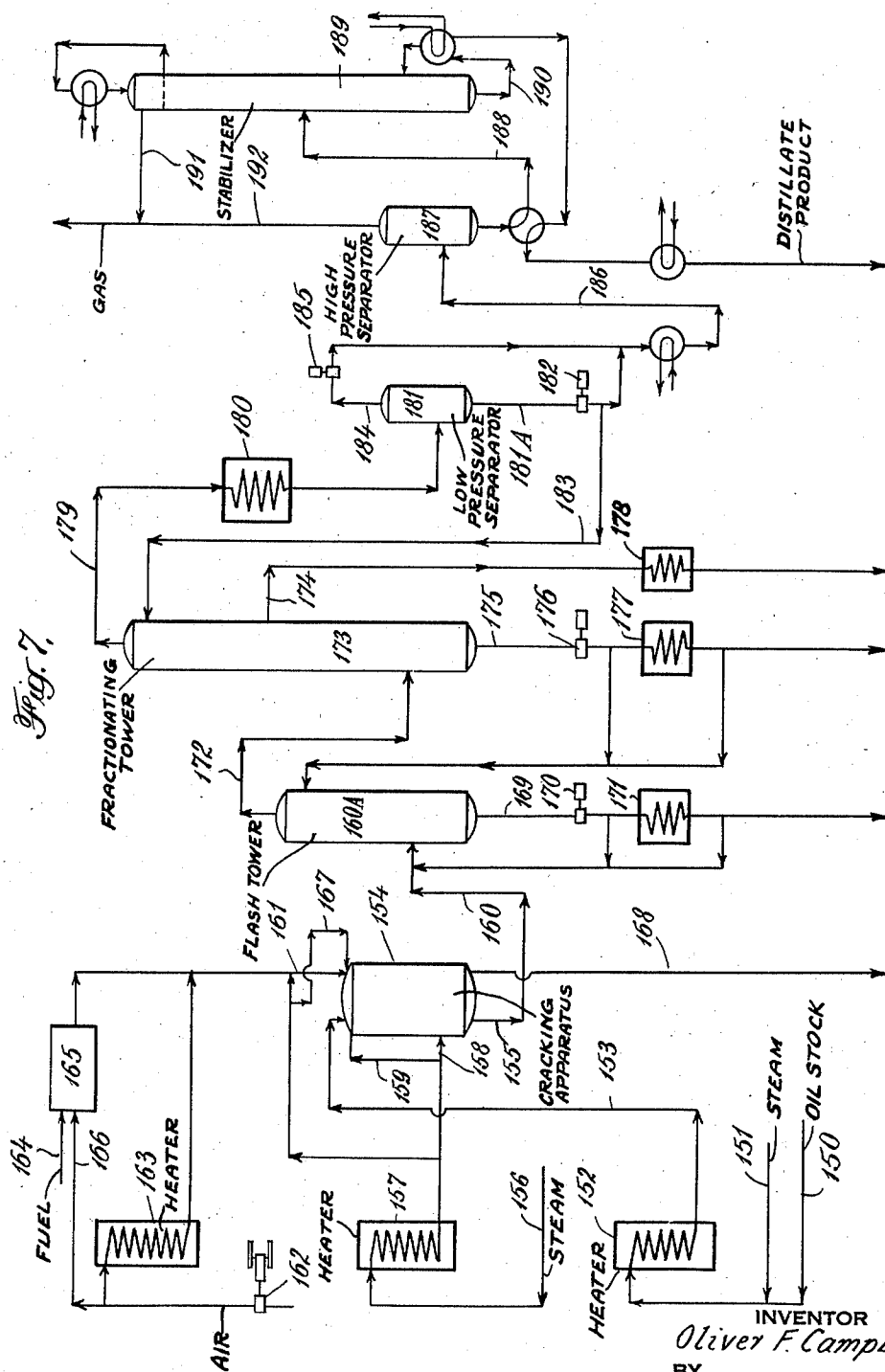
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CATALYTIC CRACKING

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4 Sheets-Sheet 4



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CATALYTIC CRACKING

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Application August 16, 1939, Serial No. 290,399

10 Claims. (Cl. 196—52)

This invention relates to catalytic cracking of hydrocarbons and provides improvements in apparatus for cracking higher-boiling hydrocarbons to produce more valuable lower-boiling hydrocarbons in the presence of a catalyst.

In heretofore customary operations, the catalytic treatment of the hydrocarbons has been conducted in an intermittent manner. The hydrocarbons to be cracked, for example a petroleum stock, are vaporized by heating under a low pressure, usually in the presence of steam to promote vaporization. The temperature of the resulting vaporous mixture of hydrocarbons, and any steam, may range from 700–800° F. to about 1000–1100° F.; the pressure may range from sub-atmospheric to as high as 100 pounds per square inch or more. Depending upon the nature of the stock to be cracked, the temperature and pressure, and the proportion of steam employed, all or only a portion of the stock may be vaporized. When unvaporized hydrocarbons remain these are usually separated and removed prior to catalyst contact. In any event, the vaporized hydrocarbons are sent to the cracking operation. There, in a reaction zone, a stream of the hydrocarbon vapors is passed in contact with a solid and usually porous or granular catalytic mass, such, for example, as fuller's earth or kieselguhr alone or admixed with various metals or metal salts. Lower-boiling hydrocarbons and "carbon" result from the ensuing cracking. The lower-boiling hydrocarbons and some of the carbon are removed from the reaction zone as formed, but a substantial portion of the carbon adheres to the catalyst and coats its surfaces and chokes its pores as it accumulates. As the carbon accumulates and fouls the catalyst, the activity of the latter decreases. When the economic limit of catalyst activity has been reached, the stream of hydrocarbon vapors to be cracked is diverted to another reaction zone containing a reactivated or regenerated catalyst mass, and the fouled mass is subjected to regeneration. This is usually accomplished by passing a hot oxidizing gas in contact with the catalyst so as to burn off the carbon accumulated on the surfaces and in the pores thereof and thus clean the catalyst for further service. Once the catalyst has been reactivated or regenerated by such treatment, the stream of vapors to be cracked is ultimately diverted back to a reaction zone containing the reactivated or regenerated catalyst mass and the operation thus proceeds.

The economic limit of catalyst activity may be reached in a very short time, even in a few sec-

onds, and, in certain catalytic cracking operations, the entire cycle time for cracking and regeneration may be less than a minute. This has necessitated the development of elaborate control mechanisms for automatically bringing about diversion of the stream of stock from a fouled catalytic mass to a regenerated one. Such control mechanisms not only increase plant investment and maintenance costs but are subject to operating difficulties. The regular production of a superior cracked product requires uniform operating conditions.

The heat of cracking reaction is composed of the heat of decomposition and the heat of recombination. Decomposition is endothermic and recombination is exothermic, and whether or not the reaction as a whole is heat-releasing or heat-consuming depends upon whether the heat of recombination or the heat of decomposition is greater. With most stocks to be cracked, at temperatures below about 975° F. the heat of decomposition generally is greater so that below this temperature cracking generally is endothermic. Above 975° F. the heat of recombination usually is the greater so that above this temperature the reaction (considered as a whole) is exothermic. When the cracking in the region of catalyst contact is an endothermic reaction (as is more often the case) it consumes considerable heat which may be supplied from the stock itself, or from an exterior source as by conduction through the walls of the chamber in which the catalyst is confined. On the other hand, regeneration involving as it does combustion of carbon, is exothermic, and its successful accomplishment requires dissipation of heat. This situation is one in which heat exchange between the cracking zone and the zone of regeneration is desirable but such exchange has heretofore been accomplished only at the expense of additional and cumbersome equipment and in an inadequate manner.

As a result of my investigations, I have developed improvements in apparatus for the catalytic cracking of hydrocarbons which permits continuous cracking of a stream of hydrocarbon stock without diverting this stream periodically as the catalyst requires regeneration which permits a substantial gain in thermal efficiency through improved heat exchange between the cracking and regeneration phases of the cycle, and which affords several advantages with respect to control. Consequent upon these improvements, the cumbersome automatic controls heretofore necessary may be eliminated with resultant savings in costs for plant, operation, and

maintenance and with greater ease of operation and improvement in products. These results are achieved in a process involving the contact of a catalytic mass with vaporized hydrocarbons with resultant cracking of the hydrocarbons and deposition of carbon on the mass and the subsequent treatment of the mass to remove the carbon therefrom prior to further contact of the mass with the hydrocarbons to be cracked by rotating the mass relatively to certain zones so that individual segments of the catalyst mass pass successively and cyclically through a first zone to which the vaporized hydrocarbons to be cracked are supplied substantially continuously and from which the resulting cracked hydrocarbons are withdrawn substantially continuously, a second zone through which a purging fluid (such, for example, as superheated steam) is passed substantially continuously, a third zone through which a hot oxidizing gas is passed substantially continuously and in which the carbon deposited on the mass is burned and a fourth zone through which a purging fluid is passed substantially continuously to remove products of the carbon combustion from the mass prior to the reintroduction thereof into the first zone, while substantially uniform conditions are continuously maintained in all four zones, particularly the first.

The above described method is described and claimed in my copending application Serial No. 290,398, filed August 16, 1939, but is carried on advantageously in the apparatus of my invention which is described and claimed hereinafter.

This apparatus provides a casing divided into at least a cracking section and a regenerative section by radially extending baffles. These sections are sealed from each other, but enclose a concentrically mounted wheel divided into a plurality of segments in each of which is disposed a catalyst. The wheel is rotatable with respect to the various sections which enclose it, so that its catalyst segments may be passed continuously through the series of sections and thus be alternately employed to crack hydrocarbons passing continuously through the cracking section and be regenerated by hot oxidizing gases in the regenerative section. More specifically, the invention provides, in apparatus for the catalytic cracking of hydrocarbons, the combination which comprises a hollow head divided around its periphery into a plurality of segmental chambers, said head having a flat bearing plate with ports therein communicating, respectively, with each of said chambers, a second hollow head disposed concentrically to the first head and having segmental chambers matching those in the first head with a flat bearing plate having ports therein corresponding to those in the first head, said bearing plates being disposed concentrically and parallel facing each other and spaced apart a fixed distance, a catalyst carrier in the form of a wheel disposed between the two bearing plates with its axis coinciding with that of the two heads and rotatable relative to the heads, said carrier being divided into a plurality of segments or compartments by radial vanes extending substantially from one bearing plate to the other, a catalytic mass disposed in the compartments of the catalyst carrier, means for forcing vaporized hydrocarbons from a chamber of one head to a corresponding chamber of the other head in contact with the catalytic mass in a compartment, means for simultaneously forcing a hot oxidizing gas from a second chamber of one head to a corresponding second chamber of the other head in

contact with the catalytic mass in another compartment, and means for simultaneously rotating the wheel relative to the heads.

In the preferred form of the apparatus of my invention, the heads are annular, the catalyst carrier wheel is rigidly mounted on a shaft disposed on the common axis of the two heads and passing therethrough; means are provided for rotating the shaft; means are provided for preventing leakage of vapor between the various sections of the apparatus; and the catalyst carrier is surrounded by an annular jacket for a hot diluent gas such as steam. The jacket space is enclosed by a drum fastened to the two heads so as to enclose the carrier, and means are provided for supplying the diluent gas (say steam) to the jacket at a pressure in excess of that prevailing in any of the chambers so that leakage of gas, if any, will take place into the carrier compartments rather than out, thereby preventing leakage to the outside and undesirable admixture of hydrocarbons and oxidizing gases within the apparatus.

There may be two or more chambers in each of the heads but preferably there are at least four, comprising respectively (along the direction of rotation of the apparatus) a chamber for hydrocarbons, a second for a purging gas such as steam, a third for the oxidizing gas, and a fourth for a purging gas to remove the products of oxidation.

The number of compartments or segments in the catalyst carrier may be two or more, but preferably a large number (such as eighteen or twenty) is provided. In any case, the segments should be of such dimensions relative to the radial distance between the ports in the bearing plates that no one catalyst segment is in contact with the ports of different chambers in the same head at the same time; that is to say a segment should be out of contact with the port supplying hydrocarbon before it comes in contact with the port which supplies purging gas, etc. This may be assured by making the radial space between ports (i. e. the distance between them in the path of rotation) greater than the radial space or angle devoted to a single segment.

These and other features of my invention will be more thoroughly understood in the light of the following detailed description taken in conjunction with the accompanying drawings in which

Fig. 1 is a plan view of apparatus of my invention having means for rotating a catalyst successively through a cracking zone, a purging zone, a regenerative zone, and a second purging zone;

Fig. 2 is a vertical section taken through the apparatus of Fig. 1 along the section line 2—2;

Fig. 3 is a horizontal section taken through the apparatus of Figs. 1 and 2 along the section line 3—3 of Fig. 2;

Fig. 4 is another horizontal section taken through said apparatus along the line 4—4 in Fig. 2;

Fig. 5 is a developed vertical diagrammatic view of one form of the apparatus of my invention;

Fig. 6 is a section of a portion of the apparatus taken along the line 6—6 of Fig. 2 and showing a type of wiper seal for sealing the various zones of the apparatus from each other;

Fig. 7 is a diagrammatic flow sheet showing the disposition of the rotating catalyst apparatus of Figs. 1 to 6 in a system for the catalytic cracking of hydrocarbons.

Referring now to the drawings and particularly

to Figs. 1, 2 and 3, it will be observed that in general the apparatus comprises a vertical shaft assembly 10 upon which is rigidly mounted a substantially cylindrical catalyst carrier wheel 11. The outer portion of the carrier wheel is enclosed by an annular casing 12 which is circular in plan and comprises a central cylindrical drum portion or jacket 13 to which is fastened at the top and bottom, respectively, a pair of hollow annular heads 14, 15. The inner wall of each head is formed by flat annular parallel bearing plates 16, 17. The heads are mirror images of each other and each is divided into four sections by radially extending baffles. These sections correspond to a cracking zone 18, a first purging zone 19, a regenerative zone 20 and a second purging zone 21 (Fig. 3). The carrier wheel is adapted to rotate successively through these zones, carrying catalyst segments mounted thereon in contact with the hydrocarbons to be cracked, thence into contact with superheated steam or other purging gas in the first purging zone, thence into contact with an oxidizing gas in the regenerative zone and again into contact with the purging gas in the second purging zone.

To consider the apparatus in greater detail, the vertical shaft assembly is connected at its upper end through a variable speed reducer 22, or other means for varying the speed of rotation, to a motor (not shown). The shaft assembly is hollow to permit water cooling. It is supported adjacent its lower end 23 by a thrust bearing 24 through which it passes. The shaft assembly at its mid-portion within the carrier wheel is enlarged and enclosed by a cylindrical wall 25 to form a cooling water chamber 26. A water inlet pipe 27 projects upwardly from the base of the shaft to a point adjacent its closed upper end 28. This pipe is stationary. Water forced into it through a lower water inlet 29 enters the cooling water chamber and flows downwardly through the lower hollow portion 30 of the shaft into a water outlet gland 31 disposed below the thrust bearing and concentrically around the water inlet pipe. The lower portion of the shaft is rotatably mounted on this gland, thus forming a sealed system. Water forced through the inlet pipe cools the interior of the shaft, flows downwardly through a rotatable coupling 32 disposed below the thrust bearing and out through the gland.

The carrier wheel 11 is rigidly fastened to the shaft adjacent its enlarged portion. Immediately adjacent the shaft, the carrier wheel has an annular chamber 33 enclosed by a cylindrical sheath 34 and upper and lower annular walls 35, 36. This chamber is filled with non-inflammable heat insulating material 37 such as Sil-O-Cel.

The outer vertical wall of the carrier wheel is a cylindrical shell 38 that is separated from the sheath by a considerable annular space. At the top and bottom of the shell 38 are fastened, respectively, outwardly projecting peripheral labyrinth seal members 39, 40. These members are disposed adjacent the plates 16, 17 that form the walls of the upper and lower heads, respectively. Each seal member has a series of concentric circular grooves 41, 42, 43 and 44, 45, 46 in the surfaces that face the plates, and into these fits a series of corresponding rings 47, 48, 49 and 50, 51, 52 that are fastened to the plates of the two casing heads thereby forming a pair of peripheral labyrinths, 53, 54, respectively, 75

at the upper and lower outer edges of the catalyst carrier wheel.

The space between the sheath and the outer shell of the carrier wheel is divided into a plurality of segmental compartments 55A, 55B, 55C, et seq. to 55R by vertical radial baffles or vanes 56A to 56R, inclusive, (Fig. 4). Any desired number of compartments may be provided, but it is desirable to have a relatively large number of them, and, in the instant case eighteen compartments are provided. The vertical baffle plates extend substantially completely from top to bottom of the carrier wheel and have straight horizontal upper and lower edges 57, 58 close to and parallel with the inner surfaces of the bearing plates of the two heads. In the lower portion of each compartment a horizontal foraminous plate 59 or other catalyst support is fastened. A porous or loose granular catalytic mass 60 or bed is disposed in each of the segmental compartments on the plates. It may be composed of any of the conventional solid catalysts suitable for catalyzing the cracking of hydrocarbons. A number of such materials are known, among them being kieselguhr or fuller's earth. The catalyst bed substantially fills the segmental compartments to a point just below the upper edge of the vanes. The catalyst bed should be porous or otherwise provide passage for gases therethrough in a vertical direction.

It will be observed that around the catalyst carrier wheel between its outer shell and the drum portion 13 of the casing there is an annular chamber 61. This annular chamber or jacket space is enclosed at its upper and lower ends by the peripheral seal members. However, unless these seals are perfect there is a tendency for gas under pressure to leak through the jacket space from one head to the other and thus by-pass the catalyst bed. With a view toward preventing such by-passing and also maintaining a proper temperature within the apparatus, steam is admitted into the annular chamber or jacket space through a pipe 62, the pressure of the steam being in excess of that maintained within the apparatus as a whole so that any leakage which occurs will be of steam from the annular chamber into the space occupied by the carrier wheel and the upper and lower heads.

An inner pair of peripheral labyrinth seals 63, 64 is provided, respectively, at the top and bottom of the carrier disk adjacent the space filled with insulating material. In this instance, a series of concentrically disposed rings 65A, 65B, 66, and 68, 69, 70 are fastened, respectively, to the upper and lower surfaces of the carrier wheel on the plates 35, 36 and project into peripheral concentric grooves 71A, 71, 72, and 74, 75, 76 formed in a pair of upper and lower bearings 77, 78 through which the shaft passes. The labyrinth seals 63, 64 or other sealing device of like form, are necessary to prevent leakage of gases from the space above and below the catalyst bed outwardly to the atmosphere. If desired, packing material may be placed in the seals.

To consider the construction of the upper and lower heads 14, 15 of the casing, reference should be made particularly to Figs. 2 and 3. The upper and lower heads are substantially mirror images of each other and are annular in form, being concentrically disposed in parallel planes. The outer portions of the heads, i. e. the portions remote from the carrier wheel are formed of curved plates 79, 80. These are welded to the inner flat annular bearing plates 16, 17. Each of the an-

nular chambers 81, 82 thus enclosed is divided into at least four segmental chambers by vertical radially extending baffles.

Thus, the upper head chamber 81 is divided into a hydrocarbon chamber 83, a first steam chamber 84, an oxidizing gas chamber 85, and a second steam chamber 86 by radial baffles 87, 88, 89, 90, and these chambers are disposed, respectively, in the cracking zone 18, the first purging zone 19, the regenerative zone 20, and the second purging zone 21. Likewise, the lower head chamber 82 is divided into four corresponding segmental chambers 91, 92, 93, 94 by baffles 95, 96, 97, 98 (see Fig. 5) and these chambers are disposed, respectively, in the cracking zone, the first purging zone, the regenerator zone and the second purging zone.

The rotation of the carrier wheel is clockwise as viewed from above. Thus, as the wheel is rotated, any segment of the catalyst bed passes successively between the chambers 83, 91, or hydrocarbon chambers of the upper and lower heads, between the chambers 84, 92 or first steam chambers, between the chambers 85, 93 or oxidizing gas chambers, and between the chambers 86, 94 or second steam chambers.

As illustrated in Figs. 3 and 5, the hydrocarbon chambers occupy more than $\frac{1}{8}$ of the respective heads. Hydrocarbon vapors to be cracked enter the upper hydrocarbon chamber 83 through a feed pipe 99 of relatively large diameter, pass from this chamber through a port 100 that corresponds in radial space to five or six catalyst segments, through these catalyst segments and a matching outlet port 101 into the lower hydrocarbon chamber 91. The resulting lower-boiling hydrocarbons are removed from this chamber 91 through an outlet pipe 102 of relatively large diameter.

Adjacent the hydrocarbon chambers, 84, 92 of the respective heads are the first steam chambers which occupy $\frac{1}{8}$ or $\frac{3}{8}$ of the respective heads. Steam is admitted into the upper chamber 84 through a pipe 84A, and passes into contact with the rotating catalyst carrier through a small port 103 in its bottom or bearing plate. This port is equal radially to about one catalyst segment and is disposed in the approximate center of the plate. The steam port 103 is separated from the hydrocarbon port 100 by a radial distance greater than that of one catalyst segment, so that such a segment must pass out of contact with the hydrocarbons before steam is admitted thereto. There is a corresponding steam port 104 in the plate of the matching lower steam chamber 92. Steam is admitted into the upper chamber 84 through a pipe 84A, and withdrawn from the lower chamber 92 through a pipe 106.

Next around the periphery of the apparatus is the regenerative section in which are disposed the oxidizing gas chambers 85, 93. These chambers occupy approximately $\frac{1}{8}$ to $\frac{7}{8}$ of the respective upper and lower heads. They are provided with a pair of segmental ports 107, 108, respectively, in the upper and lower plates through which hot oxidizing gases pass for contact with the catalyst segments to be regenerated. The ports in the regenerative section of the apparatus approximate in cross section about five or six catalyst segments and are spaced from adjacent ports by a distance equal to more than one of the segments of the catalyst wheel, for reasons hereinbefore explained. Hot air or other oxidizing gas for burning carbon from the catalyst segment is admitted into the upper chamber 85 through a pipe 109, 75

passes downwardly through the rotating catalyst segments into the corresponding lower chamber 93 of the lower head and is withdrawn therefrom through an outlet pipe 110.

The balance of the apparatus is occupied by the second purging section. This second purging section, like the first, corresponds radially to two or three of the catalyst segments. It contains the second steam chambers 86, 94 in the upper and lower heads, respectively. Steam for purging is admitted into the upper chamber through an inlet pipe 111 and passes through the adjacent catalyst segment to the steam chamber 94 in the lower head from whence the steam is withdrawn through an outlet pipe 112. Both upper and lower chambers of the second purging section are provided with small pie-shaped ports 113, 114 (equal to about one catalyst segment) through which the steam passes into and out of the catalyst segments.

To prevent leakage between the various sections of the apparatus, the upper and lower edges of each of the vanes on the catalyst carrier wheel are provided with wiper seals which bear against the inner plates of the upper and lower heads. Such a seal is shown in detail in Fig. 6, and comprises a flexible brush 115 fastened to the vane and bearing against the inside plate of the head. Seals of different construction may, of course, be provided but that illustrated is simple and effective.

The upper head is provided with four thermocouples 116, 117, 118, 119 disposed, respectively, in wells 120, 121, 122, 123 in each of the several chambers to enable proper temperature control of the system. Like thermocouples in similar wells are provided in the chambers of the lower head.

A better idea of the operation of the apparatus described hereinbefore may be obtained by reference to Fig. 5 which is a developed diagram of the apparatus. Referring now to this diagram, it will be observed that oil vapor to be cracked is admitted in the hydrocarbon chamber of the upper head. It passes from this chamber through the hydrocarbon port (corresponding to about six segments of the carrier), through these six segments and the corresponding lower hydrocarbon port into the lower hydrocarbon chamber from which it is withdrawn.

At the same time, steam is passed through the first purging section, entering first the steam compartment of the upper head, passing then through a small port (equal to about one catalyst segment) and then through the catalyst segment and the lower port into the steam chamber in the lower head. The steam, plus such substances as have been purged from the catalyst (principally entrained hydrocarbon gas) is withdrawn from the chamber in the lower head either independently or together with the cracked oil vapor from the cracking section.

Simultaneously, hot air plus steam or inert gas is introduced into the regenerating section which corresponds in this case to about six catalyst segments. The mixture of steam or inert gas with hot air enters the oxidizing gas chamber of the upper head, passes through a port therein corresponding to about five catalyst segments and through these catalyst segments and a corresponding lower port into the oxidizing gas compartment of the lower head. The excess oxidizing gas and the products of carbon combustion are then withdrawn and sent to waste or to a heat recovery system.

At the same time that certain of the catalyst segments are being subjected to contact with oil vapors, others to contact with steam in the first purging section and still others to contact with hot oxidizing gas in the regenerative section, the balance of the catalyst segments are treated in the second purging section with steam which is admitted into the upper head in its steam chamber corresponding to about two catalyst segments from whence it passes to a port corresponding to about one catalyst segment and through this catalyst segment and the corresponding lower port into the lower steam chamber from whence it is withdrawn either alone or with the exhaust gases of the regenerative section.

As shown in Fig. 5, a control valve 124 is provided on the inlet line 99 for regulating the passage of oil vapor through the cracking section and a pair of valves 126, 127 are provided in branch pipes for regulating the proportions of air and steam or inert gas supplied to the regenerative section through the pipe 109. Likewise, control valves 128, 129 are provided for regulating the supply of steam to the purging sections. Valves 130, 131 and 132, 133 are also provided on the outlets from the purging sections so that gases therefrom may be passed through bypass lines 134, 135 and mixed, if desired, with the products of the cracking and regenerative sections or else handled separately. Thus, the valves 130, 131 on the outlet of the first purging section permit exhaust gases therefrom to be mixed with the product of the cracking section or handled independently. Likewise, the valves 132, 133 on the outlet of the second purging section permit exhaust gases therethrough to be handled independently or passed into and mixed with the exhaust gases of the regenerative section. Another valve 136 is provided for controlling the outlet of the regenerative section and regulating the pressure therein.

As indicated, especially in Fig. 2, the entire outer casing of the apparatus may be covered with a heat insulating jacket 137.

As indicated hereinbefore, the cracking reaction ordinarily is endothermic but may become exothermic at temperatures in excess of about 975° F. and with certain stocks when the heat of recombination exceeds the heat of decomposition. Hence, in most instances, it is necessary to add heat to the cracking zone, but with certain stocks and under certain conditions it may be necessary to extract heat. In either case, the apparatus herein described provides convenient means for regulating the heat supplied to the cracking zone or removed therefrom, by varying the amount of heat contained in the rotating catalyst segments.

If, for example, the particular cracking reaction being carried out is strongly endothermic, it is necessary to supply to the cracking zone a relatively large amount of heat. In accordance with my invention, this heat is supplied by the rotating catalytic segments which serve a dual purpose in that they act as a heat exchanger in addition to acting as catalysts. By proper control of the speed of rotation and of the heat supplying media in the purging and regenerative sections of the apparatus, an amount of heat can be stored in the rotating catalytic segments which will be just sufficient to supply that necessary for the cracking reaction.

In the event that the cracking reaction is exothermic, the rotating catalyst segments are cooled in the zones other than the cracking zone, and are returned to the latter at a temperature below

that prevailing in the cracking zone, so that they act to extract heat.

The heat supplied and extracted from the rotating catalytic segments in the various zones will, of course, depend upon the specific heat, i. e. the heat containing capacity of a given mass of the catalyst per degree of temperature, as well as upon thermal gradients existing between the several zones and the catalyst segments passing therethrough. Consequently, the catalytic mass should have a relatively high specific heat and the mass itself should be large enough to assure ample heat carrying capacity.

Assuming that the catalyst segments are such as to carry an adequate amount of heat to or from the cracking zone, the regulation of the amount of heat so carried can be controlled in various ways. If gases of constant specific heat, temperature and volume are passing through the purging and regenerative sections, the amount of heat supplied to the cracking zone may be altered by varying the speed of rotation of the catalyst carrier. On the other hand, the amount of heat introduced into the catalyst carrier and supplied to the cracking zone may be varied by varying the temperature of the purging gases, or by varying the temperature of the oxidizing gases passed in contact with the catalyst in the regenerative zone. Since the great bulk of the heat supplied to the catalyst is supplied in the regenerative zone, this is a satisfactory point at which to regulate the amount of heat supplied. This regulation may be brought about by changing the temperature or the specific heat or both of the gases passed through the regenerative zone. However, this regulation of heat in the regenerative zone cannot be regulated without regard to the oxidizing characteristics or capacities of the gases passing therethrough. Consequently, it is convenient to provide, as illustrated in Figure 5, a source of hot oxidizing gas and of a hot diluent or inert gas, which may be inert carbonaceous gaseous products of combustion or steam or both. By regulating the temperature and proportions of these ingredients, it is possible to obtain a gas mixture which has the correct oxidizing characteristics concurrently with the proper specific heat and temperature. This condition having been attained, and assuming the correct speed of rotation of the catalyst carrier, the exact amount of heat necessary for the promotion of the catalytic cracking reaction may be supplied. By this means constant conditions can be maintained in all of the zones of the apparatus and constant streams at constant temperatures of both reaction products and reactivation products are available for further economical recovery of waste heat.

By varying the speed of rotation of the catalyst wheel or carrier, the cycle of processing and reactivation may be varied at will to give optimum activity of the catalyst for the particular hydrocarbon stock undergoing cracking. Once the desired speed of rotation for a given stock has been established, the character and amount of oxidizing gas employed in reactivation may be controlled so as to burn from the catalyst the desired proportion of the carbon content deposited thereon. Thus, if desired, all of the carbon may be burned out of the catalyst. However, it is preferable to burn substantially only the surface carbon from the catalyst, leaving some deposit of carbon within the pores of the mass. Operations so conducted result in an increased yield of more valuable hydrocarbons with

a minimum degradation or conversion of hydrocarbons to elemental carbon.

In the event that the heat of reaction cannot be supplied in the reactivation zone either from the heat of combustion, or from the sensible heat of gases introduced therein while maintaining an optimum catalyst efficiency, the apparatus may be divided into five sections rather than four, the additional section being used for raising or lowering the temperature of the catalyst bed by means of steam, inert gas, or by passing the gaseous products of reactivation through the mass. Moreover, by varying the temperature and quantity of preheated steam or other purging gas passed through the purging section, the amount of heat picked up by the rotating catalyst may be varied to some degree.

As indicated hereinbefore, the sealing steam introduced into the jacket space between the catalyst wheel and the drum of the casing tends to leak into the oil vapor being cracked as well as into the inert gas or steam-air mixture passed through the regenerative section. For this reason, the steam employed for sealing should be maintained at a temperature sufficiently high that leakage thereof into the apparatus will not reduce the temperature of the vapor streams, especially the stream of hydrocarbons. Hence, it is necessary to superheat the steam employed for sealing to a temperature slightly in excess of that of the oil vapors being treated in the cracking zone. Superheating the steam offers a further advantage by serving to reduce the amount of steam required for sealing.

In order to minimize steam consumption in the apparatus and especially steam consumption due to leakage, it is desirable to maintain the pressure of the gases employed in reactivation substantially the same as the pressure of the oil vapor entering the cracking zone while maintaining slightly higher pressures on the steam entering the purging zones and the sealing zone.

To minimize leakage from zone to zone at the bottom of the carrier wheel a back pressure should be maintained on the products from the reactivation zone substantially equal to the back pressure on the oil vapors leaving the cracking zone while maintaining a back pressure at the bottom of the two-purging zones equal to or slightly in excess of the back pressures maintained at the bottom of the cracking zone and at the bottom of the reactivation zone.

In order to maintain the desired pressure in the reactivation zone while varying the supply of oxygen thereto, the amount of steam or additional inert gas introduced into the reactivation zone may be varied inversely to the air supply so as to maintain a substantially constant volume flowing through the catalyst. This will permit the maintenance of a pressure drop through the reactivation zone equivalent to the pressure drop of the oil vapors passing through the cracking zone. The valves provided in the apparatus, as illustrated in Fig. 5, permit such variations.

Generally speaking, the portion of the apparatus employed as a regenerative zone should be approximately the same in size as that employed in cracking and both should occupy several times as much space as the purging sections. However, when it is necessary to supply a very large amount of heat to the cracking zone, it may be desirable to reduce the size of the cracking zone as compared to the regenerative zone thereby increasing the heat transfer therebetween. It should also be observed that sufficient plate must

be left between the radially spaced ports of both upper and lower heads to prevent any catalyst carrier segment of the carrier wheel from coming in contact with two zones at the same time. Thus, any individual segment of the catalyst carrier must pass completely out from under a port into the cracking zone before it passes under the port in the first purging zone, et seq.

The apparatus of Figs. 1 to 6 may be incorporated into a variety of hydrocarbon cracking systems, and utilized in conjunction with a variety of equipment for recovering and separating the cracked hydrocarbons. One means of utilizing the apparatus is illustrated in Fig. 7 which is a flow sheet of a catalytic cracking system including the rotating catalyst apparatus hereinbefore described. In this system, a petroleum stock 150 to be cracked is mixed with an appropriate amount of steam 151 and the mixture is passed to a heater 152 which vaporizes the oil substantially completely. From the heater a mixture 153 of oil vapor and steam (say, in equimolecular proportions) passes to a cracking apparatus 154, constructed as described in detail hereinbefore and indicated diagrammatically on Fig. 7. The oil vapor and steam mixture passes through the cracking section of the apparatus as the catalyst carrier thereof is rotated (at a speed of say, two revolutions per minute) and the oil is cracked and withdrawn in a mixture 155 of steam and vapors of lower boiling hydrocarbons at the lower portion of the apparatus.

A supply of steam 156 for operating the purging sections of the cracking apparatus, for admixture with hot air for the regenerative section and for sealing purposes is passed through a superheater 157, and there heated to a temperature in excess of that of the oil entering the cracking section. Part of this superheated steam is passed through a line 158 into the space between the catalyst wheel and the drum of the casing, from which it may leak through the labyrinthian seals into any of the sections of the apparatus but in so doing prevents leakage outwardly from these sections. Another part of the superheated steam passes through a line 159 into the first purging section of the apparatus and sweeps out of the catalyst segments that rotate therethrough residual oil vapors. The steam from the first purging section is permitted to intermingle with the cracked hydrocarbons exhausted from the cracking apparatus to form the mixture 155 and through a pipe line 160 the mixture is sent to a flash tower 160A.

A third portion of the steam from the superheater may be mixed with hot compressed air and inert gases in a pipe line 161 and passed through the regenerator section of the cracking apparatus. To produce the hot compressed air, atmospheric air is first compressed in a compressor 162, passed through a heater 163 and thence into the line 161. The inert gases for diluting the air and thus impeding the combustion of the carbon on the catalyst segments passing through the regenerative section may be produced by burning carbonaceous fuel 164 in hot compressed air delivered to an inert gas generator 165 through a pipe line 166. From the inert gas generator the inert gas, in which the oxygen has been substantially all consumed is sent into the pipe line 161.

Superheated steam is admitted to the second purging section through a conduit 167, and after passing through the rotating catalyst segments

is withdrawn from the lower head and may be passed to waste either independently or mixed with the exhaust gases from the regenerative section through a stack 168.

When the petroleum stock to be cracked is a relatively light oil which can be completely vaporized under prevailing temperature and pressure conditions, say a temperature ranging from 800° to 1000° F. and a pressure ranging from sub-atmospheric to in excess of 100 pounds per square inch, it is not necessary to remove unvaporized hydrocarbons prior to introduction of the mixture of oil and steam into the cracking apparatus. Otherwise, a flash chamber (not shown) should be disposed between the heater and the inlet for the oil vapors into the cracking apparatus.

If desired, one or more of the cracking apparatus or units may be connected in parallel or in series. In any event, the outlet from the cracking sections of the apparatus augmented by purging and sealing steam, all at a temperature of about 750°-1100° F. and preferably between 800°-1000° F., is sent to the flash tower 169A without release of pressure.

The flash tower temperature may be controlled either by recirculation of condensed tar or by introduction of fractionating column bottoms to give a desired tar gravity preferably less than 10° A. P. I. Both types of control are provided for in the apparatus illustrated in Fig. 7. Thus, tar may be withdrawn from the bottom of the flash tower through a line 169 and part of the tar forced through a pump 170 back into the flash tower with or without cooling in a cooler 171.

The flash tower overhead 172 passes to a fractionating tower 173. Here two gas oil cuts may be taken off—one as a side stream 174 and one as a bottom cut 175. Either or both of these streams may be recycled through the system for further processing and may be returned to the tower system either hot or cold, as desired. In the apparatus illustrated in Fig. 7, provision is made only for recirculating the bottom cut through a pump 176 and optionally either through a cooling coil 177 or directly in the hot condition.

In the apparatus illustrated in Fig. 7 the side stream cut is passed through the cooler 178 and thence is withdrawn from the system for further processing.

The overhead stream 179 of the fractionating tower is controlled to give a product within finished gasoline distillation range specifications. The overhead from the fractionating column is withdrawn and passed through a cooler 180 into a receiver 181. A portion of the condensed fractionator overhead (receiver bottoms) 181A may be returned from this receiver as reflux to the top of the fractionating column through a pump 182 and a line 183 for controlling the temperature of the top of this column.

The apparatus of Fig. 7 is designed for low pressure operation, in which case a gaseous overhead product 184 of the receiver 181 (i. e., the portion of the fractionating column overhead which remains uncondensed) is withdrawn from this receiver and would contain a large portion of hydrocarbons which should be retained in the final stabilized distillate. With this in mind, the overhead 184 from the receiver is passed through a compressor 185 and compressed to a pressure slightly above that desired for stabilization. The

compressed overhead is then mixed with part of the bottoms withdrawn from the receiver.

The mixture of receiver bottoms and compressed overhead is passed through a line 186 to a high pressure receiver 187 and subjected to a further operation from which gas and liquid are separated under a pressure of approximately 250 pounds per square inch. Such separation gives a gaseous end product that is relatively free from hydrocarbons that should be included in the liquid product or distillate.

The distillate 188 from the high pressure receiver, i. e. the bottoms product or liquid resulting from the separation under high pressure, is sent to a conventional stabilizer 189 from which a distillate 190 of the desired vapor pressure is drawn off as a bottoms product. Overhead gas 191 from the stabilizer normally is diverted together with the overhead 192 from the high pressure receiver to a polymerization plant for conversion of these gases to higher olefine for polymer gasoline.

I claim:

1. In apparatus for the catalytic cracking of hydrocarbons, the combination which comprises a hollow annular head divided around its periphery into a plurality of segmental chambers, said head having a flat bearing plate with ports therein communicating respectively with each of said chambers, a second hollow annular head disposed concentrically with the first head and having segmental chambers matching those in the first head with a flat bearing plate having ports therein corresponding to those in the bearing plate of the first head, said bearing plates being disposed concentrically and parallel facing each other and spaced apart a fixed distance, a catalyst carrier wheel disposed between the two bearing plates with its axis coinciding with that of the two heads and rotatable relative to the heads, said carrier wheel being divided into a plurality of compartments by radial vanes extending substantially from one bearing plate to the other, a catalytic mass disposed in the compartments of the catalyst wheel, means for forcing vaporized hydrocarbons from a chamber of one head to a corresponding chamber of the other head in contact with the catalytic mass in one compartment, means for simultaneously forcing a hot oxidizing gas from a second chamber of one head to a corresponding second chamber of the other head in contact with the catalytic mass in another compartment, and means for simultaneously rotating the carrier wheel relative to the heads.

2. In apparatus for the catalytic cracking of hydrocarbons, the combination which comprises a hollow head divided around its periphery into a plurality of segmental chambers, said head having a flat bearing plate with ports therein communicating respectively with each of said chambers, a second hollow head disposed concentrically with the first head and having segmental chambers matching those in the first head with a flat bearing plate having ports therein corresponding to those in the bearing plate of the first head, said bearing plates being disposed concentrically and parallel facing each other and spaced apart a fixed distance, a catalyst carrier wheel disposed between the two bearing plates with its axis coinciding with that of the two heads and rotatable relative to the heads, said carrier wheel being divided into a plurality of compartments by radial vanes extending substantially from one bearing plate to the other, a

catalytic mass disposed in the compartments of the catalyst wheel, means for forcing vaporized hydrocarbons from a chamber of one head to a corresponding chamber of the other head in contact with the catalytic mass in one compartment, means for simultaneously forcing a hot oxidizing gas from a second chamber of one head to a corresponding second chamber of the other head in contact with the catalytic mass in another compartment, means for simultaneously rotating the carrier wheel relative to the heads, an annular jacket surrounding the carrier wheel and fastened to the two heads and means for introducing a hot diluent gas into said jacket.

3. In apparatus for the catalytic cracking of hydrocarbons, the combination which comprises a hollow head divided around its periphery into at least four segmental chambers, said head having a flat bearing plate with ports therein communicating respectively with each of said chambers, a second hollow head disposed concentrically with the first head and having segmental chambers matching those in the first head with a flat bearing plate having ports therein corresponding to those in the bearing plate of the first head, said bearing plates being disposed concentrically and parallel facing each other and spaced apart a fixed distance, a catalyst carrier wheel disposed between the two bearing plates with its axis coinciding with that of the two heads and rotatable relative to the heads, said carrier wheel being divided into a plurality of compartments by radial vanes extending substantially from one bearing plate to the other, a catalytic mass disposed in the compartments of the catalyst wheel, means for passing hot hydrocarbon gases from a chamber in one head to the corresponding chamber in the other head, means for passing a hot purging gas from the second chamber in one head to the corresponding second chamber in the other head, means for passing a hot oxidizing gas from the third chamber in one head in contact with the catalyst to the corresponding third chamber in the other head, and means for passing a hot purging gas from the fourth compartment of one head into the corresponding fourth compartment of the other head.

4. In apparatus for the catalytic cracking of hydrocarbons, the combination which comprises a hollow head divided around its periphery into a plurality of segmental chambers, said head having a flat bearing plate with ports therein communicating respectively with each of said chambers, a second hollow head disposed concentrically with the first head and having segmental chambers matching those in the first head with a flat bearing plate having ports therein corresponding to those in the bearing plate of the first head, said bearing plates being disposed concentrically and parallel facing each other and spaced apart a fixed distance, a catalyst carrier wheel disposed between the two bearing plates with its axis coinciding with that of the two heads and rotatable relative to the heads, said carrier wheel being divided into a plurality of compartments by radial vanes extending substantially from one bearing plate to the other, wiper type seals disposed between the bearing plates and the adjacent edge of the vanes, a catalytic mass disposed in the compartments of the catalyst wheel, means for forcing vaporized hydrocarbons from a chamber of one head to a corresponding chamber of the other head in contact with the catalytic mass in one compartment, means for simultaneously forcing a hot oxidizing

gas from a second chamber of one head to a corresponding second chamber of the other head in contact with the catalytic mass in another compartment, and means for simultaneously rotating the carrier wheel relative to the heads.

5. In apparatus for the catalytic cracking of hydrocarbons, the combination which comprises a hollow head divided around its periphery into a plurality of segmental chambers, said head having a flat bearing plate with ports therein communicating respectively with each of said chambers, a second hollow head disposed concentrically with the first head and having segmental chambers matching those in the first head with a flat bearing plate having ports therein corresponding to those in the bearing plate of the first head, said bearing plates being disposed concentrically and parallel facing each other and spaced apart a fixed distance, a catalyst carrier wheel disposed between the two bearing plates with its axis coinciding with that of the two heads and rotatable relative to the heads, said carrier wheel being divided into a plurality of compartments by radial vanes extending substantially from one bearing plate to the other, a catalytic mass disposed in the compartments of the catalyst wheel, means for forcing vaporized hydrocarbons from a chamber of one head to a corresponding chamber of the other head in contact with the catalytic mass in one compartment, means for simultaneously forcing a hot oxidizing gas from a second chamber of one head to a corresponding second chamber of the other head in contact with the catalytic mass in another compartment, means for simultaneously rotating the carrier wheel relative to the heads, a drum surrounding the catalyst carrier wheel and joined to the two heads, and peripheral seals adjacent the points at which the drum joins the respective heads to prevent gas by-passing from one head to the other without passing through the carrier wheel.

6. In apparatus for the catalytic cracking of hydrocarbons, the combination which comprises a hollow annular head divided around its periphery into a plurality of segmental chambers, said head having a flat annular bearing plate with ports therein communicating respectively with each of said chambers, a second hollow annular head disposed concentrically with the first head and having segmental chambers matching those in the first head with a flat annular bearing plate having ports therein corresponding to those in the first head, said bearing plates being disposed concentrically with, parallel to and facing each other, a rotatable shaft disposed on the common axis of the two heads, a rotatable catalyst carrier wheel rigidly mounted on the shaft between the two bearing plates, said carrier being divided into a plurality of segments by radial vanes and extending substantially from one bearing plate to the other, a catalytic mass disposed in the segments of the carrier wheel, means for forcing vaporized hydrocarbons from the chamber of one head to the corresponding chamber of the other head in contact with a catalytic mass in a segment, means for simultaneously forcing a hot oxidizing gas from a second chamber of one head to a corresponding second chamber of the other head in contact with the catalytic mass in another segment and means for simultaneously rotating the shaft.

7. In apparatus for the catalytic cracking of hydrocarbons, the combination which comprises a hollow annular head divided around its pe-

riphery into a plurality of segmental chambers, said head having a flat annular bearing plate with ports therein communicating respectively with each of said chambers, a second hollow annular head disposed concentrically with the first head and having segmental chambers matching those in the first head with a flat annular bearing plate having ports therein corresponding to those in the first head, said bearing plates being disposed concentrically with, parallel to and facing each other, a hollow rotatable shaft disposed on the common axis of the two heads, means for forcing a cooling fluid through the hollow shaft, a rotatable catalyst carrier wheel rigidly mounted on the shaft between the two bearing plates, said carrier being divided into a plurality of segments by radial vanes and extending substantially from one bearing plate to the other, a catalytic mass disposed in the segments of the carrier wheel, means for forcing vaporized hydrocarbons from the chamber of one head to a corresponding chamber of the other head in contact with a catalytic mass in a segment, means for simultaneously forcing a hot oxidizing gas from a second chamber of one head to a corresponding second chamber of the other head in contact with the catalytic mass in another segment and means for simultaneously rotating the shaft.

8. In apparatus for the catalytic cracking of hydrocarbons, the combination which comprises a hollow annular head divided around its periphery into a plurality of segmental chambers, said head having a flat annular bearing plate with ports therein communicating respectively with each of said chambers, a second hollow annular head disposed concentrically with the first head and having segmental chambers matching those in the first head with a flat annular bearing plate having ports therein corresponding to those in the first head, said bearing plates being disposed concentrically with, parallel to and facing each other, a rotatable shaft disposed on the common axis of the two heads, peripheral seals on the respective bearing plates adjacent the shaft, a rotatable catalyst carrier wheel rigidly mounted on the shaft between the two bearing plates, said carrier being divided into a plurality of segments by radial vanes and extending substantially from one bearing plate to the other, a catalytic mass disposed in the segments of the carrier wheel, means for forcing vaporized hydrocarbons from the chamber of one head to a corresponding chamber of the other head in contact with a catalytic mass in a segment, means for simultaneously forcing a hot oxidizing gas from a second chamber of one head to a corresponding second chamber of the other head in contact with the catalytic mass in another segment and means for simultaneously rotating the shaft.

9. In apparatus for the catalytic cracking of hydrocarbons, the combination which comprises a hollow head divided around its periphery into at least four segmental chambers, said head having a flat bearing plate with radially spaced ports therein communicating respectively with each of said chambers, a second hollow head disposed

concentrically with the first head and having segmental chambers matching those in the first head with a flat bearing plate having radially spaced ports therein corresponding to those in the bearing plate of the first head, said bearing plates being disposed concentrically and parallel facing each other and spaced apart a fixed distance, a catalyst carrier wheel disposed between the two bearing plates with its axis coinciding with that of the two heads and rotatable relative to the heads, said carrier wheel being divided into a plurality of compartments by radial vanes extending substantially from one bearing plate to the other, a catalytic mass disposed in the compartments of the catalyst wheel, means for passing hot hydrocarbon gases from a chamber in one head to the corresponding chamber in the other head, means for passing a purging gas from the second chamber in one head to the corresponding second chamber in the other head, means for passing an oxidizing gas from the third chamber in one head in contact with the catalyst to the corresponding third chamber in the other head, and means for passing a purging gas from the fourth compartment of one head into the corresponding fourth compartment of the other head, the distance between the radially spaced ports in the bearing plates along the direction of rotation of the wheel being greater than the width of the compartments of the carrier wheel in the same direction.

10. In apparatus for the catalytic cracking of hydrocarbons, the combination which comprises a hollow annular head divided around its periphery into a plurality of segmental chambers, said head having a flat bearing plate with radially spaced ports therein communicating respectively with each of said chambers, a second hollow annular head disposed concentrically with the first head and having segmental chambers matching those in the first head with a flat bearing plate having radially spaced ports therein corresponding to those in the bearing plate of the first head, said bearing plates being disposed concentrically and parallel facing each other and spaced apart a fixed distance, a catalyst carrier wheel disposed between the two bearing plates with its axis coinciding with that of the two heads and rotatable relative to the heads, said carrier wheel being divided into a plurality of compartments by radial vanes extending substantially from one bearing plate to the other said radial vanes being radially spaced apart a distance substantially less than the radial width of said ports, a catalytic mass disposed in the compartments of the catalyst wheel, means for forcing vaporized hydrocarbons from a chamber of one head to a corresponding chamber of the other head in contact with the catalytic mass in one compartment, means for simultaneously forcing a hot oxidizing gas from a second chamber of one head to a corresponding second chamber of the other head in contact with the catalytic mass in another compartment, and means for simultaneously rotating the carrier wheel relative to the heads.

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