Dec. 8, 1942. O. F. CAMPBELL 2,304,398

CATALYTIC CRACKING

Filed Feb. 8, 1940 5 Sheets-Sheet 1

Fig. 1,

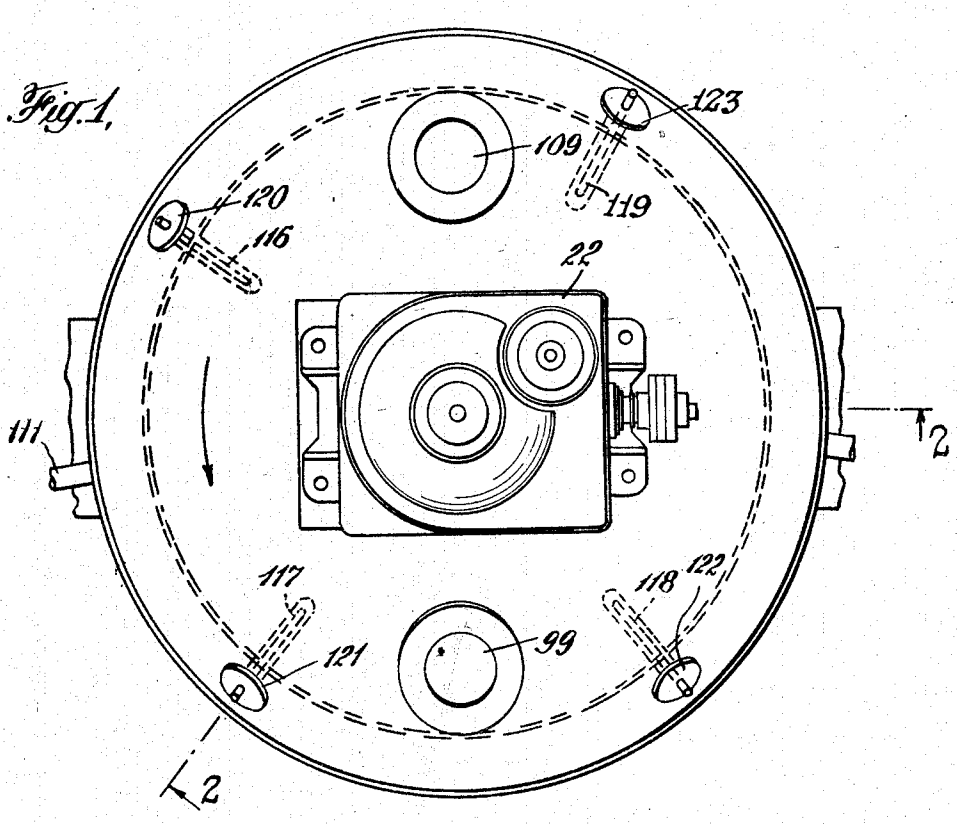
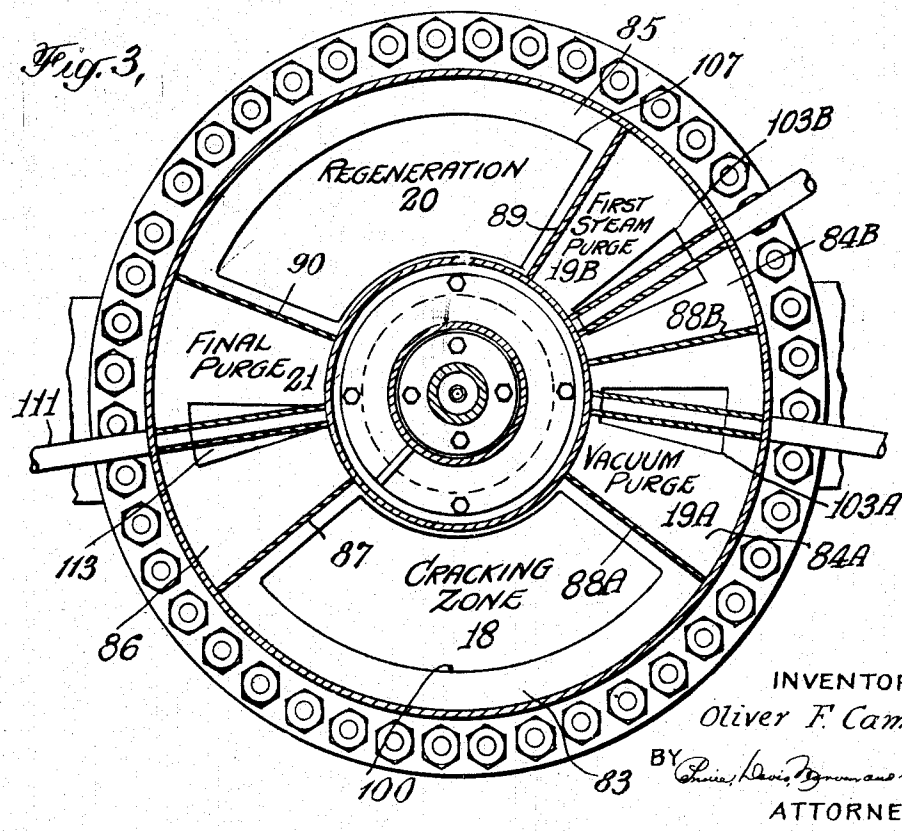


Fig. 3,



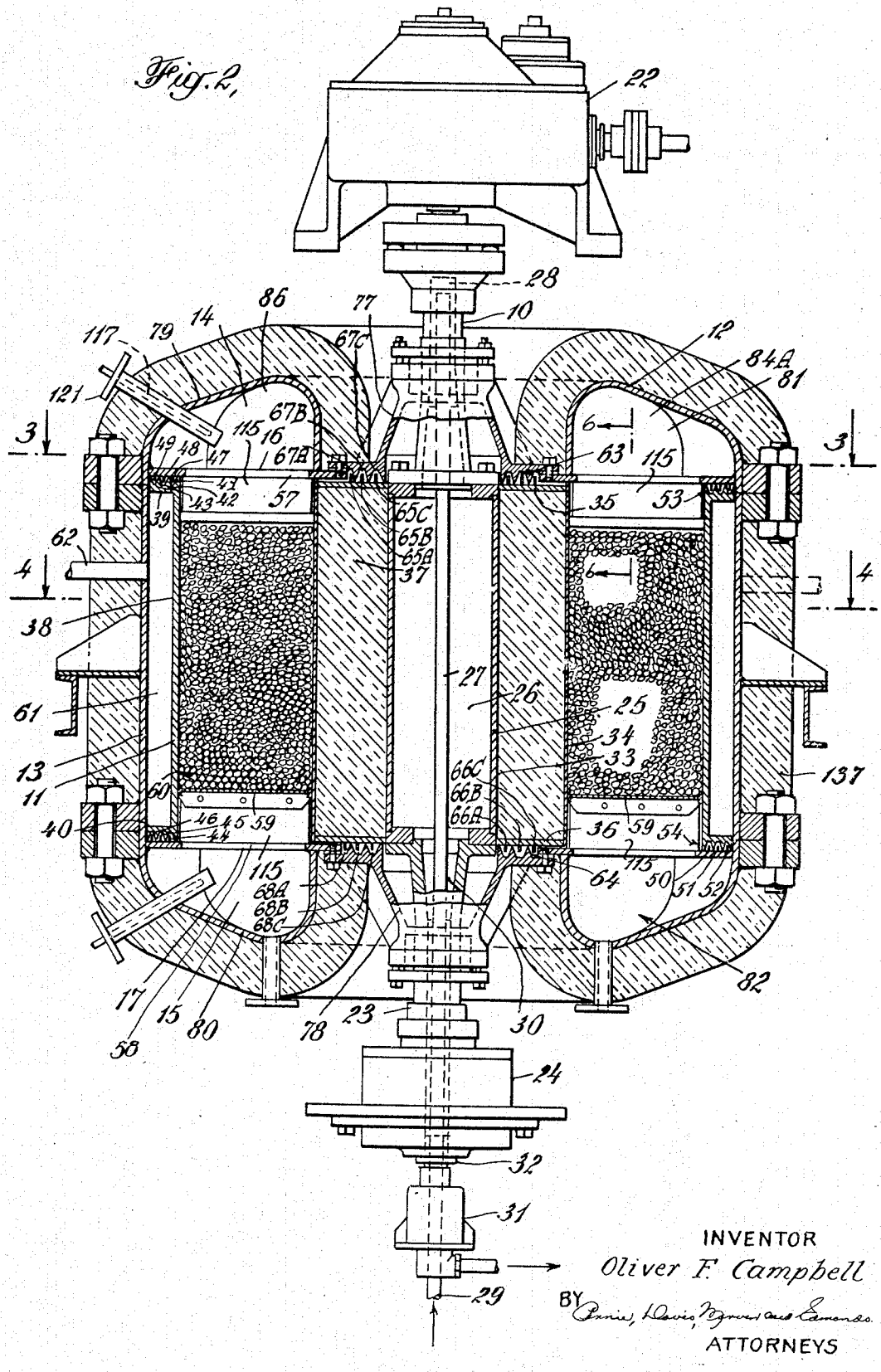
INVENTOR
Oliver F. Campbell
BY Price, Davis, Brownand Emmons
ATTORNEYS

Dec. 8, 1942. O. F. CAMPBELL 2,304,398

CATALYTIC CRACKING

Filed Feb. 8, 1940 5 Sheets-Sheet 2

Fig. 2.



INVENTOR

Oliver F. Campbell

BY Davis, Davis, Bynum and Lamond

ATTORNEYS

Dec. 8, 1942. O. F. CAMPBELL 2,304,398

CATALYTIC CRACKING

Filed Feb. 8, 1940 5 Sheets-Sheet 3

Fig. 4,

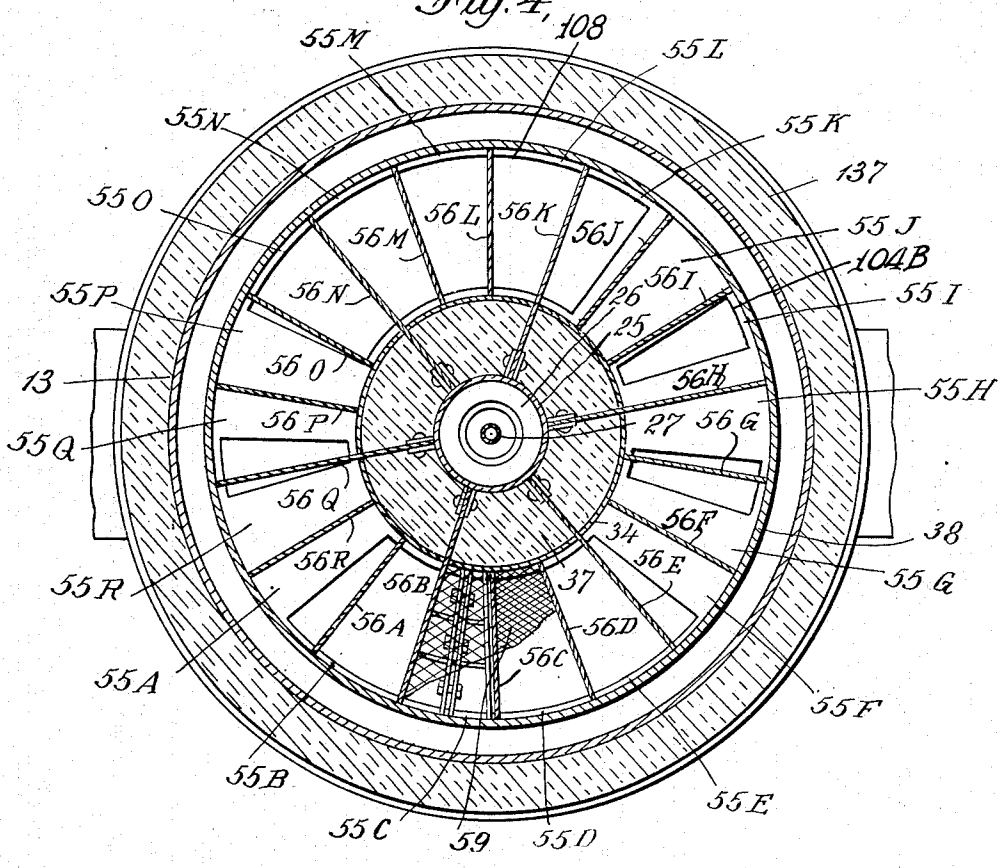
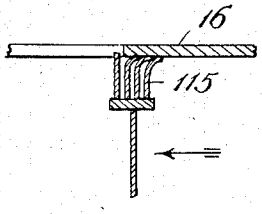


Fig. 6,



INVENTOR
Oliver F. Campbell
BY
Davis, Davis, Wynn and Symonds
ATTORNEYS

Dec. 8, 1942. O. F. CAMPBELL 2,304,398

CATALYTIC CRACKING

Filed Feb. 8, 1940 5 Sheets-Sheet 4

Fig. 5,

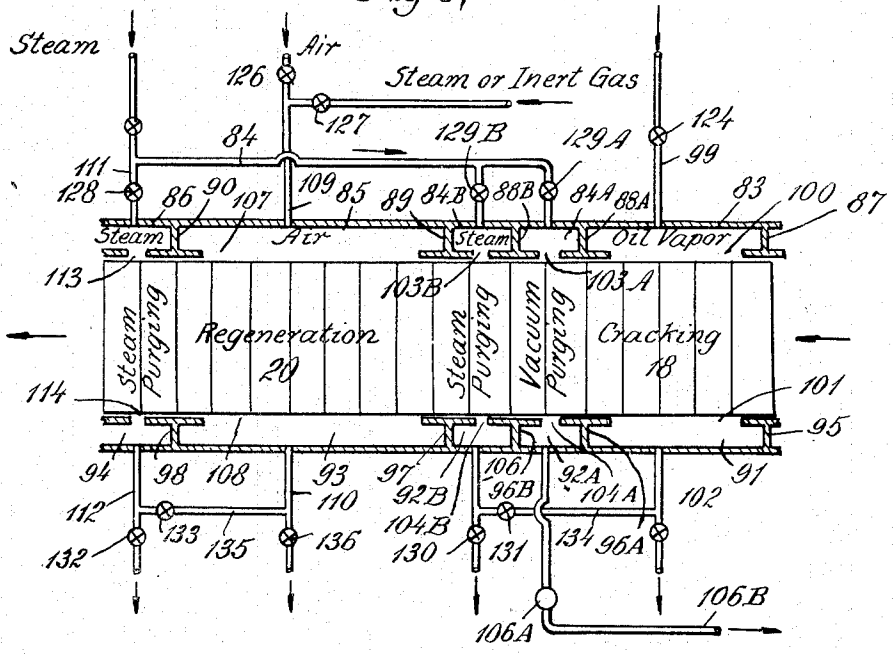
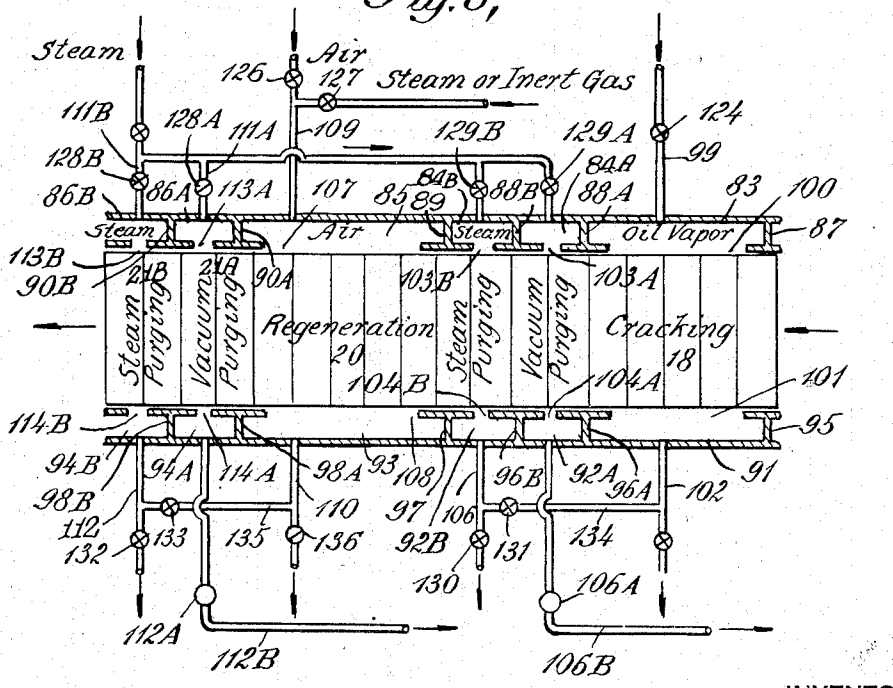


Fig. 8,



INVENTOR
OLIVER F. CAMPBELL
BY
Pennie Davis Marvin & Edmonds
ATTORNEYS

Dec. 8, 1942. O. F. CAMPBELL 2,304,398

CATALYTIC CRACKING

Filed Feb. 8, 1940 5 Sheets-Sheet 5

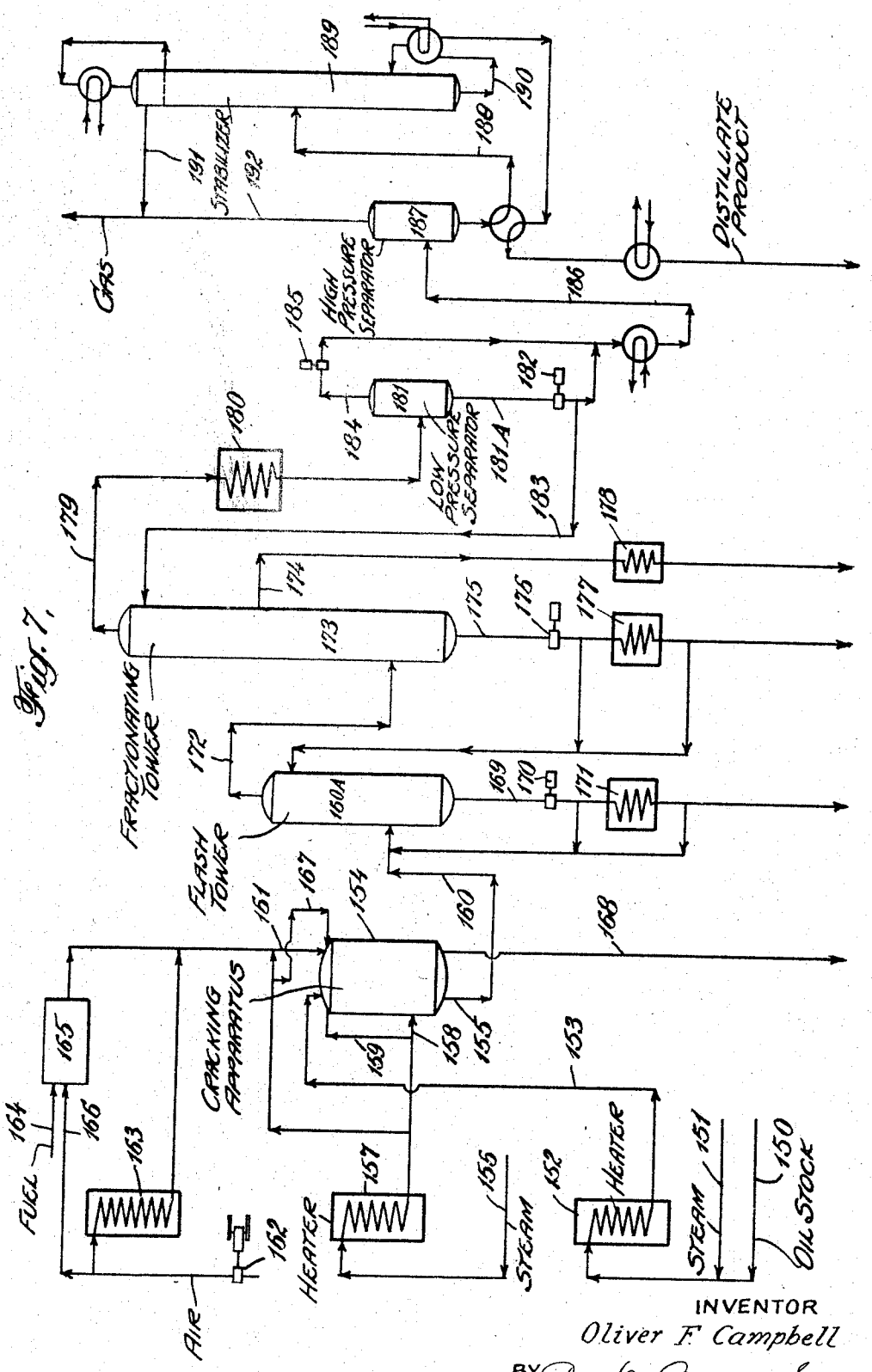


Fig. 7.

INVENTOR
Oliver F. Campbell
BY Dunn, Davis, Bynum and Lamond
ATTORNEYS

Patented Dec. 8, 1942 2,304,398

UNITED STATES PATENT OFFICE

2,304,398

CATALYTIC CRACKING

Oliver F. Campbell, Whiting, Ind., assignor to Sinclair Refining Company, New York, N. Y., a corporation of Maine

Application February 8, 1940, Serial No. 317,930

5 Claims. (Cl. 196—52)

This invention relates to catalytic cracking of hydrocarbons and provides improvements in such operations, in which higher-boiling hydrocarbons are cracked to provide more valuable lower-boiling hydrocarbons in the presence of a catalyst. This application is a continuation-in-part of my copending application Serial No. 290,398, filed August 16, 1939.

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 subatmospheric 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 seconds, 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 superior cracked products requires uniform operating conditions.

The heat of the cracking reaction is composed of the heat of decomposition and the heat of chemical condensation. Decomposition is endothermic and condensation is exothermic, and whether or not the reaction as a whole is heat-releasing or heat-consuming depends upon whether the heat of chemical condensation or the heat of decomposition is greater. When the cracking in the region of catalyst contact is an endothermic reaction (as is 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.

In my copending applications Serial Nos. 290,398 and 290,399, filed August 16, 1939 (the latter application having become U. S. Patent 2,246,345), I have described and claimed apparatus and methods for the catalytic cracking of hydrocarbons, involving continuous cracking of a stream of hydrocarbon stock without diverting this stream periodically as the catalyst requires regeneration. Such an operation permits a substantial gain in thermal efficiency through improved heat exchange between the cracking and regeneration phases of the cycle and also affords advantages with respect to control in that it permits elimination of heretofore necessary but cumbersome automatic controls (with consequent savings in costs for plant, operation and maintenance), greater ease of opera-

tion and improvement in product. These results are achieved in a catalytic cracking process by rotating segments of a catalytic mass successively and cyclically through four zones. To the first zone vaporized hydrocarbons to be cracked are supplied substantially continuously and from it the resultant cracked hydrocarbons are substantially continuously withdrawn. In the third zone, a hot oxidizing gas is introduced substantially continuously and therein carbon and other solid impurities deposited on the mass in the first zone are burned away. In the second and fourth zones, purging occurs. Thus, in the second zone gaseous impurities entrained by the mass in the first or cracking zone are removed, and in the fourth zone gaseous products entrained in the third or regenerative zone are removed.

The cycle time for such an operation may vary over wide limits, but is in general short, say of the order of 1 to 10 minutes. I have discovered that when the cycle time is short purging must be more efficient than in conventional apparatus with longer cycle times, in order to minimize loss of valuable hydrocarbons which pass into and are burned in the regenerative zone. The hydrocarbons to be purged comprise "fixed gas," gasoline, gas oil and relatively non-volatile hydrocarbons. These latter are the most difficult to purge because of their high boiling point or because they are strongly adsorbed by the catalytic surfaces or because they penetrate deeply into the pores of the mass and are not reached by purging fluids such as steam. In any event, I have found that the operation is greatly improved if the purging, at least in the second zone where hydrocarbons are removed from the catalyst, is accomplished by a sucking action. Thus, I have discovered that the efficiency of the above-described method (from the standpoint of the proportion of useful hydrocarbons of lower-boiling range produced from a given quantity of feed to the first zone) is improved greatly by purging the catalyst, at least in the second zone, by means of vacuum. Hence, in accordance with the present invention the second zone (or a portion thereof) and in some instances both the second and fourth zones (or portions thereof) are maintained under a reduced pressure (as compared with that of the cracking and regenerating zones) and preferably under pressure less than atmospheric, by means of ejectors, pumps, or other vacuum-producing apparatus connected to the exhaust sides of the purging zones.

In my presently preferred method of operation, the second zone is divided into two portions a[illegible] the direction of rotation of the catalyst. In the first portion, immediately adjacent the cracking zone, vacuum purging is practiced, and this is followed by purging with a fluid, such as steam, passed through the catalyst from an exterior source in the second portion of the second zone. The fourth zone may likewise be divided into a vacuum purging portion followed by a steam purging portion, but the advantages of vacuum purging are not so pronounced in the fourth zone, and it may be advantageous to employ only steam purging therein.

The above-described method may be carried on in a variety of apparatus, but is advantageously performed in apparatus of the type described and claimed in my copending application Serial No. 290,399, filed August 16, 1939, now U. S. Patent 2,246,345. 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 of my copending application provides, in apparatus for the catalytic cracking of hydrocarbons, the combination which comprises a hollow and preferably 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 head (preferably a mirror image of the first) 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 above-described apparatus, the heads are annular; the catalyst carrier 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. For practice of the instant invention with purging by suction, there are conveniently at least five compartments, corresponding respectively to (along the direction of rotation of the carrier wheel) a zone for hydrocarbons, a second (subdivided into two sections) for purging out the products of the first zone by vacuum and steam, in that order, a succeeding

regenerating zone for the oxidizing gas and a final zone for purging the products of oxidation by steam or other purging gas.

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 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, or through which evacuation occurs under reduced pressure. 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.

Apparatus of this general type adapted to carry out the process of my present invention is illustrated in the accompanying drawings and my invention will be more clearly understood in the light of the following detailed description in connection therewith.

In drawings:

Fig. 1 is a plan view of one form of apparatus adapted to carry out the process of my invention and having means for rotating a catalyst successively through a cracking zone, a purging zone divided into first and second sections, a regenerative zone, and a second purging zone.

Fig. 2 is a vertical 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 of Fig. 2;

Fig. 5 is a developed vertical diagrammatic view of the apparatus illustrated in Figs. 1 and 2, this being a form of apparatus embodying means for applying vacuum purging only to a portion of the first purging zone;

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; and

Fig. 8 is a developed vertical diagrammatic view of a modified form of apparatus including means for applying vacuum purging to portions of both the first and second purging zones.

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 center cylindrical drum portion or jacket 13 to which is fastened at the top and bottom, respectively, a pair of hollow annular heads 14 and 15. The inner wall of each head is formed by flat annular bearing plates 16 and 17. The heads are mirror images of each other and each is divided into five sections by radially extending baffles. These sections correspond to a cracking zone 18, a first purging zone 19 having a first vacuum purging section 19A and a first steam purging section 19B, a regenerative zone 20 and a final steam purging zone 21 (Figs. 3 and 5).

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 in succession into the first and second sections of the first purging zone for purging respectively by means of suction and superheated steam or other purging gas, thence into contact with an oxidizing gas in the regenerative zone and finally into the final purging zone for purging with an extraneous gas stream.

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 of 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 and 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 an 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, this 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 and 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 and 40. These members are disposed adjacent the plates 16 and 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 fit 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 and 54, respectively, at the upper and lower 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 and 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 of 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 designed to permit the passage of 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 annular 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 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.

The inner pair of peripheral labyrinth seals 63 and 64 are provided, respectively, at the top and the bottom of the carrier disk adjacent the space filled with insulating material. In this instance, a series of concentrically disposed rings 65A, 65B, 65C and 66A, 66B and 66C, are fastened respectively to the upper and lower surfaces of the carrier wheel on the plates 35, 36 and project into peripheral concentric grooves 67A, 67B, 67C and 68A, 68B, 68C 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 and 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 grooved plates 79 and 80. These are welded to the inner flat annular bearing plates 16 and 17. Each of the annular chambers 81 and 82 thus inclosed is divided into at least five segmental chambers by vertical radially extending baffles.

Thus, as shown in Figs. 3 and 5, the chamber 81 of the upper head preferably is divided into a series of chambers which include, reading from right to left in Fig. 5, a hydrocarbon chamber 83, a vacuum chamber 84A and a steam chamber 84B of the first purging zone, an oxidizing gas chamber 85, and a steam chamber 86 of the second purging zone by baffles 87, 88A, 88B, 89 and 90, and these chambers are disposed, respectively, in the cracking zone 18, in the vacuum section of the first purging zone 19A, in the steam purging section of the first purging zone 19B, in the regenerative zone 20, and in the second purging zone 21. Likewise, the interior 82 of the lower head is divided into five corresponding segmental chambers 91, 92A, 92B, 93 and 94 by baffles 95, 96A, 96B, 97 and 98 (see Fig. 5), and these chambers are disposed, respectively, in the cracking zone, in the vacuum section of the first purging zone, in the steam section of the first purging zone, in the regenerative zone and in the second purging zone. In short, in the preferred form of apparatus (Fig. 5), the first purging zone is divided into two portions or sections in the first of which vacuum purging occurs, with steam purging in the second.

The rotation of the carrier wheel is counterclockwise, as viewed from above, thus, as the wheel is rotated, any segment of the catalyst bed passes successively between chambers 83, 91 (i. e., the hydrocarbon chambers of the upper and lower heads), between the chambers 84A and 92A (i. e., the vacuum chambers of the first purging zone), between chambers 84B and 92B (i. e., the steam purging chambers of the first purging zone), between the chambers 85 and 93 (i. e., the oxidizing gas chambers), and between chambers 86 and 94 or the second steam chambers.

The upper vacuum chamber 84A is provided with a port 103A and a gas inlet valve 129A on a branch of line 84 so that, if desired, steam or other purging gas may be admitted to the vacuum purging section. The lower vacuum chamber 92A has a port 104A in its upper wall through which hydrocarbon gases, etc., are sucked from the catalyst passing through the vacuum purging section from the cracking section.

As illustrated in Fig. 5, the hydrocarbon chambers occupy about 9/18ths 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 about 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 83, 91, of the respective heads are the vacuum chambers 84A, 92A which occupy 2/18ths of the respective heads. Steam may be admitted into the upper chamber 84A through a branch of pipe 84, and passed into contact with a rotating catalyst carrier through the small port 103A in its bottom or bearing plate. This port is equal radially to about 1 catalyst segment and is disposed in the approximate center of the section of the plate included between baffles 88A and 88B. The steam port 103A 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 port 104A, in the plate of the matching lower vacuum chamber 92A. Steam admitted into the upper chamber 84A through the pipe 84 is sucked from the lower chamber 92A through a port 104A which is maintained under

reduced pressure by means of a vacuum pump 106A, a steam-fed ejector or other vacuum producing apparatus disposed in pipe 106B. Ordinarily, however, the valve 129A is maintained in a closed position, and the suction on the pipe 106B serves to create a vacuum within the catalyst segments passing through the vacuum purging section and to withdraw from the segments hydrocarbons entrapped therein in the cracking section prior to the passage of steam through the segments in the second section or steam purging section of the first purging zone.

Following the vacuum section of the first purging zone is the steam purging portion of the first purging zone. It comprises an upper chamber 84B supplied with steam through a branch of pipe 84 containing valve 129B and a matching lower chamber 92B. These chambers are equivalent to about two catalyst segments and are provided, respectively, with ports 103B, 104B, through which steam enters and leaves the catalyst segments.

Next around the periphery of the apparatus is the regenerative section in which are disposed oxidizing gas chambers 85, 93. These chambers occupy approximately 5/18ths of the respective upper and lower heads. They are provided with a pair of segmental ports 107 and 108, respectively, in the upper and lower bearing 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 somewhat less than 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 segments is admitted in the upper chamber 85 through a pipe 109, 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 corresponds radially to two of the catalyst segments. It contains the second steam chambers 86, 94, in the upper and lower heads, respectively. Steam for purging may be admitted into the upper chamber through an inlet pipe 111 and passed through the adjacent catalyst segment to the steam chamber 94 in the lower head from whence any steam admitted and the products purged out are withdrawn through an outlet pipe 112 connected therewith. Both upper and lower chambers of the second purging zone are provided with small pie-shaped ports 113, 114, (equal to about one catalyst segment) through which steam may pass into and out of the catalyst segment.

Purging in the second zone (following regeneration) may be accomplished by steam alone or by steam and vacuum employed separately but simultaneously. Generally speaking, purging in the second purging zone by steam alone is satisfactory, but vacuum may be employed to evacuate pores in the catalyst segments, and thereby accelerate catalytic action when the rotating catalyst is reintroduced into the cracking zone. The apparatus illustrated in Fig. 5 is adapted only to the use of steam purging in the second purging zone.

To employ steam for purging in the second purging zone in the apparatus of Fig. 5, the valve 128 on the steam line 111 is opened to admit steam into the apparatus and steam is withdrawn from the purging zone through the line 112 and handled separately through the valve 132 or sent through the valve 133 and the line 135 to merge with gases withdrawn from the regenerative zone through line 110.

If it is desired to employ both steam and vacuum for purging in the second purging zone the latter must be divided into two independent portions, as in the first purging zone of Fig. 5. Such an arrangement is illustrated in Fig. 8. The arrangement shown in Fig. 8 is similar to that shown in Fig. 5 except that the cracking and regenerating sections are reduced in width and the second purging zone is divided into a vacuum purging section 21A and a steam purging section 21B similar in all respects to the vacuum purging section 19A and the steam purging section 19B, respectively. In this arrangement the portions of the annular chambers included between baffles 87 and 90A in the upper head and baffles 95 and 98A in the lower head are divided into chambers 86A, 86B and 94A, 94B by baffles 90B and 98B, respectively. In this modified arrangement steam may be supplied to chambers 86A and 86B through branch pipes 111A and 111B containing valves 128A and 128B, and this steam may pass from the chambers to the catalyst segments through ports 113A and 113B. Gases evacuated through port 114A and vacuum chamber 94A are discharged through line 112B by the vacuum created by means of vacuum pump 112A. Similarly, steam and purged products passing through port 114B and chamber 94B are discharged through line 112. In all other respects the arrangement illustrated in Fig. 8 is similar to that shown in Fig. 5, and the same reference numerals are applied to the corresponding elements.

Steam and vacuum should not be employed together in purging due to the fact that vacuum tends to draw in oxygen-containing gases which, in admixture with purged hydrocarbons, are explosive. Vacuum and steam applied to a single purging zone also tend to increase hydrocarbon loss.

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 and 119 disposed, respectively, in wells 120, 121, 122, 123, in each of the several chambers to which fluids normally are supplied to enable proper temperature control of the system. Like thermocouples in similar wells are provided in the several 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 presently preferred form of my 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 four seg-

ments of the carrier), through these four segments and the corresponding lower hydrocarbon port into the lower hydrocarbon chamber from whence it is withdrawn.

At the same time, a catalyst segment contaminated with products, such as hydrocarbons, entrained by it in the cracking zone, is being cleaned in the vacuum section of the first purging zone prior to its passage into the steam purging section of this zone. As indicated hereinbefore, the vacuum purging section is maintained under a reduced pressure by means of the vacuum pump or ejector, which withdraws the entrained products employed, and tends to free the catalyst segments of impurities other than solids, such as carbon. Simultaneously steam is admitted into the steam section of the first purging zone, and this steam plus such substances as have been purged from the catalyst (principally entrained hydrocarbons) 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 five or 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 four 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 purging 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 being treated in the second purging section. Treatment in the second purging section preferably is similar to that in the steam section of the first purging zone, and involves driving out of the catalyst segments gaseous products of combustion entrained by the segments in the regenerative zone plus the steam introduced for purging purposes.

As shown in Fig. 5, a control valve 124 may be provided on the inlet line 99 for regulating the passage of oil vapor to the cracking section. The oil vapor flow may also be controlled on the inlet to a conventional heater (not shown) interposed in the line 99. 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, 129A and 129B are provided for regulating the supply of steam to the purging sections. Valves 130, 131 and 132, 133 are also provided, respectively, on the outlets from the steam purging section of the first zone and of the second zone so that steam plus other gases therefrom may be passed through bypass lines 134, 135 and mixed, if desired, with the products of the cracking and regenerative sections, respectively, or else handled separately. Thus, the valves 130, 131 on the outlet of the steam purging section of the first purging zone 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 zone 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 under certain conditions and with certain stocks when the heat of condensation 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 and method hereindescribed provide 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 Fig. 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 sections, 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 and gas 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.

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.

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 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 use of vacuum to improve purging tends to reduce operating costs greatly, the advantages of vacuum purging increasing as cycle time of the catalytic cracking operation is decreased. In other words, economies due to the use of vacuum purging are greater as cycle times are decreased, principally due to a saving in hydrocarbons. For some reason not clearly understood, steam or other gases introduced from an exterior source require a considerable time in contact with a catalyst segment to purge it efficiently of hydrocarbons, unless the purging gas is assisted first by a reduced pressure.

Generally speaking, the degree or the amount of suction to be maintained upon the purging sections will depend upon several factors, including: (1) the introduction of steam or other purging gas from an exterior source into the purging zones, which tends to reduce the suction or, conversely, to increase the pressure in the purging zones; (2) the degree of a pressure maintained in the cracking zone and regenerative zone. The greater the pressure in these zones, the greater is the tendency for leakage through the seals into adjacent purging zones, if a high degree of vacuum is maintained in these zones.

To take a specific example, in an operation in which the pressure in the cracking zone and regenerative zone is maintained at about 10 lbs. per sq. in. (gauge), effective operation is at-

tained if a vacuum of about 29 inches Hg is maintained in the vacuum section of the first purging zone.

Employment of vacuum to maintain reduced pressure in the purging zones not only brings about a saving of hydrocarbons but also some improvement in catalyst efficiency, with the result that the capacity of cracking apparatus is increased or the character of the cracked product is improved, or both. Vacuum evacuation of the purging zones offers other advantages in that it may permit conduct of operations with a considerably shorter cycle time. As cycle times are shortened, there is a marked improvement of character of product and in cracking efficiency. Thus, the yield of gasoline per unit of catalyst is increased substantially and there is also a minor tendency for an increase in the octane rating of the product. A further advantage of vacuum purging resides in the fact that it lengthens catalyst life, by reducing the quantity of steam in contact with the catalyst which tends to have a slow but positive deleterious effect.

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 may pass through a line 159 into the first purging section of the apparatus and there aid in sweeping out of the catalyst segments that rotate therethrough residual oil vapors. The steam from the first purging section may be 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 may be admitted to the second purging section through a conduit 167, and after passing through the rotating catalyst segments be withdrawn from the lower head and 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 lbs. per sq. in., 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 sealing steam and any purging steam employed (all at a temperature of about 750°–1100° F. and preferably between 800°–1000° F.) is sent to the flash tower 160A 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 recirculation of 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 lbs. per sq. in. Such separation gives a gaseous end product which 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 olefin for polymer gasoline.

It will be understood, of course, that the advantages of vacuum purging apply whether or not it is practiced in the second zone following cracking, or in the fourth zone following regeneration, or in both the second and fourth zones. Thus, in accordance with my invention vacuum and steam purging may be practiced in the second zone with steam purging in the fourth zone, or vice versa. Moreover, it may be advantageous in certain operations to practice a steam and vacuum purging in both the second and fourth zones.

I claim:

1. In the catalytic cracking of hydrocarbons involving the contact of a catalytic mass with vaporized hydrocarbons with resultant deposition of carbon on the mass and the subsequent treatment of the mass in an oxidizing atmosphere to burn the carbon and regenerate the mass for further contact with the hydrocarbons, the improvement which comprises rotating the catalytic mass successively and substantially continuously relative to and through a first zone to which the vaporized hydrocarbons are supplied substantially continuously and from which the resulting cracked hydrocarbons are substantially continuously withdrawn, a second zone having a first portion maintained under a pressure substantially less than that in the first zone and from which vapors entrained by the rotating catalytic mass are sucked substantially continuously and a second portion through which a purging gas is passed from an extraneous source, a succeeding regenerative zone through which a hot oxidizing gas is passed substantially continuously and in which the carbon on the mass is oxidized, the resulting carbonaceous gases being withdrawn substantially continuously from said regenerative zone and a final purging zone from which entrained gaseous products of the carbon combustion in the regenerative zone are removed substantially continuously.

2. In the catalytic cracking of hydrocarbons involving the contact of a catalytic mass with vaporized hydrocarbons with resultant deposition of carbon on the mass and the subsequent treatment of the mass in an oxidizing atmosphere to burn the carbon and regenerate the mass for further contact with the hydrocarbons, the improvement which comprises rotating the catalytic mass successively and substantially continuously relative to and through a first zone to which the vaporized hydrocarbons are supplied substantially continuously and from which the resulting cracked hydrocarbons are substantially continuously withdrawn, a second zone having a first portion maintained at a pressure substantially less than that in the first zone and from which vapors entrained by the rotating mass are sucked substantially continuously, a second portion of the second zone through which a hot purging gas is passed substantially continuously, the hot purging gas together with gaseous products removed from the catalytic mass in the second portion being removed from said portion, a succeeding regenerative zone into which a hot oxidizing gas is passed substantially continuously and in which the carbon on the mass is oxidized, the resulting carbonaceous gases being withdrawn substantially continuously from said regenerative zone, and a final purging zone in which the rotating catalytic mass is purged of the gaseous products of the carbon combustion entrained in the regenerative zone by passing a hot purging gas therethrough prior to reintroduction of the mass into the first zone.

3. In the catalytic cracking of hydrocarbons involving the contact of a catalytic mass with vaporized hydrocarbons with resultant deposition of carbon on the mass and the subsequent treatment of the mass in an oxidizing atmosphere to burn the carbon and regenerate the mass for further contact with the hydrocarbons, the improvement which comprises rotating the catalytic mass successively and substantially continuously relative to and through a first zone to which the vaporized hydrocarbons are supplied substantially continuously and from which the resulting cracked hydrocarbons are substantially continuously withdrawn, a second zone the first portion of which is maintained under a pressure substantially less than that prevailing in the first zone and from which hydrocarbon gases are sucked substantially continuously and the second portion of which is treated with a hot purging gas that is passed substantially continuously therethrough, the hot purging gas together with gaseous products entrained by the mass in the second portion being withdrawn therefrom substantially continuously, a succeeding regenerative zone through which a hot oxidizing gas is passed substantially continuously and in which the carbon on the mass is oxidized, the resulting carbonaceous gas being withdrawn substantially continuously from said regenerative zone, and a final purging zone through which a hot purging gas is passed substantially continuously to remove gaseous products of the carbon combustion from the mass, the hot purging gas together with the gaseous products of combustion entrained by the mass in the regenerative zone being withdrawn from the final purging zone and the resulting purged catalytic mass being reintroduced into the first zone.

4. In the catalytic cracking of hydrocarbons involving the contact of a catalytic mass with

vaporized hydrocarbons with resultant deposition of carbon on the mass and the subsequent treatment of the mass in an oxidizing atmosphere to burn the carbon and regenerate the mass for further contact with the hydrocarbons, the improvement which comprises rotating the catalytic mass successively and substantially continuously relative to and through a first zone to which the vaporized hydrocarbons are supplied substantially continuously and from which the resulting cracked hydrocarbons are substantially continuously withdrawn, a second zone divided into two portions, the first of which is maintained at a pressure substantially less than that of the first zone and from which hydrocarbons entrained in the first zone are sucked substantially continuously and the second of which is purged by means of a hot gas passed therethrough, a succeeding regenerative zone through which a hot oxidizing gas is passed substantially continuously and in which the carbon on the mass is oxidized, the resulting carbonaceous gases being withdrawn substantially continuously from said regenerative zone, and a final purging zone into which superheated steam is introduced substantially continuously and from which the resulting mixture of superheated steam and carbonaceous gases is withdrawn substantially continuously, the catalytic mass being reintroduced into the first zone.

5. In the catalytic cracking of hydrocarbons involving the contact of a catalytic mass with vaporized hydrocarbons with resultant deposition of carbon on the mass and the subsequent treatment of the mass in an oxidizing atmosphere to burn the carbon and regenerate the mass for further contact with the hydrocarbons, the improvement which comprises rotating the catalytic mass successively and substantially continuously relative to and through a first zone to which the vaporized hydrocarbons are supplied substantially continuously and from which the resulting cracked hydrocarbons are substantially continuously withdrawn, a second zone from which vapors entrained by the rotating catalytic mass in the first zone are purged substantially continuously, a succeeding regenerative zone through which a hot oxidizing gas is passed substantially continuously and in which the carbon on the mass is oxidized, the resulting carbonaceous gases being withdrawn substantially continuously from said regenerative zone, and a final purging zone having a first portion maintained under a pressure substantially less than that in said regenerative zone and from which carbonaceous gases entrained by the rotating catalyst in said regenerative zone are removed substantially continuously by suction and a second portion through which a hot purging gas is passed substantially continuously, the rotating catalyst being returned from the final purging zone to the first zone.

OLIVER F. CAMPBELL.

CERTIFICATE OF CORRECTION.

Patent No. 2,304,398. December 8, 1942.

OLIVER F. CAMPBELL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, first column, line 34, after the word "vertical" insert --section--; and in the drawings, Sheets 1 and 3, Figures 1 and 4 should read as shown below instead of as in the patent -

Fig. 1

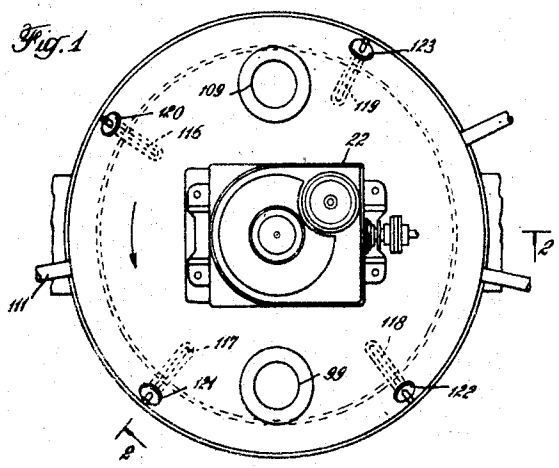
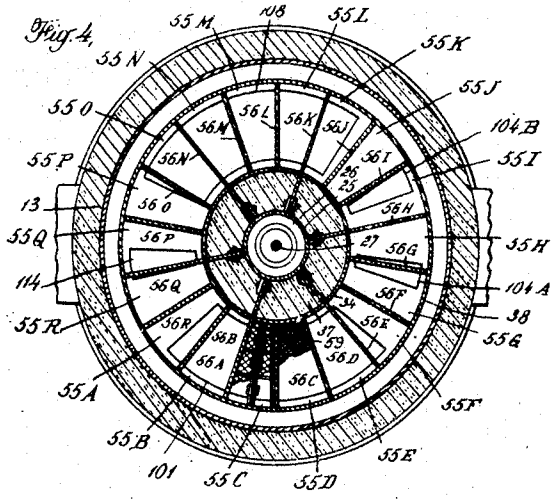


Fig. 4



and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 30th day of March, A. D. 1943.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.