Oct. 27, 1942. L. S. KASSEL 2,300,033

PROCESS FOR CATALYTIC CONVERSION OF HYDROCARBONS

Filed Nov. 30, 1939 2 Sheets-Sheet 1

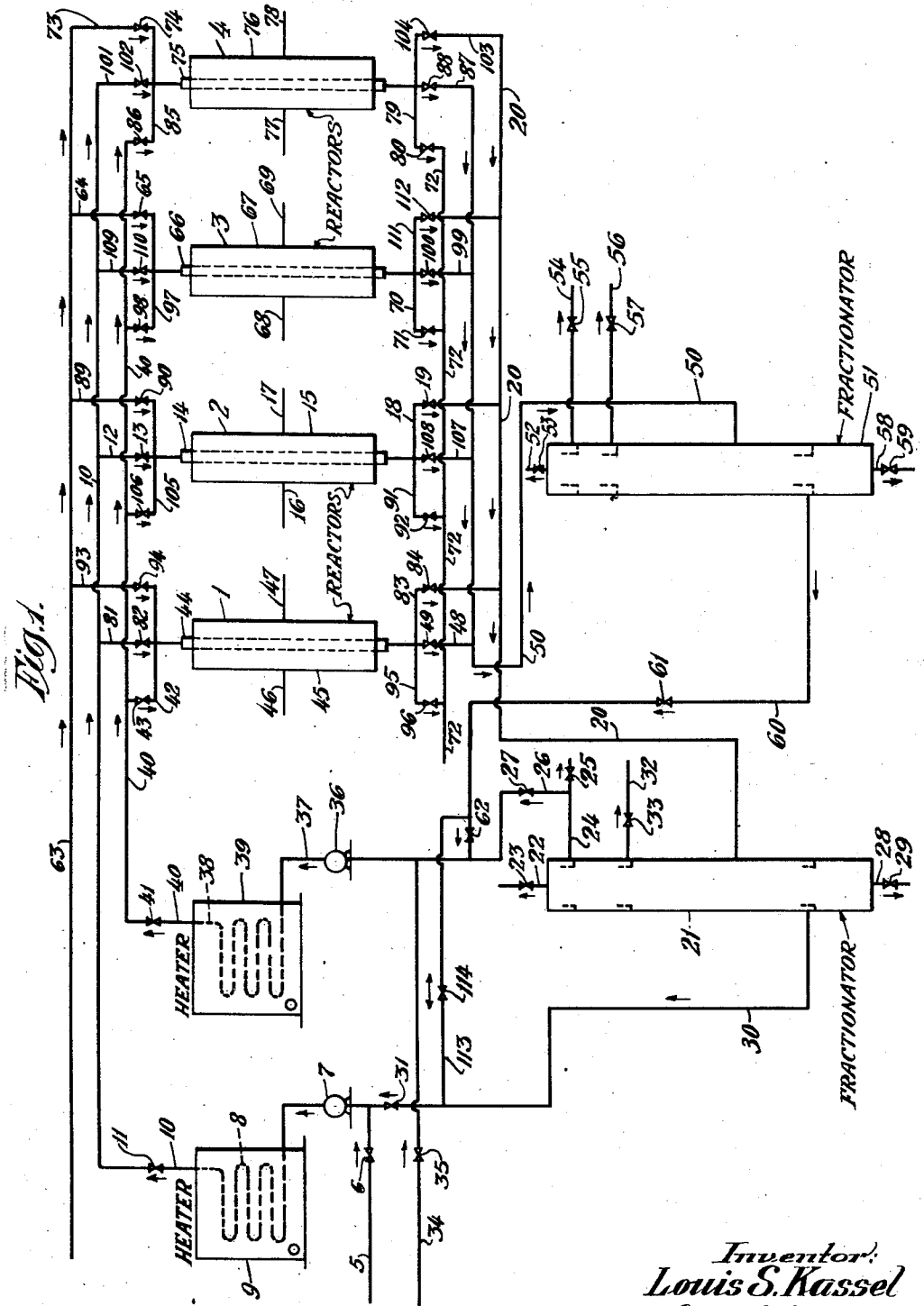

FIG. 1.

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Filed Nov. 30, 1939 2 Sheets-Sheet 2

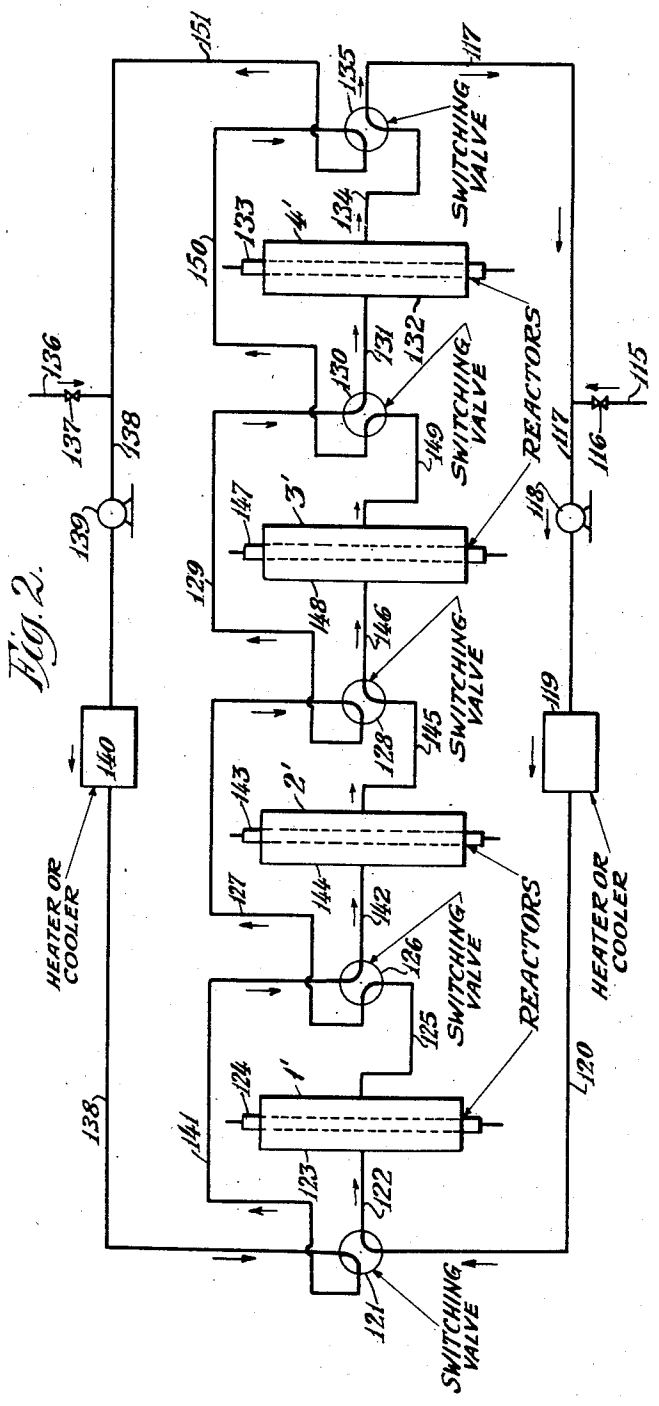

Fig. 2.

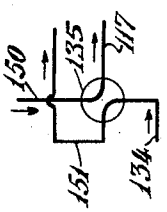

Fig. 7.

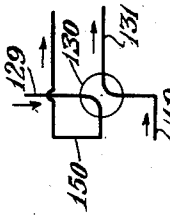

Fig. 6.

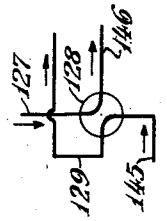

Fig. 5.

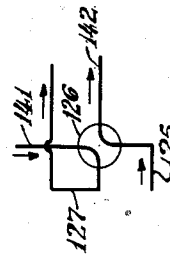

Fig. 4.

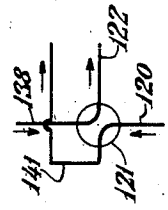

Fig. 3.

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Patented Oct. 27, 1942

2,300,033

UNITED STATES PATENT OFFICE

2,300,033

PROCESS FOR CATALYTIC CONVERSION OF HYDROCARBONS

Louis S. Kassel, Chicago, Ill., assignor to Universal Oil Products Company, Chicago, Ill., a corporation of Delaware

Application November 30, 1939, Serial No. 306,935

5 Claims. (Cl. 196—52)

This invention relates to a process for the catalytic conversion of hydrocarbon oils into motor fuels of high antiknock value. More particularly, it concerns the conversion of hydrocarbon oils of petroleum origin into substantially olefin-free gasoline suitable for use as an aviation base fuel.

The use of various catalytic masses for the production of increased yields of high antiknock motor fuel has been practiced. Under certain conditions of operation involving temperatures in excess of approximately 900° F. and relatively low pressures, gasoline and gases containing large percentages of olefin hydrocarbons are produced by the catalytic cracking of hydrocarbon oils of higher than gasoline boiling range. The gasolines produced are of good antiknock value, which makes them particularly desirable for use as motor fuel.

When such gasolines are subjected to the action of certain catalytic masses at relatively low temperatures, e. g., of the order of 500–900° F., substantially olefin-free gasolines are obtained accompanied by little or no change in the antiknock value. As a consequence the combination process offers a good method of producing substantially saturated gasoline suitable for use in aviation fuels.

The catalytic masses employed in these reactions comprise particularly the so-called silica-alumina, silica-zirconia, or silica-alumina-zirconia composites made by the separate or simultaneous precipitation of silica and an oxide of alumina and/or zirconia under conditions such that alkali metal ions are eliminated. Other cracking catalysts such as acid-treated clays may also be used, although they are not necessarily exactly equivalent.

The catalysts may be used for producing olefin-free gasoline, and after being substantially spent for this purpose, can be used at higher temperatures for producing additional yields of an olefin-containing gasoline.

Eventually the catalysts require regeneration in order to restore activity which has been decreased largely due to an accumulation of carbonaceous or hydrocarbonaceous deposits on their surfaces. In reactivating the catalytic masses, temperatures of the order of those employed in the high temperature cracking step or even higher are necessary, namely, approximately 900–1500° F. A combination process using a low temperature processing step followed by a high temperature processing step and finally by reactivation, offers advantages. The present invention is a process utilizing these steps to produce substantially saturated gasoline of desirable properties from hydrocarbon oils.

In one specific embodiment the present invention comprises a continuous catalytic process for converting normally liquid hydrocarbons into high yields of desirable products including substantially olefin-free, high antiknock distillate suitable for use in aviation fuel which comprises converting said hydrocarbons in a plurality of substantially identical conversion stages serially arranged, wherein the flow of hydrocarbons to, and withdrawal of reaction products from, the entire group of said conversion stages is substantially constant, and wherein the repeated sequence of steps is carried out at each of said conversion stages in a cyclic manner comprising a primary step wherein a stream of hydrocarbon is contacted with freshly reactivated catalytic material under conditions of temperature and pressure adequate to effect substantial conversion thereof to substantially olefin-free distillate, a secondary step in which a separate stream of hydrocarbons is contacted with partially spent catalyst previously used in said primary step under conditions of pressure and relatively higher temperature adequate to produce substantial yields of relatively olefinic gasoline, a tertiary step in which said catalyst used in said primary and secondary steps is partially reactivated by treatment with oxygen-containing gas at a temperature substantially higher than that used in said primary step, and a quaternary step in which the reactivation is completed while the catalyst temperature is being restored to that suitable for said primary step, recovering the gas and gasoline formed, returning a portion of the insufficiently converted oil for further conversion while maintaining those conversion stages operating in said primary and quaternary steps in heat exchange relationship by means of a circulating fluid heat exchange medium, and maintaining those conversion stages operating in said secondary and tertiary steps in heat exchange relationship by means of a separate circulating fluid heat exchange medium.

The two temperature levels may be achieved and maintained by the use of two separate circuits of heat exchange fluids so arranged that each catalyst region may be brought into heat exchange relationship with the fluid in either circuit. One method of accomplishing this is illustrated in Figure 2, which will be explained in detail later in the specifications. The materials which may be used as heat exchange media include low melting metals or alloys, alkali metal hydroxides, mixtures of salts melting below 450–500° F., etc.

Figure 1 is a diagrammatic representation of one embodiment of the present invention showing a process hook-up involving the use of the various temperature levels contemplated for process and reactiviation and illustrating the cyclic manner in which the various steps are carried out.

Figure 2 is a diagrammatic representation of

the heat exchange system which may be used in conjunction with the process flow illustrated in Figure 1.

Figures 3 to 7 inclusive show the settings of the switching valves opposite to the settings shown in Figure 2, and are used in describing the flow of heat exchange media during the various steps of the process cycle.

The drawings should not be interpreted as limiting the invention to the exact apparatus or equipment shown since obviously numerous types of reactors or variations of the type shown could be employed. These are understood to be included within the scope of the present invention. The apparatus consists essentially of four or more manifolded reactors together with suitable fractionation, heating, condensing, pumping, etc., equipment. The reactors may comprise any suitable type, of which that illustrated is a simple diagrammatic representation, consisting of one or more catalyst tubes or chambers disposed in a shell through which heat exchange media can be circulated. It should also be understood that the invention may be carried out without the use of the heat exchange media, in which case the reactors will be of somewhat different design since obviously the shells surrounding the tubes or chambers would be dispensed with in this case. Under these circumstances the catalyst tubes or chambers may be insulated or may be enclosed in an externally heated zone.

The entire operation involves a repeated cycle of four phases. During all of these phases, the flows to and from the entire group of reactors remain the same, but the flows to and from each separate reactor may change with each change of phase. It will be sufficient, therefore, to describe the flow completely for a single phase and more briefly for the other three. It is obvious that the choice of phase to be described first and completely is entirely arbitrary.

Referring to Figure 1, the hydrocarbon oil charge is introduced through line 5, valve 6, pump 7, and enters coil 8 which is disposed in heater 9. The oil may be heated to a temperature of approximately 900–1200° F. and at a pressure of substantially atmospheric to slightly superatmospheric, say of the order of 50–150 pounds per square inch. The oil then passes through line 10 and valve 11 to line 12, valve 13 and enters catalyst tube 14 of reactor 2. The catalyst tube may be surrounded by shell 15 having inlet line 16 and outlet line 17 through which heat exchange media may be circulated. The reaction products pass through line 18 and valve 19 to line 20 and pass thence to fractionator 21. The gaseous fraction which contains olefinic hydrocarbons suitable for conversion into gasoline by polymerization and/or alkylation methods is removed through line 22 and valve 23. Gasoline may be withdrawn through line 24 and valve 25 to storage. The gasoline produced is of high antiknock value, and is relatively olefinic in character, being suitable for use as an automobile fuel. As an alternative, a part or all of the gasoline may be passed through line 26, valve 27 to line 37 for conversion to substantially olefin-free distillate suitable for use in aviation motor fuels in a manner which will be described hereinafter.

A residue unsuitable for further conversion may be withdrawn through line 28 and valve 29. Insufficiently converted oil may be passed through line 30, valve 31, and pump 7 to be recirculated for further conversion in the process. A higher boiling fraction of naphtha or other side cut material may be withdrawn from fractionator 21 through line 32 and valve 33.

Hydrocarbon oil which may be the same or different from that used in the relatively high temperature step just described is introduced through line 34, valve 35, pump 36 and line 37 to coil 38 which is disposed in heater 39. The oil is heated to a temperature within the range of approximately 500–900° F. and a pressure of approximately 50–1000 pounds per square inch. The heated oil passes through line 40, valve 41 to line 42 and valve 43 into catalyst tube 44 which is disposed in reactor 1. Reactor 1 is similar to reactor 2 and has a shell 45 with inlet 46 and outlet 47 through which heat exchange medium may be circulated. The reaction products are removed through line 48, valve 49 to outlet 50 and passed to fractionator 51.

Gaseous products may be removed through line 52 and valve 53. Substantially saturated gasoline suitable for use in aviation fuel may be removed through line 54 and valve 55. A side-cut of naphtha or higher boiling oil may be removed through line 56 and valve 57. A residual oil may be withdrawn through line 58 and valve 59. A portion of insufficiently converted oil may be recirculated by passing through line 60, valve 61, valve 62 to line 37 and thus returned to the lower temperature reaction stage for further conversion. Reactivation gases are introduced through line 63, line 64, valve 65 into reactor 3 which is similar to reactors 1 and 2, and contains catalyst tube 66 in shell 67 which is equipped with inlet and outlet lines 68 and 69. Reactivation during this stage is carried out at a temperature in excess of that used in reactor 2, being normally within the range of 900–1500° F. and preferably not exceeding approximately 1350° F. The reactivation gases pass through line 70, valve 71 to line 72. A portion of them may be recirculated in a manner not shown. Reactivation gases pass from line 63 through line 73, valve 74 to reactor 4 which is similar to reactors 1, 2 and 3, and contains catalyst tube 75 disposed in shell 76 having inlet and outlet lines 77 and 78 for the circulation of heat exchange fluid. The reactivation gases pass through line 79 and valve 80 to line 72. The temperature in reactor 4 is restored to the level of reactor 1 during this step.

After a time governed by the state of activity of the catalyst in the various reactors, the flows are switched and the next phase of the cycle is begun. In this case, the heated hydrocarbons from line 10 enter reactor 1 through line 81 and valve 82, and pass thence through line 83 and valve 84 to line 20 to be disposed of as previously described. At the same time the oil from line 60 passes through line 85, valve 86 and reactor 4 to line 87, valve 88, line 50 and fractionator 51. Reactivation gases enter reactor 2 from line 63 by way of line 89 and valve 90, and are passed to line 72 through line 91 and valve 92. The reactivation gases continue to pass through reactor 3 as previously described except that during this phase the temperature in the reactor is being restored to that used for processing in the lower temperature range.

After a suitable interval, the valve settings are changed to those of the third phase of the cycle. In this phase reactor 1 is being reactivated at the higher temperature, reactor 2 at the lower temperature, reactor 3 is processing at the lower temperature and reactor 4 is processing at the higher temperature. Reactivation gases from line 63 are

passed through reactor 1 by way of line 93 and valve 94, and passed thence to line 72 by way of line 95 and valve 96. Reactivation gases continue to pass through reactor 2 as previously described while the temperature is being returned to the level for use in the lower temperature processing step. Oil from line 40 is introduced to reactor 3 through line 97 and valve 98, and is removed through line 99 and valve 100 to line 50 and thence to fractionator 51. At the same time, oil from line 10 is pased through line 101, valve 102 to reactor 4 which is operating in the higher temperature range, leaving the reactor through line 103 and valve 104 which joins with line 20 and passes to fractionator 21.

After another suitable interval the valve settings are again changed so that reactor 1 is being cooled to the lower temperature range, reactor 2 is processing in the lower temperature range, reactor 3 is processing in the higher temperature range, and reactor 4 is reactivating at the higher temperature. In this case reactivation gases continue to pass through reactor 1 as just described while the temperature is being restored to the lower temperature level. Hydrocarbons from line 40 pass to reactor 2 through line 105 and valve 106, passing thence through line 107 and valve 108 to line 50 and then to fractionator 51. At the same time the oil from line 10 is introduced into reactor 3 through line 109 and valve 110. After conversion in the higher temperature range, the reaction products pass through line 111 and valve 112 to line 20 and thence to fractionator 21. Reactivation gases during this phase of the cycle are introduced into reactor 4 through line 73 and valve 74, and are passed to line 72 by way of line 79 and valve 80. According to the operation just described, separate streams of hydrocarbon oil are processed under different conditions of temperature and pressure to produce products of substantially different characteristics, namely, a relatively olefinic gasoline from the high temperature conversion step, and a substantially saturated gasoline from the lower temperature conversion step. Aside from the position of the two conversion steps in the cycle of operation, the higher and lower temperature steps are not related. According to one alternative, these steps may be further related in several ways which are about to be described.

According to one alternative, recycle oil from fractionator 21 may be passed through line 113, valve 114, line 60 and valve 62 to line 37 where it is combined with the charging stock from line 34 and valve 35 for conversion in the lower temperature step. If so desired, little or no oil need be charged through line 34, so that the oil being charged to the lower temperature conversion step comprises essentially or entirely insufficiently converted oil from fractionators 21 and 51.

According to another alternative a part or all of the insufficiently converted oil from fractionator 51 may be passed through line 60, valve 61, line 113 and valve 114 to line 30 and thence by previously described routes to the high temperature conversion step. At the same time a part of the oil from line 60 may be passed through valve 62 to line 37 and thus be recirculated to the lower temperature conversion step.

According to another alternative which was indicated earlier in the description, a fraction or all of the gasoline from fractionator 21 may be passed through line 24, line 26, valve 27, pump 36 and line 37 to the lower temperature conversion step wherein it is converted to substantially olefin-free gasoline suitable for use in aviation fuel. Although the gasoline may be treated in this manner without the addition of either recycle oil from fractionator 51 or fresh charging stock from line 34, it is also within the scope of the invention to add oil from either or both of these sources to the gasoline fraction being treated. Since fractions used for aviation fuel rarely have more than a 300° F. end-point, and since the fraction boiling above 300° F. and having an end-point within the normal gasoline boiling range is of good anti-knock qualities, it is within the scope of the invention to pass a fraction suitable for conversion to aviation fuel through line 24, etc., to the low temperature conversion step, and at the same time withdraw a naphtha fraction as indicated through line 32 and valve 33 for use in automobile fuels.

Certain pumps, heat exchangers, condensers, stabilizers and other auxiliary equipment necessary to the operation of such a process have been omitted in the interests of simplifying the drawings.

Referring to Figure 2, a heat exchange medium which may comprise any suitable liquid material such as mixtures of molten salts, metals or metal alloys and the like, is introduced through line 115, valve 116, line 117, pump 118, and passes through exchanger 119 wherein it may be heated or cooled as desired. When the medium is first introduced it is heated to the desired reaction temperature. The medium passes through line 120 to switching valve 121 and thence to reactor 1', entering through line 122 into shell 123. Reactor 1' contains catalyst tube 124, which may comprise reaction chambers or a plurality of manifolded tubes containing catalyst particles disposed therein. It should be mentioned at this point that reactors 1', 2', 3' and 4' of Figure 2 are identical to reactors 1, 2, 3, and 4 of Figure 1 respectively. Still referring to Figure 2, reactor 1' in this case is being used in the process phase at the lower temperature range of 500–900° F. The medium passes through line 125 and switching valve 126, line 127, valve 128, line 129, switching valve 120, line 131 to shell 132 of reactor 4'. This reactor is similar to reactor 1' and contains catalyst tube 133. In this step of the processing cycle, reactor 4' is being returned from the higher temperature reactivation phase of the cycle to the lower temperature reactivation phase at 500–900° F. The fluid medium passes through line 134, switching valve 135 to line 117 where it is picked up by pump 118 and recirculated. When the system is filled with the heat exchange medium, valve 116 is closed. Line 115 and valve 116 may be used as a means of draining the system when the plant is shut down.

Sufficient molten medium to fill the second heat exchange system is introduced through line 136 and valve 137, passing into line 138 and pump 139. The molten mixture passes through exchanger 140 which may be a heater or cooler as is necessary for the particular operation being carried out. The salt passes through switching valve 121, line 141, switching valve 126, line 142 to reactor 2', which is similar to reactors 1' and 4' and contains catalyst tube 143 disposed in shell 144. Reactor 2' is at this point being used in the high temperature processing phase at 800–1200° F. The medium leaves reactor 2' through line 145, passes through switching valve 128, line 146 to reactor 3' which is similar to the other catalytic reactors and contains tube 147 disposed in shell 148. Reactor 3' is in the

higher temperature reactivation phase of the cycle in the range of 900–1500° F. The medium leaves the reactor through line 149, switching valve 130, line 150, switching valve 135, returning through line 151 to pump 139 whereby it is recirculated.

The switching valves are four-way valves which are set in the positions indicated in Figure 2 when operating as just described. In order to carry out a complete cycle of operation, it is necessary to change the valve settings in order to direct the flow of heat exchange media to the proper reactors. Figures 3–7, inclusive, show the settings of valves 121, 126, 128, 130 and 135 opposite to the settings as shown in Figure 2. The lines and valves are numbered to correspond with the numberings in Figure 2 so that these figures could be superimposed on the valves as illustrated in Figure 2 and would correspond in every way except as to the position of the switching valve proper. Figures 3–7 are referred to in order to describe the flow of heat exchange media when carrying out the complete cycle of processing steps previously described in connection with Figure 1. According to the valve setting just described in connection with Figure 2, reactor 1' is processing at the lower temperature, reactor 2' processing at the higher temperature, reactor 3' reactivating at the higher temperature, and reactor 4' reactivating at the lower temperature.

When the operation is shifted in the course of the regular cycle so that reactor 1' is processing at the higher temperature, reactor 2' regenerating at the higher temperature, reactor 3' regenerating at the lower temperature and reactor 4' processing at the lower temperature, the valves are in the following positions: valve 121 as in Figure 3; 126 as in Figure 4; 128 as in Figure 5; 130 as in Figure 6, and 135 as in Figure 2.

In the next regular step in the operation, reactor 1' is reactivating at the higher temperature, reactor 2' reactivating at the lower temperature, reactor 3' processing at the lower temperature, and reactor 4' processing at the higher temperature, the valve positions are: valve 121 as in Figure 3; valves 126, 128, and 130 as in Figure 2 and valve 135 as in Figure 7.

In the next step of the cycle wherein reactor 1' is reactivating at the lower temperature, reactor 2' processing at the lower temperature, reactor 3' processing at the higher temperature, and reactor 4' reactivating at the higher temperature, the valve positions are: valve 121 as in Figure 2, and valves 126, 128, 130 and 135 as in Figures 4, 5, 6, and 7 respectively.

The cycle is completed when the valves are switched to the original position shown in Figure 2 wherein reactor 1' is processing at the lower temperature, reactor 2' processing at the higher temperature, reactor 3' reactivating at the higher temperature, and reactor 4' reactivating at the lower temperature.

The following example is given to illustrate the usefulness and practicability of the invention but should not be construed as limiting it to the exact conditions, apparatus, catalysts, charging stocks, etc. used therein.

The catalyst used was a silica-alumina-zirconia composite prepared by precipitating the hydrogels of the various components followed by drying, forming into pellets and calcining. A Mid-Continent gas oil was charged to the high temperature step as described in the foregoing specifications using a temperature of 950° F. and a pressure of approximately 50 pounds per square inch. The 400° F. end-point gasoline formed in this way was separated for use as an automobile fuel. The C_3 and C_4 olefins contained in the gas were polymerized to form additional yields of high octane number motor fuel using a solid phosphoric acid catalyst made by reacting liquid phosphoric acid with kieselguhr, forming into shapes and calcining. Another portion of the gas oil was charged to the low temperature conversion step to produce substantial yields of substantially saturated fuel. The temperature was maintained at 750° F. and the pressure at 100 pounds per square inch. A 300° F. end-point gasoline having an octane number of 77 and suitable for use as an aviation base motor fuel was separated. A 300–400° F. cut was separated as a side-cut and blended with the olefinic gasoline produced in the higher temperature conversion step to augment the yields of automobile motor gasoline. Minor portions of residual oil suitable for fuel were withdrawn from both the higher and lower temperature conversion steps. A total yield of 78% of gasoline, including the polymer gasoline produced by polymerization of the olefins in the gas, was realized. Approximately 35% of the total yield was aviation base gasoline and the remainder was useful as automobile fuel.

The yields of aviation base fuel could be still further increased by hydrogenating the C_3 cut of the polymers produced, and by charging a regulated amount of the gasoline produced in the high temperature conversion step to the low temperature conversion step, together with the hydrocarbon charging stock and/or a portion of the recycle stock. This indicates the advantages of the process because of the considerable flexibility of operation made possible.

I claim as my invention:

1. A continuous process for converting hydrocarbon oil into high yields of substantially olefin-free gasoline which comprises converting said oil in a plurality of catalytic conversion stages serially arranged wherein the repeated sequence of steps is carried out at each of said catalytic conversion stages comprising a primary step of contacting an olefin-containing gasoline mixed with insufficiently converted oil produced as hereinafter described, with a cracking catalyst under conditions of temperature and pressure adequate to effect substantial conversion thereof into substantially olefin-free gasoline, a secondary step of contacting said hydrocarbon oil with a cracking catalyst under conditions of temperature and pressure adequate to produce substantial conversion thereof into olefin-containing gasoline and insufficiently converted oil for conversion in said primary step, a tertiary step of partially reactivating said cracking catalyst used in said primary and secondary steps with an oxygen-containing gas at a temperature in excess of that used for processing in said primary step, a quaternary step of completing the reactivation of said cracking catalyst with an oxygen-containing gas while restoring the temperature to that required for processing in said primary step, maintaining said primary step and said quaternary step in heat exchange relationship by means of a circulating fluid heat exchange medium, maintaining said secondary step and said tertiary step in heat exchange relationship by means of a separate circulating fluid heat exchange medium, recovering the gasoline from said primary step, recovering the gas from said

secondary step, and withdrawing a minor portion of residue unsuitable for further conversion.

2. A continuous process for converting hydrocarbon oil into high yields of substantially olefin-free gasoline which comprises converting said oil in a plurality of conversion stages serially arranged wherein the repeated sequence of steps is carried out at each of said conversion stages comprising a primary step of contacting said hydrocarbon oil together with an olefin-containing gasoline produced as hereinafter described with a cracking catalyst under conditions of temperature and pressure adequate to effect substantial conversion thereof to substantially olefin-free gasoline, a secondary step of contacting the insufficiently converted oil from said primary step with said cracking catalyst under conditions of temperature and pressure adequate to effect substantial conversion thereof into olefin-containing gasoline for conversion in said primary step, a tertiary step of partially reactivating said catalyst with an oxygen-containing gas at a temperature in excess of that used in said secondary step, and a quaternary step of completing the reactivation of said cracking catalyst with an oxygen-containing gas while restoring the temperature to that required in said primary step, maintaining those conversion stages operating in said primary and quaternary steps in heat exchange relationship by means of a circulating fluid heat exchange medium, maintaining the conversion stages operating in said secondary and tertiary steps in heat exchange relationship by means of a separate circulating heat exchange medium, and recovering the gasoline from said primary step.

3. A continuous process for converting hydrocarbon oil into high yields of substantially olefin-free gasoline which comprises converting said hydrocarbon oil in a plurality of conversion stages serially arranged wherein the repeated sequence of steps is carried out at each of said conversion stages comprising a primary step of contacting a portion of said hydrocarbon oil mixed with gasoline and insufficiently converted oil produced as hereinafter described with a cracking catalyst under conditions of temperature and pressure adequate to effect substantial conversion thereof to substantially olefin-free gasoline, a secondary step of contacting a major portion of said hydrocarbon oil with a cracking catalyst under conditions of temperature and pressure adequate to effect substantial conversion thereof into olefin-containing distillate and insufficiently converted oil for conversion in said primary step, a tertiary step of partially reactivating said cracking catalyst used in said primary and secondary steps with an oxygen-containing gas at a temperature in excess of that used for processing in said primary step, and a quaternary step of completing the reactivation of said cracking catalyst with an oxygen-containing gas while restoring the temperature to that required for processing in said primary step, maintaining those conversion stages operating in said primary and quaternary steps in heat exchange relationship by means of a circulating fluid heat exchange medium, maintaining those conversion stages operating in said secondary and tertiary steps in heat exchange relationship by means of a separate circulating fluid heat exchange medium, recovering the gasoline from said primary step and returning a portion of the insufficiently converted oil from said primary step for further conversion.

4. A continuous process for converting hydrocarbon oil into high yields of substantially olefin-free gasoline which comprises converting said hydrocarbon oil in a plurality of conversion stages serially arranged wherein the repeated sequence of steps is carried out at each of said conversion stages comprising a primary step of contacting a portion of said hydrocarbon oil mixed with the olefin-containing reaction products of catalytic cracking produced as hereinafter described with a cracking catalyst under conditions of temperature and pressure adequate to effect substantial conversion thereof to substantially olefin-free gasoline, a secondary step of contacting a portion of said hydrocarbon oil with said cracking catalyst under conditions of temperature and pressure adequate to effect substantial conversion thereof into olefin-containing reaction products for conversion in said primary step, a tertiary step of partially reactivating said cracking catalyst used in said primary and secondary steps with an oxygen-containing gas at a temperature in excess of that required for processing in said primary step, and a quaternary step of completing the reactivation of said cracking catalyst with an oxygen-containing gas while restoring the temperature to that required for processing in said primary step, maintaining those conversion stages operating in said primary and quaternary steps in heat exchange relationship by means of a circulating fluid heat exchange medium, maintaining those conversion stages operating in said secondary and tertiary steps in heat exchange relationship by means of a separate circulating fluid heat exchange medium, recovering the gasoline from said primary step and returning a portion of the insufficiently converted oil to said secondary step for further conversion.

5. A continuous process for converting hydrocarbon oil into substantial yields of gasoline which comprises converting said hydrocarbon oil in a plurality of conversion stages serially arranged wherein the repeated sequence of steps is carried out at each of said conversion stages comprising a primary step of contacting an olefin-containing gasoline of not more than 300° F. end-point produced as hereinafter described with a cracking catalyst under conditions of temperature and pressure adequate to effect substantial conversion thereof to substantially olefin-free gasoline, a secondary step of contacting said hydrocarbon oil with a cracking catalyst under conditions of temperature and pressure adequate to effect substantial conversion thereof into olefin-containing gasoline, the 300° F. end-point fraction of which is converted in said primary step, a tertiary step of partially reactivating said cracking catalyst which has been used in said primary and secondary steps with an oxygen-containing gas at a temperature in excess of that used for processing in said primary step, and a quaternary step of completing the reactivation of said cracking catalyst with an oxygen-containing gas while returning the temperature to that required for processing in said primary step, recovering the gasoline from said primary step, recovering the gas and gasoline from said secondary step and supplying a portion of said gasoline having an end-point of approximately 300° F. to said primary step, recovering a fraction boiling above 300° F. and returning a portion of the insufficiently converted oil to said secondary step.

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