

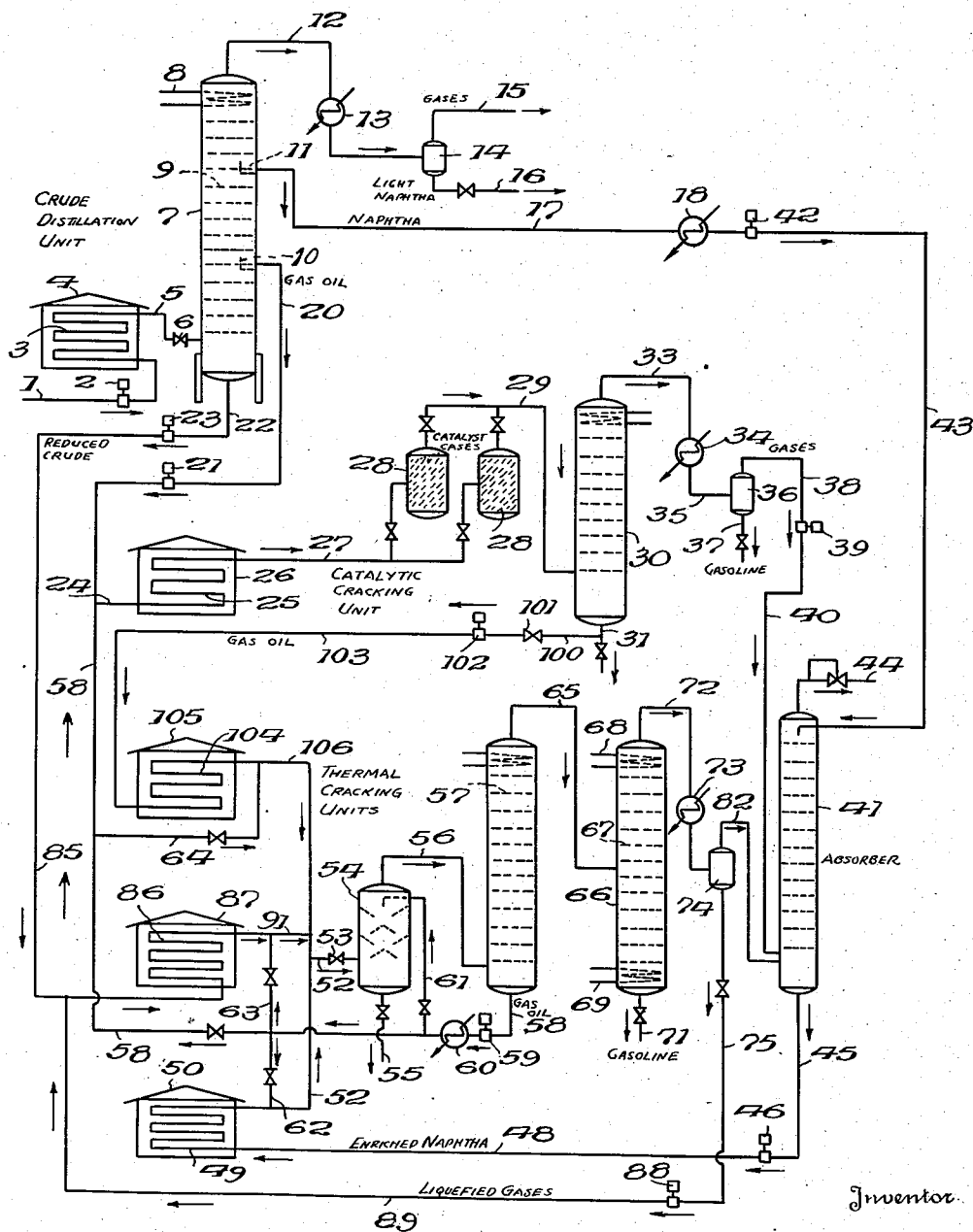
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CRACKING HYDROCARBON OILS

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CRACKING HYDROCARBON OILS

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In my prior co-pending application Serial No. 247,504, filed December 23, 1938, of which this application is in part a continuation, I have disclosed various processes for cracking hydrocarbon oils to obtain gasoline hydrocarbons useful as motor fuel and having high anti-knock value when so used.

In particular, said prior application discloses various improved methods of obtaining gasoline hydrocarbons from crude petroleum stocks, wherein such stocks are first distilled to recover a plurality of fractions (including a residual fraction) of different boiling-point ranges, these fractions are segregated and subjected to catalytic cracking and to thermal cracking, respectively, and products recovered in the thermal cracking operation, such as normally gaseous hydrocarbons and distillate fractions boiling above the gasoline boiling-point range, are delivered to the catalytic cracking operation, and vice versa.

In one of the modifications or embodiments disclosed in Serial No. 247,504, and to which this specification particularly relates, a crude petroleum oil is first distilled to recover a naphtha fraction, an intermediate clean distillate or gas-oil fraction, and a residual fraction or reduced crude. The gas-oil fraction is subjected to catalytic cracking, and the naphtha fraction and reduced crude are subjected to thermal cracking in separate conversion zones. The products from the catalytic cracking are fractionated in more or less conventional manner to recover a gas-oil fraction, a gasoline fraction and residual gases, while the combined products from the thermal cracking zones are similarly fractionated in a separate fractionating system.

An important feature of this particular operation, as disclosed in Serial No. 247,504, resides in the delivery of the gas-oil or "recycle stock" fraction recovered from the products from the thermal cracking zones to the catalytic cracking zone for conversion in admixture with the virgin gas oil recovered in the initial crude distillation operation. This is especially advantageous for the reason that it increases the total amount of charging stock which can be subjected to catalytic cracking, thereby increasing the over-all yield and octane number of gasoline from the entire unit.

Thus, catalytic cracking operations, especially those of the so-called "fixed bed" type, require stocks which are clean, i. e. from residual or "black" constituents which tend upon conversion to yield large amounts of tar and carbon.

On the other hand, reduced crudes and other "black oils," containing substantial amounts of residual constituents, are for much the same reason difficult to crack in non-catalytic operations, under conditions drastic enough to yield large amounts of high-octane gasoline; carbon formation becomes excessive at high temperatures such as are used in cracking gas oil and other clean stocks.

However, such reduced crudes may be subjected without difficulty to non-catalytic cracking at comparatively mild temperatures, thereby resulting in the formation of comparatively large quantities of clean distillates, or gas oils, boiling largely above the gasoline boiling point range. Such gas oils, or recycle stocks, can be subjected to thermal cracking at more drastic temperatures, but I have found that they represent excellent stocks for delivery to catalytic cracking operations yielding large amounts of high-octane gasoline.

Conversely, the gas-oil fractions recovered in catalytic cracking operations do not represent ideal stocks for further catalytic cracking operations. Consequently, as also disclosed in Serial No. 247,504, the intermediate or gas-oil fractions recovered in the catalytic cracking operation are advantageously subjected to thermal cracking in a separate zone, and the products of such cracking fractionated along with other products of conversion, particularly the products of conversion from the other thermal cracking operations.

In the operation described, further improvement in the over-all yield and octane number of the gasoline produced is made possible by conducting the thermal cracking operations in the presence of normally gaseous hydrocarbons having three and four carbon atoms, respectively, per molecule.

To this end, the residual gases recovered in the various cracking operations are collected and fractionated to recover C₃ and C₄ constituents, the segregated gases thus recovered being delivered to the thermal cracking zones in admixture with the oils introduced thereto.

Operating in this manner, it is possible to increase the temperatures and degrees of cracking in the thermal cracking zone, thereby increasing the yield and quality of the gasolines produced in cracking the oils, and at the same time to effect the conversion of the C₃ and C₄ constituents to gasoline-like hydrocarbons of exceptionally high anti-knock value.

Operations of this character, known as "gas

reversion" operations, are best conducted in the manner set forth and disclosed in U. S. Patents Nos. 2,135,014, 2,135,108 and 2,135,109 to Povl Ostergaard, that is to say, by increasing the temperature and degree of conversion per pass to points above those which could be maintained, under otherwise similar conditions and without undue carbon deposition, if the same oils were cracked in the same apparatus in the absence of the recirculated gases.

Such gas reversion operations show optimum advantages when applied to the cracking of naphtha and heavy residual stocks, respectively, as in the process of my invention. In particular, the presence of normally gaseous hydrocarbons in the zone wherein the residual oil is cracked is of especial advantage in making it possible to operate at higher temperatures and thereby to increase the yield of intermediate products suitable for charging to the catalytic cracking zone.

A large number of catalytic cracking processes have been proposed, all characterized by the presence of a catalyst of one type or another in the conversion zone, and in many cases by the employment of relatively low pressures; this is particularly true of the so-called "fixed bed" type of process in which the hydrocarbons to be converted, usually in vapor form, are passed through a stationary bed of porous or spaced catalytic material. The Houdry process, employing as a typical catalyst an activated hydrosilicate of alumina or the like, is a process of this type. On account of the periodic interruption of this type of process, which is necessary in order to effect periodic regeneration of the catalyst employed, and for certain other reasons, the pressures employed in such catalytic processes are for the most part extremely low, rarely if ever exceeding 60 pounds per square inch in the catalyst contact zone. For this reason, it is somewhat difficult to combine gas recirculation and conversion operations with such catalytic cracking operations in an efficient and effective manner. Moreover, this type of process in general tends to produce rather high yields of normally gaseous hydrocarbons and such processes are for the most part lacking in ultimate economy and advantages with respect to the cracking or reforming of naphtha and similar light stocks, as well as the conversion of heavy residual stocks.

In accordance with my invention, however, it is possible to secure the maximum advantages and economies of both thermal and catalytic conversion operations in a combining and unitary manner, together with advantages and economies which could not be obtained with respect to either type of operation considered alone. Thus, as aforesaid, the quantity of suitable charging stock available for delivery to the catalytic cracking zone may be enhanced by the delivery to this zone of intermediate condensate produced in the thermal cracking operation, the production of which is in turn enhanced by conducting the thermal cracking operation in the presence of recycled C_3 and C_4 hydrocarbons. The normally gaseous hydrocarbons produced in the catalytic cracking zone may advantageously be used to enhance and augment those produced in the thermal cracking zone. The various individual cracking operations are carried out under conditions which utilize to the fullest extent the various advantages of the individual operations and permit a high degree of flexibility in the operation.

The segregation of the C_3 and C_4 hydrocarbons

produced in the several cracking operations may be variously accomplished, but is preferably effected by subjecting the fractionated gasoline-free products of conversion to scrubbing with the naphtha fraction about to be delivered into one of the thermal conversion zones; i. e. the naphtha re-forming zone. In order to lighten the load on the final absorber, to provide additional flexibility and to provide for the segregation of normally gaseous hydrocarbons for delivery to other thermal cracking zones, a pressure condensation step is advantageously provided ahead of the absorber in order to recover a liquefied propane-butane fraction, which is then recycled to one or more of the conversion zones in admixture with the oil traversing the same. In the preferred embodiment of my invention herein-after described in detail, the liquefied gas fraction thus recovered is advantageously recycled to the thermal conversion zone wherein the residual or reduced crude fraction is subjected to relatively mild cracking temperature, i. e. to a "viscosity breaking" or mild cracking operation conducted for the purpose of producing a large yield of relatively high-boiling clean distillate, rather than gasoline.

In order that my invention may be fully set forth and understood, I now describe with reference to the drawing accompanying and forming a part of this specification, various forms and manners in which my invention may be practiced and embodied. In this drawing,

The single figure is a more or less diagrammatic elevational view of apparatus for manufacturing gasoline of high anti-knock value from petroleum oil, in accordance with my invention.

The drawing is primarily diagrammatic in character and has been simplified as much as possible in order to show the essential details of operation and without encumbering this disclosure with detailed description and explanation of many more or less obvious minor modifications, such as the use of heat exchangers and the like, the application of which will be obvious to those skilled in the art.

Referring now to the drawing, a crude petroleum charging stock is introduced into the system through a pipe 1 by means of a pump 2 and preheated to a suitable distilling temperature, usually a temperature at which no substantial cracking is effected, by means of a heat pipe coil 3 located within a furnace 4. Such preheating temperatures will be of the order of 700° to 750° F. It will be understood that the preheating may be accomplished in various manners, as for example by heat exchange in other portions of the system to be described hereinbelow, and that the same considerations will apply to other portions of the unit in which heating and cooling operations are involved.

The preheated crude oil then passes through a line 5 having a valve 6 into a distilling column or flash tower 7 of more or less conventional design. This column is provided with suitable cooling or refluxing devices, such as bell trays 9, and with trap-out trays 10 and 11 disposed at spaced points in the column.

By reason of the heat imparted to the crude oil and the low or atmospheric pressure maintained in the column 7, distillation takes place and a considerable portion of the crude oil is vaporized. The light products, including any fixed gases which may be present, and light virgin gasoline, are withdrawn from the head of the col-

umn through a line 12 to a condenser 13 and a separator 14, from which the fixed gases and the light virgin gasoline are removed through lines 15 and 16, respectively.

Heavy virgin naphtha suitable for re-forming is withdrawn as a side stream from the trap-out tray 11 and passes through a line 17 to a cooler 18. As will be understood by those skilled in the art, the cooler 18 and all other coolers and condensers illustrated are water-cooled devices of more or less conventional type, effective to reduce the temperature of the vapors or oil passing therethrough to approximately atmospheric temperature or a little above. However, it will be understood that more drastic cooling may be applied wherever necessary or desirable.

A gas-oil fraction is withdrawn from the trap-out tray 10 and passes through a line 20 to a pump 21, while all of the crude oil constituents which are not vaporized in the column 7, representing a reduced crude fraction, are eventually withdrawn from the bottom of the tower 7 through a line 22, passing to a pump 23.

The gas-oil fraction withdrawn from the trap-out tray 10, after passing through the pump 21, is delivered through a line 24 to suitable heating means such as a still or pipe coil 25 located within a furnace 26, and in passing through the coil 25 is heated to a temperature sufficient to promote conversion of the oil in the presence of the catalyst with which the oil is subsequently to be brought into contact, and also sufficient to vaporize the oil more or less completely. The vapors leaving the coil 25 pass through a valved manifold vapor line 27 into one of a plurality of catalyst cases 28. These catalyst cases are provided with inlet and outlet manifold connections, as shown, in such a manner that they may be alternated as desired, so that regeneration of the catalyst in one or more of the cases 28 may be effected while the catalyst in another case is on stream.

While I do not wish to limit myself to any particular catalyst or to any specific conditions of temperature and pressure, it may be stated that a suitable catalyst comprises an activated hydrosilicate of alumina and that typical conditions of temperature and pressure at this point are from 800° to 900° F., and from atmospheric to 20 pounds per square inch gauge; such catalysts and such conditions are typical of the Houdry process. However, various modifications of the Houdry process are disclosed in an article entitled "Catalytic processing by the Houdry process" found at page R-570 of the National Petroleum News for Nov. 30, 1938, and in the patents listed in that article, while various other catalytic cracking processes are described in prior patents and in the literature.

Under the influence of the catalyst and the heat applied to the oil, conversion takes place, resulting in the formation of gasoline and other useful hydrocarbons. The converted vapors leave the "on stream" catalyst case 28 through a manifold line 29 and enter a fractionating column 30, which, as shown, may be of more or less conventional design and which is operated to condense and recover constituents having boiling points higher than those desired in the final gasoline fraction. The gas-oil condensate thus obtained is removed from the bottom of the column 30 through a line 31, while the gasoline and lighter vapors pass through a line 33 to a condenser 34 and thence through a line 35 into a separator 36. Condensed gasoline is withdrawn

from the separator 36 through a valved line 37, while the gases and vapors remaining undensified are removed from the separator 36 through a line 38 and passed to a compressor 39, from which they are delivered through a line 40 to an absorber 41.

The cooled naphtha fraction leaving the cooler 18 is delivered by means of a pump 42 and a line 43 to the upper part of the absorber 41 and passes downwardly through the absorber 41 in countercurrent to the stream of gases rising through the absorber 41, thereby scrubbing the gases and absorbed normally gaseous hydrocarbons containing three or four carbon atoms per molecule. The conditions within the absorber 41 are regulated in accordance with the amount and character of the gases introduced so as to effect an absorption of all or any desired portion of the C₃ and C₄ hydrocarbons from the gas. The residual gases, comprising for the most part C₃ and lighter hydrocarbons, leave the top of the absorber through a valved outlet line 44.

The enriched naphtha leaving the absorber 41 and containing C₃ and C₄ hydrocarbons removed by absorption in the absorber 41 then passes through a line 45 to a pump 46 which in turn delivers it through a line 48 into an elongated pipe coil 49 of restricted cross-sectional area located within a heating furnace 50 and wherein the naphtha is subjected to thermal conversion at an elevated temperature in the presence of the C₃ and C₄ hydrocarbons. Substantial conversion is obtained at various temperatures and pressures, ranging for example from about 950° to 1400° F. and from about 100 to 2000 pounds per square inch gauge pressure. However, the best results are obtained when the operation is conducted in the manner set forth and claimed in U. S. Patent 2,135,014 to Povl Ostergaard, that is to say, the admixture of oil and normally gaseous hydrocarbons is subjected to a high cracking temperature substantially in excess of the maximum temperature to which the oil alone could be subjected in identical apparatus and under otherwise identical conditions of conversion without such excessive deposition of carbon as to prevent continuous operation of the unit for extended periods of time, and ordinarily ranging from about 25° to 300° F. higher than the aforesaid maximum temperature.

During the passage of the oil and normally gaseous hydrocarbons through the coil 49, conversion takes place. The heated products are then discharged through a vapor-transfer line 52, having a pressure-reducing valve 53, into a tar separator 54. Under the influence of the pressure reduction and of cooling, supplied as will hereinafter be shown, vapor separation takes place, tar being withdrawn from the bottom of the separator 54 through a valved line 55. The separated vapors then pass through a line 56 into a fractionating column 57 which, as shown, may be of more or less conventional design.

In the fractionating column 57 sufficient cooling is effected to cause the condensation of constituents heavier than are desired to be retained in the final gasoline condensate. These condensed constituents, which may be referred to as gas-oil or recycle stock, are withdrawn from the bottom of the fractionating column 57 through a line 58 wherein is located a pump 59 and a cooler 60. A portion of the gas oil thus withdrawn is then delivered from the cooler 60 through a valved reflux line 61 into the upper portion of the tar separator 54, as a cooling me-

dium. Another portion of the gas oil passes through a valved quenching line 62 to the vapor-transfer line 52, serving as a quenching medium for the hot products of conversion leaving the coil 49. Other portions of the gas oil are withdrawn through quenching lines 63 and 64, for use as hereinafter described, while the remainder of the gas oil recovered in the tower 57 passes through the line 58 and the line 24 into the preheating coil 25, whence it is delivered to one of the catalyst cases 28 in admixture with the virgin gas oil recovered in the initial distilling operation and subjected to catalytic conversion for the production of gasoline.

The uncondensed vapors leaving the top of the column 57 pass through a line 65 into a gasoline condenser and rectifier 66. Various types of apparatus may be used at this point for condensing and stabilizing the gasoline produced in the system, such for example as that shown and claimed in U. S. Patent 2,134,816 to Povl Ostergaard. In the instance illustrated, however, I have for simplicity's sake shown a conventional rectifying column 66 provided with suitable plates or trays 67, cooling means located in the head of the column, and heating means 69 located in the foot of the column. The heat supplied to the heating coil 69 may be supplied from hot oil produced elsewhere in the system, as for example by causing all or a portion of the gas-oil condensate leaving the column 57 to traverse the coil 69. In any event, however, rectification takes place in the column 66, with the result that stabilized condensate is withdrawn from the bottom thereof through a valved line 71. The remaining gases pass overhead through a line 72 leading to a condenser 73 and a separator or accumulator 74.

By virtue of the pressures maintained in this portion of the system, and which will ordinarily run from 100 to 300 pounds per square inch, a portion of the C_3 and C_4 constituents present in the gases is caused to be condensed in the condenser 73 and to collect in the accumulator 74 in liquefied form. Operation of the condenser 73 at temperatures somewhat below atmospheric may be resorted to in order to condense a larger portion of the C_3 and C_4 hydrocarbons at this point than would be possible if the condenser 73 were operated at atmospheric temperature.

The condensate thereby obtained, comprising liquid butane and propane, together with their unsaturated analogues, is removed from the accumulator 74 through a valved line 75 for use as shown hereinafter.

The gases and vapors remaining uncondensed in the condenser 73 leave the accumulator 74 through a line 82 and enter the bottom of the absorber 41 where they are scrubbed with naphtha, in admixture with the gases leaving the accumulator 36 of the catalytic cracking unit, as described hereinabove. The C_3 and C_4 constituents removed by such absorption are transferred, in admixture with the naphtha, to the coil 49 for conversion as aforesaid.

Heavy reduced crude unvaporized in the flash tower 7 is withdrawn therefrom through the line 22, passing to the pump 23 as described above. From the pump 23 the reduced crude passes through a line 85 and is delivered to a pipe coil 86 located within a heating furnace 87. Before being introduced into the coil 86, however, the reduced crude is joined by propane-butane condensate recovered in the separator 74, the latter being delivered to the coil by means

of the line 75, a pump 88, a line 89 and a portion of the line 85.

The temperatures employed in the coil 86 will, of course, be lower than those employed in the coil 49, which receives enriched naphtha from the absorber 41. Typical operating temperatures and pressures for the coil 86 will run from 850° to 1000° F. and from 100 to 2000 pounds per square inch, respectively. In any event however, the best results are secured, as in the coil 49, while operating in the manner disclosed and claimed in U. S. Patent 2,135,014 to Povl Ostergaard and as referred to hereinabove, keeping in mind the character of the charging stock.

In any event however, the operation conducted in the coil 86 takes place under temperatures relatively mild compared to those employed in the coil 49, being in the nature of a mild cracking or "viscosity breaking" operation, similar to conventional operations of this character conducted for the purpose of producing large quantities of relatively high-boiling clean distillate rather than gasoline, but differing from conventional "viscosity breaking" temperatures in that, by reason of the presence of C_3 and C_4 hydrocarbons, somewhat higher temperatures and higher degrees of conversion per pass can be, and advantageously are, employed than would be the case if the normally gaseous constituents were not present.

The hot products of conversion leaving the coil 86 are discharged through a transfer line 91 into the transfer line 52 where they mingle with the products of conversion from the coil 49 and then pass into the tar separator 54 and subsequent fractionating units. It will thus be seen that the gas oil produced in the mild cracking operation conducted in the coil 86 is subsequently recovered in the fractionating column 57 for transfer to the catalytic cracking operation, while the gasoline and gases produced in the same operation are recovered in the fractionating column 67 and the absorber 41, respectively. However, as aforesaid, the operation of the coil 86 is such that only a relatively small amount of gasoline is produced in the conversion taking place therein, it being more advantageous to operate for the production of a large amount of gas oil, suitable for conversion into high-octane gasoline in the catalytic conversion unit.

As has been shown hereinabove, gas-oil constituents recovered in the thermal cracking operation are delivered for further conversion into the catalytic cracking operation. The gas oil recovered in the catalytic cracking operation and removed from the bottom of the column 30 may be recycled, if desired, to the catalytic cracking operation itself or to a separate catalytic cracking operation.

However, the gas oil recovered from the column 30 is preferably delivered to a separate coil, wherein cracking of this stock is conducted without a catalyst, and the products of such cracking may be fractionated along with products of conversion from the thermal cracking operations.

Thus, the catalytically produced gas oil recovered from the column 30 may be delivered by means of a line 100 having a valve 101 to a pump 102, to be delivered by the pump 102 through a line 103 to an elongated cracking coil 104 disposed within a suitable furnace 105. The products of conversion leaving the coil 104, after being quenched by gas oil delivered through the

line 64, are then passed through a transfer line 108 and a portion of the transfer line 52 into the tar separator 54 for separation and fractionation as aforesaid.

Specific temperatures and pressures for effecting conversion or cracking in the coil 104 need not be given, since these will be obvious to one skilled in the art, and are in fact well-known.

The various gasolines recovered in the system described and illustrated hereinabove at 16, 37 and 71, may be combined and blended in any desired proportions, thus producing the final motor fuel product, or they may be used separately. Moreover, these gasolines may be blended with addition agents, as for example with the usual anti-knock agents, such as tetraethyl lead and the like.

At this point it may be pointed out in general the lead susceptibility of catalytically cracked gasoline often does not compare with the lead susceptibility of thermally cracked gasolines, such as those produced in the thermal cracking zones of the system described hereinabove.

In referring to catalytic cracking processes, I have in mind in general those processes, usually carried out at pressures of less than 100 pounds per square inch at elevated temperatures ranging from 700° to 1100° F., wherein a catalyst of one sort or another is employed to promote conversion reactions tending to form gasoline-like hydrocarbons.

I have referred principally hereinabove to the Houdry process, but it will be understood that other types of catalytic processes and other catalysts may be employed. Such catalytic cracking processes are numerous and well-known in the art and need not be catalogued here in full. However, by way of exemplification, it may be stated that among the catalysts which have been proposed for use in processes of this character and which to the extent that they are individually useful and advantageous may be employed in the catalytic cracking zone of the processes described hereinabove, are the following: nickel and compounds thereof, such as nickel oxide; chromium and compounds thereof, such as chromic oxide; compounds of nickel and chromium, such as nickel chromate; phosphorus compounds, especially metaphosphates, including those of chromium and uranium; aluminas; adsorbent clays; fluridin; bauxite; molybdenum sulfide; and a wide variety of other compounds, particularly compounds of metals and alkaline earth metals. Many of these catalysts have entirely different specific actions, some favoring dehydrogenation, some scission of carbon-carbon linkages, some isomerization, some cyclization reactions, and other alkylation reactions, but for the purposes of the present invention, all of these may be considered to come under the general category of catalytic cracking catalysts. Most of these catalysts are preferably employed at low pressures, with regeneration at periodic intervals, but my invention, in so far as it deals with catalytic cracking, is not so limited.

In referring to "normally gaseous hydrocarbons having three to four carbon atoms per molecule," I mean propane, propylene, butanes and butylenes, all of which are normally gaseous in a pure state under atmospheric pressure and temperature conditions. It will be understood, however, that these constituents may or may not exist in gaseous form at different points in the systems illustrated, and consequently the expression referred to is not intended to imply that

these constituents are actually present as gases, for at many points they will exist in the liquid form, by virtue of the pressures employed or because of the presence of liquid oils in which they are absorbed, or both.

While I have described and illustrated my invention hereinabove with respect to numerous operating examples and specific operating details, it is not my intention to limit my invention in its broadest aspect to such details or exemplifications. My invention may be variously practiced and embodied within the scope of the claims hereinafter made.

What I claim is:

1. The process of producing gasoline motor fuel of high anti-knock value from a crude petroleum which comprises: fractionally distilling a crude petroleum to recover a naphtha fraction, a gas-oil fraction and a residual fraction; subjecting said gas-oil fraction to conversion in the presence of a catalyst effective to promote pyrolysis reactions and fractionating the resultant products of conversion to recover gasoline and heavier constituents therefrom; subjecting said residual fraction to thermal conversion at a temperature effective to cause the formation of relatively large amounts of gas-oil constituents boiling above the gasoline boiling-point range; subjecting said naphtha fraction to thermal conversion at a temperature effective to cause the formation of gasoline hydrocarbons of higher anti-knock value, fractionating the combined products of said thermal conversion operations to separate and recover a residual fraction, a gas-oil fraction, a gasoline fraction and normally gaseous hydrocarbons; delivering the last-mentioned gas-oil fraction to the catalytic conversion zone for conversion in admixture with said first-mentioned gas-oil fraction; and recirculating at least a portion of said normally gaseous hydrocarbons to the naphtha-conversion zone for conversion in the presence of said naphtha fraction.

2. A process of producing gasoline motor fuel of high anti-knock value from a crude petroleum which comprises: fractionally distilling a crude petroleum to recover therefrom a naphtha fraction, a residual fraction and an intermediate fraction; subjecting said intermediate fraction to conversion at a relatively low pressure in the presence of a catalyst effective to promote pyrolysis reactions and separately fractionating the resultant products of conversion to recover gasoline and heavier constituents therefrom; subjecting said naphtha fraction to thermal conversion at a high cracking temperature and under a relatively high superatmospheric pressure, effective to cause the reformation of said naphtha to gasoline-like products having an increased anti-knock value; subjecting said residual fraction to thermal conversion at a relatively low cracking temperature, effective to cause the formation of lower boiling products; combining and fractionating the resultant products of conversion of said naphtha fraction and said residual fraction to recover gasoline and heavier constituents, including a gas-oil fraction, therefrom; delivering said gas-oil fraction to said catalytic cracking operation for conversion together with said intermediate fraction; recovering normally gaseous hydrocarbons having 3 to 4 carbon atoms per molecule from fractionated products of conversion of the several cracking operations referred to above; and delivering said normally gaseous hydrocarbons to the thermal conversion

operations in admixture with the naphtha fraction and said residual fraction respectively.

3. The process of producing gasoline motor fuel of high anti-knock value from a crude petroleum which comprises: fractionally distilling a crude petroleum to recover therefrom a naphtha fraction, a residual fraction and an intermediate fraction; subjecting said intermediate fraction to conversion at a relatively low pressure in the presence of a catalyst effective to promote pyrolysis reactions and separately fractionating the resultant products of conversion to recover gasoline and heavier constituents therefrom; subjecting said naphtha fraction to thermal conversion at a high cracking temperature and under a relatively high superatmospheric pressure, effective to cause the re-formation of said naphtha to gasoline-like products having an increased anti-knock value; subjecting said residual fraction to thermal conversion at relatively low cracking temperature, effective to cause the formation of lower-boiling products; combining and fractionating the resultant products of conversion of said naphtha fraction and said residual fraction to recover gasoline and heavier constituents therefrom; recovering normally gaseous hydrocarbons having 3 to 4 carbon atoms per molecule from fractionated products of conversion of the several cracking operations referred to above by absorption in said naphtha fraction prior to conversion thereof, and delivering the thereby enriched naphtha fraction containing said normally gaseous hydrocarbons to the naphtha reforming operation for conversion as aforesaid.

4. The process of producing gasoline motor fuel of high anti-knock value from a crude petroleum which comprises: fractionally distilling a crude petroleum to recover therefrom a naphtha fraction, a residual fraction and an intermediate fraction; subjecting said intermediate fraction to conversion at a relatively low pressure in the presence of a catalyst effective to promote pyrolysis reactions and separately fractionating the resultant products of conversion to recover gasoline and heavier constituents therefrom; subjecting said naphtha fraction to thermal conversion at a high cracking temperature and under a relatively high superatmospheric pressure, effective to cause the re-formation of said naphtha to gasoline-like products having an increased anti-knock value; subjecting said residual fraction to thermal conversion at a relatively low cracking temperature effective to cause the formation of lower-boiling products; combining and fractionating the resultant products of conversion of said naphtha fraction and said residual fraction to recover gasoline and heavier constituents therefrom; recovering normally gaseous hydrocarbons having 3 to 4 carbon atoms per molecule from fractionated products of conversion of the several cracking operations re-

ferred to above; and delivering said normally gaseous hydrocarbons to the naphtha-reforming operation in admixture with said naphtha fraction for conversion as aforesaid.

5. The process of producing gasoline motor fuel of high anti-knock value from a crude petroleum which comprises fractionally distilling a crude petroleum to recover a naphtha fraction, a heavier distillate fraction and a residual fraction; subjecting said distillate fraction to conversion in the presence of a catalyst effective to promote pyrolysis reactions and fractionating the resultant products of conversion to recover gasoline and heavier constituents therefrom; subjecting said naphtha fraction and said residual fraction to thermal conversion in separate zones; fractionating the combined products of said thermal conversion zones to separate and recover a residual fraction, a gas-oil fraction and a gasoline fraction; and recycling gaseous hydrocarbons having 3 to 4 carbon atoms per molecule, produced in the aforesaid conversion operations, to the thermal conversion operations for conversion in admixture with said naphtha fraction and said residual fraction, respectively.

6. The process of producing gasoline motor fuel of high anti-knock value from a crude petroleum which comprises: fractionally distilling a crude petroleum to recover a naphtha fraction, a gas-oil distillate fraction and a residual fraction; subjecting said gas-oil distillate fraction to cracking in a catalytic conversion zone in the presence of a catalyst effective to promote pyrolysis reactions and fractionating the resultant products of conversion to recover gasoline and heavier constituents therefrom; subjecting said residual fraction to mild cracking in a thermal conversion zone at a temperature effective to cause the formation of relatively large amounts of gas-oil constituents boiling above the gasoline boiling point range; fractionating the products of such thermal conversion to separate and recover a residual fraction, a gas-oil fraction, a gasoline fraction and a liquefied gas fraction; delivering the last-mentioned gas-oil fraction together with the first-mentioned gas-oil distillate fraction to the catalytic conversion zone as aforesaid; delivering the liquefied gas fraction in admixture with said first-mentioned residual fraction to the thermal conversion zone as aforesaid; scrubbing residual gases from the catalytic and thermal conversion zones with said naphtha fraction to remove normally gaseous hydrocarbons having 3 to 4 carbon atoms per molecule; subjecting the thereby enriched naphtha fraction to thermal conversion in a separate zone at relatively high temperature, and combining the products of conversion with the products of conversion from the first-mentioned thermal conversion zone as aforesaid.

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