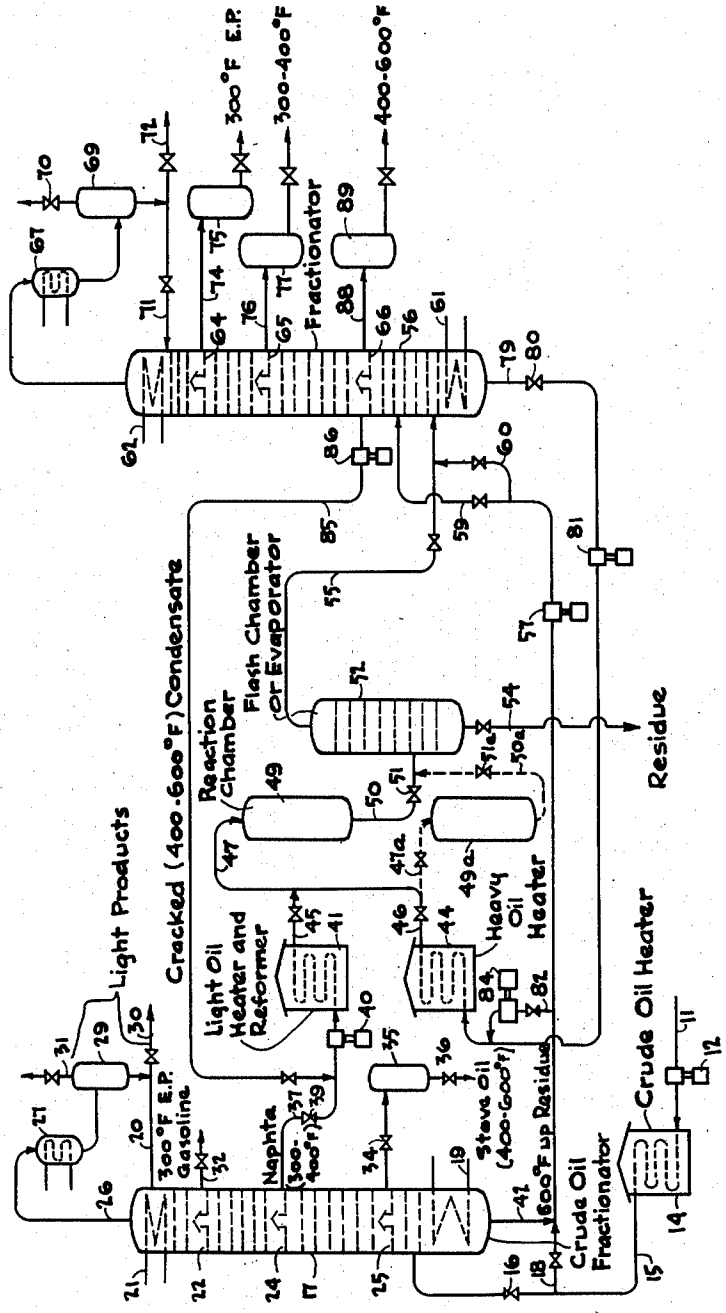
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THERMAL CONVERSION OF HYDROCARBONS

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THERMAL CONVERSION OF HYDROCARBONS

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This invention relates to the treatment of hydrocarbon oils to produce lighter hydrocarbons therefrom. More particularly, the invention relates to the treatment of crude oil or partially topped crude oil and/or reduced crude obtained therefrom to effect conversion thereof to motor fuel and other valuable products under conditions of highest efficiency with the production of gasoline constituents of high antiknock value.

It is an object of the present invention to provide a method of treating a plurality of hydrocarbon oil fractions of differing boiling ranges, such as may be obtained from a crude oil or partially topped crude oil, wherein at least two of said hydrocarbon fractions, and selected products produced therefrom, are treated under conditions selected for each oil to produce motor fuel products, and intermediate products suitable for further conversion, to effect a combined operation of highest efficiency and particularly with a minimum requirement in apparatus.

It is a further object of the invention to provide an improved method for the conversion of reduced cruded oil to lighter products including gasoline of high antiknock properties. A still further object is to provide a method wherein a heavy naphtha and a relatively heavy hydrocarbon oil such as reduced crude are simultaneously treated in combination to effect reforming of the naphtha to produce gasoline constituents of improved quality and the cracking of the heavy oil to produce gasoline constituents of high antiknock value as well as of intermediate products.

Another object of the invention is to provide a method of the above nature wherein intermediate cracked products thus formed, and which are intermediate in boiling range between the heavy naphtha and reduced crude, are themselves treated in combination with heavy naptha and/or with reduced crude to produce therefrom gasoline constituents of good quality.

Still another object is to treat a plurality of hydrocarbon oil fractions of differing boiling ranges and differing in their refractoriness toward heat in a manner so as to effect a deeper cracking of the heavier and more readily cracked fraction(s) while at the same time avoiding appreciable coking of the material.

The above-mentioned objects will be better understood and other objects will become apparent from the following description of the invention, taken together with the accompanying drawing which is a flow diagram of an apparatus and method for carrying out the present invention.

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The present invention contemplates the separation of a crude petroleum oil or of a partially topped crude oil into a plurality of fractions, including a low boiling fraction such as a full-range straight run gasoline or a heavy naphtha, a high boiling residual fraction (a reduced crude) and an intermediate fraction boiling higher than gasoline, such as a stove oil fraction, separately subjecting the low boiling fraction and the high boiling fraction to elevated conditions of temperature and pressure to effect cracking and/or reforming of the low boiling fraction to produce constituents of improved antiknock value and substantial cracking and conversion of the residual fraction but insufficient to cause appreciable coking thereof, admixing the products of both fractions without further addition of heat thereto and maintaining the admixture at a substantially reduced linear velocity in a non-catalytic thermal reaction zone with deeper cracking of the residual fraction by utilizing the sensible heat of the more drastically heated naphtha and the production of further amounts of gasoline hydrocarbons of high antiknock values. The combined resulting product is then separated into a high boiling residue which cannot be further cracked without substantial coking and into a vaporized overhead fraction. The vaporized overhead fraction is fractionated into a plurality of fractions including a cracked gasoline fraction of improved value, a high boiling residual fraction which is recycled to the cracking zone for treating the residual oil fraction and a cracked hydrocarbon fraction of intermediate boiling range between that of the heavy naphtha and residual oil fractions produced first from the feed oil, which intermediate fraction, being a cracked product, is more refractory than the straight run intermediate (stove oil) fraction of the first fractionation in the same boiling range, and may be and is recycled in the system to be subjected to cracking in admixture with the low boiling straight run fraction in the reforming zone therefor.

It will be seen that by the method described above, all of the portion of the higher boiling (residual) fraction from the first fractionation which is at any time cracked to produce lower boiling material may be converted to useful gasoline of improved value or to lighter hydrocarbons, without the production as final product of intermediate boiling material which is of too high boiling point to be utilized as gasoline. Whereas intermediate cracked products are produced in the process, they can be subjected to the severe

cracking and reforming treatment in the same heating, cracking and reforming zone as the low boiling straight run fraction without cracking thereof to deleterious coke, because of the increased refractory character of this cracked intermediate (stove oil-boiling range) fraction over that of the equivalent (in boiling range) straight run stove oil fraction. This is true particularly since, in the process of the invention, this cracked fraction is substantially free of less refractory straight run material.

It is preferred to countercurrently contact the heavy (residual) oil from the first fractionation operation, prior to heat treatment thereof, with the vaporized products of the thermal conversion operations, in the lower section of the second fractionating zone, and to utilize the bottoms product therefrom as feed oil to the cracking furnace for the heavier oil. In this manner any vaporizable heavy (residual) material which is produced as a result of the thermal treatments, will be admixed with the first residual material and returned to the conversion operations without loss thereof. Furthermore, this countercurrent contacting serves as a heat exchange means to provide adequate refluxing in the lower section of the fractionating zone to effect complete condensation of the intermediate cracked fraction for separation and recycle thereof for further cracking and reforming.

An important feature of the present invention is the separation of the intermediate cracked oil fraction and combining it with the lower boiling straight run distillate fraction and subjecting the two fractions together to the same severe reforming and cracking conditions.

A number of advantages is secured by the practice of the method of the present invention. Among them are the following more important and significant ones:

(1) The octane number of the heavier straight run gasoline fraction is materially increased in addition to the production of a large proportion of a similar gasoline fraction made from cracking heavier oils.

(2) The temperature of the light oil heater may be maintained at a high level and by carrying a larger quantity of sensible heat to the reaction chamber more severe cracking of the heavy oil stock is obtained without the coking of furnace tubes than could otherwise be obtained.

(3) By providing a reaction chamber (zone of reduced linear velocity, enlarged cross-section and of reduced confining surface per volume of reactants), wherein the high sensible heat of the lighter oil is utilized more completely to effect deeper heating and conversion of the heavier oil without deleterious coking, the time of subjecting the reactants to conversion conditions may be materially and advantageously increased since increased linear velocity is not now required to sweep any coke formed from narrow confining and heat transfer tubes as is accomplished by the prior method of passing a naphtha fraction through an elongated cracking zone of restricted cross-section while applying heat to said elongated zone to subject the naphtha to cracking conditions of temperature and pressure adequate for the purpose and introducing a heavy (residual) oil to the same elongated cracking zone intermediate the ends thereof into admixture with the naphtha after it has been subjected to substantial conversion therein whereby said residual oil is raised to a cracking temperature to effect conversion thereof to lighter products during the passage of the admixed hydrocarbons through the remainder of the elongated cracking zone.

(4) As already indicated hereinbefore, the intermediate condensate cut separated from the vapors of the combined cracked product, which intermediate cut has too high a boiling range (400–600° F., preferably 450–550° F.) may now be recracked in the light oil heater along with the lighter oil (heavy naphtha) feed thereto. This recycle stream, in the absence of any straight run stove oil (boiling range of 400–600° F.), can receive the same high temperature treatments as the lighter straight run naphtha (300–400° F.), since the two materials are of similar refractoriness. This makes it possible to utilize the same equipment for treating both fractions, thus making it possible advantageously to convert the intermediate cracked fraction to more valuable lighter hydrocarbons of high antiknock value without the outlay of any further capital for additional plant equipment.

(5) An unusually high yield of C_3, C_4 and C_5 olefins is obtained because of the reforming operation, the heavy recycle cracking, and the more severe cracking of the heavy oil. These olefins are increasingly valuable as feed stock for polymerization and alkylation operations as well as for a diversity of chemical manufacturing operations.

(6) The presence of light reforming products in the admixture which is fed to the flash chamber or evaporator for the purpose of separating the vapors from the heavy residue admixed therewith permits a more complete recovery of the vaporizable products for a given operation bottoms temperature. In other words, for a selected bottoms temperature, which in turn is determined by the thermal characteristics of the materials involved, a heavier residue may be produced, thus representing a smaller fraction of feed material which is withdrawn from the system as residual product.

Having described the invention in a general manner and having set forth advantages to be obtained from its practice, the invention will now be described in more detail with reference to the accompanying drawing, but it is to be understood that the invention is not to be limited by such reference but is capable of other modifications which may be beyond the physical limitations of the particular apparatus indicated.

Crude oil or partially topped crude oil is introduced into the system through line 11 provided with a pump 12. The crude oil may be heated by any suitable means, such as by heat exchange with hot gases or vapors produced in the system, or the oil may be preliminarily heated partially by such means and raised to the final temperature desired by passage through a coil located in the relatively cool part of a cracking furnace, or such coil may be separately heated, or the crude oil may be heated entirely by passage through such a heated coil. For purposes of illustration and without intending to limit the invention thereby a separate heater 14 provided with a suitable heating coil to which line 11 connects is indicated. In heater 14 the crude oil or partially topped crude oil is heated to a distillation temperature which will depend on the extent of distillation desired and on the nature of the charge oil. Generally speaking, the oil may be heated to a temperature of 500° to 800° F. under a pressure of from atmospheric to 100 pounds per square inch gage (p. s. i. g.). The heated oil is withdrawn from heater 14 through a line 15 which

is provided with a valve 16 to effect any desired reduction in pressure. Line 15 connects with the lower portion of a crude flash and fractionating column or tower 17 wherein the separation of vapors and reduced crude is effected. The reduced crude descends to the bottom of the tower 17 and the heating of the crude oil under conditions maintained in tower 17 is regulated to effect vaporization of the majority of constituents boiling below 550°–650° F. (preferably below 660° F. under atmospheric pressure), whereby the crude oil or partially topped crude oil which may have had an original gravity of 25° to 45° A. P. I. is distilled to leave a reduced crude having a gravity of 10° to 30° A. P. I. Auxiliary heating means 19 may be provided in the bottom of the tower 17 to secure the desired distillation, if necessary.

Conditions of temperature and pressure are maintained in tower 17 to effect condensation of a part of the vapors whereby the vapors leaving its top consist of a mixture of light hydrocarbons. For example, the tower may be maintained at a pressure from atmospheric to 25 pounds per square inch with a bottom temperature of 500° to 650° F. and a top temperature of 275° to 325° F. Any suitable means such as liquid reflux as indicated by line 20 or a cooling coil as indicated by 21 may be provided at or in the upper portion of the tower 17 to effect maintenance of the desired temperature at that point. Trap-out trays 22, 24 and 25 are provided at suitable intervals above the point of introduction of the heated crude oil to collect from the liquids condensed from the vapors a light naphtha fraction having an end-point boiling temperature of about 300° F. (atmospheric pressure), a light oil or heavy naphtha condensate having a boiling range, for example, of about 300° to 400° F. (atmospheric pressure) and a virgin light gas oil (stove oil) having, for example, a boiling range of about 400° to 600° F. Other specific cuts or fractions may be obtained if desired and found to be more satisfactory depending on the nature of the particular crude oil or oil mixture being utilized for the feed charge in the operation of the process.

The overhead vaporous products are withdrawn from the top of tower 17 through a line 26, at least partially condensed in a suitable condenser 27 and collected in a suitable vessel 29. A portion of the condensate thus produced may be returned through line 20 to the top of tower 17 as reflux condensate while the remainder is withdrawn through a line 30. Uncondensed vapors or gaseous materials are vented or withdrawn through a line 31. The light naphtha (light gasoline) condensate is withdrawn from trap-out tray 22 within tower 17 through a line 32 and may be utilized as such or as light blending material for ultimate consumption. The virgin light gas oil (stove oil) condensate which collects on trap-out tray 25 is withdrawn from tower 17 through a line 34 and transferred to a storage vessel 35 from which it is withdrawn through a valved line 36 as it is desired. The heavy naphtha condensate is withdrawn from trap-out tray 24 through line 37 provided with a valve 39, by means of pump 40 located in line 37. Line 37 connects with the coil of the reforming heater 41. For convenience of representation, reforming heater 41 is shown as a separate heater. It will be understood that this representation for purposes only of illustration, however, is not intended to limit the invention to that particular arrangement. The function of heater 41 may be equally well performed by a coil located suitably in a furnace which also serves to heat one or more other coils through which different liquids are passed, such as the coil used for cracking the reduced crude and heavy recycle oil, that is heater 44.

The heavy naphtha is heated as it passes through heater 41 to a suitable reforming temperature of from about 900° to 1100° F. at a pressure of 100 to 1000 pounds per square inch to effect cracking of the naphtha with accompanying polymerization and other conversion reactions to effect the production of a reformed naphtha having improved antiknock properties. Simultaneously with the heating of the heavy naphtha in heater 41, reduced crude is withdrawn from the bottom of tower 17 through line 42, countercurrently contacted as will be described hereinafter with vaporous reformed and cracked products of a prior cracking and reforming operation of the process and then conducted to the heating coil of a suitable heater 44. The heavy oil (reduced crude) is heated in the coil of heater 44 to a temperature of from about 850° to 975° F. at a pressure of from about 100 to about 1000 pounds per square inch, a temperature of the order of 875° to 925° F. at a pressure of the order of 250 to 450 p. s. i. a. (pounds per square inch absolute) representing a preferred combination of operating conditions. The reduced crude withdrawn from tower 17 is ordinarily at a temperature of 500° to 700° F. The reduced crude thus heated in heater 44 whereby at least a partial cracking of the oil is effected, however, the temperature to which the oil is heated in heater 44 and the period of time of residence of the oil therein are adjusted so as to effect a maximum of cracking and conversion without the formation of coke therein.

The heated and cracked products from heaters 41 and 44 are withdrawn through lines 45 and 46, respectively, each of which is provided with suitable valves for maintaining optimum cracking pressures in each coil, and the separate products therein are combined in line 47 (which may be of negligible length) and then delivered to a reaction chamber 49 of enlarged cross-section wherein the linear velocity of the admixture is materially decreased and the hydrocarbon substances are permitted to undergo further conversions with the production of further amounts of valuable lower molecular weight hydrocarbons. Even if the conditions maintained in the heaters 41 and 44 are such that when the admixture of products reaches the reaction chamber 49 there is then deeper cracking of the heavy oil of such a degree as to produce an appreciable amount of coke, many of the advantages of the invention are still realized and the disadvantage of the coke formation is now readily obviated by the provision of a second reaction chamber 49*a* in parallel with chamber 49 and which may be used alternately therewith, one chamber being de-coked by burning out or otherwise removing the coke while the other chamber is on-stream. Alternate lines 47*a* and 50*a* are provided for directing the admixture through chamber 49*a*. Since the reaction chambers do not require the transfer of heat through the walls thereof and since they are of enlarged cross-section, the removal of the coke in a decoking operation is readily effected. The presence of the gaseous reforming products from the heat treatment of the heavy naphtha in heater 41 in the admixture with the heavy oil makes

it possible to heat the heavy oil and its cracked products to a higher temperature, utilizing the additional sensible heat of the heavy naphtha reformed products, to effect a higher temperature with greater conversion of the heavy oil without coke formation therefrom in the reaction chamber 49. On the other hand, the present invention may be operated for the deliberate formation of coke in the chambers, with advantages being secured due to deeper cracking as a result of increased availability of sensible heat for the purpose. When the process is so operated, various suitable means, such as well known hydraulic or mechanical means, may be utilized for removing the coke from the chambers.

The cracked products from the reaction chamber are withdrawn therefrom through line 50 provided with a valve 51 to effect any desired reduction in pressure. The line 50 connects with a flash chamber separator 52, which, if it is desired may be provided with fractionating means therein such as a number of bubble-cap plates. The separator 52 may be maintained at or below the pressure in the reaction chamber 49 and the heaters 41 and 44, but preferably the pressure is somewhat lower than that of the reaction chamber whereby separation of vapors and liquid residue is effected to produce vapors containing the desired constituents. The temperature of the constituents in the flash chamber 52 may be 700° to 850° F., preferably 775° to 825° F. If it is desired or necessary, a quenching oil may be introduced into the separator 52 at a point above the point of introduction of the cracked products by any suitable means (not shown), which quenching oil may be a portion of a higher boiling light fraction obtained by a subsequent fractionation of the cracked and vaporized products and which may or may not contain absorbed therein some of the separated hydrocarbons of still lower molecular weight. The liquid residue separated in the flash chamber is withdrawn therefrom through a valved line 54 for use elsewhere, for example, as a fuel oil, road oil, etc. The vapors separated in flash chamber 52 are withdrawn therefrom through a valved line 55. Line 55 connects with the lower portion of a fractionating column 56 for introduction of the vapors thereinto. Preferably the flashing of the cracked products from the heaters and reaction chamber in flash chamber 52 is controlled to effect the production of vapors containing products boiling above 650° to 800° F., at a pressure of from atmospheric, or even subatmospheric, to a pressure which is substantially above atmospheric but below the pressure in the reaction chamber, whereby constituents of heavy gas oil are contained therein. As already discussed hereinabove, the presence of the large number of moles of light products in the cracked products makes it possible to remove more completely the lighter constituents therefrom in the vapors.

The operations of reaction chamber 49 and flash chamber 52 may be carried out in a single vessel, if desired, with slight modifications, for example, the mixed heated products in line 47 may be fed into a vessel similar to reaction chamber 49 by means of an open-end pipe which extends from the top or side thereof into the vessel and to a point in the vertical axis thereof, with the open end disposed in the lower half of the vessel. The vessel will be provided with a bottom outlet (such as 54 in chamber 52) for the withdrawal of heavy residue and with a top outlet (such as 55 in chamber 52) for the withdrawal of vaporous products. By maintaining a suitable level of heavy oil in the bottom of the vessel (and/or recycling a portion thereof as gas-scrubber to a high point in the vessel) the temperature of the heavy oil in the bottom may be maintained as high as possible without obtaining undesirable cooking and the time period for maintaining the vaporous mixture under conversion conditions may be independently adjusted as desired. The process may be operated in a somewhat similar manner if it is desired to produce coke. The principal difference being that the temperature of operation is increased as much as possible and the heavy oil residue to be withdrawn from the bottom of the reaction chamber is eliminated. The production of coke by this method has an advantageously low content of volatile material on account of the unusually high temperature at which it is produced in the reaction chamber.

The separated vapors of the cracked products are introduced into the fractionator 56 so as to be intimately contacted therein with reduced crude oil (residual oil) taken from the bottom of tower 17. The reduced crude is fed by means of line 42, pump 57 therein, and then by either or both of parallel valved lines 59 and 60 to the lower portion of the fractionator 56. Fractionator 56 may be provided with suitable heating means, such as a heating coil 61, placed in the bottom portion thereof, and is also provided with suitable cooling means, such as a cooling coil 62, placed in the top portion thereof. The fractionating column is also provided with suitable trap-out plates therein 64, 65, and 66 and with suitable outlet means for the withdrawal of gaseous overhead material and liquid residual material as well as any desired condensate cuts formed by the condensation of the various normally liquid hydrocarbons in the cracked product. The overhead gaseous product is at least partially condensed in condenser 67 and collected in a storage vessel 69, from which the non-condensed lighter hydrocarbons may be vented or withdrawn through a valved line 70, a portion of the condensed product may be returned through a line 71 to the top of the fractionator 56 as a reflux, and the remainder of the condensed product may be withdrawn through a valved line 72. The lighter naphtha (gasoline) fraction is withdrawn from trap-out tray 64 through line 74 and delivered thereby to a suitable storage vessel 75. The heavier naphtha (300°–400° F.) condensate cut of improved antiknock properties is withdrawn from trap-out tray 65 by means of a line 76 and delivered thereby to a suitable storage vessel 77.

The fractionating column 56 is operated in such a manner as to produce a light cracked oil fraction which is substantially free of straight run hydrocarbons and therefore is of sufficiently high refractoriness as to be advantageously treated with the straight run heavy naphtha from the feed charge in the light oil heater and reformer 41 without the deleterious formation of coke therein. In order to accomplish this, the operation of fractionator 56 must be coordinated with that of fractionator 17. Thus, fractionator 17 should be operated to remove in the more volatile fractions all straight run material boiling below about 600° F. and thus to produce a reduced crude bottoms fraction such as that when it is countercurrently contacted with the cracked products in the lower portion of fractionator 56, there will be no appreciable proportion of straight run material

of the stove oil boiling range present which is separated in the light cracked oil fraction of corresponding boiling range. At the same time it is desired that the residual oil withdrawn from the bottom of fractionator **56** will contain all of the straight run material which boils at 600° F. or higher and also heavier portions of cracked products removed from the flash chamber in the vapor products.

The fractionator **56** is operated under conditions so that the bottoms residual product is at a temperature of from about 600° to 800° F. and usually at least from 25° to 200° F. higher than the temperature of the reduced crude as withdrawn from the fractionator **17**. The pressure maintained in the fractionator **56** may be adjusted as desired, but, because of the presence of relatively volatile hydrocarbons in the cracked products, it has been found preferable to operate under a pressure which is substantially above atmospheric pressure, for example from about 25 to about 150 p. s. i. a.

The heavy residual oil withdrawn from the bottom of fractionator **56** through line **79**, which is provided with a suitable valve **80** and a pump **81**, is delivered thereby to the coil in heater **44** for treatment as already described hereinbefore. The residual oil in line **79** may be admixed, if desired, with a portion of the reduced crude in line **42** by means of by-pass line **82** and pump **83** placed therein. When the process is first being placed in operation only reduced crude taken from tower **17** may be directed to and passed through heater **44**. As the operation proceeds, the reduced crude may then be gradually replaced by residual oil taken from the bottom of fractionator **56**. Any combinations of various proportions of the two residual oils may be employed depending on the particular requirements of a given system.

Any part or all of the light cracked oil fraction (intermediate fraction) boiling between the end boiling point of the desired cracked naphtha fraction (gasoline of high antiknock value) and the lowest boiling point of the heavy oil (residual oil) is withdrawn from trap-out tray **66** through a line **85**, which is provided with a pump **86** and is delivered thereby to line **39** wherein it is admixed with straight run naphtha and therewith delivered to the light oil heater and reformer **41**, wherein the intermediate cracked oil is subjected to cracking and reforming treatment for the conversion thereof to more valuable lighter products. If it is not desired to recycle all of the intermediate cracked condensate, either because of limitations placed on the process by physical limitations of the apparatus, or because of a demand for a portion of the product to be used as such or in some other operation, or for other reasons, a portion of this cracked fraction may be transferred, as by means of a line **87**, to a suitable storage vessel **89**. Also, in the practice of the invention, it may be found to be desirable to utilize as feed to the light oil heater only intermediate cracked condensate if the amount formed in the process is sufficient for the purposes. This represents a particularly desirable method of operating the process of the invention when the available charge stocks to be handled are largely heavy crude and/or even reduced crudes obtained from other operations and wherein the amount of straight run heavy naphtha fraction which is available is of a very limited nature. In that case, after starting-up of the operations by the use of straight run heavy naphtha to effect the

first cracking of the heavy oil by the process of the invention the straight run heavy naphtha may be gradually replaced by an intermediate cracked light oil fraction produced in the process until only said intermediate fraction is being subjected to the heat treatment and reforming conditions in the light oil heater or reformer **41**. Also, when the available charge stocks are largely straight run reduced crude and a relatively small proportion of crude oil, such that when the two are combined in suitable proportions or proportions which represent the ratio of their availabilities and then the ratio of straight run light oil fraction of a stove oil range (400–600° F.) available therein to intermediate cracked oil fraction of similar boiling range produced in a cycle of the operation of the process of the invention, then an advantageous embodiment of the invention is one in which a selected mixture of straight run reduced crude and crude oil, after the process is on-stream, is fed directly to the lower part of the fractionator **56**. Thus, the straight run reduced crude from a fractionator **17** may be admixed with a suitable proportion of crude oil taken from line **15**, if desired, by means of a valved line **18**, and the admixture delivered by means of lines **42**, **59** and **60** and pumps **57** to the fractionator **56**. In this embodiment of the invention it is preferred to select the operating conditions so that the intermediate cracked fraction which is directed to the reforming heater does not contain more than about ten per cent of straight run material. The presence of as much as ten per cent of straight run material of this intermediate temperature range in the material recycled to heater **41** is not detrimental, because of its dilution with the more refractory substances. However, on account of the non-linearity of the relationship involved between refractoriness of the recycle mixture and proportion of straight run hydrocarbons of the indicated boiling range therein, the presence of more than about ten per cent of such straight run material results in rapidly rising deleterious coking in the cracking coil.

Other means not shown may be provided for withdrawing from the system any desired portion of any fuel oil, reduced crude, heavy gas oil, light gas oil or heavy naphtha for treat or use elsewhere, it being understood that the proportions of these intermediate products employed in the system for further treatment may be regulated as desired or necessary to effect control of the operation of the process of the invention. It is to be understood that the invention is not to be limited by the fact that the means for collection and withdrawal of the various intermediate products is limited to means for conveying them for further treatment in the system since the drawing has been limited to the illustration of such means in the interests of simplicity of presentation of the subject matter of the invention.

Towers or fractionators **17** and **56** and also flash chamber **52**, if it is desired, are suitably provided with trays, bubble caps and other suitable gas and liquid contact means to effect the evaporation, stripping, condensation and absorption incidental to the desired fractionation of the vapors passing therethrough. Reaction chambers **49** and **49a** are provided with suitable auxiliary feed lines and discharge lines provided with the required control valves and the like for blowing air or oxygen through them to effect oxidation and removal of any coke formed there-

in when it is desired to decoke by burning, or with other suitable removable closure means when mechanical removal of coke is desired.

The cracking of the heavy fraction (reduced crude) from the distillation of crude oil by first heating said heavy fraction to a cracking temperature but below the temperature at which any appreciable amount of coking occurs and then mixing the thus heated heavy fraction with a suitable heavy naphtha fraction which has been heated to a still higher temperature, which higher temperature is a reforming temperature for said naphtha fraction and at which temperature said heavy fraction would be subjected to coking if heated directly thereto, effects a transfer of at least a portion of the sensible heat of the heated naphtha fraction to heat the heavy fraction to a temperature intermediate of the two first-mentioned temperatures whereby the heavy fraction is converted still further to more desirable products without the formation of any substantial amount of deleterious coke.

In order to illustrate the method of practicing the invention, without in any way limiting the invention thereby, the essentials of a preferred embodiment of the invention are described with reference to the accompanying drawing. A crude oil of a gravity of about 30° A. P. I. is fractionated in a fractionator such as 17 to produce a naphtha fraction (300°–400° F., about 45° A. P. I.) and a reduced crude bottoms fraction (600° F. and up, about 20° A. P. I.) and these two separated fractions are processed in accordance with the invention as described hereinbefore and an intermediate cracked fraction of about 30° A. P. I. is formed and separated in the process and is recycled to the light oil heater 41. Fractionator 56 is operated at a top temperature of about 350° F. and a bottom temperature of about 700° F., and under a pressure of about 90 p. s. i. a. A heavy oil residue is withdrawn from the bottom of the fractionator at the bottoms temperature of about 700° F. and fed to the coil of heater 44 wherein it is heated to a temperature of about 905° F. at a pressure of about 330 p. s. i. a. At the same time an intermediate cracked fraction having a boiling range of the order of 450° to 550° F. is withdrawn from fractionator 56 and fed to the heating coil of heater 41 wherein it is heated to a temperature of about 1050° to 1100° F. at a pressure of about 330 p. s. i. a. The ratio of the heavy oil and the light oil heated in the heaters 44 and 41, respectively, is from about one to one to about two to one by volume. Upon mixing the products from the two heaters the temperature of the mixture is of the order of about 950° to 1000° F. and, after passing through the reaction chamber 49, with heat loss due to reaction, radiation, etc., the mixture is withdrawn at a temperature of about 915° F. The admixture is then flashed to a pressure of about 100 p. s. i. a. and a temperature of about 830° F. with the separation in flash chamber 52 of a heavy residue which is withdrawn from the bottom thereof at a temperature of 830° F. and of vaporous overhead withdrawn therefrom at a temperature of about 820° F. The overhead is then subjected to fractionation in fractionator 56, as described above.

I claim as my invention:

1. A thermal process of conversion of a low octane number naphtha cut to give a higher octane number product simultaneously with deep cracking of a heavy oil cut, which process comprises: heating a low octane number straight run naphtha cut having an end boiling point of about 400° F. to a cracking and reforming temperature therefor of from about 1050° to 1100° F. at a pressure of about 330 p. s. i. a. while separately and simultaneously heating a petroleum residual heavy oil cut having an initial boiling point of at least about 600° F. to a lower cracking temperature therefor of about 905° F. at a pressure of about 330 p. si .i a. for a time insufficient to cause appreciable coking thereof; combining the thus heated naphtha products and the thus heated heavy oil in the ratio of from about 1:1 to about 2:1 of heavy oil to light oil and passing the combined products without further addition of heat thereto from an external source through a reaction zone of enlarged cross-section and thereby effecting deeper cracking and conversion of the heavy oil by raising the temperature thereof by excess of sensible heat in the heated naphtha products; separating a vaporous product having a wide boiling range from the reaction zone; fractionating the separated vaporous product into a plurality of fractions comprising a high octane number gasoline naphtha fraction, a residual heavy oil fraction having an initial boiling point of at least about 600° F. and a light cracked oil fraction of intermediate boiling range of from about 450° to 550° F. and substantially free from straight run petroleum hydrocarbons boiling within the same boiling range; recycling at least a substantial portion of said light cracked oil fraction to the first-mentioned reforming zone for further treatment therein under conditions the same as those in the first above-described cracking and reforming temperature operation; and recycling at least a substantial portion of said heavy oil fraction to the first-mentioned cracking zone for further treatment therein under conditions similar to those used in the previous operation.

2. A thermal process of conversion of a low octane number naphtha cut to give a higher octane number product simultaneously with deep cracking of a heavy oil cut, which process comprises: heating a low octane number straight run naphtha cut having an end boiling point of about 400° F. to a cracking and reforming temperature therefor of from about 900° to 1100° F. at a pressure of from 100 to 1000 pounds per square inch adapted to effect cracking of the naphtha and conversion thereof with the production of a reformed naphtha having improved antiknock properties and simultaneously heating a petroleum residual heavy oil cut having an initial boiling point of at least about 600° F. to milder cracking conditions therefor of a temperature of from about 850° to 975° F. at a pressure of from about 100 to 1000 pounds per square inch, the temperature being selected to be lower than the temperature to which the naphtha cut is heated, for a time adapted to effect a maximum of cracking and conversion of the heavy oil without causing appreciable coking thereof; combining the thus heated naphtha products and the thus heated heavy oil in the ratio of from about 1:1 to about 2:1 of heavy oil to light oil and passing the combined products without further addition of heat thereto from an external source through a reaction zone of enlarged cross-section and thereby effecting deeper cracking and conversion of the heavy oil by raising the temperature thereof by excess of sensible heat in the heated naphtha products; separating a vaporous product having a wide boiling range from the reaction zone; frac-

tionating the separated vaporous product into a plurality of fractions comprising a high octane number gasoline naphtha fraction, a residual heavy oil fraction having an initial boiling point of at least about 600° F. and a light cracked oil fraction of intermediate boiling range within the range of from about 400° to 600° F. and substantially free from straight run petroleum hydrocarbons boiling within the same range; recycling at least a substantial portion of said light cracked oil fraction to the first-mentioned reforming zone for further treatment therein under conditions the same as those in the first above-described cracking and reforming temperature operation; and recycling at least a substantial portion of said heavy oil fraction to the first-mentioned cracking zone for further treatment therein under conditions similar to those used in the previous operation.

3. A thermal process of converting a heavy oil fraction of the character of a straight run reduced crude to lighter hydrocarbons of high antiknock value, which process comprises: heating a light cracked oil fraction having a boiling range within the range of from about 400° to 600° F., and being substantially free from straight run petroleum hydrocarbons boiling within the same boiling range, to a cracking and reforming temperature therefor of from about 900° to 1100° F. at a pressure of from 100 to 1000 pounds per square inch adapted to effect cracking of the cracked oil and conversion thereof with the production of a gasoline naphtha product having high octane value and simultaneously heating a petroleum residual heavy oil cut having an initial boiling point of at least about 600° F. to milder cracking conditions therefor of a temperature of from about 850° to 975° F. at a pressure of from about 100 to 1000 pounds per square inch, the temperature being selected to be lower than the temperature to which the cracked oil fraction is heated, for a time adapted to effect a maximum of cracking and conversion of the heavy oil without causing appreciable coking thereof; combining the thus heated cracked oil fraction and the thus heated heavy oil in the ratio of from about

1:1 to about 2:1 of heavy oil to cracked oil and passing the combined products without further addition of heat thereto from an external source through a reaction zone of enlarged cross-section and thereby effecting deeper cracking and conversion of the heavy oil by raising the temperature thereof by excess of sensible heat in the heated cracked oil products; separating a vaporous product having a wide boiling range from the reaction zone; fractionating said vaporous product in a fractionating zone in the presence of a mixture of a major proportion of a straight run reduced crude and of a minor proportion of a heavy crude oil and separating from said fractionating zone a plurality of fractions including a high octane number gasoline naphtha fraction, a second heavy oil fraction of similar initial boiling point as that of the first above-mentioned heavy oil fraction and a light cracked oil fraction of intermediate boiling range within the range of from about 400° to 600° F. and also containing not more than ten per cent by volume of straight run hydrocarbons; recycling at least a substantial portion of said separated light cracked oil fraction to the first-mentioned reforming zone for further treatment therein under conditions the same as those in the first above-described cracking and reforming temperature operation; and recycling at least a substantial portion of said heavy oil fraction to the first-mentioned cracking zone for further treatment therein under conditions similar to those used in the previous operation.

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