INTEGRATED FRACTIONATION, FLUID COKING AND CATALYTIC CRACKING PROCESS FOR HYDROCARBON OILS

Charles E. Jahnig, Rumson, Frank T. Barr, Summit, and James W. Brown, Elizabeth, N. J., assignors to Esso Research and Engineering Company, a corporation of Delaware

Application September 29, 1953, Serial No. 382,977

2 Claims. (Cl. 196—49)

The present invention relates to an integrated conversion process and system for hydrocarbon oils. More particularly, it relates to a system for carbon conversion with provision for substantially complete extinction or conversion to coke of the heavy ends of petroleum.

The invention includes a number of features such as the utilization of hot coker products for supplying heat to the system by the separation of catalyst contaminants from coker gas oil by passing through the fractionator before catalytic cracking, the combination of catalytic cracker bottoms plus fractionator bottoms as coker feed, and others as will be explained in greater detail hereinafter.

In the conversion of hydrocarbon oils such as petroleum crudes to commercial products, various attempts have been made in the past to obtain a maximum of products of high economic value such as gasoline, and a minimum of products of low economic value such as heavy pitches and other residua. Various processes have been devised and a number are in use, e. g. for topping the crude, vacuum distilling the topped crude, and coking the residuum. Virgin gasoline obtained in the topping operation always has substantial value, though it may be somewhat below other types of naphtha products in octane rating. The virgin gas oil obtained by taking a deeper cut is usually of substantial value also because it is a feedstock for art systems. Virgin feeds produced by catalytically cracking a virgin gas oil is usually of high quality and is much in demand.

The products boiling above virgin gas oil are usually much less valuable, although the residuum from a vacuum distilled crude can be partially converted to a gas oil by coking and the coker feed can be cracked to produce a reasonably good motor fuel. In one process, the vapor effluent from coking goes directly into a catalytic cracking zone. However, this process involves difficulties with most feedstocks due to contamination of the catalyst used for cracking. Gas oils obtained by drastic thermal treatment of residua tend to contain heavy ends and to include objectionably high proportions of ash or ash-forming constituents and contaminants such as nickel and vanadium salts, and the like. While the process previously suggested for passing the coker effluent vapors directly to a catalytic cracker is frequently efficient in conservation of heat and it is highly useful for some stocks or some operating conditions, it is not always satisfactory for other stocks or for other conditions.

A conversion system described in an application of Barr et al., Serial No. 392,646, filed August 5, 1952, upon which the present invention is an improvement, has several advantages over prior art systems, e.g. in thermal efficiency of fractionation, in simplicity of apparatus, etc. As described therein a feedstock, which may be either a whole crude or a topped or reduced crude, is fed to a fractionator along with the total effluent from a catalytic cracking zone. The heat from the latter contributes substantially to the over all economy of fractionation. These advantages are largely retained in the instant case, with the additional feature that in the present invention the total coker effluent, including all materials entrained or otherwise included therein and especially metal contaminants, is taken directly from the coker to the product fractionator. This not only supplies additional heat to the fractionator, which is often desirable, but it returns the ash-forming and other contaminating materials to the coker where they are ultimately deposited on the coke and removed entirely from the liquid coker products.

Another advantage of the present invention is the reduction of the load on the catalytic cracking zone, as compared with the dual zone (coking followed by cracking) process described above. The gas and naphtha formed in the coking zone are not passed through the cracking zone. Hence its over all capacity can be kept to a minimum. Moreover, heat balance in the cracking zone is more easily maintained.

While various general features and objects have been suggested above, these and others will become more fully apparent from a detailed description of the presently preferred form of the invention. For this purpose, reference will next be made to the attached drawing wherein the single figure illustrates in vertical elevation, and partly in section, a system for hydrocarbon conversion.

In the drawing, feed such as a topped crude may be brought through a line 10 into a vacuum tower 11 of conventional type. Alternatively, the feed may be brought into a fractionator 50, to be more fully described below, when the use of the relatively expensive vacuum tower is not economically justifiable. In either case a bottoms fraction and a more volatile fraction or fractions are obtained.

The vacuum tower outlet 12 is connected to or comprises a conventional condensing means such as a cooling coil or condenser 13 and a water separator 14. The separator is connected to a vacuum pump 15 on the vapor side and with a liquid pump 17. From pump 17 the distillate oil passes through a line 19 to the catalytic cracker feed line 21. The bottoms from vacuum tower 11 pass through line 23 to a coker feed line 25. Valve 27 may be provided in line 25.

The bottoms or residuum feed line 25, which introduces the heavy stock into a coking zone, is connected to a manifold leading to nozzles 31, 33, by means of which the bottoms residuum is injected into a fluidized bed of solids 34 in a coker vessel 35. The vessel 35 preferably has a lower section or portion 37 of reduced cross-section, which may serve as a stripping zone. A tapering or upwardly expanding section 39 above the stripping zone, an enlarged upper section 41 constituting the top of the coking zone proper, and disengaging section 43, preferably of somewhat smaller cross-section than the top part of coking zone 41. The precise configuration or design of the coking vessel forms no part of the present invention. However, the coking zone must be such that a bed of finely divided solid particles, which are good heat carriers, but are relatively inert catalytically, may be fluidized therein. Such particles, as is well known in the art, may be metal shot, beads, sand, pumice, etc., but coke particles of a size within the general range of 50 to 400 microns average particle diameter are usually preferred. The reason for this is that coke is produced in the process, is readily available, and is a reasonably good heat carrier. It is also quite inexpensive or of relatively low economic value.

Hot solid inert particles are brought into the reactor 35 through a line 45 from a heater or burner vessel 47. As is now well known in the art, these particles are preheated in vessel 47 to a temperature between about 900° and 1500° F., either by burning coke formed in the coking
vessel, or by burning extraneous fuel, or both. A fluidizing gas, such as steam may be injected into coking vessel 55 through line 48. The oil feed to the coker vessel is injected into or onto and among the preheated solid particles therein in such a manner as to secure as uniform distribution as possible. As far as practicable, each particle is coated with a thin layer or film of the feed. The heat of the particle evaporates the volatile constituents of the oil film and converts the residue to coke and to cracked vapors and gases. The coke is deposited upon the particle and each of the coated particles thus tends to grow or increase in size while in the reactor.

The vaporized and cracked products pass from the coking reactor 47 through a gas-solids separator 49 with a solids return line 51 extending into the fluidized solids bed 34. The gaseous or vaporous products, now relatively free of entrained solids, pass out through a line 53 into a line 55 leading to the fractionator 50 previously mentioned.

Spent solid particles, carrying coke deposits, are withdrawn by gravity through a stripping zone 37 at the bottom of the reactor vessel. A stripping gas such as steam is introduced through a line 59 into this stripping zone which may be provided with baffles 61 to improve distribution of the stripping gas. The spent particles pass through a coarse screening device 63 into an outer line 65 through which they are conveyed to the heater vessel 47. Solid particles sometimes agglomerate or grow to such dimensions that they cannot conveniently be fluidized and such are diverted by the coarse screening device 63 into withdrawal line 67 from which they may be removed through a closure such as the large valve 69 and 70. In the burning or heating vessel 47, the spent particles are introduced through a standpipe or conduit 71 wherein they may be fluidized and propelled by a suitable gas stream, such as steam, admitted through a line 73. A baffle or distributing device 75 above the outlet of line 71 spreads out the inflowing particles in the heater. A fluidizing gas which supports combustion, such as air or oxygen, is introduced into the burner by means of a line 77. A fuel gas is introduced through a line 79 for starting up the burner, after which the combustion-supporting gas reacts with the coke deposited on the solid particles to supply the necessary heat. However, the extraneous heating gas from line 79 may be burned preferentially where it is desired to produce maximum coke as a product of the process. Product coke is withdrawn through line 67, or it may be withdrawn from the system at any other suitable point, such as outlets (not shown) from lines 65 or 69.

The fluidizing gas in a vessel 47 form a bed 81 whose upper level 83 is controlled by suitable means, shown herein as a notched weir 85 constituting the upper end of a withdrawal line 87. The latter connects through suitable connecting line 89 to the return line 45 which carries the hot solids back to the reactor vessel 35. Suitable means are provided, as is well understood in the art, for keeping the solids fluidized or otherwise mobile in lines 65, 69, 45, etc.

Returning now to the fractionator 50, the feed thereto, through line 55, as well as the original feed through a line 90, is fractionated to produce at least a naphtha or motor fuel cut, a gas oil cut, and a bottoms fraction. The arrangement preferably is such that both the light products from the cracking operation, to be described below, and from the coking operation, pass through the flash zone and assist in vaporizing the heavy ends. Gaseous products are withdrawn overhead through a line 91, naphtha through line 53, and gas oil through line 95. The bottoms fraction, reduced to a minimum by the ample heaters in the light products from both coking and cracking is passed through line 97 to the coke feed line 25. Other fractions, not shown, may be taken from the fractionator if desired. Modifications can be made in the fractionation system, for example the naphtha product may be taken overhead as a vapor and then condensed.

The gas oil in line 95 is taken through line 21 into the inlet 102 of a catalytic cracking vessel 100. Preferably this is a fraction boiling about 430° and 1050° F. The latter is preferably of the fluidized solids type but other conventional types of cracking apparatus may be used in some cases. Cracked products are returned to this fractionator 50 through a line 101 connecting with line 55, independently if desired. The operation of such a cracking system is well known and needs no detailed description.

The feed to the catalytic cracker may be recycled to extinction if desired. The end point of this gas oil may be controlled by using a proper temperature in the feed zone of the fractionator 50. In this manner the amount of contaminants in the catalytic cracker feed can be minimized and the Conradson carbon may be controlled. The amount of recycling from catalytic cracker to fractionator and return can be adjusted to keep the desired heat balance in the catalytic cracking operation. Thus cracking severity can be reduced and recycling increased to transfer more heat to the fractionator. Conversely, by reducing recycling and increasing severity of cracking, less heat is transferred to the fractionator. Good fractionation is desirable between the gas oil and the fractionation range can be accurately controlled in this system. The amount of crude produced in catalytic cracking can also be controlled. A wash stream of clean gas oil can be used below the gas oil draw-off in the fractionator to reduce contamination by the fresh feed of the gas oil going to the catalytic cracking unit.

It will be understood that hot fresh or regeneratet catalyst may be supplied to the catalytic cracker from a suitable source or from a regenerator through line 102. The spent catalyst will be stripped in a stripping zone 103 by means of a stripping gas such as steam admitted through a line 105. The spent catalyst is then returned to the conventional regenerator, not shown, through a line 107.

It will be understood also that crude or preferably a topped crude feed may be fed either to the vacuum tower 11 or directly to the product fractionator 50 or both, as may be desirable, and that various other arrangements may be made as will be apparent to those skilled in the art. The properties of the products from the fractionator, e.g. through line 90, it should be introduced substantially above the inlet of the hot vapors from line 55. The vapors from coking and from cracking can be introduced at different heights to vary the temperature gradient in the fractionator as desired. The liquid in the bottom of the fractionator is probably quenched, by suitable conventional means not shown, to keep its temperature below about 700° F. and avoid coking in this vessel. The fractionator bottom may be steam stripped if desired. In each of the vessels 47 and 100 appropriate gas-solids separating means such as cyclones 112 are included and operated in a conventional manner to remove solids from the exit gases or vapors. The flue gases from the heater or burner vessel 47 are taken overhead through a suitable pressure control valve 114 and outlet 116 for suitable heat transfer and/or other disposition.

In some cases it is not desirable to recycle to extinction in the cracking step, as suggested above. For this purpose a partial condenser 120 is inserted in line 101. Condensation is just sufficient to remove a purge stream, which may be withdrawn through a line 122.

It is believed that the operation of this system will be sufficiently clear from the above description, the recitation of minor operating details being considered unnecessary for those skilled in the art.

What is claimed is:

1. A hydrocarbon conversion process which comprises,
in combination, the steps of: initially separating a crude feed in a fractionation zone to obtain a bottoms fraction, a gas oil fraction boiling immediately above said bottoms fraction within the limits of 430–1050° F. and lighter material which is withdrawn as product; converting said gas oil fraction by contact with a fluid bed of cracking catalyst in a catalytic cracking zone to vaporous catalytic conversion products and coke which is deposited on said cracking catalyst; converting said bottoms fraction by contact with a fluid bed of finely divided inert coke particles in a coking zone to vaporous coker conversion products and coke which is deposited on said finely divided inert coke particles; maintaining the temperature of said catalytic cracking zone by circulating said cracking catalyst through an external regeneration zone wherein coke deposits on the catalyst are removed by combustion; maintaining the temperature of said coking zone by circulating said finely divided coke particles through an external heating zone wherein the coke particles are heated by partial combustion; returning said vaporous catalytic and coker conversion products to said fractionation zone below the inlet of said crude feed to supply heat for the separation of said crude feed; separating the conversion products therein along with the crude feed whereby said bottoms fraction and gas oil fraction are ultimately converted entirely into said lighter materials which are withdrawn as product, and coke; and maintaining the heat balance of said catalytic cracking and fractionation zones through adjustment of the gas oil recycle to the cracking zone in response to changes in cracking severity.

2. The process of claim 1 wherein said bottoms fraction in said fractionation zone is quenched to maintain the temperature thereof below about 700° F., whereby coking in said fractionation zone is avoided.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Inventor</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,312,230</td>
<td>Belchetz</td>
<td>Feb. 23, 1943</td>
</tr>
<tr>
<td>2,388,055</td>
<td>Hemminger</td>
<td>Oct. 30, 1945</td>
</tr>
<tr>
<td>2,636,844</td>
<td>Kimberlin et al.</td>
<td>Apr. 28, 1953</td>
</tr>
<tr>
<td>2,644,785</td>
<td>Harding et al.</td>
<td>July 7, 1953</td>
</tr>
<tr>
<td>2,717,862</td>
<td>Murphree</td>
<td>Sept. 13, 1955</td>
</tr>
<tr>
<td>2,766,184</td>
<td>Blanding</td>
<td>Oct. 9, 1956</td>
</tr>
</tbody>
</table>

OTHER REFERENCES