July 6, 1971 R. C. MASON, JR 3,591,485

COMBINATION CATALYTIC CRACKING PROCESS

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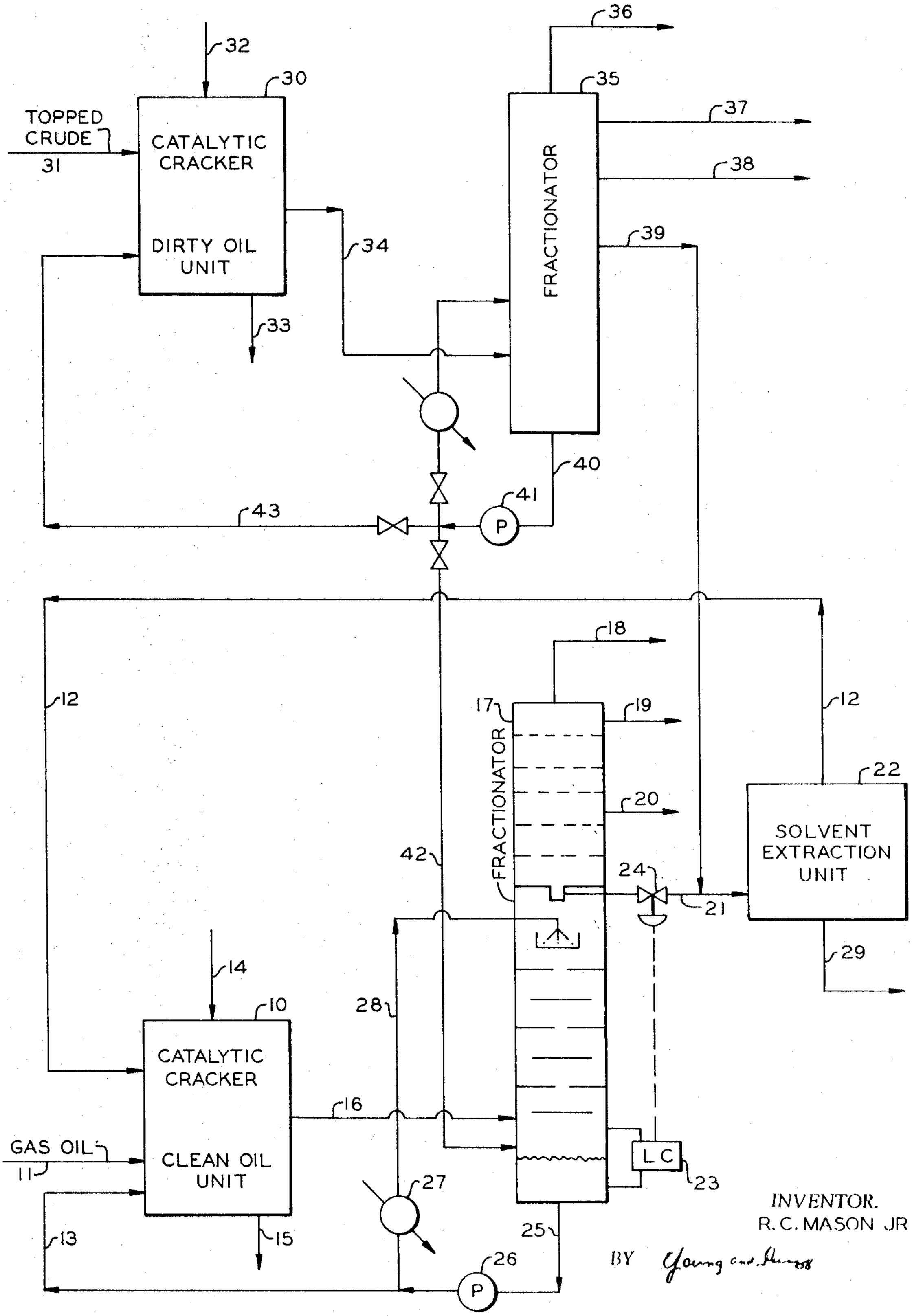

FIG. 1

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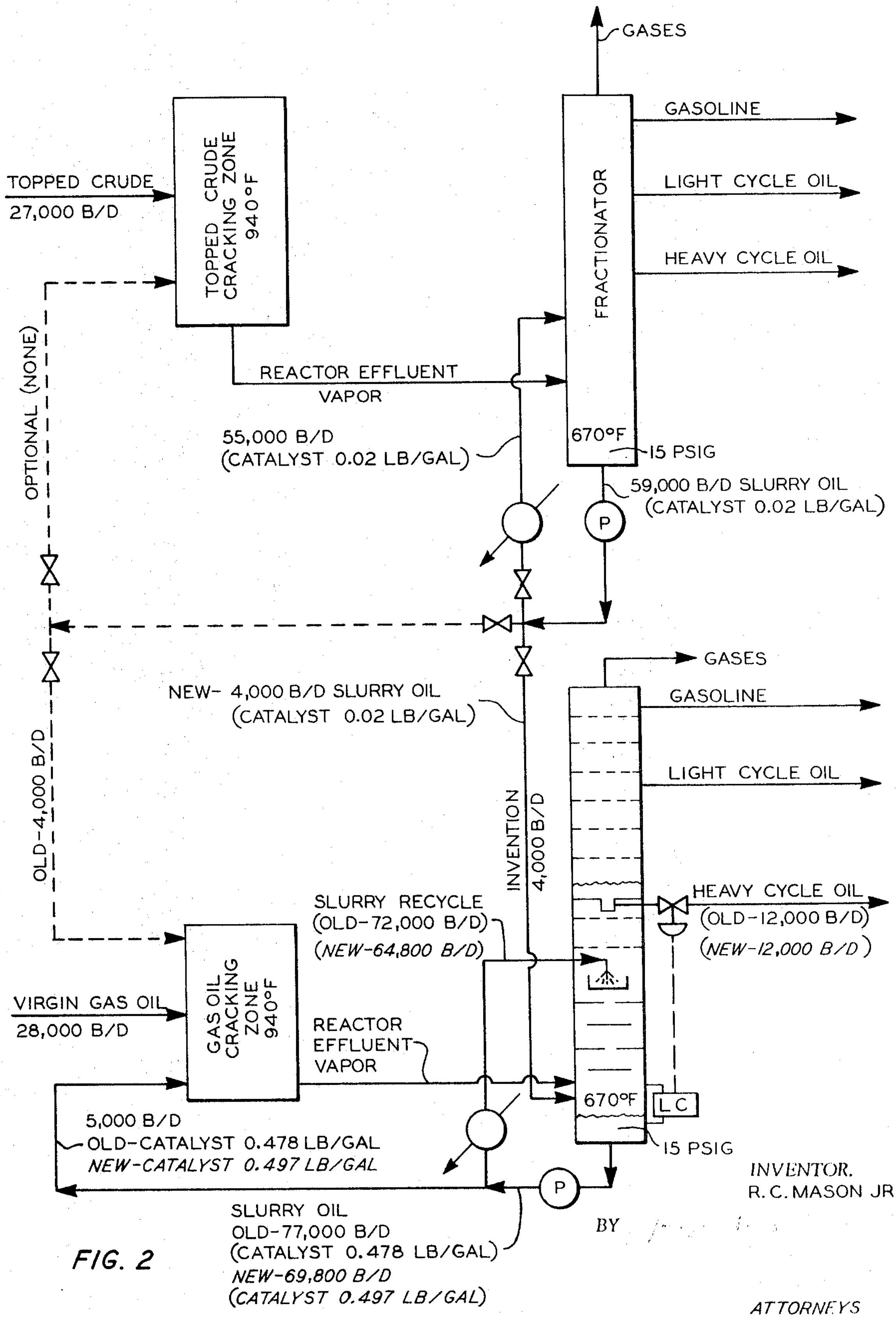

FIG. 2

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COMBINATION CATALYTIC CRACKING PROCESS

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ABSTRACT OF THE DISCLOSURE

In a system wherein a dirty oil fluid catalytic cracking system and a clean oil catalytic cracking system are operated, the slurry oil from the dirty oil unit is, at least in part, charged to the fractionator for the clean oil unit to dilute the catalyst loading of the clean oil unit's slurry, which minimizes erosion of the slurry pumps, increases heavy cycle oil production, and decreases gas and coke production.

BACKGROUND OF THE INVENTION

This invention relates to a catalytic process wherein hydrocarbons are catalytically converted to more valuable products. In one aspect, this invention relates to a modification of a catalytic cracking operation wherein at least two cracking steps are conducted at substantially the same levels of conversion and wherein the slurry oil removed from one step is passed along with the reactor effluent from the other step to the same fractionation zone. In another aspect, the invention relates to a method for increasing the yield and improving the quality of products obtained in a catalytic cracking operation, wherein the cracking steps are operated substantially at the same levels of conversion. In still another aspect, the invention relates to a method and means for decreasing coke and hydrogen production in a catalytic cracking operation wherein the feed stream is contaminated with metal compounds such as nickel, vanadium, or iron.

The conversion of oils is well known. Also, the specific conditions for converting virgin or cracked oils of various kinds are fairly well established in the art. There are known also certain combinations of operations, each of which is designed to produce certain advantages of operations, yield, or product quality or a combination of one or more of these related objects.

It is known to employ two or more cracking zones wherein feed stocks containing differing concentrations of contaminating metals are separately cracked. An improved process for operating a plurality of cracking zones in the hydrocarbon conversion process has recently been proposed wherein a relatively refractory highly paraffinic, low metal-content hydrocarbon is supplied to a first catalytic cracking zone operated at high conversion level; a less refractory, high metal-content hydrocarbon feed is supplied to a second catalytic cracking zone operated at low conversion; and the heavy cycle oil and decant oil from the two cracking zones are solvent extracted to provide a raffinate stream which is passed as a portion of the feed stock to the first catalytic cracking zone. The aromatic oil from the solvent extraction step is valuable as a carbon black process feed stock.

This new method of operation has greatly increased the catalyst life in the clean oil cracking step which is operated at high conversion levels; however, the clean oil charged to the clean oil unit did not provide the sufficient coke laydown on the catalyst to provide the required amount of heat in the regeneration step to operate the catalytic cracking unit. It was found that the heat requirements in the regeneration step of the clean oil unit could be met by passing a portion of the highest boiling fraction of the low level conversion catalytic cracking unit to the clean oil unit so as to provide a coke laydown on the clean catalyst which will be sufficient to supply the necessary heat to operate the clean oil units satisfactorily.

It has now been found that an improved operation occurs when the cracking steps are conducted at substantially the same levels of conversion when, at least, a portion of the slurry oil recovered from the dirty oil cracking zone effluent is charged along with the clean oil cracking zone effluent to the same fractionation zone. The new operation, according to the invention, produces additional heavy cycle oil instead of low value gas and coke produced in the conventional operation which additional heavy cycle oil allows production of about 10,000 pounds of additional carbon black per day.

Accordingly, the object of this invention is to provide a method for improving the quality and quantity of products obtained in a catalytic cracking operation employing a plurality of cracking steps.

It is also an object of this invtntion to provide a method of operating a cracking operation employing a plurality of cracking steps so as to decrease the amount of coke and hydrogen produced.

Still another object of this invention is to provide a method for operating a catalytic cracking process employing a plurality of cracking steps so as to increase production of heavy cycle oil with a resultant increase in the production of carbon black.

Another object of this invention is to provide a method for operating a catalytic cracking process employing a plurality of cracking steps so as to decrease the reboiler heat load on the clean oil fractionation zone.

Other objects and advantages will be apparent to one skilled in the art upon study of this disclosure including the detailed description of the invention and the appended drawings.

STATEMENT OF THE INVENTION

According to the present invention, at least a portion of the highest boiling fraction (slurry oil) of the dirty oil catalytic cracking unit recovered as the bottoms product in the fractional distillation of the catalytic cracking step effluent is passed to the clean oil fractionation zone along with the effluent from the clean oil catalytic cracking unit so as to increase production of heavy cycle oil and decrease the amount of low value gas and coke produced.

In accordance with one embodiment of the invention, a substantial portion of the total bottoms product recovered as the fractionator bottoms from the dirty oil catalytic cracking unit is charged to the clean oil catalytic cracking zone fractionator below the vapor feed thereto. When desired, all of the total bottoms product recovered as fractionator bottoms from the dirty oil unit is charged to the clean oil fractionator. In some instances, however, it is preferable to recycle at least a portion of the total bottoms product recovered as the fractionator bottoms from the dirty oil unit to the dirty oil cracking zone reactor and pass the remainder to the clean oil fractionation zone.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is a diagrammatic flow plan of one embodiment of the invention.

FIG. 2 is a diagrammatic flow plan of a specific preferred embodiment of the invention.

Referring now to FIG. 1, a hydrocarbon feed stream is fed to catalytic cracking zone **10** by way of line **11**.

The feed stream introduced by way of line **11** is made up of gas oil and other distillates so that the metal content of the feed stream is quite small. The recycle streams which can be introduced by way of lines **12** and **13** make up the total feed to the catalytic cracking zone **10**. A heater (not shown) heats the fresh feed and recycle streams to a temperature slightly under that at which thermal cracking might occur prior to admission to the cracking zone **10**. Hot regenerated catalyst is added to the catalytic cracking zone **10** by way of line **14** and used catalyst is removed by way of line **15** and passed to a regeneration zone (not shown) and is then returned to the catalytic cracking zone **10** at a temperature higher than the catalytic cracking temperature so that the mixture of heated oil and regenerated catalyst achieves the desired cracking temperature in the cracking zone.

The catalyst can be any desired type cracking catalyst and in the embodiment of the invention being described the catalyst is a silica-alumina cracking catalyst. Also, in the embodiment of the invention presently described, the catalytic cracking reactors are of the fluidized flow employing a finely divided catalyst, a regenerator also employing the fluid-solids flow technique, along with fractionating facilities and other facilities make up the system known in the art as an FCC unit.

The hydrocarbon effluent from catalytic cracking zone **10** is passed through line **16** to the product fractionator **17** wherein the effluent products are separated into fractions having diffierent boiling ranges from whence C_4 and lighter materials are removed by way of line **18**, a gasoline cut is removed by way of **19**, and light cycle oil is removed by way of line **20** to form the various products of the process. Heavy cycle oil is removed by way of line **21** and passed to a solvent-extraction plant **22**. The rate of withdrawal of heavy cycle oil in line **21** is controlled by liquid level controller **23** which measures liquid level in the bottom of fractionator **17** which liquid level controller adjusts the opening of control valve **24**. Total bottoms product including catalyst fines carried over from catalytic cracking unit **10** by way of line **16** is removed from the base of fractionator **17** by way of line **25**, passed through pump **26**, and at least a portion of the slurry oil removed as bottoms is passed by way line **13** to clean oil cracking unit **10** as recycle.

A portion of the slurry oil removed by way of line **25** is passed through cooler **27** and reintroduced into fractionator **17** by way of line **28**. There is no decant oil produced by fractionator **17**.

A conventional solvent-extraction process is employed in zone **22** utilizing liquid sulfur dioxide as the solvent to extract aromatic hydrocarbons. The aromatic compounds are absorbed from the oil so as to produce a paraffinic raffinate which can be returned to the cracking zone **10** by way of line **12**. Any suitable solvent can be utilized to extract aromatics from the oil. An aromatic-containing extract oil is removed from zone **22** by way of line **29** for use as feed for a carbon black producing system.

A second hydrocarbon feed stream comprising topped crude, pitch, and other hydrocarbon fluids containing relatively large amounts of metal contaminants or coke and gas forming components is fed to a second catalytic cracking zone **30** by way of line **31**. Heat is provided to the feed stream by means of a heater (not shown). Hot regenerated catalyst and make-up catalyst for catalytic cracking zone **30** are introduced by way of line **32**, and used catalyst is removed and passed to a regeneration zone (not shown) by way of line **33**, or discarded if desired. Reaction effluent from catalytic cracking zone **30** is passed by way of line **34** to a second product fractionator **35**. C_4 and lighter hydrocarbons are removed from zone **35** by way of line **36**, a gasoline fraction is removed by way of line **37**, and a light cycle oil is removed by way of line **38**. Heavy cycle oil is removed by way of line **39** and passed to a solvent-extraction zone **22** along with the heavy cycle oil in line **21**. As indicated above, the aromatic hydrocarbon product which comprises the extract from solvent-extraction zone **22** is recovered by line **29** for use as a feed to a carbon black producing plant (not shown) or for other desired use.

In accordance with the invention, the total bottoms product from fractionator **35** or slurry oil is removed by way of line **40**, passed through pump **41**, and all, or a substantial portion of the total bottoms oil net product can be passed by way of line **42** and introduced into a lower portion of fractionator **17**. The slurry oil passed by way of line **42** introduced into a lower portion of fractionator **17** is introduced at a point below the vapor feed removed from catalytic cracker **10** by way of line **16**. If desired, a portion of the slurry oil removed from the base of fractionator **35** can be passed by way of line **43** as recycle to catalytic cracking unit **30**.

Catalytic cracking zone **10** and **30** can be operated at different or substantially the same conversion levels and at different or substantially the same temperature. Ordinarily each of the zones will be operated at a temperature in the range 805–970° F. The conversion level in each zone can vary from about 30 to 80 percent, preferably about 50 percent for each zone.

The dirty oil will often be operated at a temperature 870–960° F. and a conversion of 30–60 percent, whereas the clean oil unit will often be operated at a temperature in the range 905–970° F. at a conversion level in the range 50–80 percent.

The amount of slurry oil passed from the dirty oil fractionator to the clean oil frationator will ordinarily be such that the amount of catalyst per gallon of oil the slurry removed from the clean oil unit does not exceed 0.5 pound of catalyst per gallon of oil. As indicated above, the total bottoms make from the dirty oil frationator, i.e., all of the slurry oil, can be passed to the clean oil fractionator. If, however, the amount of catalyst in the slurry oil removed from the clean oil fractionator unit exceeds the maximum amount (about 0.5#/gallon) desired then a portion of the total bottoms from the dirty oil fractionator can be recycled to the dirty oil cracking unit.

FIG. 2 illustrates a specific example of the operation of the invention and demonstrates the advantages obtained by operating according to the invention. There will be noted that operating conditions, i.e., temperature for the dirty oil unit and the clean oil unit, according to the invention are the same, whereas in the prior operation the dirty oil unit is generally operated at a somewhat lower temperature than the clean oil unit. The operation illustrated in FIG. 2 shows the flow of slurry oil from the dirty oil fractionator being passed to the fractionator following the clean oil unit or if desired some can be returned to the dirty oil cracking unit. In the prior method, the slurry oil recovered from the dirty oil fractionator was passed as part of a feed to the clean catalytic cracking oil unit.

Operation according to the invention produces additional heavy cycle oil instead of low value gas and coke produced in the conventional operation. In the specific example, the invention gains some $300 to $400 per day in oil product value. The additional heavy cycle oil is extracted to produce aromatic oil for carbon black manufacture. About 120 barrels per day additional heavy cycle oil will allow production of about 10,000 pounds carbon black.

Also, less slurry recycle to the clean unit fractionator is required by using the invention. This decreases the cooler heat load since less cooling is required with the less recycle. The addition of slurry oil to the clean oil fractionator cuts down the heat load and, hence, the amount of recycle slurry required.

The above advantages are illustrated in the following table wherein data obtained from prior operation are compared with data obtained from operating according to the invention.

COMPARATIVE DATA

	Old way	Invention
Topped crude cracking:		
Charge, b./d	27,000	27,000
Cracking temp.:		
° F	940	940
Range,° F	870–960	870–960
Conversion:		
Percent	50	50
Range, percent	30–60	30–60
Topped crude unit fractionator:		
Bottom temp.,° F	670	670
Bottom press., p.s.i.g	15	15
Slurry oil, b./d	4,000	4,000
Catalyst, lb./gal	0.02	0.02
Gas oil cracking:		
Charge, b./d	28,000	28,000
Slurry from dirty unit, b./d	4,000	None
Slurry from clean oil unit, b./d	5,000	5,000
Catalyst, lb./gal	0.478	0.497
Cracking temp.:		
° F	940	940
Range,° F	905–970	90 –970
Conversion:		
Percent	60	60
Range, percent	50–80	50–80
Clean oil unit fractionation:		
Slurry from dirty unit, b./d	None	4,000
Catalyst, lb./gal		0.02
Slurry reflux, b./d	72,000	64,800
Catalyst, lb./gal	0.478	0.497
Heavy cycle oil yield, b./d	12,000	12,120
Slurry to reactor, b./d	5,000	5,000
Catalyst, lb./gal	0.478	0.497

The quantity of catalyst fines contained in the slurry oil removed from the dirty oil fractionator depends, in part, upon the quantity of this slurry oil which is recycled to the dirty oil cracking unit. Preferably none of this slurry oil is recycled to the dirty oil cracking unit (and it contains, thusly, about 0.02 pound of catalyst per gallon). The slurry oil from the dirty oil fractionator is substantially metal-contaminant-free and, preferably, is all charged to the clean oil fractionator in accordance with the invention. This is done so that that amount of slurry oil (removed from the dirty oil fractionator) that is recovered in the slurry oil removed from the clean oil fractionator will be cracked in the clean oil catalytic cracking zone wherein the catalyst contains a relatively low amount of metal contaminants, resulting in less coke and gas production therefrom. The total slurry oil recovered from the clean oil fractionator is recycled to extinction in the clean oil catalytic cracking zone. It is this recycle operation, in part, which causes a build-up in the catalyst level in the slurry oil, and the slurry pumps presently used cannot properly handle oils having more than about 0.5 pound of catalyst per gallon due to erosion, etc.

The low catalyst content slurry oil from the dirty oil fractionator is cooler than the vapor charged from the clean oil cracker to the clean oil fractionator. The addition of this cooler slurry oil from the dirty oil fractionator to the clean oil fractionator allows the use of less recycle of cooled slurry oil from the clean oil fractionator back to the clean oil fractionator, and therefore there is less load on the bottoms cooler of the clean oil fractionator. However, the slurry oil from the dirty oil fractionator does add a small portion of catalyst fines to the clean oil fractionator, which fines are also removed from the bottom thereof in the slurry oil. Since the slurry oil charged from the clean oil fractionator to the clean oil cracker is the same in the prior operation as in the invention, the solids content of the slurry oil from the clean oil fractionator is slightly increased when operating in accordance with the invention. It can be seen that charging too much slurry oil from the dirty oil fractionator to the clean oil fractionator can bring the catalyst level up to an amount above the maximum allowable.

I claim:

1. An improved process for catalytically converting hydrocarbon fluids to valuable products which comprises:
   (a) passing a gas oil stream having a low metal contaminant content to a first catalytic cracking zone wherein said stream is subjected to catalytic cracking,
   (b) passing the effluent obtained in step (a) to a first fractionation zone wherein the cracked products are separated into separate distillate fractions comprising light hydrocarbons, gasoline, cycle oils, and a catalyst-containing bottoms product,
   (c) returning at least a portion of said bottoms product to said first fractionation zone and recycling the remainder to said first catalytic cracking zone,
   (d) passing a topped crude stream having a high metal contaminant content to a second catalytic cracking zone wherein said stream is subjected to catalytic cracking,
   (e) passing the effluent obtained from step (d) to a second fractionation zone wherein the cracked products are separated into separate distillate fractions comprising light hydrocarbons, gasoline, cycle oils, and a catalyst containing bottoms product, and
   (f) passing at least a portion of said bottoms product obtained in step (e) to said first fractionation zone along with effluent from said first catalytic cracking zone as feed for said first said fractionation zone, the amount of said bottoms product passed to said first fractionation zone being sufficient to increase the heavy cycle oil yield from that first fractionation zone but insufficient to increase the ratio of catalyst to oil in excess of 0.5 pound of catalyst per gallon of oil removed from the bottom of said first fractionation zone and returned to said first catalytic cracking zone.

2. A process according to claim 1 wherein the first catalytic cracking step is conducted at a temperature in the range 905–970° F. and a conversion level in the range of about 50–80 percent, and the second catalytic cracking step is conducted at a temperature in the range of 870–960° F. and a conversion level of about 30–60 percent conversion.

3. A process according to claim 1 further comprising:
   (g) passing the heavy cycle oils obtained from said first and second fractionation zones to a solvent extraction zone wherein the oils are separated into an aromatics-containing extract phase, and into a paraffin-containing raffinate phase, and
   (h) passing at least a portion of said raffinate phase to said first catalyst cracking zone.

4. A process according to claim 1 wherein all of the catalyst containing bottoms product obtained from said second fractionation zone is passed to a lower portion of said first fractionation zone and is introduced below the vapor feed comprising the effluent from said first catalytic cracking zone to said first fractionation zone, and further wherein both of said catalytic cracking steps are carried out at about the same temperature and about the same conversion level.

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U.S. Cl. X.R.

208—80