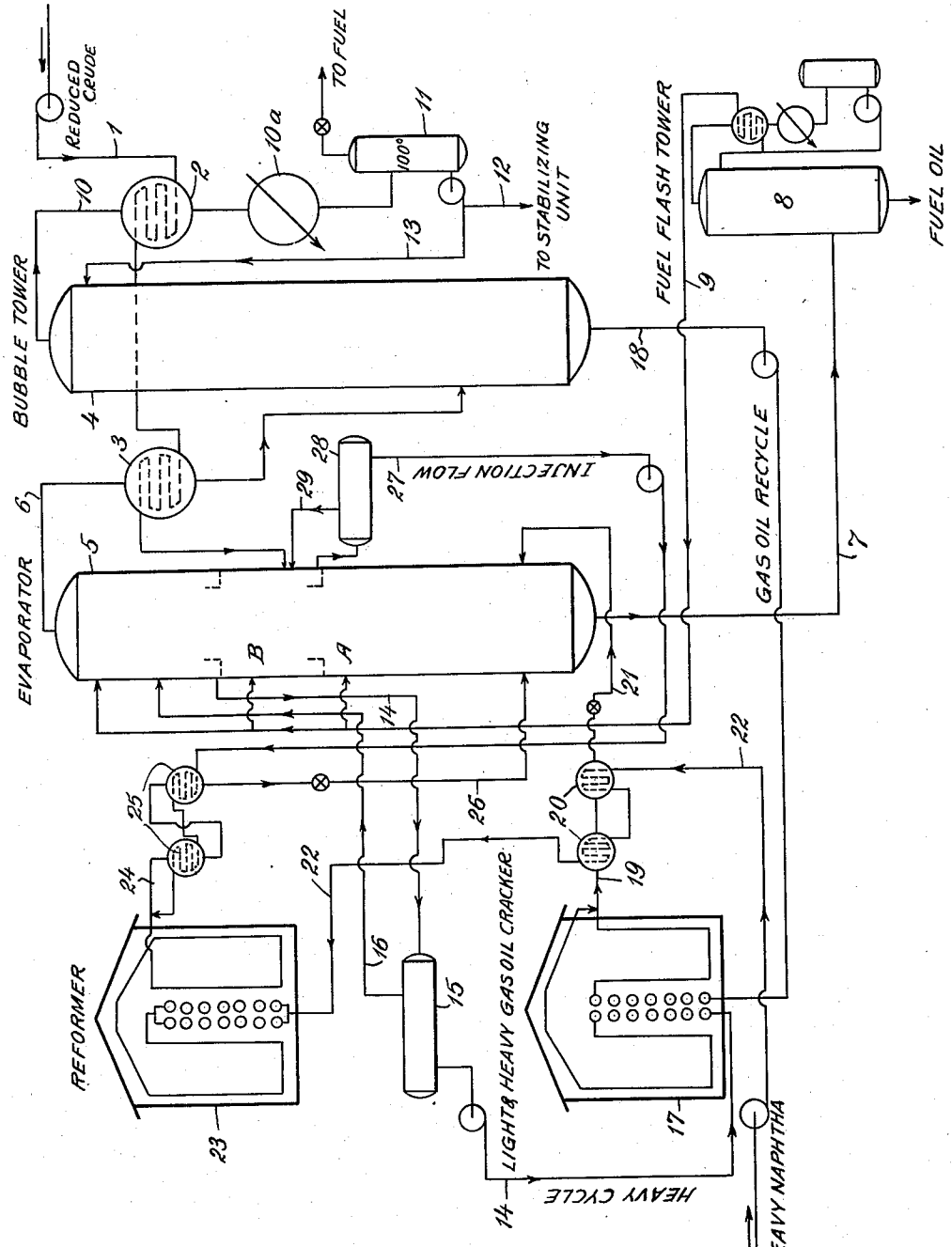
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COMBINATION CRACKING OPERATION

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COMBINATION CRACKING OPERATION

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1 Claim. (Cl. 196—58)

This invention relates to the conversion of hydrocarbon oils. More particularly the invention relates to a method for selective cracking, reforming and viscosity breaking petroleum oils.

It is an object of this invention to provide an efficient method for selective cracking, reforming and viscosity breaking of petroleum oils. Another object of this invention is to provide a method of viscosity breaking reduced crude which affords more efficient heat utilization.

In operating a conversion system in accordance with a preferred embodiment of our invention, a reduced crude heated by exchange is fed into an evaporator tower which receives all of the hot streams of the system. An overhead from the evaporator tower passes to a bubble tower. The residue from the bottom of the evaporator tower passes to a fuel flash tower. A heavy gas oil fraction withdrawn from near the top of the evaporator tower and a light gas oil withdrawn from the bottom of the bubble tower are passed through separate coils of a cracking furnace and then passed together through external transfer line heat exchangers. From the transfer line exchangers the cracked gas oils are passed into the bottom of the evaporator tower. A heavy naphtha fraction heated by exchange with the cracked gas oils in the transfer line exchangers is passed into a reforming furnace. From the reforming furnace the reformed naphtha passes through additional external transfer line heat exchangers and then is passed into the bottom of the evaporator tower.

A reduced crude fraction is withdrawn from near the middle of the evaporator tower and passed through the transfer line exchangers of the reformer furnace in indirect heat exchange with the reformed heavy naphtha passing therethrough and then injected into the reformed heavy naphtha line going into the exchangers and thereby flowed through the transfer line exchangers with the reformed heavy naphtha and then into the bottom of the evaporator tower.

For a more complete understanding of the present invention reference will be had to the accompanying drawing wherein the figure is a diagrammatic drawing of a preferred conversion system employing our invention.

In the drawing reduced crude is fed through line 1, containing exchangers 2 and 3 of the bubble tower 4 and evaporator tower 5, respectively, into the middle of evaporator tower 5. Overhead distillate from the evaporator tower is passed by line 6 through exchanger 3 into bubble tower 4. Residue from the evaporator tower 5 is passed through line 7 to fuel flash tower 8, the flash distillate from which is returned to the top of evaporator tower 5 through line 9.

Overhead distillate from bubble tower 4 passes through line 10 containing exchanger 2 and cooler 10a to a separator 11. Uncondensed gas from chamber 11 passes to fuel and liquid is sent principally through line 12 to a stabilizing unit (not shown) with a portion being returned through line 13 to the top of tower 4 as reflux.

A heavy gas oil fraction withdrawn from tower 5 through line 14, containing vapor separator 15 from which vapors are returned to tower 5 through line 16, is sent to one set of coils in the light and heavy gas oil cracker 17. Light gas oil withdrawn from the bottom of bubble tower 4 is sent through line 18 to the other set of coils in cracker 17. The cracked heavy and light gas oil withdrawn from cracker 17 are fed together through line 19 into the external transfer line exchangers 20, and from exchangers 20, the gas oils pass through line 21 to the bottom of tower 5.

Heavy naphtha is passed by line 22 through transfer line exchangers 20 wherein it is heated up by indirect heat exchange with the cracked light and heavy gas oil passing therethrough. The heavy naphtha passes from exchangers 20 to the coils of the reformer furnace 23 and is subjected reforming therein. The heavy naphtha withdrawn from reformer 23 through line 24 is fed into transfer line exchangers 25, and from exchangers 25, the heavy naphtha passes through line 26 into the bottom of tower 5.

A reduced crude fraction withdrawn from near the middle of tower 5 is passed by line 27, containing gas separator 28 from which vapors are passed back to tower 5 through line 29, to transfer line exchangers 25. The reduced crude fraction is passed through exchangers 25 and heated up to approximately viscosity breaking temperature therein by indirect heat exchange and the thus heated reduced crude fraction is then injected into the reformed heavy naphtha line 24 leaving reformer furnace 23 and fed along with the reformed heavy naphtha back through exchangers 25 and viscosity broken therein and then passed along with the reformed heavy naphtha through line 26 into the bottom of tower 5.

An important feature of the present invention is the dual function of the transfer line exchangers of the reformer furnace, i. e., the function of serving as an external unfired heating chamber for heating the reduced crude frac-

tion up to approximately viscosity-breaking temperatures and the further function of serving as an external unfired viscosity-breaking unit for the reduced crude fraction. Thus, as seen above, these exchangers heat the reduced crude fraction up to temperature by heat exchange and then viscosity breaks the heated reduced crude as it is fed back through the exchangers in admixture with reformed heavy naphtha. It is obvious, of course, that use may be made of this important feature of our invention in conversion systems other than the preferred embodiment described herein.

The construction and operation of the reformer transfer line exchangers must be such as to afford proper contacting time of the oils passing therethrough at the required temperatures for viscosity breaking of the reduced crude.

If it is required to control the volume of injected oil over wide ranges, this may be accomplished by introduction of reflux from line **9** into tower **5** at points A and B. The introduction at A will affect the gravity of the fuel eliminated and tend to produce a lighter cycle in the injection flow stock passing through line **27** to exchangers **25**. With increased reflux at B, the rate of injection flow will increase, whereas a decrease of reflux produces less injection flow material.

Since the temperatures and contact times may vary inversely over an appreciable range and may be somewhat different depending on the particular oils and fractions being treated and the amount of viscosity breaking desired, it would be difficult to specify any definite values for these conditions which would suit all operations. However, as such conditions as these are often encountered by workers in the art, it is believed little trouble will be had in adapting the present invention to any particular operation.

On the other hand, if precise determination of soaking time is desired, it may be made as shown in the following sample calculation for determining proper soaking time in exchangers **25** to give a 10% crack per pass on black oil under certain given conditions.

Sample calculation

Soaking time can be calculated from the average volume of the oil vapors in the soaking zone and the volume of the soaking zone. The volume of the soaking zone is calculated from the cold volume of oil feed in barrels per day and the soaking factor.

The soaking factor is defined as $K_T/K_{800^\circ\ F.}$ × (coil vol. in cu. ft./bbl./day). K_T/K_{800} is the ratio of the cracking reaction velocity constant at a temperature T to the value at 800° F. In general, the soaking factor is evaluated by graphical integration of a plot of K_T/K_{800} vs cu. ft./bbl./day.

Soaking volume.—Given that the oil vapors enter exchanger or soaking zone at 936° F. and leave at 850. By assuming the temperature falls logarithmically intermediate temperatures can be found and, hence, K_T/K_{800}. In the following table the first column gives the fraction of the total exchanger volume, the second column the corresponding temperatures, the third column the value of K_T/K_{800}, and in the fourth column the integration by Simpson's rule. The total feed to the soaking zone is 7000 B/D of heavy naphtha and 8000 B/D of black oil, a total of 15000 B/D.

Using V for exchanger volume and h for width of strip in Simpson's rule

Fraction of exchanger volume	Temperature	K_T/K_{800}	Integration $h=0.25\times\frac{V}{15000}$
	° F.		
0.00	936	39.0	39.0
0.25	914	22.7	90.8
0.50	893	13.3	26.6
0.75	873	7.5	30.0
1.00	850	4.2	4.2
			190.6

Then by Simpson's rule for integration the soaking factor is—

$$\frac{1}{3}\times 190.6\times 0.25\times\frac{V}{15000}=0.00106V$$

From data for Magnolia operation, it is known that the soaking factor should be numerically equal to 0.065 to give a 10% C/P on the black oil. Hence—

$$0.065=0.00106\ V$$

and

$$V=61.4 \text{ cu. ft.}$$

Oil vapor volume.—Because of the extreme conditions imposed on the oil vapor, its volume cannot be calculated from the ideal gas law without using a deviation factor. The average temperature is about 890% F. and the pressure about 600 lbs./sq. in. absolute in the soaking zone.

Black oil for injection.—Given that the A. S. T. M.—50% point is 850° F., the API gravity is 20° and the U. O. P. characterization factor is 11.5, it can be determined that the average molecular weight is 370 and that the critical temperature and pressure are 1160° F. and 175 lbs./sq. in. respectively. The deviation factor is then determined to be 0.517.

Reformed gasoline.—Given the gravity as 58.3° API and the temperature at which 10, 30, 50, 70, and 90% is evaporated in the A. S. T. M. distillation as being 157°, 223°, 275°, 323°, 375° F. respectively. These data determine the U. O. P. characterization factor as being 12.0, the molecular weight at 116.5, and the critical temperature and pressure to be 595° F. and 398 lbs./sq. in. The deviation factor is then 0.755.

Gas.—By assuming a molecular weight of 33, the critical temperature and pressure of the gas will be about 104° F. and 691 lbs./sq. in. The deviation factor is 0.993.

Mols and liquid volumes of materials.—Black oil.

At the average condition about 5% converted to gasoline, hence

8000×0.95=7600 B/D of black oil (20° API equivalent to 7.778 lbs./gal.)

The number of mols per minute is

$$\frac{7600\times 42}{24\times 60}\times 7.778\times\frac{1}{370}=4.65$$

Gasoline.

Total cold volume about 7000+400=7400 B/D (58.3° API equivalent to 6.206 lbs./gal.)

The number of mols per minute is

$$\frac{7400\times 42}{24\times 60}\times 6.206\times\frac{1}{116.5}=11.5$$

Gas.

Assume same number of mols formed as of gasoline.

Vapor volumes.—The corrected gas law is

$$V=\mu n\frac{RT}{P}$$

$$R \text{ is } 10.71\frac{\text{cu. ft.}\times\text{lbs./sq. in.}}{\text{deg. Rankine}}$$

$$V=\mu n\frac{10.71\times 1350}{600}=\mu n\times 24.12$$

Black oil	$24.12\times 4.65\times 0.517=$	58.0 cu. ft.
Gasoline	$24.12\times 11.50\times 0.755\doteq$	209.3 cu. ft.
Gas	$24.12\times 11.50\times 0.993=$	275.2 cu. ft.
Total volume		542.5 cu. ft.

$$\text{Soaking time}=\frac{61.4}{542.5}=0.113 \text{ minutes—or } 6.8 \text{ sec.}$$

It is to be understood that the proper soaking time for exchangers **20** may be similarly calculated. Likewise similar calculations will give proper soaking time in any of the transfer line exchangers for any particular operation. Normally in practice, however, workers skilled in the art could probably roughly estimate proper conditions based on their experience with similar problems and by adjustments arrive at satisfactory operating conditions, as is often done in cracking practice.

While the transfer line exchangers of the reformer furnace have been described and shown as the viscosity-breaking unit, it is to be understood that other transfer line exchangers for an oil of sufficiently high temperature might be used such as the transfer line exchangers **20** of the light and heavy gas oil cracker **17**. Likewise the transfer line exchangers of one oil line might be used to preheat the reduced crude fraction and the transfer line exchangers of another oil line used to viscosity break the fraction. Thus the reduced crude fraction in the preferred embodiment shown might be preheated in exchangers **20** of cracker **17** and viscosity broken in exchangers **25** of reformer **23**. It is to be understood further that the present invention is not restricted to the exact cracking and reforming system herein shown but, as is obvious, may be applied to such systems in general.

The temperature to which the reduced crude fraction should be preheated before being injected into the reformed naphtha should be sufficiently high that when combined with reformed heavy naphtha the mixture will have an efficient viscosity breaking temperature. This preheated temperature of the reduced crude fraction will depend therefore on the temperature of the reformed naphtha or other stock and the relative proportions of the oils being mixed. As a matter of practice it will be found that the reduced crude fraction usually should be preheated to substantially the viscosity breaking temperature before being injected into the reformed heavy naphtha. It will be noted that by the present invention wherein the reduced crude fraction is preheated and viscosity broken in an external unfired zone, the fraction is never subjected to the conditions of directly fired tubes with the attendant danger of coke deposition.

In order to further illustrate the present invention we will describe a specific operation using a mid-continent reduced crude, however, it is to be understood the invention is not to be limited by this example as there may be variations therefrom without departing from the scope of the invention.

Reduced crude from a mid-continent stock is fed at the rate of 6000 bbl./day through line **1** containing exchangers **2** and **3** into evaporator tower **5**. Tower **5** is maintained under 250 lbs./sq. in. pressure and has a temperature of 720° F. at the top and 800° F. at the bottom. Vapor from the top of tower **5** passes through line **6** containing exchanger **3** into bubble tower **4**. Bubble tower **4** is maintained under a pressure of 240 lbs./sq. in. and has a top temperature of 420° F. and a bottom temperature of 600° F. Residue from tower **5** passes through line **7** to fuel flash tower **8**, the flash distillate from which is returned to the top of tower **5** and the residue yields 2730 bbls./day of fuel oil.

Overhead vapor from bubble tower **4** passes through line **10** containing exchanger **2** and cooler **10***a* to vapor separator **11** which is maintained under a pressure of 225#/sq. in. and at a temperature of 100° F. The gaseous product removed from the top of separator **11** goes to fuel, while the residue is withdrawn at the bottom, a portion of which is returned through line **13** as a reflux to the top of bubble tower **4**, and the remainder of which is sent through line **12** to a stabilizing unit (not shown).

Light gas oil recycle withdrawn through line **18** at the bottom of bubble tower **4** is passed at the rate of 10,000 bbls./day to one set of coils in cracker **17**. Heavy gas oil withdrawn through line **14** from near the top of tower **5** passes into vapor separator **15** maintained at 715° F., the vapor from which returns to tower **5** through line **16**, and the liquid from which passes at the rate of 9000 bbls./day to the other set of coils in cracker **17**. The cracked light gas oil at a temperature of 980° F. and the cracked heavy gas oil at a temperature of 925° F. are combined in line **16** and fed together under a pressure of 750#/sq. in. into exchangers **20** and then through line **21** into the bottom of tower **5**. The cracked gas oils remain in exchangers **20** for about 42 seconds, in which it is subjected to soaking for about 21 seconds since only about one-half of the exchanger volume is above 800° F.

Heavy naptha at the rate of about 700 bbls./day is fed through line **22** containing exchanger **20**, wherein it is heated up by exchange with the cracked gas oil, to reformer furnace **23**, the reformed heavy naptha leaves the reformer furnace at a temperature of around 1000° F. through line **24** where it is mixed with a reduced crude fraction and the mixture fed into exchangers **25** at a temperature of about 936° F. The mixture remains in exchangers **25** for about 7 seconds during which time viscosity breaking of the reduced crude fraction admixed therewith occurs. The mixture leaves exchanger **25** at a temperature of about 850° F. and is passed through line **26** into the bottom of tower **5**.

The reduced crude fraction which is to be combined with the reformed heavy naphtha is withdrawn from near the middle of tower **5** through line **27** and passed into vapor separator **28** which is maintained at 750° F. Vapors from separator **28** are returned to tower **5** through line **29**. The liquid from separator **28** passes through line **27** at the rate of 800 bbls./day to exchangers **25** and passes through exchangers **25** wherein it is heated up by exchange and then injected into the reformed heavy naphtha in line **24** leaving reformer furnace **23** and fed back through exchangers **25**, in admixture with the reformed heavy naphtha, as described above.

We claim:

In a petroleum conversion process wherein a reduced crude is passed to an evaporator tower,

an overhead vapor from said tower is passed to a bubble tower, light gas oil from said bubble tower and heavy gas oil from said evaporator tower are sent through separate heated coils under selective cracking conditions therefor and the cracked oils therefrom are passed to said evaporator tower, and wherein preheated naphtha is passed through a heated reforming coil under reforming conditions to effect substantial reforming thereof, the improvement which comprises passing a reduced crude withdrawn from said evaporator tower through an external unfired soaking zone to preheat same to a predetermined temperature, introducing such preheated reduced crude into substantially reformed naphtha withdrawn from said heated reforming coil and regulating the predetermined temperature and amount of the preheated reduced crude so introduced that the resultant temperature of the mixture is at an efficient viscosity-breaking temperature for the reduced crude, passing the mixture through said unfired soaking zone under viscosity-breaking conditions, in indirect heat exchange with said reduced crude passing therethrough alone, to effect a substantial viscosity-breaking of the reduced crude which is mixed with said naphtha, and then passing the mixture from said soaking zone to said evaporator tower for separation into vaporous and liquid products.

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CERTIFICATE OF CORRECTION.

Patent No. 2,284,493. May 26, 1942.

HENRY D. NOLL, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, second column, line 30, after "subjected" insert --to--; page 2, second column, line 31, for "890%" read --890°--; page 3, second column, line 37, for "line 16" read --line 19--; line 44, for "700" read --7000--; line 66, for "800" read --8000--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 29th day of September, A. D. 1942.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal)