June 2, 1964 N. W. MITCHELL 3,135,683

DOUBLE UNIT CATALYTIC CRACKING

Filed Aug. 28, 1961 2 Sheets-Sheet 1

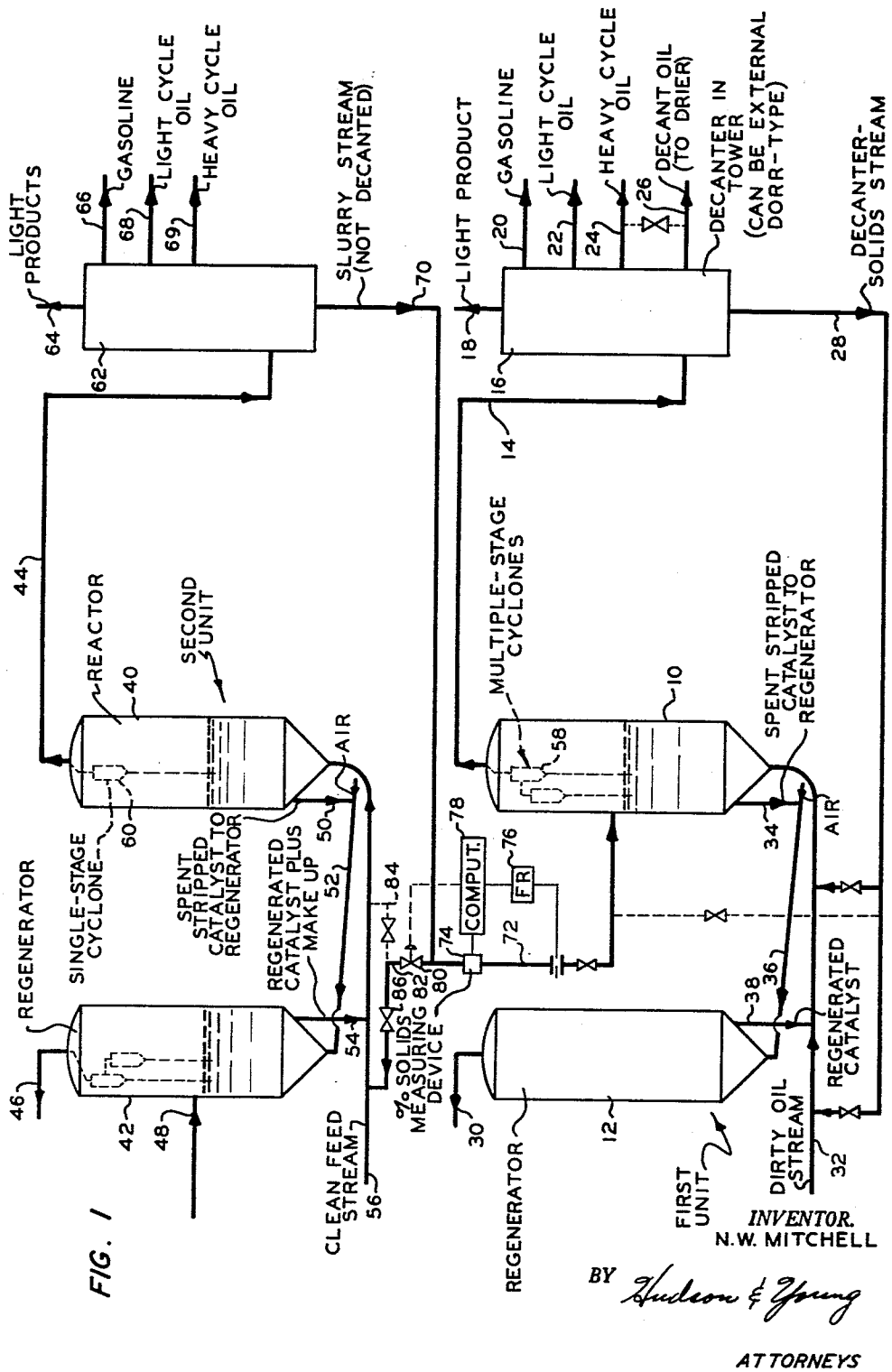

FIG. 1

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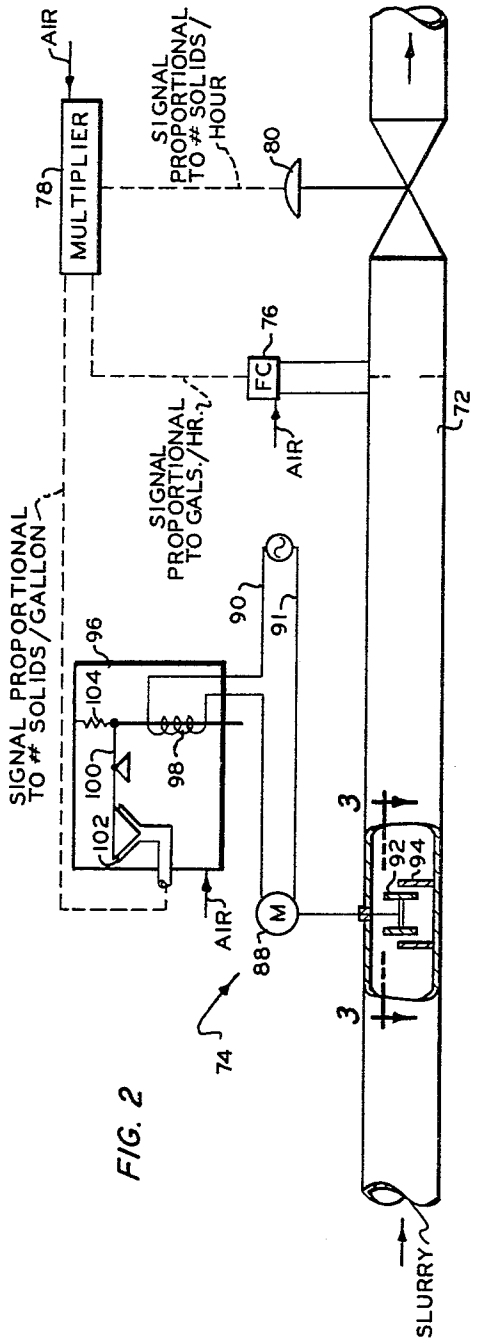

FIG. 2

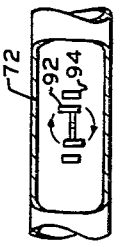

FIG. 3

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United States Patent Office 3,135,683 Patented June 2, 1964

3,135,683

DOUBLE UNIT CATALYTIC CRACKING

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Filed Aug. 28, 1961, Ser. No. 134,419
11 Claims. (Cl. 208—78)

This invention relates to an improved process and arrangement of apparatus for separately catalytically cracking two different hydrocarbon feed stocks of substantially different concentrations of metal contaminants.

It is conventional practice in petroleum refineries to fractionate crude oil to obtain a gaseous fraction, a gasoline fraction, a kerosene or distillate fraction, and a virgin gas oil fraction, leaving a bottoms fraction comprising topped crude. The virgin gas oil fraction has a smaller concentration of metal contaminants than the original crude but it does contain a minor concentration of metals such as nickel, vanadium, iron and other less troublesome metals which are usually deposited on the cracking catalyst in a subsequent cracking operation to produce gasoline. The major portion of the contaminating metals are left in the topped crude which is also subsequently subjected to catalytic cracking to produce gasoline. This invention is concerned with an improved process and arrangement of apparatus for separately catalytically cracking separate streams of a "cleaner" oil, such as gas oil, and a "dirtier" oil, such as topped crude, in separate catalytic cracking units which produces more gasoline per pound of catalyst and makes greater utility of the catalyst.

Accordingly, it is an object of the invention to provide an improved process and arrangement of apparatus for catalytically cracking two hydrocarbon feed stocks in separate reactors, one of said feeds containing an appreciable concentration of metal contaminants deleterious to cracking, the other feed containing substantially less of the contaminants. Another object is to improve the gasoline yield and decrease the coke and gas formation in cracking a relatively clean oil, such as a gas oil. A further object is to provide better use of a cracking catalyst when simultaneously cracking a topped crude and a gas oil in separate reactors to produce gasoline. An additional object is to provide a unique method and arrangement of apparatus for controlling the flow rate of catalyst solids from one unit to the other in such a two unit system. Other objects of the invention will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises passing separate hydrocarbon streams containing different amounts or concentrations of metal contaminants (designated "clean" oil and "dirty" oil) to separate reactors in contact with a suitable cracking catalyst, circulating spent catalyst from each reactor to a separate regenerator and regenerated catalyst back to its respective reactor, adding all makeup catalyst to the clean oil reactor, discarding all spent catalyst (worn out) from the dirty oil unit, supplying make up catalyst to the dirty oil reactor by passing a substantial amount of catalyst overhead in the effluent from the clean oil reactor to a fractionator where the

catalyst collects in the bottoms oil, and passing a catalyst-oil slurry from the bottom of the fractionator, preferably without decanting, to the dirty oil reactor.

Ordinarily, a small amount of catalyst passes from the multi-stage cyclones in the reactor thru the effluent product line. The amount in this line is far too small to provide the required amount of makeup catalyst for passing to the dirty oil reactor, but a greatly increased amount of catalyst in the effluent is provided by utilizing only a single-stage cyclone system in the upper section of the clean oil reactor. The rate of flow of catalyst in the slurry fed to the dirty oil reactor is controlled to provide the desired amount of makeup catalyst commensurate with the amount of catalyst discarded from the dirty oil unit. This is done by sensing the concentration of solids in the slurry and the rate of slurry flow, and regulating the rate of flow to provide the desired amount of solids flow.

A more complete understanding of the invention may be had by reference to the accompanying schematic drawing in which FIGURE 1 is a view showing a preferred arrangement of apparatus for effecting the invention; FIGURE 2 is a view showing an arrangement of controls on the slurry flow in the catalyst transfer conduit of FIGURE 1; and FIGURE 3 is a fragmentary plan view taken on the line 3—3 of FIGURE 2.

Referring to FIGURE 1, a first fluid catalytic cracking unit comprises a reactor 10 and a regenerator 12. An effluent line 14 from reactor 10 connects with a fractionator 16 from which lines 18, 20, 22, 24, and 26 lead to carry off various reactants. The bottom section of fractionator 16 is provided with a decanter (not shown); or, alternatively, a decanter of the external door-type may be connected with effluent line 28 leading from the bottom of the fractionator.

An effluent line 30 from regenerator 12 dispels flue gas containing a minor concentration of catalyst fines. Dirty hydrocarbon feed is introduced to reactor 10 thru line 32 and spent catalyst is withdrawn thru line 34 which connects with line 36 carrying regeneration fluid (air) and catalyst into regenerator 12. Regenerated catalyst is withdrawn from regenerator 12 thru line 38 which feeds into oil feed line 32.

A second catalytic cracking unit comprises a reactor 40 and a regenerator 42 which are provided with effluent lines 44 and 46, respectively. Fresh or new catalyst is introduced to regenerator 46 thru line 48. Spent catalyst is withdrawn from reactor 40 and passed thru line 50 to line 52 which feeds regeneration fluid (air) together with entrained catalyst into regenerator 42. Regenerated catalyst is passed thru line 54 into clean oil feed line 56 leading into reactor 40.

Reactor 10 of the first unit is equipped with multi-stage cyclones 58 in order to return as much particulate catalyst to the dense fluidized bed therein as possible; but reactor 40 is equipped with only a single-stage cyclone separator system 60 so that adequate particulate catalyst passes overhead with the effluent hydrocarbon product thru line 44 to fractionator 62. This fractionator is provided with effluent line 64, 66, 68, and 69 for withdrawal of separated products. Fractionator 62 does not contain a decanter in its lower section as does fractionator 16,

thereby avoiding the step of decanting the oil which collects in the bottoms product in the fractionator. The catalyst-oil slurry is passed thru lines **70** and **72** into the light catalyst phase in reactor **10**.

The flow of solids in line **72** is controlled by a control system which permits the required amount of catalyst solids to flow into reactor **10** to compensate for the amount of catalyst discarded from the system. The control system comprises a density meter **74** in line **72** and a flow recorder **76** therein. A computer or multiplier **78** receives the signals from instruments **74** and **76** and emits a signal proportional to the product of the received signals. This output signal from instrument **78** controls the amount of flow thru motor valve **80** in line **82** to maintain a constant rate of flow thru line **72**. In this way the surplus of solids flowing thru line **70** over the required amount to be passed thru line **72** is passed thru line **82** into line **56** thru either of valved lines **84** or **86**.

FIGURE 2 illustrates a specific arrangement of controls suitable for effecting the process of the invention. The conventional rate of flow controller **76** is positioned in line **72** upstream of motor valve **80** and density meter **74** is positioned in this line upstream of instrument **76**. Multiplier **78** is responsive to the air signals from instruments **74** and **76** and is in control of motor valve **80**.

Density meter **74** comprises a constant speed motor **88** supplied from a power source thru leads **90** and **91**. The shaft of motor **88** extends into conduit **72** and has positioned thereon a rotor **92** which revolved between plates **94** so that the power required to operate motor **88** is dependent upon the amount of solids flowing thru conduit **72**. Further details of the arrangement of rotor **92** between plates **94** is shown in FIGURE 3. Enclosed within air box **96** is a solenoid **98** which is connected with the lever **100** of air valve **102**. Lever **100** is under the tension of spring **104**. As the current in lead **90** varies, the pull on solenoid **98** also varies so as to control the amount of opening of valve **102** and thereby the output air signal of instrument **74**. This signal is proportional to the pounds of solids per gallon of fluid flowing in line **72**. Flow controller **76** emits a signal which is proportional to the gallons per hour of fluid flowing thru line **72**. Multiplier **78** converts the signals received from instruments **74** and **76** into a signal which is proportional to the pounds of solids per hour flowing thru line **72** and controls the opening of motor valve **80** so as to provide the set flow in pounds of solids per hour thru line **72**.

The instrument arrangement illustrated in FIGURE 2 can be utilized in the arrangement illustrated in FIGURE 1 and it can also be utilized in a system in which recycle line **82** is omitted.

The following example is presented to illustrate operating conditions and results obtained in a catalytic cracking system arranged in accordance with the system shown in the drawing. In this system a conventional rate of flow controller transmits a signal to a conventional multiplier, which signal is proportional to the volume of slurry per unit of time through that conduit; a density meter on this slurry line transmits a signal to the multiplier, which signal is proportional to the pounds of solids per unit volume of flow; the multiplier transmits a signal proportional to the product of volumes per unit of time and pounds per unit volume, which signal, of course, is proportional then to pounds per unit time.[1] This signal from the multiplier actuates control of the valve to control flow of slurry (solids containing) to the dirty oil reaction system.

[1] $\frac{\text{Volumes}}{\text{Unit time}} \times \frac{\text{Pounds solids}}{\text{Volume}} = \frac{\text{Pounds solid}}{\text{Unit time}}$, or lb./hr. of catalyst

EXAMPLE

The following data illustrate operation in accordance with the invention.

Clean oil reaction system:	
Reactor:	
Pressure, p.s.i.g.	10
Temperature, ° F.	910
Space velocity [1]	2
Catalyst/oil wt. ratio	6
Conversion, vol. percent	55
Catalyst:	
Silica-alumina—	
Particle size, microns	10–150
Metals content, p.p.m. [2]	400
Regenerated catalyst, ° F.	1,125
Dirty oil reaction system:	
Reactor:	
Pressure, p.s.i.g.	13
Temperature, ° F.	895
Space velocity [1]	15
Catalyst/oil wt. ratio	15
Conversion, vol. percent	36
Catalyst:	
Silica-alumina—	
Particle size, microns	10–150
Metals content, p.p.m. [2]	4,500
Regenerated catalyst, ° F.	1,125
Clean fresh oil charge, bbl./day	20,000
Admixture of virgin and vacuum gas oils produced from Mid-Continent crude oil by conventional steps. Relatively low in metals contaminants.	
Temperature, ° F.	720
Dirty oil charge, bbl./day	18,000
Topped crude oil produced by conventional distillation of Mid-Continent crude oil. Relatively high in metals contaminants.	
Temperature, ° F.	740
Slurry stream from clean unit fractionation to dirty oil unit as makeup catalyst therefor:	
Bbl./day	3,000
Pounds catalyst/bbl. of slurry	40
Metals content of catalyst, p.p.m. [2]	400

[1] Weight of oil per hour per weight of catalyst in the reaction zone.
[2] Measured as oxides of nickel, iron, and vanadium.

Certain modifications of the invention will become apparent to those skilled in the art and the illustrative details disclosed are not to be construed as imposing unnecessary limitations on the invention.

I claim:

1. A process for catalytically cracking a first feed stock containing catalyst-contaminating metals in a first cracking unit including a first reactor and a first regenerator and a second feed stock containing a lesser amount of contaminating metals in a second cracking unit including a second reactor and a second regenerator, there being a small catalyst loss and replacement in the two units amounting to a fraction of a percent of the amount circulated per day, which process comprises circulating catalyst from said first reactor to said first regenerator for regeneration and back to said first reactor in admixture with said first feed stock; circulating catalyst from said second reactor to said second regenerator for regeneration and back to said second reactor in admixture with said second feed stock; passing sufficient new catalyst to said second unit to replace substantially all catalyst discarded from the two units; withdrawing from said first unit substantially all metal contaminated catalyst to be discarded from the two units; passing cracked effluent from said second unit thru a catalyst recovery system therein and operating said recovery system so as to pass at least all required relatively clean make-up catalyst for said first unit to the lower section of a first

fractionator to recover hydrocarbons therefrom whereby said make-up catalyst is recovered in a catalyst-oil slurry from the bottom of said fractionator without decanting; passing said slurry to said first reactor to provide all of the make-up catalyst fed thereto; passing cracked effluent from said first reactor, containing substantially less catalyst than aforesaid effluent, to a second fractionator to recover hydrocarbons therefrom; and separately recovering cracked hydrocarbons from said fractionators.

2. The process of claim 1 wherein the amount of catalyst in said slurry is in excess of the required amount of make-up catalyst and slurry containing said excess is passed to said second reactor.

3. The process of claim 1 wherein a continuous stream of said slurry is passed from said first fractionator, a portion passing to said second reactor and a portion passing to said first reactor; and including the step of regulating the flow to said first reactor so as to provide the required amount of make-up catalyst.

4. The process of claim 1 wherein contacting in said reactors is effected with fluidized solid catalyst particles and the slurry passed to said first reactor is sprayed into the dilute phase therein to effect cooling and to knock out catalyst particles from the vapors produced in the cracking step therein.

5. The process of claim 1 wherein said first feed is a member of the group consisting of topped crude and residuum oil and said second feed is a member of the group consisting of raffinate and a gas oil.

6. The process of claim 1 wherein said first feed is a topped crude and said second feed is a gas oil.

7. Hydrocarbon cracking apparatus for cracking two different hydrocarbon feeds comprising a first cracking unit for cracking a first feed containing catalyst-contaminating metals including a first fluidized bed reactor having means for introducing said first hydrocarbon feed and particulate catalyst thereto, multi-stage cyclone separators therein, a gaseous effluent line leading from the last stage of said separators, a catalyst withdrawal line for spent catalyst, and a first fractionator connected with said effluent line; a second cracking unit for cracking a second feed containing a lesser amount of catalyst-contaminating metals than said first feed including a second fluidized bed reactor having means for introducing said second hydrocarbon feed and particulate catalyst thereto, a single-stage cyclone separator system therein having a gaseous effluent line leading therefrom, said separator system being operable to pass at least the amount of catalyst required as make-up catalyst in said first unit, a catalyst withdrawal line, and a second fractionator free of decant means having its lower section connected with last said effluent line; conduit means connecting the bottom of said second fractionator directly with an inlet in said first reactor for transferring catalyst-oil slurry thereto; and means connected with said conduit means for regulating the flow rate of solids in said slurry.

8. The apparatus of claim 7 wherein said means for regulating flow rate of solids in said slurry comprises a motor valve in said conduit means and means for sensing the flow rate of solids in the slurry in said conduit means and regulating said motor valve to provide a desired flow rate of solids.

9. The apparatus of claim 7 wherein said means for regulating flow rate of solids in said slurry comprises a motor valve in said conduit means; means for measuring weight of solids per unit volume of slurry flowing in said conduit means per unit of time and emitting a signal proportional to said weight; a flow controller in said conduit means which emits a signal proportional to flow rate of slurry therein; and means responsive to aforesaid signals which receives same and emits a signal proportional to the product of aforesaid signals to said motor valve to regulate the flow rate of slurry to provide said desired flow rate of solids.

10. The apparatus of claim 7 wherein said means for regulating flow rate of solids in said slurry comprises a motor valve in said conduit means; a constant speed electric motor having a rotor across the path of flow in said conduit means which offers resistance to turning proportional to solids content of said slurry; an electrical power supply connected with said motor; means for sensing the rate of current to said motor emitting an air signal proportional to said rate; means for sensing flow rate of slurry in said conduit means and emitting an air signal in proportion to said rate; means responsive to both air signals and emitting a composite air signal proportional to rate of flow of solids in weight per unit of time, said motor valve being operated by said composite air signal.

11. The apparatus of claim 7 including a recycle line leading from said conduit means to said second reactor, and wherein said means for regulating rate of solids flow comprises a motor valve in said recycle line; a solids meter in said conduit means downstream of said recycle line; a flow rate controller in said conduit means downstream of said meter; a multiplier sensitive to signals of said meter and said controller in operative control of said motor valve.

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