

[54] MEANS AND METHOD FOR
AUTOMATICALLY CONTROLLING
THE HYDROGEN TO HYDROCARBON
MOLE RATIO DURING THE
CONVERSION OF A HYDROCARBON

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abandoned.

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208/DIG. 1

[51] Int. Cl. C10g 35/04, G06g 7/58

[58] Field of Search.....235/151.12, 151.1,
235/150, 150.1, 151.3, 151.34, 151.35;
208/134, 138, 139, DIG. 1; 196/132; 23/230
R, 232 R, 252 R, 254 E, 255 E

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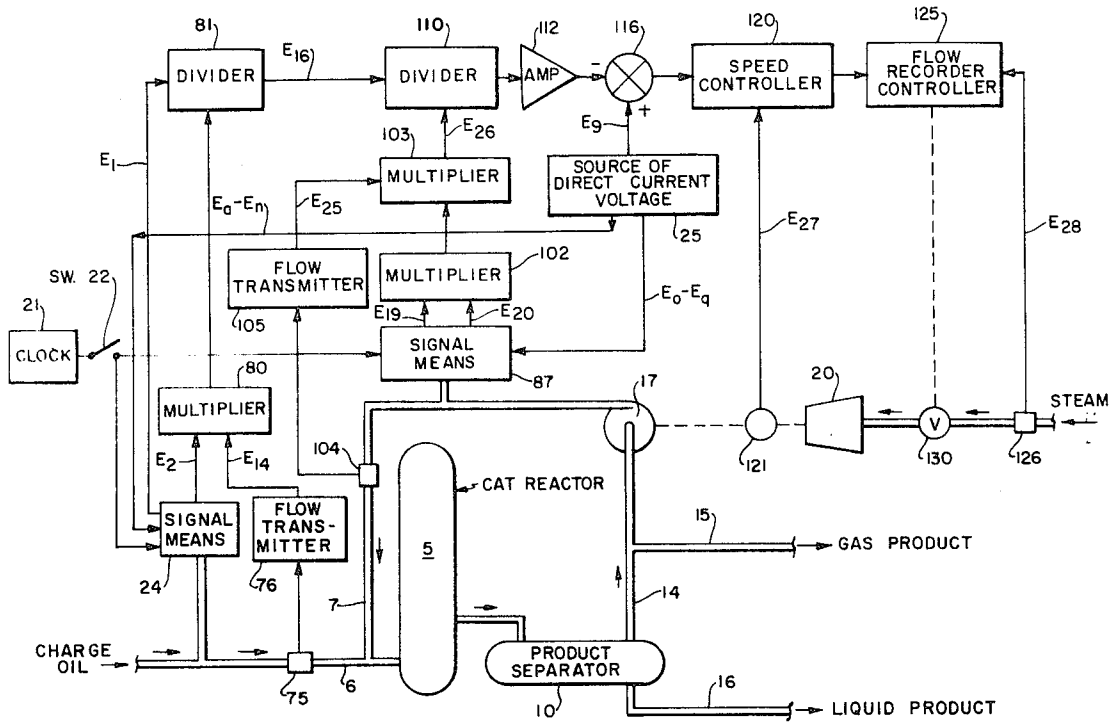
[57] ABSTRACT

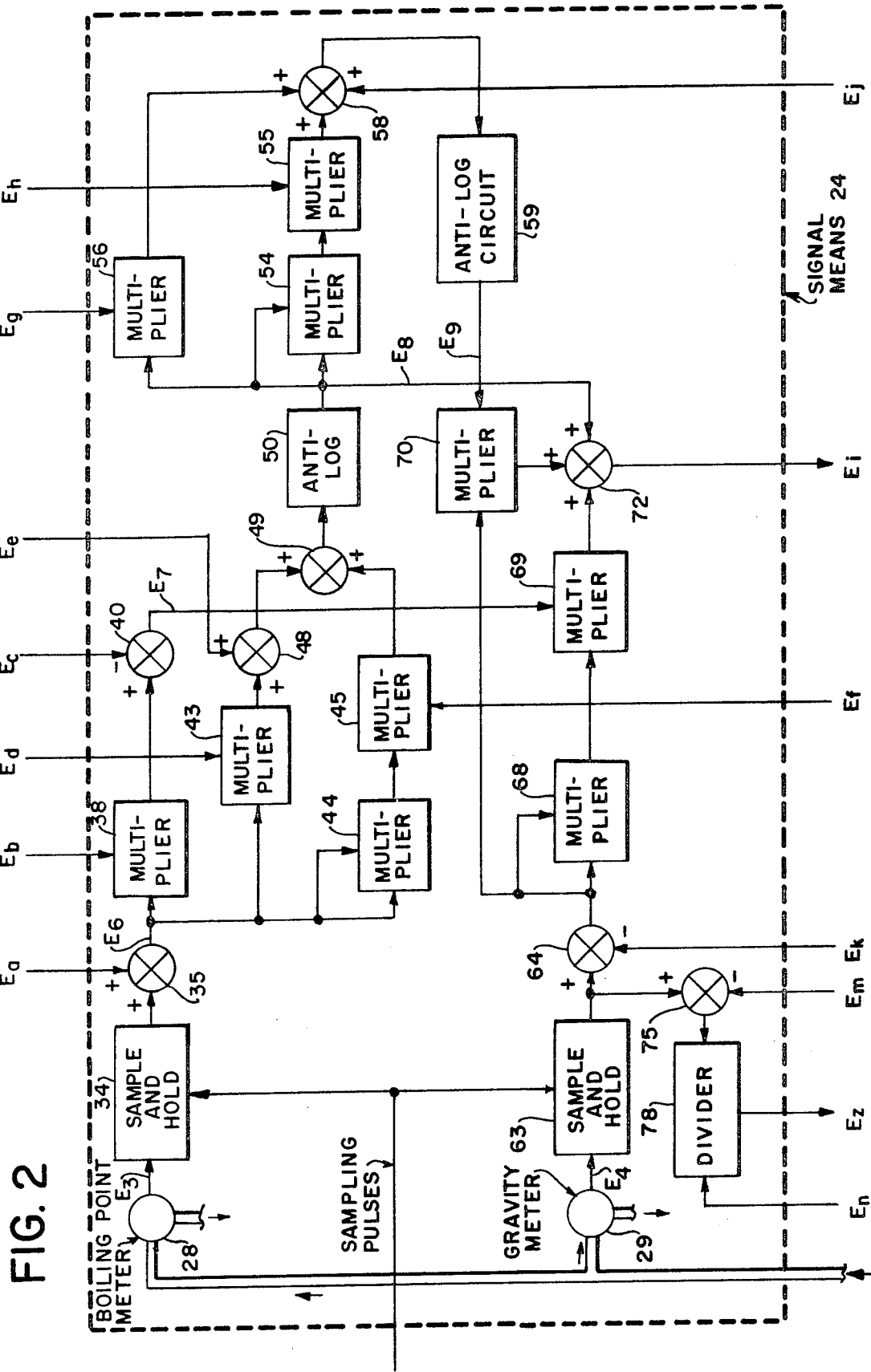
In a hydrocarbon converting unit in a petroleum refinery, the hydrogen to hydrocarbon mole ratio is controlled in accordance with the following equation:

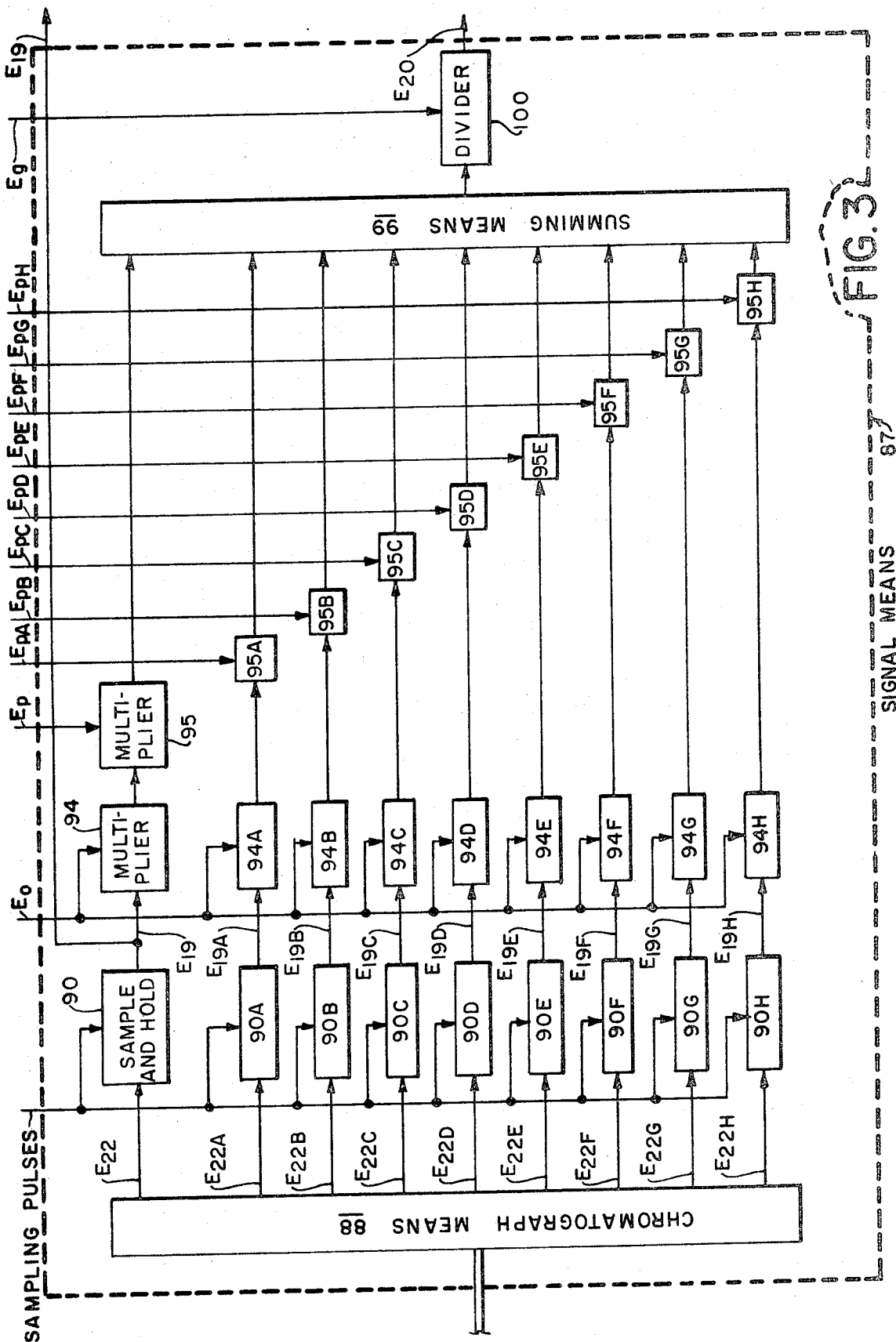
$$H_2/HC = \frac{V_H G_g F_g}{13261.21 \times \frac{G_c F_c}{M_c}}$$

where V_H is the volume percent hydrogen in recycle gas, G_g is the specific gravity of the recycle gas, F_g is the flow rate of the recycle gas, G_c is the specific gravity of charge oil, F_c is the charge oil flow rate, M_c is the average molecular weight of the charge oil and the term 13261.21 is a conversion factor. Signal means sample the charge oil and the recycle gas and provide signals corresponding to the specific gravity of the charge oil G_c and of the recycle gas G_g , the average molecular weight M_c of the charge oil and the quantity of hydrogen V_H in the recycle gas. Flow transmitters sense the flow rates F_c and F_g of the charge oil and the recycle gas, respectively, and provide corresponding signals. An analog computer computes the hydrogen to hydrocarbon mole ratio in accordance with the aforementioned equation and the signals from the signal means and the flow transmitters and provides an output corresponding thereto. An error signal is developed using an output from the analog computer and a reference signal corresponding to a desired value for the hydrogen to hydrocarbon mole ratio. The error signal is used to control the hydrogen entering the hydrocarbon converting unit so as to maintain the hydrogen to hydrocarbon mole ratio at the desired value.

8 Claims, 3 Drawing Figures







MEANS AND METHOD FOR AUTOMATICALLY CONTROLLING THE HYDROGEN TO HYDROCARBON MOLE RATIO DURING THE CONVERSION OF A HYDROCARBON

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation as to all subject matter common to U.S. application Ser. No. 97,571 filed Dec. 14, 1970, and now abandoned, by Walker L. Hopkins, William D. White and Luther F. Champion and assigned to Texaco Inc., assignee of the present invention, and a continuation-in-part for all additional subject matter.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to controlling hydrocarbon converting units and, more particularly, to controlling the hydrogen to hydrocarbon mole ratio during the hydrocarbon conversion.

2. Description of the Prior Art

Previously, control of the hydrogen to hydrocarbon mole ratio of a catalytic reforming operation in an oil refinery was done manually. An article appearing in the "Oil and Gas Journal," Volume 58, No. 13 on Mar. 28, 1960 and entitled *Computer Control of Catalytic Reforming Processes* by Mr. Reuben Silver, stated that catalytic reforming could be controlled by a computer and mentions that the hydrogen to hydrocarbon mole ratio was a variable in the catalytic reforming operation. However, the subject article did not disclose the apparatus for automatically controlling the hydrogen to hydrocarbon mole ratio. Furthermore, it is not obvious to one skilled in the art in reading the article how the hydrogen to hydrocarbon mole ratio may be automatically controlled.

The device of the present invention monitors some of the operating parameters of a hydrocarbon converting operation, such as catalytic reforming, and regulates the recycle gas flow in accordance with the monitored parameters to provide automatic control of the hydrogen to hydrocarbon mole ratio.

SUMMARY OF THE INVENTION

A system for controlling the hydrogen to hydrocarbon mole ratio of a mixture in a hydrocarbon converting unit in which the hydrogen and the hydrocarbon entering the hydrocarbon converting unit are sensed and corresponding signals are provided. A signal corresponding to the hydrogen to hydrocarbon ratio is developed in accordance with the hydrogen and the hydrocarbon signals. A circuit provides an error signal corresponding to the difference between the ratio signal and a reference signal corresponding to a predetermined hydrogen to hydrocarbon mole ratio. The error signal is used to control one of the entrants to the hydrocarbon converting unit.

One object of the present invention is to automatically control the hydrogen to hydrocarbon mole ratio during the conversion of hydrocarbon.

Another object of the present invention is to control the hydrogen to hydrocarbon mole ratio during the conversion of the hydrocarbon in accordance with the equation

$$H_2/HC = \frac{V_H G_R F_R}{13261.21 \times \frac{G_C F_C}{M_C}}$$

Another object of the present invention is to automatically control the hydrogen to hydrocarbon mole ratio in an operating hydrocarbon converting unit in accordance with sensed quantities of charge oil and gas entering the hydrocarbon converting unit so that said control is substantially instantaneous.

Another object of the present invention is to improve the economy of the hydrocarbon converting operation by maintaining the hydrogen to hydrocarbon mole ratio at a predetermined optimum value.

The foregoing and other objects and advantages of the invention will appear more fully hereinafter from a consideration of the detailed description which follows, taken together with the accompanying drawings wherein one embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawings are for illustration purposes only and are not to be construed as defining the limits of the invention.

DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a block diagram of a system, constructed in accordance with the present invention, for controlling the hydrogen to hydrocarbon mole ratio during the catalytic reforming operation in a refinery.

FIGS. 2 and 3 are detailed block diagrams of the two signal means shown in FIG. 1.

DESCRIPTION OF THE INVENTION

During catalytic reforming processing of oil, gas containing hydrogen is recycled from a product separator to the catalytic reforming reactor. The gas is used to reduce the rate of coke formation on the catalyst in the catalytic reforming reactor to retard the reduction in effectiveness of the catalyst due to the coke formation. The recycling of the gas requires the use of steam power which represents an economic cost, the rate of flow of the oil in the process represents another economic cost, and the effectiveness of the catalyst represents yet another economic cost.

It is not practical for the recycle gas to have a constant rate since the charge oil's molecular weight, composition and flow rate as well as the composition of the gas may vary. An important facet of the process is to control the hydrogen to hydrocarbon mole ratio as a function of the aforementioned economic costs. The hydrogen to hydrocarbon mole ratio controls the build-up of coke on the catalyst.

Referring to FIG. 1, charge oil enters a catalytic reactor 5 by way of a line 6 while recycle gas enters line 6 by way of a line 7. The reformate from reactor 5 enters a product separator 10 where it is separated into gas, part of which is discharged through a line 15, and into a liquid which is discharged through a line 16. A portion of the gas in line 14 is fed back to reactor 5 as recycle gas by a compressor 17 driven by a steam motivated turbine 20. The hydrogen to hydrocarbon mole ratio is controlled by controlling the steam being applied to turbine 20 thereby controlling the amount of hydrogen entering reactor 5, as hereinafter explained.

When activated to the 'on' position, an on-off switch 22 passes sampling pulse from a clock 21 to signal means 24, 87 for controlling signal means 24, 87 to provide for the operation of the device of the present

invention, as hereinafter explained. Switch 22 blocks the sampling pulses from clock 21 when in the 'off' position.

Signal means 24 samples the charge oil in line 6 and provides signal E_1 , E_2 corresponding to the average molecular weight M_c and the specific gravity G_c , respectively, of the sample charge oil in accordance with direct current voltages E_a through E_n , from a source 25 of direct current voltages, and the following equations:

$$M_c = X + Y (API-30) + Z(API-30)^2 \quad (2)$$

where

$$X = 10^{(1.60783 + .0016007(50\%) - .45(10^{-6} \times 50\%)^2)} \quad (3)$$

$$Y = 10^{(-.4244 + .00152X + .45(10^{-5})X^2)} \quad (4)$$

$$Z = -.0133 + .516(10^{-4})(50\%) \quad (5)$$

$$G_c = (141.5/API + 131.5) \quad (6)$$

where 50 percent is the ASTM 50 percent boiling point in °F, and API is the API gravity at 60°F.

Signal means 24, shown in detail in FIG. 2, includes analyzers 28, 29 which provide signals E_3 and E_4 corresponding to the boiling point and the API gravity of the charge oil. The effluent from analyzers 28, 29 may be returned to line 6 or disposed of as slop.

Analyzer 28 may be a boiling point analyzer of the type manufactured by the Technical Oil Tool Corporation as their model 6500. Analyzer 29 is a Dynatol density analyzer. A suitable analyzer for the density analysis is the series 300G manufactured by the Automation Products, Inc. and which is temperature compensated so that signal E_4 corresponds to the API gravity at 60°F.

Signal E_3 from analyzer 28 is applied to a conventional type sample and hold circuit 34 which is controlled by the sampling pulses passed by switch 22. The output from sample and hold circuit 34 is summed with direct current calibration voltage E_a by summing means 35 to provide a signal E_6 corresponding to the 50 percent boiling point.

A signal E_7 corresponding to Z in the equation 5 is developed by a multiplier 38 and subtracting means 40. Multiplier 38 multiplies signal E_6 with direct current voltage E_b corresponding to the term $0.516(10^{-4})$ in equation 5 to provide a product signal to summing means 40. Subtracting means 40 subtracts direct voltage E_c corresponding to the term .0133 in equation 5 from the product signal to provide signal E_7 .

A signal E_8 corresponding to X in equation 3 is developed by multipliers 43, 44 and 45, summing means 48, 49 and an antilog circuit 50. Multiplier 43 multiplies the 50 percent boiling point signal E_6 with direct current voltage E_d , corresponding to the coefficient .0016007 in equation 3, to provide a product signal to summing means 48 where it is summed with direct current voltage E_e corresponding to the term 1.60783 in equation 3. Multiplier 44 in effect squares signal E_6 and provides a corresponding signal to multiplier 45. Multiplier 45 multiplies the signal from multiplier 44 with direct negative current voltage E_f , corresponding to the term $-.45(10^{-6})$ in equation 3, to provide a signal. Summing means 49 sums the signal from multiplier 45 with the signal from summing means 48. Antilog circuit 50 provides signal E_8 in accordance with the sum signal from summing means 49. Antilog circuits 50, 59 are operational amplifiers, each having a function genera-

tor type feedback element, which may be of the PC-12 type manufactured by Electronics Associates.

A signal E_9 corresponding to Y in equation 4 is developed by multipliers 54, 55 and 56, summing means 58, and antilog circuit 59. Signal E_8 from antilog circuit 50 is multiplied with direct current voltage E_g , corresponding to the coefficient .00152 in equation 4, by multiplier 56 to provide a corresponding signal. Signal E_8 is effectively squared by multiplier 54 and the resulting signal is multiplied with direct current voltage E_h , corresponding to the coefficient $.45 \times 10^{-5}$ in equation 4, by multiplier 55 to provide a corresponding signal. Antilog circuit 59 provides signal E_9 in accordance with a sum signal from summing means 58 relating to the summation of the signals from multipliers 55, 56 and negative direct current voltage E_j corresponding to the term $-.4244$ in equation 4.

A conventional type circuit 63 samples and holds signal E_4 from analyzer 29. The output from hold circuit 63 has direct current voltage E_k , corresponding to term 30 in equation 2, subtracted from it by subtracting means 64. The output from subtracting means 64 is squared by a multiplier 68 and the resulting signal is multiplied with signal E_7 from subtracting means 40 by a multiplier 69. The output from subtracting means 64 is also multiplied with signal E_9 from antilog circuit 59 by a multiplier 70. Outputs from multipliers 69, 70 and signal E_8 from antilog circuit 50 are summed by summing means 72 to provide signal E_1 .

Signal E_2 is developed by converting signal E_4 corresponding to the API gravity at 60° to specific gravity G_c in accordance with equation 6.

Signal E_4 has direct current voltage E_m , corresponding to the term 131.5 in equation 6, added to it by summing means 75. A divider 78 divides direct current voltage E_n , corresponding to the term 141.5 in equation 6, by the output from adding means 75 to provide signal E_2 .

Referring again to FIG. 1, conventional types sensing means 75 and flow transmitter 76 cooperate to provide a signal E_{14} corresponding to the flow rate of the charge oil in line 6. Signals E_2 , E_{14} are multiplied by a multiplier 80 to provide a product signal to a divider 81. Divider 81 divides the product signal from multiplier 80 with signal E_1 from signal means 24 to provide a signal E_{16} corresponding to the term $F_c G_c / M_c$ in equation 1.

Signal means 87 provides signals E_{19} , E_{20} corresponding to the percent volume of hydrogen V_h in the recycle gas and to the specific gravity G_g of the recycle gas, respectively. Signal means 87 is shown in detail in FIG. 3. Chromatographic means 88 which includes a chromatograph that may be of the type manufactured by Beckman Instruments with a Beckman model 620 programmer and a Beckman model D analyzer, providing signals E_{22} through E_{22H} corresponding to the hydrogen, methane, ethane, propane, normal butane, isobutane, normal pentane, isopentane, and the hexanes and heavier constituents, respectively, of the recycle gas. Sample and hold circuits 90 through 90H periodically sample and hold signals E_{22} through E_{22H} in response to the sampling pulses from switch 22 to provide signals E_{19} through E_{19H} , respectively. The specific gravity of the recycle gas is determined in accordance with the following equation:

$$G_g = \sum_{i=1}^{i=29} \left(\frac{\text{Vol. \% of constituent } i}{100} \times \frac{\text{molecular weight of constituent } i}{29} \right)$$

Signals E_{19} through E_{19H} are applied to multipliers 94 through 94H, respectively, where they are multiplied with a direct current voltage E_o corresponding to 0.01 to provide product signals. The product signals from multipliers 94 through 94H are multiplied with direct current voltages E_p through E_{pH} , respectively, by multipliers 95 through 95H. The product signals from multipliers 95 through 95H correspond to the molecular weights of hydrogen, methane, ethane, propane, normal butane, isobutane, normal pentane, isopentane and the hexanes constituents, respectively, and are summed by summing means 99 to provide a sum signal. The sum signal from summing means 99 is divided by direct current voltage E_q , corresponding to the term 29 in equation 6, by a divider 100 to provide specific gravity signal E_{20} .

Referring to FIG. 1, signals E_{19} , E_{20} are multiplied with each other by a multiplier 102 to provide a product signal, corresponding to the product $V_H G_p$ to a multiplier 103. A conventional type sensing element 104 and a flow transmitter 105, which may also be of a conventional type, senses the flow rate F_p of the recycle gas and provides a corresponding signal E_{25} to multiplier 103 where signal E_{25} is multiplied with the signal from multiplier 102 to provide a signal E_{26} corresponding to product $V_H G_p F_p$ of equation 1. Signal E_{26} is divided by signal E_{16} from divider 81 by a divider 110 to provide an output to an amplifier 112 having a gain corresponding to $1/13261.21$. Although an amplifier is used, a multiplier for multiplying the output from divider 110 with a direct current voltage corresponding to $1/13261.21$ may also be used. The output from amplifier 112 corresponds to the actual hydrogen to hydrocarbon mole ratio.

Source 25 provides a variable amplitude direct current reference voltage E_p which corresponds to a desired hydrogen to hydrocarbon mole ratio such as the current economical optimum hydrogen to hydrocarbon mole ratio. Ratio controller 116 provides an output signal to a conventional type speed controller 120, in accordance with output from amplifier 112 and voltage E_p , to change its set point accordingly. Speed controller 120 also receives a signal E_{27} from a tachometer 121 corresponding to the rotational speed of turbine 20. Speed controller 120 acts as a safety device to prevent turbine 20 from exceeding its speed limitation. When the speed of turbine 20 differs from the set point speed of speed controller 120, speed controller 120 provides a signal to flow recorder controller 125 receiving a signal E_{28} , which corresponds to the flow rate of the steam to turbine 20, from a sensing element 126. The signal from speed controller 120 adjusts the set point of flow recorder controller 125. Flow recorder controller 125 provides a pneumatic control signal to a valve 130 corresponding to the difference between the signal from sensing element 126 and the set point to control the flow of the steam thereby controlling the flow rate of the recycle gas.

The device of the present invention was heretofore described in terms of analog computing elements. It would be obvious to one skilled in the art to use a digital computer to control the hydrogen to hydrocarbon mole ratio. Analog signals E_3 , E_4 , E_{14} , E_{19} , E_{20} and E_{25} are converted to digital signals by conventional type analog-to-digital converters. The digital computer is programmed to solve the aforementioned equations, using the digital signals, to provide a digital output cor-

responding to the difference between the actual hydrogen to hydrocarbon mole ratio and the target hydrogen to hydrocarbon mole ratio. The digital output is converted to an analog signal by a conventional type digital-to-analog converter, which is applied to speed controller 120.

Although a hydrogen to hydrocarbon mole ratio control system for a catalytic reforming unit has been disclosed, the control system may also be used for the hydrogenation of middle distillates (kerosine and light gas oils). If the charge oil is lube oil, which requires processing by a hyfinishing unit, signal means 24 would have to be modified to provide a signal corresponding to the molecular weight of the lube oil. However, the overall control concept would not change.

The device of the present invention as heretofore described automatically maintains the hydrogen to hydrocarbon mole ratio during a hydrocarbon converting operation in accordance with the equation disclosed in the abstract and a desired hydrogen to hydrocarbon mole ratio. The device of the present invention economically controls the hydrogen to hydrocarbon mole ratio in an operating catalytic reforming unit in accordance with a predetermined optimum value using sensed conditions of charge oil and gas entering the catalytic reforming unit so that said control is substantially instantaneous.

What is claimed is:

1. A system for controlling the hydrogen to hydrocarbon mole ratio during the operation of a hydrocarbon converting unit, comprising means for sensing the flow rate F_c of the hydrocarbon and providing a corresponding signal, a pair of meters receiving some of the hydrocarbon, one meter providing a signal corresponding to the boiling point of the hydrocarbon, the other meter providing a signal corresponding to the API gravity of the hydrocarbon, means connected to the one meter for converting the signal from the one meter to a signal corresponding to the 50 percent boiling point of the hydrocarbon, computing means connected to the other meter and to the converting means for providing signal corresponding to the specific gravity G_c and the average molecular weight M_c of the hydrocarbon in accordance with the output from the other meter and from the converting means and the following equations:

$$G_c = (141.5/API + 131.5)$$

$$M_c = X + Y(API-30) + Z(API-30)^2,$$

$$X = 10^{(1.60783 + .0016007(50\%BP) - .45(10^{-6} \times 50\%BP)^2)},$$

$$Y = 10^{(-.4244 + .00152X + .45 \times 10^{-5})X^2},$$

$$Z = -.0133 + .516(10^{-4})(50\%BP),$$

where API is the API gravity, means for sensing hydrogen entering the hydrocarbon converting unit and providing corresponding signals, means connected to the computing means and to the hydrocarbon sensing means for providing a ratio signal corresponding to the hydrogen to hydrocarbon mole ratio in accordance with the signals from the hydrogen sensing means and the computing means, means for providing a reference signal corresponding to a predetermined hydrogen to hydrocarbon mole ratio, means connected to the ratio signal means and to the reference signal means for providing a signal corresponding to the difference between

the ratio signal and the reference signal, and means connected to the signal difference means for controlling one of the entrants to the hydrocarbon converting unit in accordance with the signal so as to control the hydrogen to hydrocarbon mole ratio.

2. A system as described in claim 1 in which the controlled entrant is the hydrogen and is a constituent of a gas entering the hydrocarbon converting unit.

3. A system as described in claim 2 in which the hydrogen sensing means includes means connected to the ratio signal means for sensing the flow rate F_g of the gas containing the hydrogen and providing a corresponding signal to the ratio signal means, chromatographic means for sampling the gas and providing signals corresponding to the percent volumes of different constituents of the gas, means connected to the chromatograph means and to the ratio signal means for conducting the signal corresponding to the percent volume of hydrogen V_H in the gas from the chromatographic means to the ratio signal means, and first computing means connected to the chromatographic means and to the ratio signal for providing a signal corresponding to the specific gravity G_g of the gas in accordance with the signals from the chromatographic means and the following equation:

$$G_g = \frac{\sum_{i=1}^{i=n} \frac{\text{volume percent of constituent } i \text{ of the gas}}{100} \times \text{molecular wt. of constituent } i}{29}$$

4. A system as described in claim 3 in which the ratio signal means provides the ratio signal in accordance with the signal from the hydrocarbon flow rate sensing means, the gas flow rate sensing means and the first and second computing means and the following equation:

$$H_2/HC = \frac{V_H G_g F_g}{13261.21 \times \frac{G_g F_g}{M_c}}$$

where V_H is the percentage volume of hydrogen in the gas, G_g is the specific gravity of the gas, F_g is the rate of flow of the gas, G_c is the specific gravity of the hydrocarbon, F_c is the rate of flow of the hydrocarbon,

and M_c is the average molecular weight of the hydrocarbon.

5. A method for controlling the hydrogen to hydrocarbon mole ratio in a hydrocarbon converting unit, which comprises providing signals corresponding to hydrogen entering the hydrocarbon converting unit, sensing the flow rate F_c of hydrocarbon entering the hydrocarbon converting unit, providing a signal corresponding to the sensed hydrocarbon flow rate F_c , sensing the boiling point of the hydrocarbon, providing a signal corresponding to the 50 percent boiling point in accordance with the sensed boiling point, sensing the API gravity of the hydrocarbon, providing a signal corresponding to the sensed API gravity, providing a signal corresponding to the specific gravity G_c of the hydrocarbon in accordance with the API gravity signal in the following equation:

$$G_c = (141.5/API + 131.5)$$

where API is the API gravity, providing a signal corresponding to the average molecular weight M_c of the hydrocarbon in accordance with the API gravity signal, the 50 percent boiling point and the following equations:

$$\begin{aligned} M_c &= X + Y(API-30) + Z(API-30)^2, \\ X &= 10^{(1.60783 + .0016007(50\%) - .45(10^{-6}(50\%)^2))}, \\ Y &= 10^{(-.4244 + .00152X + .45(10^{-5})X^2)}, \\ Z &= .0133 + .516(10^{-4})(50\%) \end{aligned}$$

15 determining the ratio of hydrogen to hydrocarbon in accordance with the sensed hydrogen signals, the hydrocarbon flow rate F_c signal and the hydrocarbon specific gravity G_c and molecular weight M_c signals; providing a reference signal corresponding to a predetermined hydrogen to hydrocarbon mole ratio, providing an error signal corresponding to the difference between the ratio signal and the reference signal; and controlling the quantity of one of the entrants to the hydrocarbon converting unit in accordance with the error signal.

20 6. A method as described in claim 5 in which the controlled entrant is the hydrogen and the hydrogen is a constituent of a gas entering the hydrocarbon converting unit.

7. A method as described in claim 6 in which the step of providing signals corresponding to the hydrogen entering the hydrocarbon converting unit includes sensing the flow rate F_g of the gas containing the hydrogen, providing a signal corresponding to the sensed flow rate F_g of the gas, sensing the percent volume of different constituents of the gas, providing a signal corresponding to the sensed percent volume V_H of hydrogen in the gas, providing signals corresponding to the percent volumes of the other constituents of the gas, providing a signal corresponding to the specific gravity G_g of the gas in accordance with the constituents signals and the following equation:

$$G_g = \frac{\sum_{i=1}^{i=n} \frac{\text{volume percent of constituent } i \text{ of the gas}}{100} \times \text{molecular wt. of constituent } i}{29}$$

8. A device adapted to receive oil and to receive voltages for providing signals substantially corresponding to the molecular weight and to the specific gravity of the oil, comprising means for sensing the 50 percent boiling point and the API gravity of the received oil and providing signals thereto, a pair of sample and hold circuits, connected to the sensing means and controlled by a received voltage, one sample and hold circuit periodically samples and holds the signal from the sensing means corresponding to the 50 percent boiling point of the oil to provide an output, while the other sample and hold circuit periodically samples and holds the signal from the sensing means corresponding to API gravity of the oil to provide an output, and a computing network connected to the pair of sample and hold circuits for providing the signal substantially corresponding to the molecular weight M_c of the received oil in accordance with the outputs from the sample and hold circuits.

cuits, some of the received voltages and the following equations:

$$M_c = X + Y(API-30) + Z (API-30)^2$$

$$Z = -.0133 + .0000516(50\%)$$

$$X = 10^{(1.60783 + .0016007(50\%) - .45(10^{-6} \times 50\%)^2)},$$

and

$$Y = 10^{(-.4244 + .00152X + .45(10^{-5})X^2)}$$

where API is the API gravity of the received oil, and 50 percent is the 50 percent boiling point of the received oil; and a second computing network connected to the

other sample and hold circuit for a signal corresponding to the specific gravity G_c of the oil in accordance with the output corresponding to the API gravity from the other sample and hold circuit, some of the received voltages and the following equation:

$$G_c = (141.5/API + 131.5) .$$

where API is the API gravity of the hydrocarbon.

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