

[54] MEANS AND METHOD FOR ON-LINE DETERMINATION OF THE AROMATIC, NAPHTHENE AND PARAFFIN CONTENTS OF CHARGE OIL

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[56] References Cited

UNITED STATES PATENTS

3,497,449 2/1970 Urban 235/151.12 X

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[57] ABSTRACT

Outputs corresponding to the naphthene and the paraffin volume percent contents of charge oil being reformed by a catalytic reforming unit, along with an output corresponding to the aromatic volume percent content, are provided during

the reforming operation in accordance with the following equations:

$$(1) \{ \Delta T_1 + 2.94(H-8) + 0.104662(P-550) + 0.141123(M-117.5) + 0.002308(T-930)^2 + 0.036641(H-8)(T-930) \} - [85.83793 + 0.5510265(T-930) + 8.664779(RSV-0.476) + 0.0115268(P-550)(H-8) + 0.000602621(P-550)(T-930) + 2.529782(RSV-0.476)(H-8) + 0.1537442(H-8)^2] \\ XN_1 = \frac{0.5470904 + 0.008687601(T-930) - 0.0016322(P-550)}{62.5 - 2FA},$$

$$(2) \{ \Delta T_2 + 0.07751601(P-550) + 1.85(H-8) + 0.383795(M-117.5) + 13.4276(RSV-0.476) + 0.005342901(T-930)^2 + 0.061907(T-930) + 0.278497(RSV-0.476)(T-930) + 0.005999501(T-930)(M-117.5) \} \\ XN_2 = \frac{[44.29602 + 0.000998862(P-550)(T-930) + 0.2464407(H-8)^2] - 0.8316077 + 0.008959372(T-930) - 0.0024203(P-550)}{62.5 - 2FA},$$

(3) Naphthene content = $0.5(XN_1 + XN_2)$
and
(4) Paraffin content = $100 - FA - \text{naphthene content}$

Where ΔT_1 and ΔT_2 are the temperature drops across the first and second reactors, FA is the aromatic content of the charge oil in percent volume, M is the average molecular weight of the charge oil, T is the weighted average reactor inlet temperature in °F, P is the inlet pressure of the first reactor in psig, H is the hydrogen to hydrocarbon mole ratio and RSV is the reciprocal liquid hourly space velocity. Signals are provided, corresponding to different sensed operating conditions and properties of the charge oil during the reforming operation, to analog computers. The analog computers provide signals in accordance with Equations 1 and 2 which are used to develop outputs corresponding to the aromatic, naphthene and paraffin contents of the charge oil.

12 Claims, 3 Drawing Figures

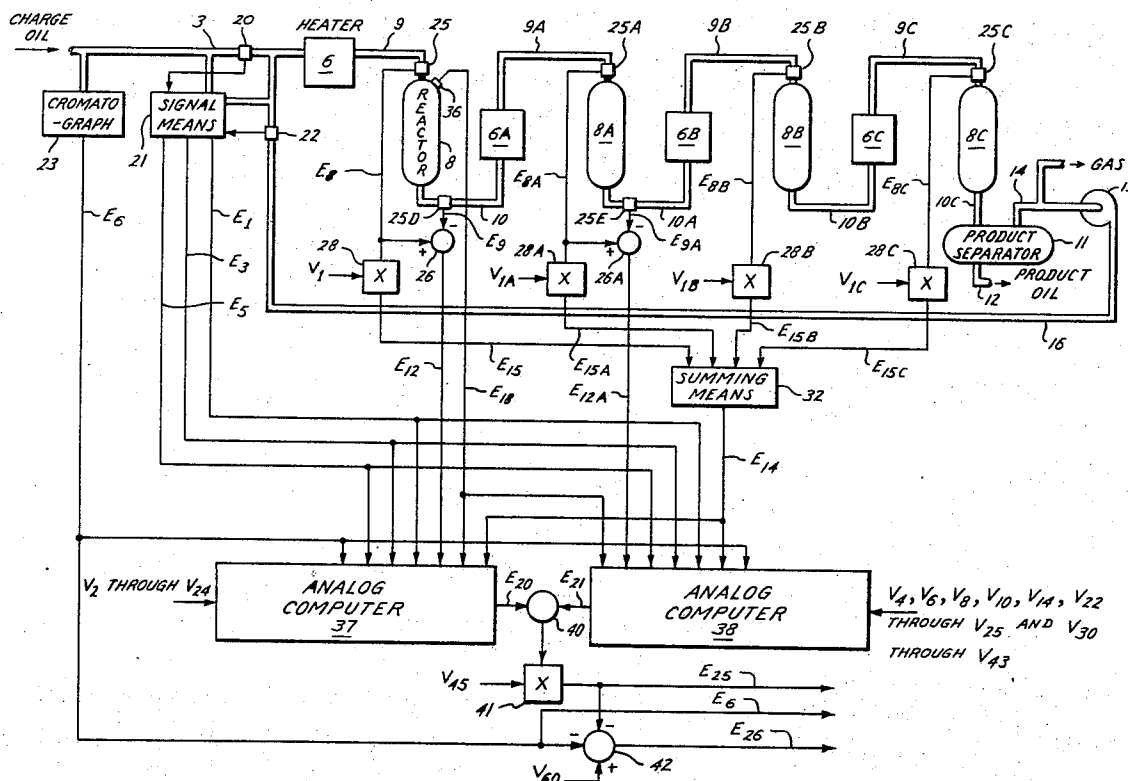
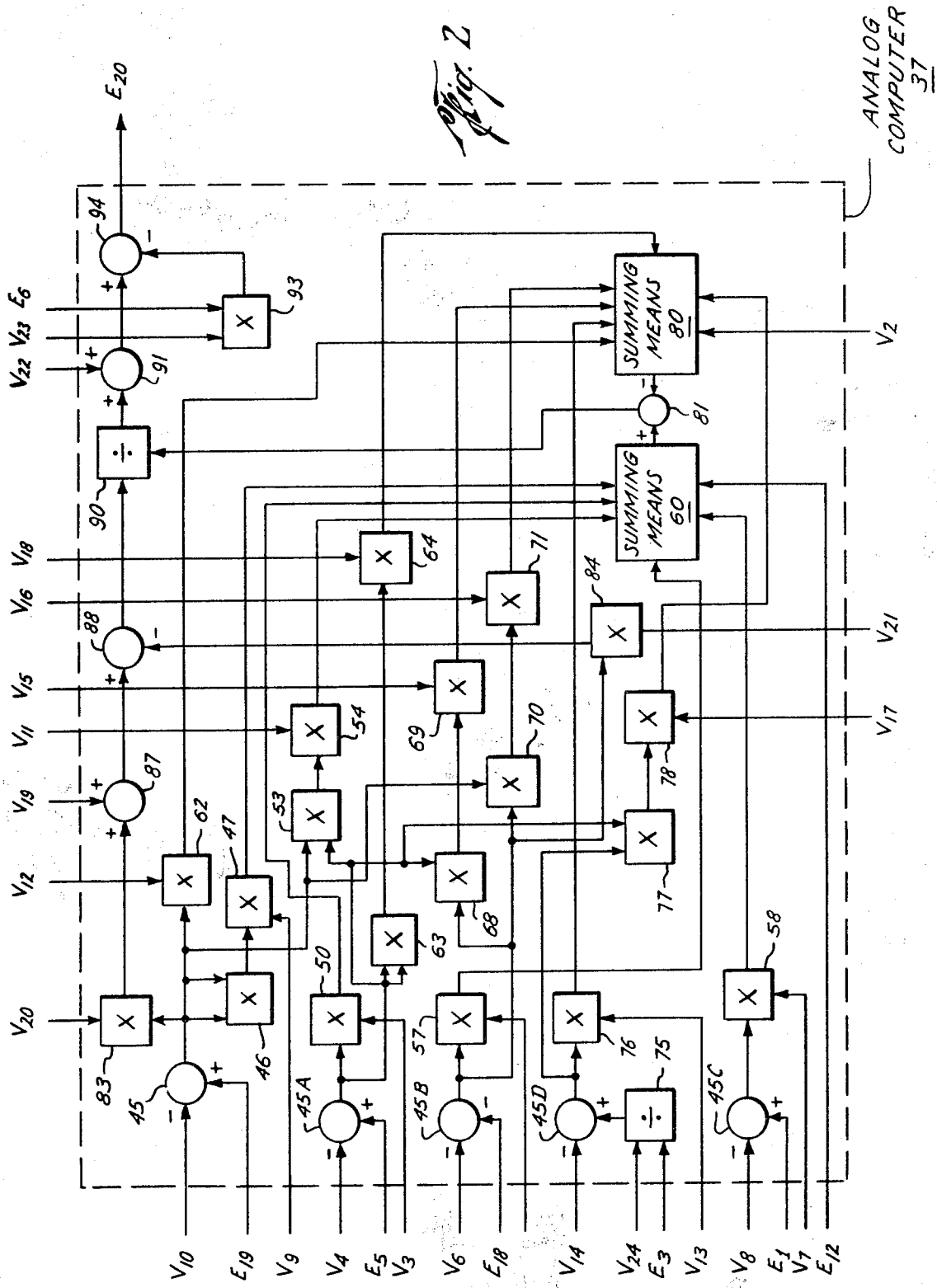


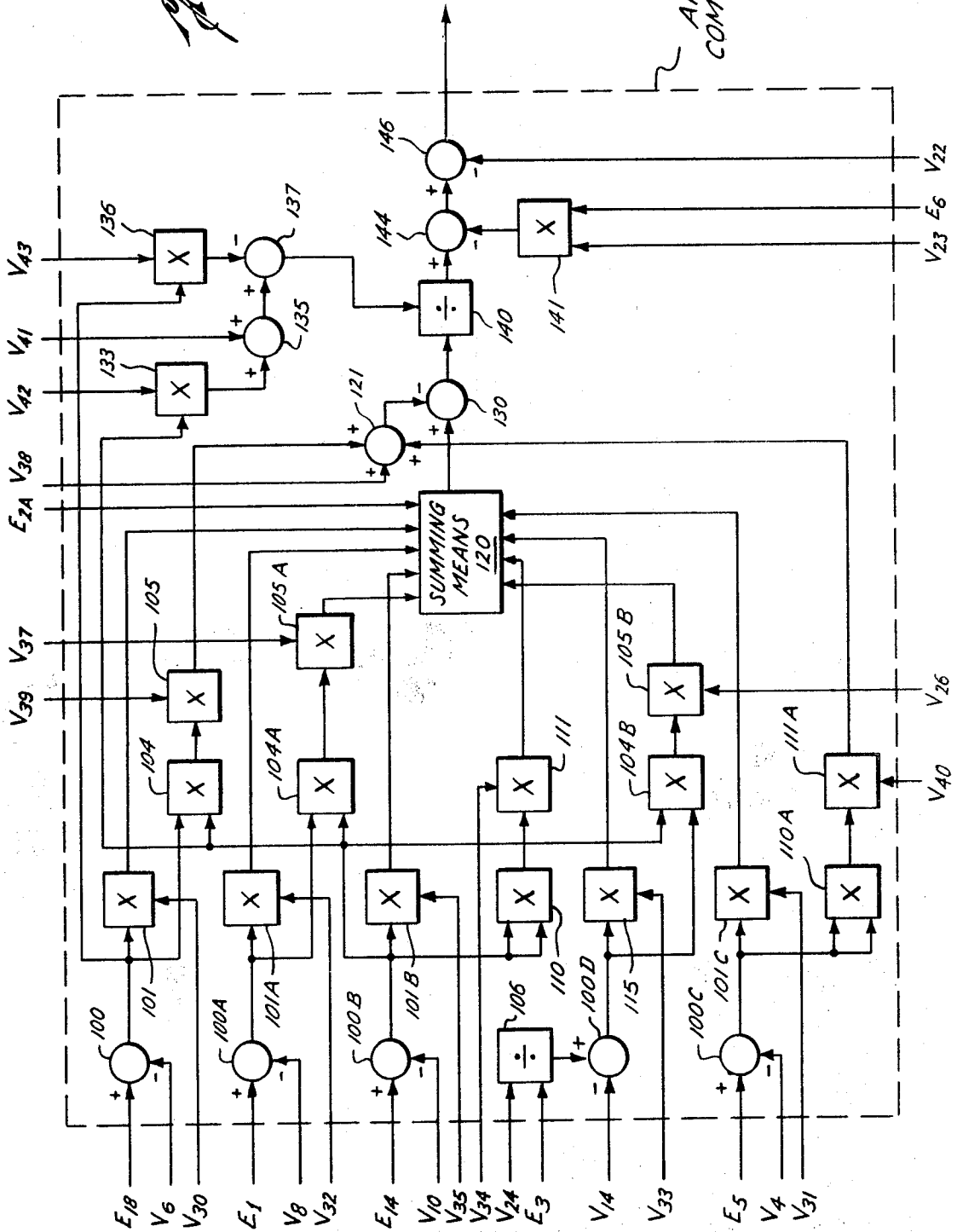
Fig. 2



ANALOG
COMPUTER
37

Fig. 3

ANALOG
COMPUTER
38



MEANS AND METHOD FOR ON-LINE DETERMINATION OF THE AROMATIC, NAPHTHENE AND PARAFFIN CONTENTS OF CHARGE OIL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to petroleum refineries and, more particularly, to a system and method for use with a catalytic reforming unit.

2. Description of the Prior Art

A magazine article entitled "Computer Control of Catalytic Reforming Processes," by Reuben Silver, appeared in the Mar. 28, 1960 issue of *Oil and Gas Journal*. In the article, Mr. Silver lists process variables for catalytic reforming; however, he does not state how these process variables may be used to determine the aromatic, naphthene and paraffin contents of the charge oil. Nor is it obvious to one skilled in the art how the aromatic, naphthene and paraffin contents may be determined on-line, during the catalytic reforming operation, based on the aforementioned magazine article.

SUMMARY OF THE INVENTION

An output is provided corresponding to the concentration of an ingredient in charge oil being reformed in a catalytic reforming unit. The catalytic reforming unit includes two or more reactors and recycles a portion of the gas product during the reforming process. Sensors sense the temperatures of the oil in the reactors. A pressure sensor senses the pressure in at least one reactor and provides a corresponding signal. The charge oil and the recycle gas are sampled while sensors provide signals corresponding to the flow rates of the charge oil and the recycle gas. A circuit provides signals corresponding to the average molecular weight M of the of the charge oil and the hydrogen to hydrocarbon mole ratio H in accordance with the charge oil and the recycle gas samples and the charge oil and recycle gas flow rate signals. A chromatograph samples the charge oil and provides a signal corresponding to the aromatic content FA of the charge oil. A network connected to the temperature and pressure sensors and to the previously mentioned circuit provides the output corresponding to the content of an ingredient in the charge oil, in accordance with the temperature signals, the pressure signal, the aromatic content FA signal, the average molecular weight M signal and the hydrogen to hydrocarbon mole ratio H signal.

One object of the present invention is to determine the naphthene content of the charge oil with an on-line system during catalytic reforming.

Another object of the present invention is to determine the aromatic content of the charge oil with an on-line system during catalytic reforming.

Another object of the present invention is to determine the paraffin content of the charge oil with an on-line system during catalytic reforming.

Another object of the present invention is to provide an on-line system for determining the naphthene and paraffin contents of the charge oil during catalytic reforming in accordance with sensed temperatures of the reactors in a catalytic reforming unit, a sensed pressure in a reactor, the aromatic content, the average molecular weight of the charge oil and the hydrogen to hydrocarbon mole ratio.

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 is a partial block diagram and a partial schematic diagram of a catalytic reforming unit with a system constructed in accordance with the present invention, for providing outputs

corresponding to the naphthene and paraffin contents of charge oil being reformed by the catalytic reforming unit.

FIGS. 2 and 3 are detailed block diagrams of analog computers shown in FIG. 1.

DESCRIPTION OF THE INVENTION

During catalytic reforming, a portion of the naphthenes in the charge oil is converted to aromatics. The aromatic content of the reformed oil determines the quality of the reformed oil and is directly related to the naphthene content of the charge oil. The system of the present invention provides for on-line measuring of the aromatic, naphthene and paraffin contents of the charge oil so that the control of the catalytic reforming process may be improved.

Referring to FIG. 1, there is shown a catalytic reforming unit in which charge oil in a line 3 enters a heater 6. The charge oil is heated to a predetermined temperature and supplied through line 9 to a fixed bed catalytic reactor 8 where a reaction occurs. The effluent leaves reactor 8 by way of a line 10. During the catalytic reaction, there is a temperature drop so that the effluent in line 10 must be heated again before charging to the next reactor. The effluent from reactor 8 is subjected to three more stages of catalytic reaction by reactors 8A, 8B and 8C; with heating prior to each stage provided by heaters 6A, 6B and 6C; before being applied to a product separator 11. Elements identified by a number with a suffix are connected and operate in a similar manner as elements having the same number without a suffix. Product separator 11 provides product oil in a line 12 and gas in a line 14. A portion of the gas is recycled by a conventional compressor 15 through a line 16. The recycle gas enters line 3 and is used to retard the deterioration of the catalyst in reactors 8 through 8C.

The operation of a catalytic reforming unit of the type shown in FIG. 1 is explained in greater detail in U.S. Application Ser. No. 806,766, now U.S. Pat. No. 3,563,883, filed Dec. 30, 1968 by Westby et al., of which the present inventor is a joint inventor, and assigned to Texaco Inc. assignee of the present invention.

A conventional flow rate sensor 20 senses the flow rate of charge oil in line 3 and provides a corresponding signal to signal means 21 which is also continuously sampling the charge oil and the recycle gas in lines 3 and 16, respectively. Signal means 21 receives a signal corresponding to the flow rate of the recycle gas in line 16 from a conventional flow rate sensor 22. Signal means 21 embodies the elements and concepts of U.S. Ser. No. application 97,571 filed Dec. 14, 1970 by W. L. Hopkins et al., of which the present inventor is a joint inventor, and assigned to Texaco Inc. assignee of the present invention. In the description of the last mentioned U.S. application, signals E_1 , E_{14} , and the output from amplifier 112 correspond to the average molecular weight M of the charge oil, to the flow rate of the charge oil and to the hydrogen to hydrocarbon mole ratio H respectively, and are signals E_1 , E_3 and E_8 , respectively, in the description of the present invention.

Chromatograph means 23 samples the charge oil in line 3 and provides a signal E_8 corresponding to the aromatic content FA of the charge oil. Chromatograph means 23 includes a chromatograph which may be of the type manufactured by Beckman Instruments with a Beckman Model 620 programmer and a Beckman Model D analyzer.

As previously mentioned, there occurs a temperature drop in each reactor during the reaction. It has been noted from empirical data that the temperature drop across the first two reactors substantially effect the determination of the naphthene and paraffin contents of the charge oil while the final two reactors have little effect on the determination. Temperature sensors 25 through 25C, which may be thermocouples, sense the inlet temperatures to reactors 8 through 8C, respectively, and provide corresponding signals E_8 through E_{8C} , respectively. Sensors 25D and 25E sense the outlet tem-

peratures of reactors 8 and 8A, respectively, by sensing the temperature of the effluent leaving those reactors and provide signals E_9 and E_{24} , respectively, corresponding to the sensed outlet temperatures. Signals E_9 , E_9 are applied to subtracting means 26 which subtracts signal E_9 from signal E_8 to provide a signal E_{12} corresponding to the temperatures drop at ΔT_1 across reactor 8. Similarly, signal E_{24} is subtracted from E_{8A} by subtracting means 26A to provide a signal E_{12A} corresponding to the temperature drop ΔT_1 across reactor 8A.

A weighted average inlet temperature T signal E_{14} is developed by weighting each inlet temperature according to the percentage of the overall catalyst in the corresponding reactor. Inlet temperatures signals E_8 through E_{8C} are supplied to multipliers 28 through 28C, respectively, where they are multiplied with direct current voltages V_1 through V_{1C} , respectively, corresponding to the weighting factors for the reactors to provide signals E_{15} through E_{15C} , respectively. Summing means 32 sums signals E_{15} through E_{15C} to provide the T signal E_{14} . For example, when reactor 8 through 8C have 20, 20 and 40 percent, respectively, of the catalyst in the catalytic reforming unit, voltages V_1 through V_{1C} correspond to 0.2, 0.2, 0.2 and 0.4, respectively. Let the inlet temperatures of reactors 8 through 8C be 940° , 930° , 920° and 950° F. Signals 15 through 15C would then correspond to 188° , 186° , 184° and 380° F. and signal E_{14} would correspond to 938° F. A conventional pressure transducer 36 senses the inlet pressure P of reactor 8 and provides a corresponding signal E_{18} .

An analog computer 37, which will hereinafter be described in detail, uses signals E_1 , E_3 , E_5 , E_6 , E_{12} , E_{14} and E_{18} along with received direct current voltages V_2 through V_{25} to provide a signal E_{20} in accordance with equation 1 of the abstract.

The following table relates direct current voltages to corresponding terms or coefficients in Equation 1:

Voltage	Term or coefficient	Voltage	Term or coefficient
V_2	85.83793	V_{14}	0.476
V_3	2.94	V_{15}	0.0115268
V_4	8	V_{16}	0.000602621
V_5	0.104662	V_{17}	2.529762
V_6	550	V_{18}	0.1537442
V_7	0.141123	V_{19}	0.5470904
V_8	117.5	V_{20}	0.008687601
V_9	0.0023208	V_{21}	0.0016322
V_{10}	930	V_{22}	62.5
V_{11}	0.036641	V_{23}	2
V_{12}	0.5510265	U_{24}	Known volume of catalyst
V_{13}	8.664779		

Similarly, an analog computer 38, which will also be hereinafter described in detail, uses signals E_1 , E_3 , E_5 , E_6 , E_{12A} , E_{14} and E_{18} along with received direct current voltages V_4 , V_6 , V_8 , V_{10} , V_{14} , V_{22} through V_{25} and V_{30} through V_{43} to provide a signal E_{21} in accordance with Equation 2 of the abstract.

The following table relates the received direct current voltages to the terms or coefficients in Equation 2.

Voltage	Term or coefficient	Voltage	Term or coefficient
V_4	8	V_{33}	13.4276
V_6	550	V_{34}	0.005342901
V_8	117.5	V_{36}	0.061907
V_{10}	930	V_{38}	0.278497
V_{14}	0.476	V_{37}	0.005999501
V_{22}	62.5	V_{38}	44.29602
V_{23}	2	V_{39}	0.0009998862
V_{24}	Known volume of catalyst	V_{40}	0.2464407
V_{30}	0.07751601	V_{41}	0.8316077
V_{31}	1.85	V_{42}	0.008959372
V_{32}	0.383795	V_{43}	0.0024203

The naphthene content is determined by using the XN_1 signal E_{20} and the XN_2 signal E_{21} in accordance with equation 3 of the abstract. Summing mean 40 sums signals E_{20} , E_{21} to provide a signal to a multiplier 41. Multiplier 41 multiplies the sum signal from summing means 40 with a direct current voltage V_{45} , corresponding to 0.5 to provide a signal E_{25} which corresponds to the naphthene content of the charge oil.

The sum of the paraffin content and the naphthene content and the aromatic content of the charge oil constitutes a whole. Therefore, the paraffin content can be determined by subtracting the naphthene and aromatic contents from 100 which is done by subtracting means 44. Subtracting means 44 subtracts signals E_8 , E_{25} from a direct current voltage E_{80} , which corresponds to 100, to provide a signal E_{25} corresponding to the paraffin content of the charge oil.

Referring to Fig. 2, there is shown a detailed block diagram of analog computer 37. Subtracting means 45, 45A, 45B and 45C subtract voltages V_{10} , V_4 , V_6 and V_8 , respectively, from signals E_{14} , E_8 , E_{18} and E_1 , respectively, to provide signals corresponding to the terms $(T-930)$, $(H-8)$, $(P-550)$ and $(M-117.5)$, respectively, in Equation 1. A multiplier 46 effectively squares the signal from subtracting means 45 to provide a signal corresponding to $(T-930)^2$. The signal from multiplier 46 is multiplied with voltage V_9 by a multiplier 47 to provide a signal corresponding to $0.0023208(T-930)^2$. A multiplier 50 multiplies the signal from subtracting means 45A with voltage V_3 to provide a signal corresponding to $2.94(H-8)$.

The signals from subtracting means 45, 45A are multiplied together by a multiplier 53 to apply a signal to another multiplier 54. Multiplier 54 multiplies the signal from multiplier 53 with voltage V_{11} to provide a signal corresponding to $0.036641(T-930)(H-8)$.

Multipliers 57, 58 multiply the signals from subtracting means 45B and 45C with voltages V_5 and V_7 , respectively, to provide signals corresponding to $0.104662(P-550)$ and $0.141123(M-117.5)$, respectively. Summing means 60 sums the signals from multipliers 47, 50, 54, 57 and 58 and the ΔT_1 signal E_{12} .

Voltage V_{12} is multiplied with the signal from subtracting means 45 by a multiplier 62 to provide a signal corresponding to $0.5510265(T-930)$. The output from subtracting means 45A is effectively squared by a multiplier 63 and the square signal multiplied with voltage V_{18} by another multiplier 64 to provide a signal corresponding to $0.1537442(H-8)^2$. A multiplier 68 multiplies the outputs from subtracting means 45A, 45B together and the resulting signal is multiplied with voltage V_{15} by a multiplier 69 to provide a signal corresponding to $0.0115268(P-550)(H-8)$. Multipliers 70, 71 are arranged in a similar manner as multipliers 68 and 69, respectively, to multiply the outputs from subtracting means 45, 45B and voltage V_{16} to provide a signal corresponding to $0.000602621(T-930)(P-550)$.

A divider 75 divides the voltage V_{24} by charge oil flow rate signal E_2 to provide a signal corresponding to the reciprocal space velocity RSV to subtracting means 45D. Subtracting means 45D subtracts voltage V_{14} from the RSV signal from divider 75 to provide a signal corresponding to $(RSV-0.476)$. The output from subtracting means 45D is multiplied with voltage V_{13} by a multiplier 76 to provide a signal corresponding to $8.664779(RSV-0.476)$. A multiplier 77 multiplies the outputs from subtracting means 45A, 45D together and the resulting signal is multiplied with voltage V_{17} by a multiplier 78 to provide a signal corresponding to $2.529762(RSV-0.476)(H-8)$.

Summing means 80 sums the signals from multipliers 62, 64, 69, 71, 76, and 78 and voltage V_2 . Subtracting means 81 subtracts a sum signal from summing means 80 from a sum signal from summing means 60 to provide a signal corresponding to the numerator of the fraction in Equation 1.

The outputs from subtracting means 45, 45B are multiplied with voltages V_{20} and V_{21} , respectively, by multipliers 83, 84 to provide signals corresponding to $0.008687601(T-930)$ and $0.0016322(P-550)$, respectively. The signal from multiplier 75 is summed with voltage V_{19} by summing means 87 to pro-

vide a sum signal. The signal from multiplier 84 is subtracted from the sum signal from summing means 87 by subtracting means 88 to provide a signal corresponding to the denominator of the fraction in Equation 1. A divider 90 divides the numerator signal from subtracting means 81 by the denominator signal from subtracting means 88. The resulting signal is applied to summing means 91 where it is summed with voltage V_{22} . A multiplier 93 multiplies voltage V_{23} and the EA signal E_6 together and the resulting signal which corresponds to $2FA$, is subtracted from the signal provided by summing means 94 by subtracting means 92 to provide the XN_1 signal E_{20} .

Referring to FIG. 3, analog computer 38 includes subtracting means 100 through 100C which subtract voltages V_8 , V_8 , V_{10} and V_4 from signals E_{18} , E_1 , E_{14} and E_5 , respectively, to provide signals corresponding to ($P-550$), ($M-117.5$), ($T-930$) and ($H-8$), respectively. Multipliers 101 through 101C multiply the signals from subtracting means 100 through 100C, respectively, with voltages V_{30} , V_{32} , V_{35} and V_{31} , respectively, to provide signals corresponding to $0.07751601(P-550)$, $0.383795(M-117.5)$, $0.061907(T-930)$ and $1.85(H-*)$, respectively.

A multiplier 104 multiplies the signals from subtracting means 100, 100B together and the resulting signal is multiplied with voltage V_{36} by a multiplier 105 to provide a signal corresponding to $0.0009998862(P-550)(T-930)$. Similarly, multipliers 104A and 105A multiply the signals from subtracting means 100A, 100B and voltage V_{37} to provide a signal corresponding to $0.005999501(T-930)(M-117.5)$. Multipliers 104B, 105B cooperate in a similar manner to provide a signal corresponding to $0.278497(RSV-0.476)(T-930)$ in accordance with the signals from subtracting means 100B, 100D and voltage V_{36} . Subtracting means 100D provides the ($RSV-0.476$) signal by subtracting voltage V_{14} from the output from a divider 106 which divides the voltage V_{24} by the charge oil flow rate signal E_3 .

Multipliers 110, 110A effectively square the signals from subtracting means 100B and 100C, respectively, and the resulting signals are multiplied with voltages V_{34} and V_{40} by multipliers 111 and 111A, respectively, to provide signals corresponding to $0.005342901(T-930)^2$ and $0.2464407(H-8)^2$, respectively. The signal from subtracting means 100D is multiplied with voltage V_{33} by a multiplier 115 to provide a signal corresponding to $13.4276(RSV-0.476)$.

Summing means 120 sums the ΔT_2 signal E_{12A} with the signals from multipliers 101, 101A, 101B, 101C, 105A, 105B, 111 and 115; while summing means 121 sums the signals from multipliers 105, 111A and voltage V_{38} . Subtracting means 130 subtracts the signal from summing means 121 from the signal from summing means 120 to provide a signal corresponding to the numerator of the fraction in Equation 2.

The signal from subtracting means 100B is multiplied with voltage V_{42} by a multiplier 133 to provide a signal corresponding to $0.008959372(T-930)$ which is summed with voltage V_{41} by summing means 135. The signal from subtracting means 100 is multiplied with voltage V_{43} by a multiplier 136 to provide a signal corresponding to $0.0024203(P-550)$. Subtracting means 137 subtracts the signal from multiplier 136 from the sum signal from summing means 135 to provide a signal corresponding to the denominator of the fraction in Equation 2.

A divider 140 divides the numerator signal from subtracting means 130 by the denominator signal from subtracting means 137. A multiplier 141 multiplies voltage V_{23} , and the FA signal E_6 together; the resulting signal, which corresponds to $2FA$, is subtracted from the signal from divider 140 by subtracting means 144. Summing means 146 sums the signal from subtracting means 144 which voltage V_{22} to provide the XN_2 signal E_{21} .

There may be a slight constant error between the measured naphthene content, using Equations 1 and 2, and the actual naphthene content for a particular catalytic reforming unit. When known, the error can be compensated for by adding to or subtracting from the numerators of the fractions in Equations 1, 2. This may be accomplished by applying a direct cur-

rent voltage to summing means 60 or 80, depending on the nature of the correction, to affect the numerator of the fraction in Equation 1 accordingly. Similarly, another direct current voltage may also be applied to summing means 120 or 121 to compensate for the error.

It would be obvious to one having ordinary skill in the art to use a digital computer to determine the naphthene, paraffin, and aromatic contents of the charge oil. All that would be necessary would be to convert signals E_1 , E_3 , E_5 , E_6 , E_{18} and E_9 through E_{8C} , E_9 and E_{24} to digital signals, using conventional analog-to-digital converters, and to program the digital computer to solve the equations in the abstract.

The device of the present invention as heretofore described determines the aromatic, naphthene and paraffin contents of charge oil during the reforming of the charge oil by a catalytic reforming unit. The determination is made in accordance with sensed temperatures of reactors in the catalytic reforming unit, a sensed pressure in a reactor, the average molecular weight of the charge oil and the hydrogen to hydrocarbon mole ratio.

What is claimed is:

1. A system for providing an output corresponding to a content of an ingredient of charge oil being reformed by a catalytic reforming unit having a plurality of reactors and recycling a portion of the gas product, comprising chromatograph means for sampling the charge oil and providing a signal corresponding to the aromatic content FA of the charge oil, means for providing signals corresponding to sensed temperatures of the reactors, means for sensing the pressure P in at least one reactor and providing a signal corresponding thereto, means for sensing the flow rates of the charge oil and the recycle gas and providing corresponding signals, means connected to the flow rate signal means and sampling the charge oil and the recycle gas for providing signals corresponding to the average molecular weight M of the charge oil and the hydrogen to hydrocarbon mole ratio H in accordance with flow rate signals and the samples, and means connected to the chromatograph means, to the temperature signal means, to the pressure sensing means and to the molecular weight-mole ratio signal means for providing the output corresponding to the content of an ingredient in the charge oil, in accordance with the temperature signals, the pressure signal, the average molecular weight M signal and the hydrogen to hydrocarbon mole ratio H signal.

2. A system as described in claim 1 in which the output corresponds to the naphthene content of the charge oil.

3. A system as described in Claim 2 further comprising means connected to the chromatograph means and to the output means for providing another output corresponding to the paraffin content of the charge oil in accordance with the aromatic content signal, the naphthene content output and the following equation:

Paraffin content = $100 - \text{aromatic content} - \text{naphthene content}$

4. A system as described in claim 2 in which the temperature signal means provides a signal for each sensed inlet temperature of the reactors and a signal for each sensed outlet temperature of the first two reactors, and the sensed pressure is the sensed pressure in the first reactor.

5. A system as described in claim 4 in which the output means includes a circuit receiving the inlet temperature signals and direct voltages, each direct current voltage corresponding to a percent of the catalytic reforming units catalyst present in a different reactor, and providing a signal corresponding to the average weighted temperature T of all the inlet temperatures and subtracting means connected to the temperature sensed means, one subtracting means receiving the inlet and outlet temperature signals for the first reactor and providing a signal corresponding to the temperature drop ΔT_1 across the first reactor, the other subtracting means receiving the inlet and outlet temperature signals and providing a signal corresponding to the temperature drop ΔT_2 across the second reactor.

6. A system as described in claim 5 in which the output means includes computer means connected to the circuit, to the subtracting means, to the chromatograph means, to the pressure sensing means and to the molecular weight-mole ratio means for providing the output in accordance with the T signal, the ΔT_1 and ΔT_2 signals, the FA signal, the P signal, the charge oil flow rate signal and the H signal, a received direct signal current voltage corresponding to the volume of the catalyst in the catalytic reforming unit and the following equations:

$$\begin{aligned}
 & \{ \Delta T_1 + 2.94(H-8) + 0.104662(P-550) \\
 & + 0.141123(M-117.5) + 0.002308(T-930)^2 \\
 & + 0.036641(H-8)(T-930) \} - \{ 85.83793 \\
 & + 0.5510265(T-930) + 8.664779(RSV-0.476) \\
 & + 0.0115268(P-550)(H-8) + 0.000602621(P-550)(T-930) \\
 & + 2.529762(RSV-0.476)(H-8) + 0.1537442(H-8)^2 \} \\
 XN_1 = & \frac{\quad}{0.5470904 + 0.008687601(T-930) - 0.0016322(P-550)} + 62.5 - 2FA, \\
 & \{ \Delta T_2 + 0.07751601(P-550) + 1.85(H-8) + 0.383795(M-117.5) \\
 & + 13.4276(RSV-0.476) + 0.005342901(T-930)^2 + 0.061907(T-930) \\
 & + 0.278497(RSV-0.476)(T-930) + 0.005999501(T-930)(M-117.5) \} \\
 XN_2 = & \frac{-\{ 44.29602 + 0.0009998862(P-550)(T-930) + 0.2464407(H-8)^2 \}}{0.8316077 + 0.008959372(T-930) - 0.0024203(P-550)} + 62.5 - 2FA,
 \end{aligned}$$

and output corresponding to naphthene content = $0.5(XN_1 + XN_2)$

where RSV is reciprocal space velocity which is the volume of the catalyst divided by the flow rate of the charge oil.

7. A method for determining an ingredient of charge oil being reformed by a catalytic reforming unit having reactors and recycling a portion of the gas product, sensing temperatures of the reactors, sensing the pressure of at least one reactor, sensing the flow rate of the charge oil, sensing the flow rate of the recycle gas, sampling the charge oil, sampling the recycle gas, determining the average molecular weight M of the charge oil in accordance with the sensed flow rate of the charge oil and the charge oil sample, determining the hydrogen to hydrocarbon mole ratio H in accordance with the sensed flow rates of the charge oil and the recycle gas and with the samples of the charge oil and the recycle gas, determining the aromatic content FA of the charge oil in accordance with the charge oil sample and determining the ingredient content of the charge oil in accordance with the sensed temperatures,

$$\begin{aligned}
 & \{ \Delta T_1 + 2.94(H-8) + 0.104662(P-550) \\
 & + 0.141123(M-117.5) + 0.002308(T-930)^2 \\
 & + 0.036641(H-8)(T-930) \} - \{ 85.83793 \\
 & + 0.5510265(T-930) + 8.664779(RSV-0.476) \\
 & + 0.0115268(P-550)(H-8) + 0.000602621(P-550)(T-930) \\
 & + 2.529762(RSV-0.476)(H-8) + 0.1537442(H-8)^2 \} \\
 XN_1 = & \frac{\quad}{0.5470904 + 0.008687601(T-930) - 0.0016322(P-550)} + 62.5 - 2FA, \\
 & \{ \Delta T_2 + 0.07751601(P-550) + 1.85(H-8) + 0.383795(M-117.5) \\
 & + 13.4276(RSV-0.476) + 0.005342901(T-930)^2 + 0.061907(T-930) \\
 & + 0.278497(RSV-0.476)(T-930) + 0.005999501(T-930)(M-117.5) \} \\
 XN_2 = & \frac{-\{ 44.29602 + 0.0009998862(P-550)(T-930) + 0.2464407(H-8)^2 \}}{0.8316077 + 0.008959372(T-930) - 0.0024203(P-550)} + 62.5 - 2FA, \\
 & \text{and the naphthene content} = 0.5(XN_1 + XN_2),
 \end{aligned}$$

the sensed pressure, the aromatic content FA the average molecular weight M and the hydrogen to hydrocarbon mole ratio H .

8. A method as described in claim 7 in which the ingredient content of the charge oil to be determined is the naphthene content.

9. A method as described in claim 8 further comprising determining the paraffin content of the charge oil in accordance with the aromatic content FA and the naphthene content of the charge oil and the following equation:

$$\text{paraffin content} = 100 - \text{aromatic content} - \text{naphthene content.}$$

10. A method as described in claim 8 in which the sensed temperatures are the inlet temperatures of the reactors and the outlet temperatures of the first two reactors, and the sensed pressure is the sensed pressure in the first reactor.

11. A method as described in claim 10 in which the determining of the naphthene content step includes determining the aromatic content FA of the charge oil, determining the temperature drops ΔT_1 and ΔT_2 across the first and second reactors, respectively, from the inlet and outlet temperatures of the first and second reactors, weighting the inlet temperature of each reactor in accordance with the percent of the catalytic reforming unit catalyst contained in the reactor, and summing the weighted temperatures to obtain, the average weighted temperature T .

12. A method as described in claim 11 in which the naphthene content is determined in accordance with the temperature drops ΔT_1 and ΔT_2 , the sensed charge oil flow rate, the hydrogen to hydrocarbon mole ratio H , the average molecular weight M of the charge oil, average weighted inlet temperature T , and the pressure P and the following equations:

where RSV is the reciprocal space velocity which is determined by dividing the known volume of the catalyst in the catalytic reforming unit by the flow rate of the charge oil.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,666,932 Dated MAY 30, 1972

Inventor(s) WILLIAM D. WHITE

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

" ΔT " at Column 3, line 9 should read -- ΔT_2 --

"supplied" at Column 3, line 13 should read --applied--

"E₂₅" at Column 4, line 14 should read --E₂₆--

"P-550)" at Column 4, line 53 should read --(P-550)--

"EA" at Column 5, line 8 should read --FA--

"1.85(H-*)" at Column 5, line 21 should read --1.85(H-8)--

"M-M-117.5" at Column 5, line 29 should read --(M-117.5)--

"signed" at Column 6, line 69 should read --signal--

"direct signal current" at Column 7, line 8 should read

--direct current signal--

"XN" at Column 7, line 51 should read --XN₂--

Signed and sealed this 9th day of January 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents