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Hopkins et al.

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[54] **MEANS AND METHOD FOR CONTROLLING THE STRENGTH OF ACID IN AN ALKYLATION UNIT**

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[73] Assignee: **Texaco, Inc.,** New York, N.Y.

[22] Filed: **Aug. 5, 1971**

[21] Appl. No.: **169,443**

[52] **U.S. Cl.** ....**235/151.12,** 23/255 E, 208/DIG. 1, 235/150.1, 260/683.43

[51] **Int. Cl.** **C07e 3/52,** G06g 7/58

[58] **Field of Search**......................235/151.12, 150.1; 23/230 R, 232 E, 252 R, 253 R, 254 E, 255 E; 260/683.4, 683.43, 683.46, 683.59, 683.62; 208/133, 134, **DIG. 1**

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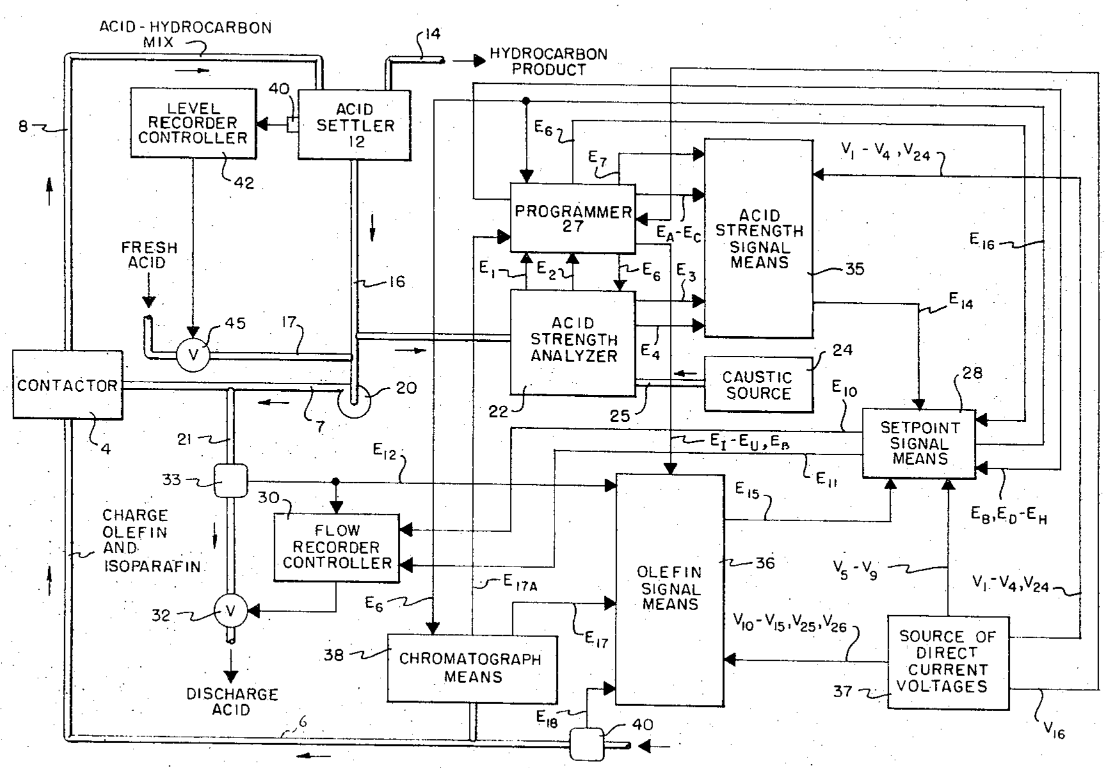
Primary Examiner—Joseph F. Ruggiero
Attorney—Thomas H. Whaley et al.

[57] **ABSTRACT**

A system controls the strength of acid used as the catalyst in an alkylation unit, which reacts olefins with isoparaffin, in accordance with the average strength of the acid and the anticipated required strength of the acid. A signal corresponding to the average acid strength is developed by analog computers solving equations, hereinafter disclosed, using an output from an acid analyzer corresponding to the density of the acid and a signal corresponding to the volume of caustic used in analyzing the acid. An anticipated required acid strength signal is developed by an analog computer from signals, corresponding to the flow rate and composition of the olefin, from a flow rate sensor and chromatograph means, respectively, in accordance with equations hereinafter disclosed. Another analog computer provides signals for setting the set point of a flow recorder controller in accordance with the average acid strength signal, the anticipated required acid strength signal and equations hereinafter disclosed. The flow recorder controller controls the flow rate acid being discharged from the alkylation unit so as to control the quantity of fresh acid entering the alkylation unit thereby controlling the strength of the acid.

13 Claims, 7 Drawing Figures



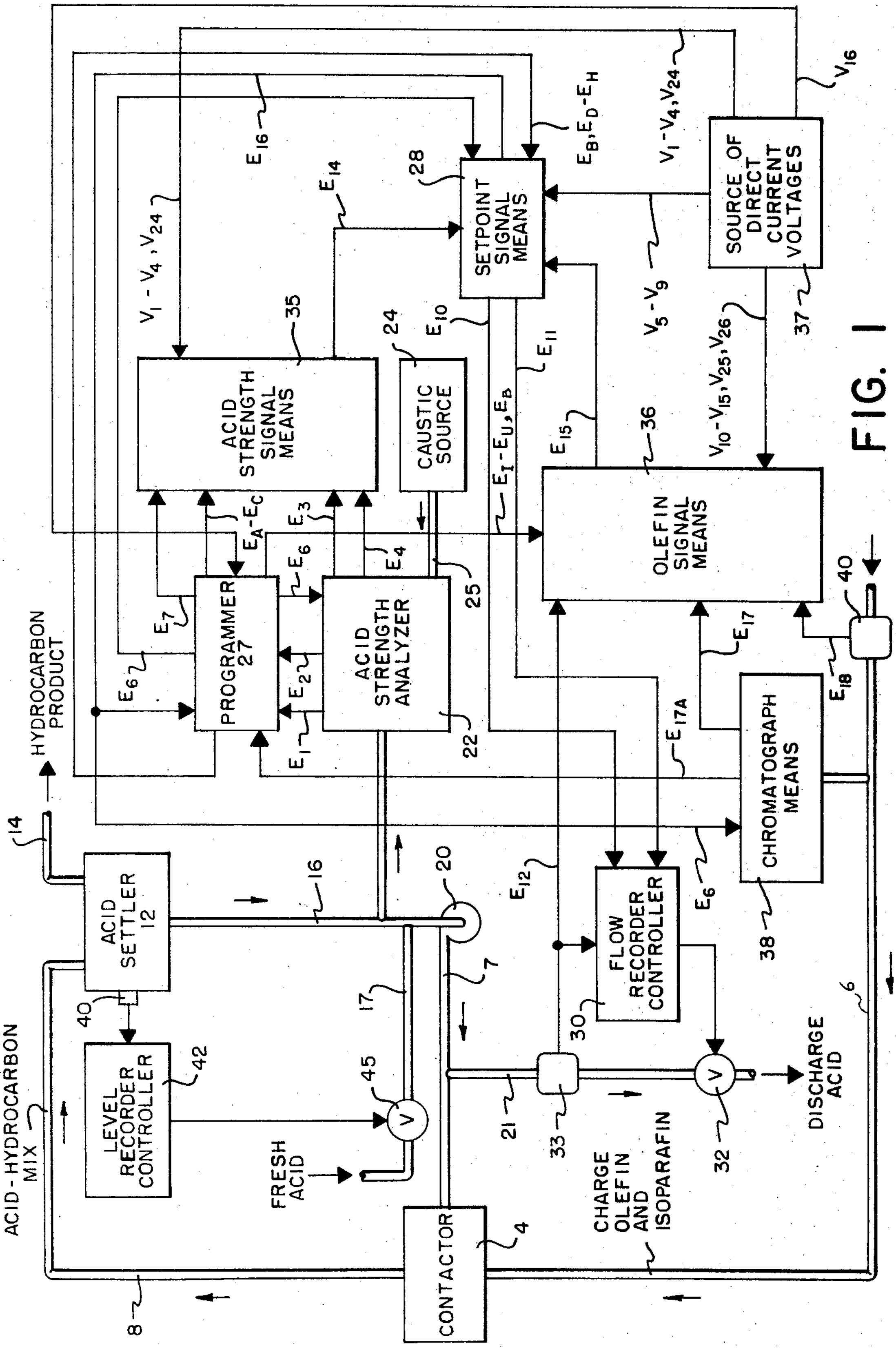
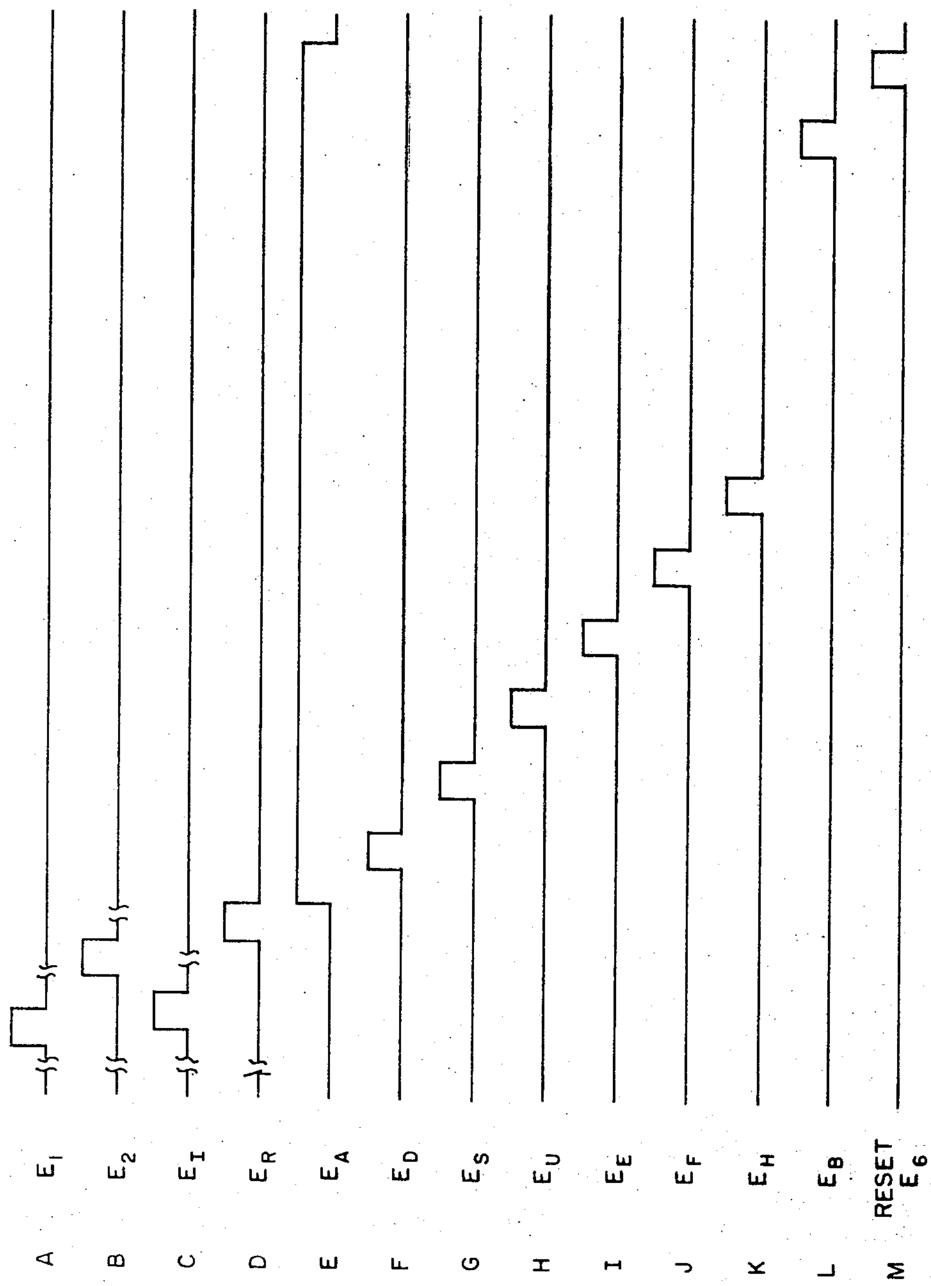

ACID STRENGTH SIGNAL MEANS
CAUSTIC SOURCE
SETPOINT SIGNAL MEANS
SOURCE OF DIRECT CURRENT VOLTAGES
OLEFIN SIGNAL MEANS
PROGRAMMER 27
ACID STRENGTH ANALYZER
CHROMATOGRAPH MEANS
FLOW RECORDER CONTROLLER
ACID SETTLER 12
LEVEL RECORDER CONTROLLER
CONTACTOR
HYDROCARBON PRODUCT
ACID-HYDROCARBON MIX
FRESH ACID
CHARGE OLEFIN AND ISOPARAFIN
DISCHARGE ACID
$V_1 - V_4, V_{24}$
$V_5 - V_9$
$V_{10} - V_{15}, V_{25}, V_{26}$
V_{16}
$E_B, E_D - E_H$
$E_I - E_U, E_B$
$E_A - E_C$

FIG. 1

FIG. 2



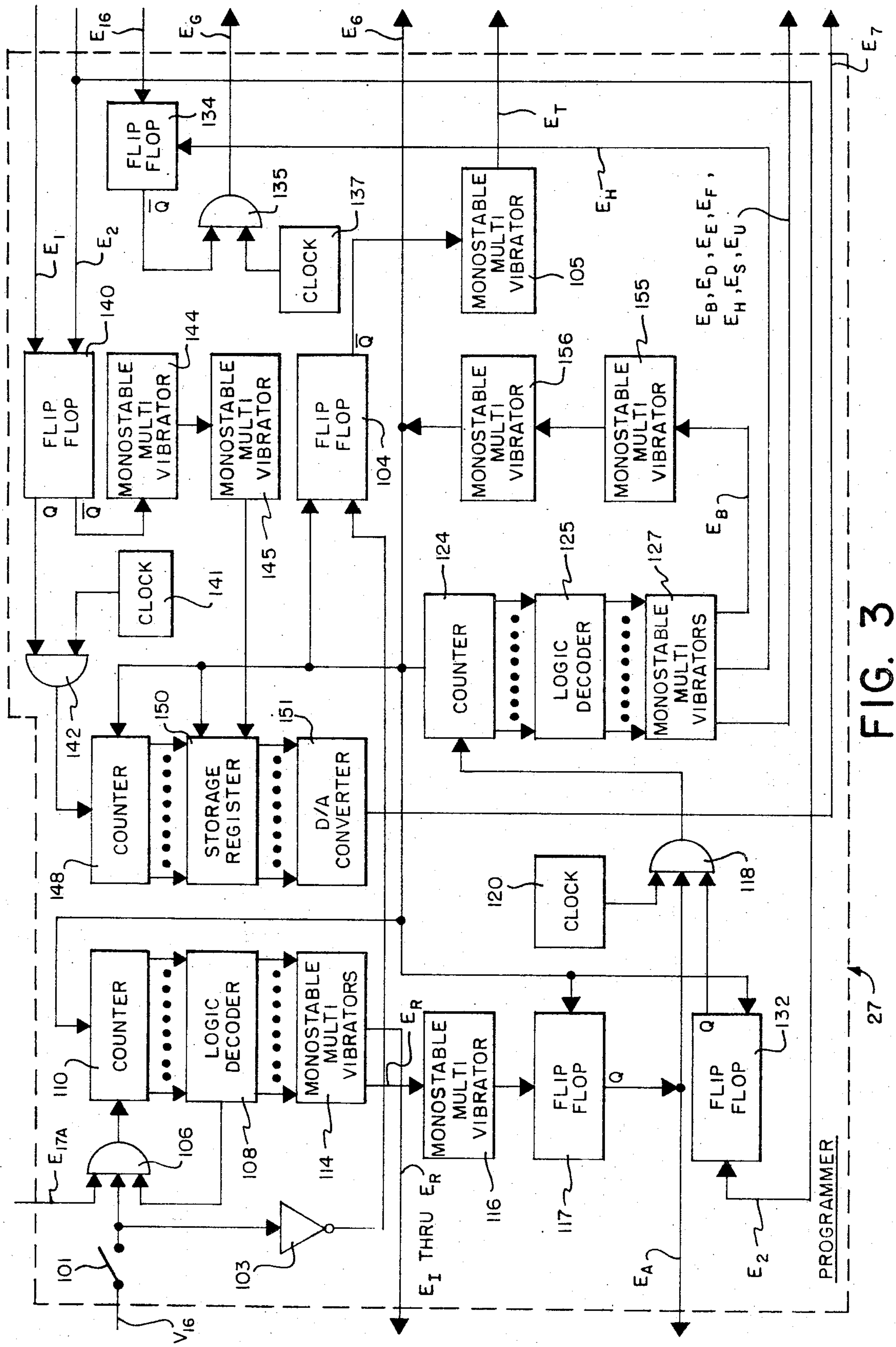

FLIP FLOP
MONOSTABLE MULTI VIBRATOR
CLOCK
COUNTER
STORAGE REGISTER
D/A CONVERTER
LOGIC DECODER
MONOSTABLE MULTI VIBRATORS
PROGRAMMER
E_I THRU E_R
$E_B, E_D, E_E, E_F, E_H, E_S, E_U$

FIG. 3

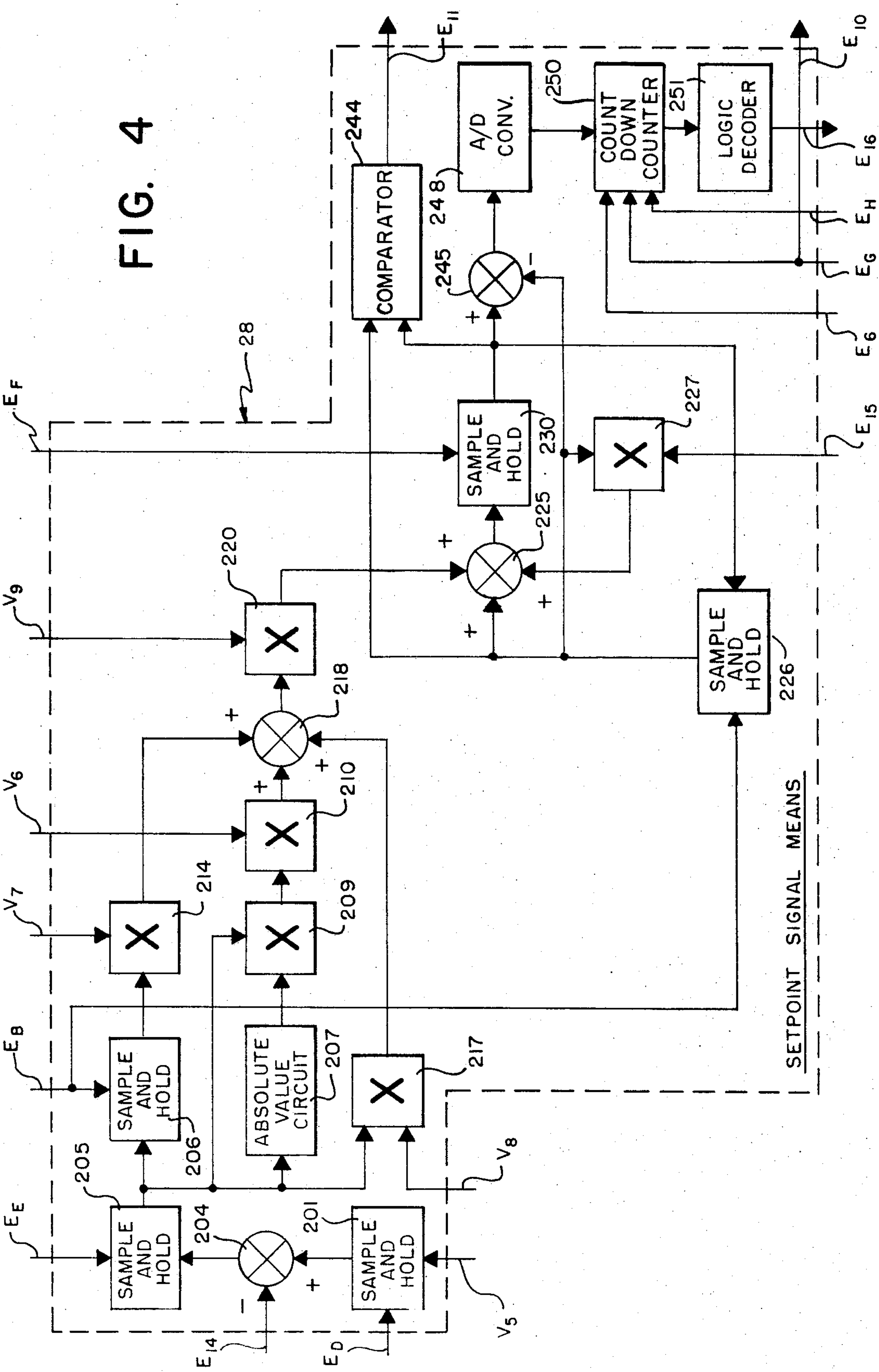

SAMPLE AND HOLD
SAMPLE AND HOLD
ABSOLUTE VALUE CIRCUIT
COMPARATOR
A/D CONV.
COUNT DOWN COUNTER
LOGIC DECODER
SETPOINT SIGNAL MEANS
201
204
205
206
207
209
210
214
217
218
220
225
226
227
230
244
245
248
250
251
28

FIG. 4

FIG. 5

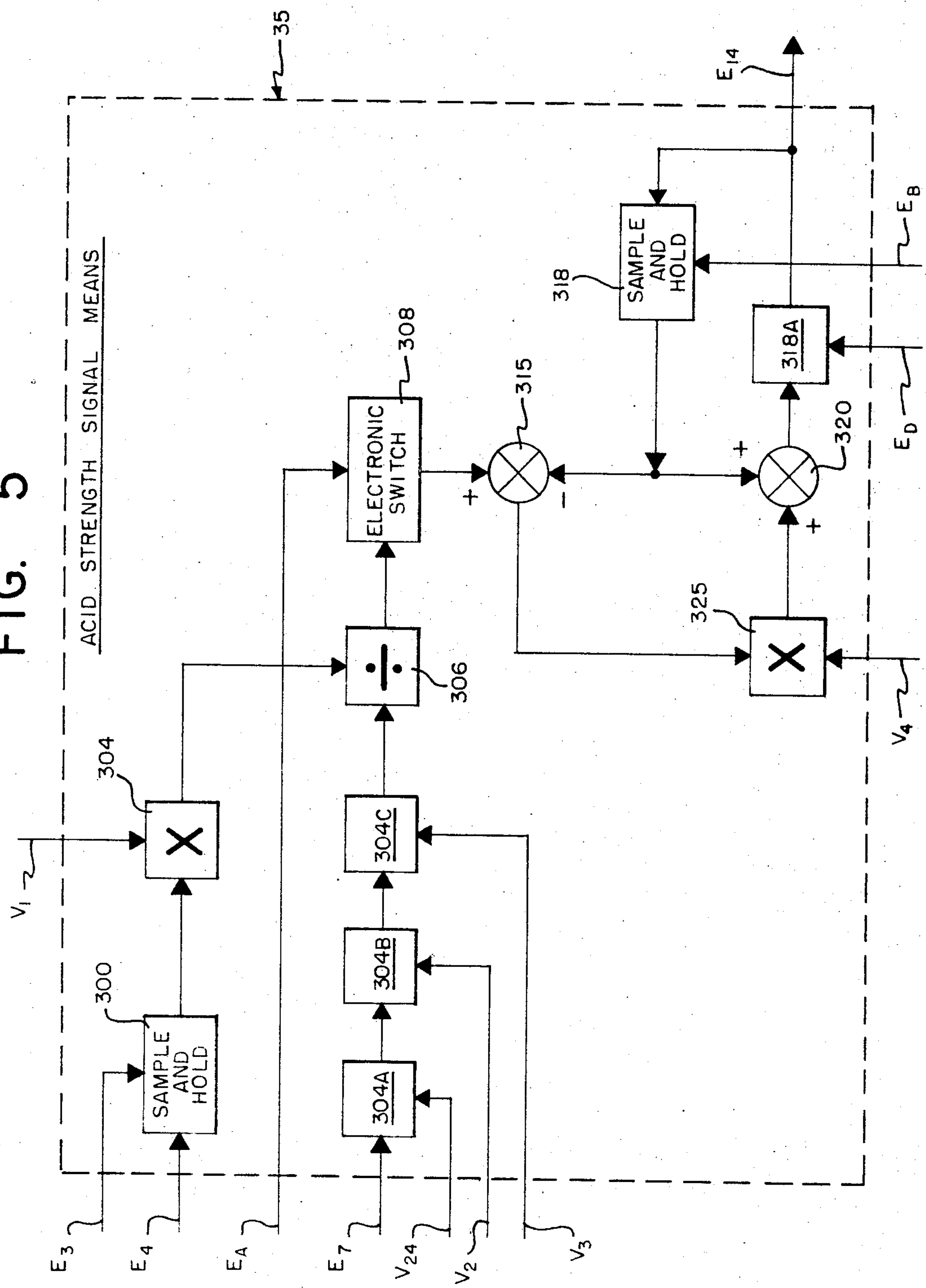
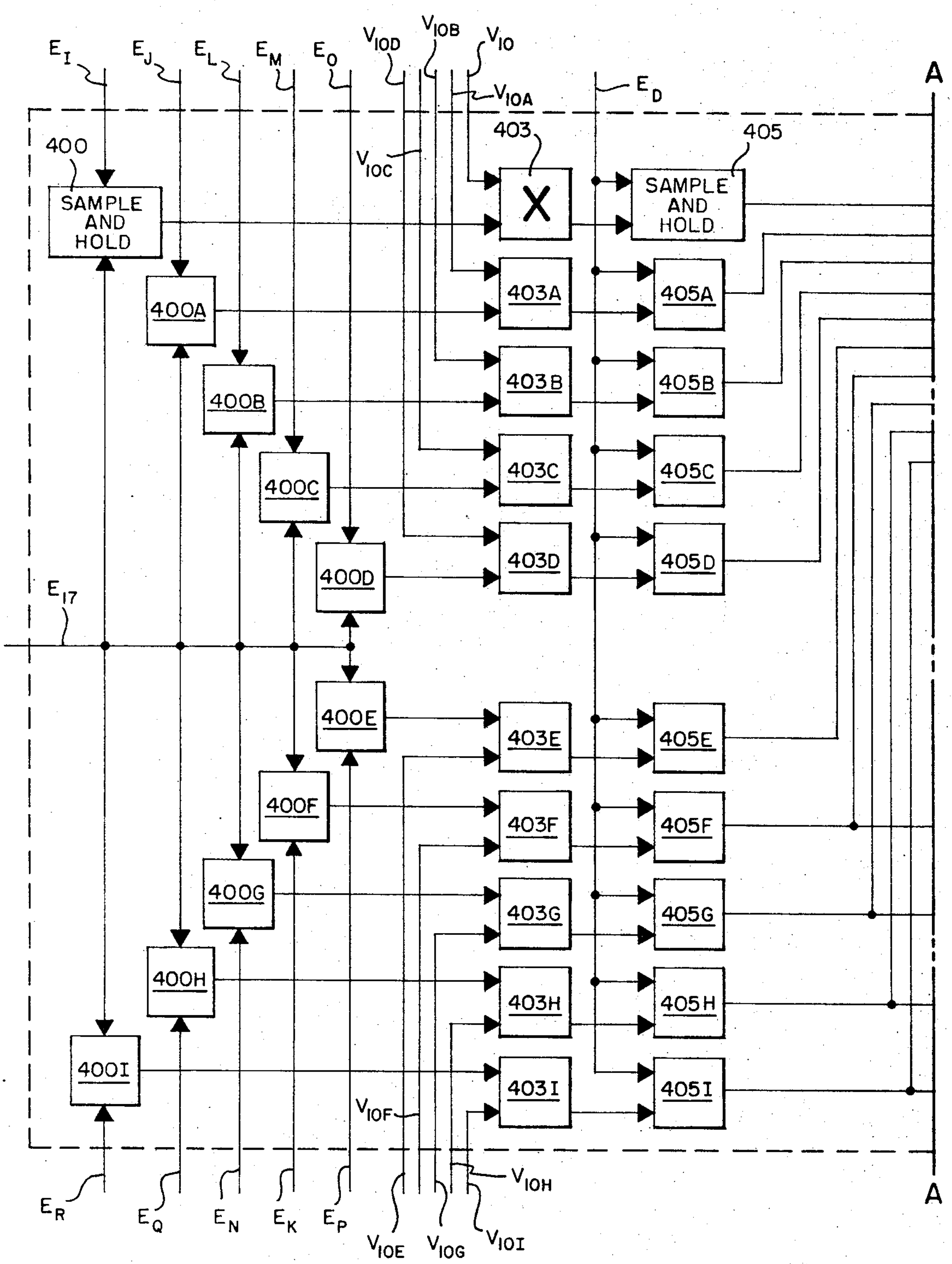
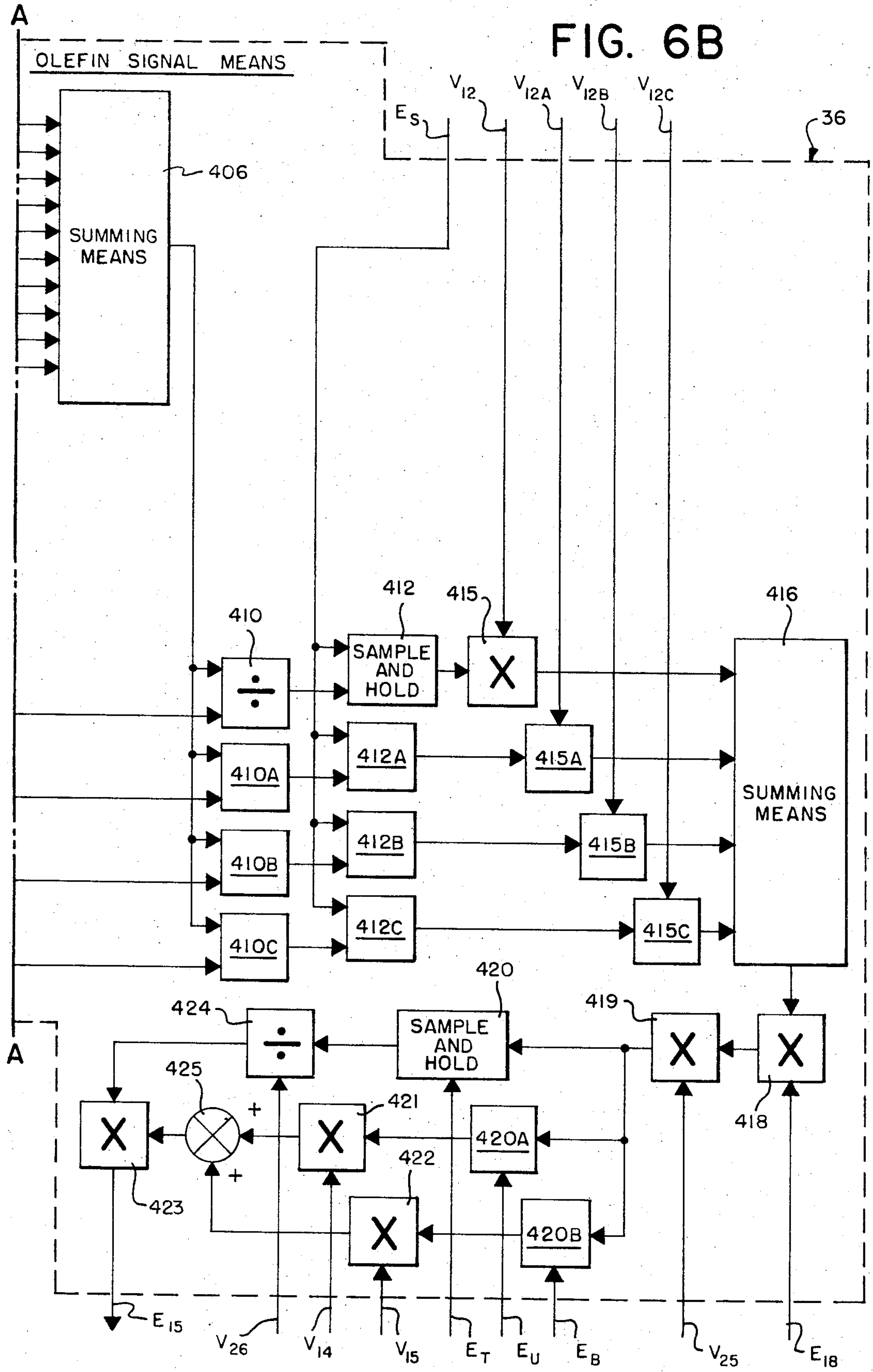

ACID STRENGTH SIGNAL MEANS
35
SAMPLE AND HOLD
300
X
304
V_1
E_3
E_4
E_A
E_7
V_{24}
V_2
V_3
304A
304B
304C
306
ELECTRONIC SWITCH
308
315
+
-
SAMPLE AND HOLD
318
318A
320
+
+
325
X
E_{14}
E_B
E_D
V_4

FIG. 6A



E_I
E_J
E_L
E_M
E_O
V_{IOD}
V_{IOB}
V_{IO}
V_{IOA}
V_{IOC}
E_D
A
400
SAMPLE AND HOLD
403
X
405
SAMPLE AND HOLD
400A
400B
400C
400D
400E
400F
400G
400H
400I
403A
403B
403C
403D
403E
403F
403G
403H
403I
405A
405B
405C
405D
405E
405F
405G
405H
405I
E_{17}
V_{IOF}
V_{IOH}
E_R
E_Q
E_N
E_K
E_P
V_{IOE}
V_{IOG}
V_{IOI}
A

FIG. 6B


A
OLEFIN SIGNAL MEANS
SUMMING MEANS
406
E_S
V_{12}
V_{12A}
V_{12B}
V_{12C}
36
410
412
415
416
SAMPLE AND HOLD
X
410A
412A
415A
410B
412B
415B
410C
412C
415C
SUMMING MEANS
420
424
419
SAMPLE AND HOLD
A
425
421
420A
418
422
423
420B
E_{15}
V_{26}
V_{14}
V_{15}
E_T
E_U
E_B
V_{25}
E_{18}

MEANS AND METHOD FOR CONTROLLING THE STRENGTH OF ACID IN AN ALKYLATION UNIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to alkylation units and, more particularly, to a control system for an alkylation unit.

2. Description of the Prior Art

Heretofore, acid control systems, such as the system disclosed in U.S. application, Ser. No. 169,385 filed on Aug. 5, 1971 by Child et al, and assigned to Texaco Inc., assignee of the present invention, uses a feedforward signal determined from the different inputs to the alkylation unit.

The system of the present invention is substantially different in that the composition of a single input is determined to develop the feedforward signal. The system of the present invention further distinguishes over the prior art by using the feedforward signal and a feedback signal corresponding to the acid strength to achieve a greater degree of control. It is not obvious, to one skilled in the art, from the aforementioned application that a feedback signal may be combined with a feedforward signal. Nor is it obvious how to combine the feedforward and feedback signals.

SUMMARY OF THE INVENTION

A system controls the strength of acid in an alkylation unit. The alkylation unit reacts isoparaffin and olefins in the presence of acid to provide an acid-hydrocarbon mixture to a settler where the hydrocarbon is separated from the acid to provide a hydrocarbon product and acid. A proportion of the acid from the settler is recycled while the remaining acid is discharged from the processing unit. Fresh acid is added to the recycle acid to replace the discharged acid thereby affecting the strength of the acid. A control device controls the quantity of the fresh acid entering the processing unit in accordance with the control signal. A sensing circuit provides a signal corresponding to the strength of the acid in the processing unit while another sensing circuit senses the constituents and a condition of the olefin and provides corresponding signals. A control network develops the control signal in accordance with the signals from the two sensing circuits.

One object of the present invention is to provide a rapid response control system for controlling the acid strength in an alkylation unit.

Another object of the present invention is to combine acidity measurements with measurements of the olefin's composition and flow rate to provide a control signal for controlling the strength of an acid in an alkylation unit.

Another object of the present invention is to provide a signal corresponding to the strength of the acid in an alkylation unit.

Another object of the present invention is to provide a signal corresponding to an anticipated required acid strength as determined in accordance with the quantity of acid consuming constituents of olefin entering an alkylation unit.

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 block diagram of a system, constructed in accordance with the present invention, for controlling the strength of acid in an alkylation unit which is also partially shown in schematic form.

FIG. 2 is a diagrammatic representation of voltage wave forms occurring during a typical cycle of operation of the system shown in FIG. 1.

FIGS. 3 through 5 are detailed block diagrams of the programmer, the set point control signal means and the acid strength signal means shown in FIG. 1, respectively.

FIGS. 6A and 6B, when matched along line A—A, is a detailed block diagram of the olefin signal means shown in FIG. 1.

DESCRIPTION OF THE INVENTION

Referring to FIG. 1, there is shown a portion of an alkylation unit in which an olefin is reacted with isoparaffin in the presence of a catalyst, such as sulfuric or hydrofluoric acid, to form a higher molecular weight isoparaffin. For purpose of explanation, the acid in the following description shall be sulfuric acid. The olefin may be butylene, propylene or a mixture of butylene and propylene, while the isoparaffin may be isobutane. The control system shown in FIG. 1 controls the strength of the acid during the reaction by determining the actual acid strength and comparing the actual acid strength with a desired acid strength. The control system also anticipates changes in the acid strength due to changes in the quantities of acid consuming constituents of the charge olefin to control the acid strength accordingly so as to speed up the control process. The charge olefin and isoparaffin enters a contactor **4**, by way of a line **6**, where the olefin and isoparaffin are contacted with acid entering by way of a line **7**. Contactor **4** provides an acid-hydrocarbon mix by way of a line **8** to an acid settler **12**. Settler **12** separates the hydrocarbon product from the acid and the hydrocarbon product is discharged through a line **14** while the acid is removed by way of a line **16**. Acid settler **12** may be the only acid settler in the unit or it may be the last acid settler of a group of acid settlers. Fresh acid enters line **16** by way of a line **17** as needed to maintain a desired acid strength. A pump **20** pumps the acid from line **16** into line **7**. A portion of the acid in line **7** is discharged by way of a line **21**. The discharge acid may be provided to another alkylation unit or disposed of.

An acid strength analyzer **22** periodically samples the acid in line **16** and provides signals E_1 through E_4. Acid strength analyzer **22** may be of the type fully disclosed in U.S. application Ser. No. 881,359 filed on Dec. 2, 1969 by R. A. Culp et al and assigned to Texaco Inc., assignee of the present invention. The acid sample is analyzed by titrating the sample with caustic from a source **24** entering analyzer by way of a line **25** at a constant rate. The start of each sampling cycle of the acid in line 16 is controlled by a reset signal E_6 from a programmer 27, as hereinafter described.

Signal E_1, shown in FIG. 2A, from analyzer 22 occurs at the time at which titration is initiated, while signal E_2, shown in FIG. 2B, occurs at the time at which titration is completed. The occurrence of pulse signal E_3 indicates that the amplitude of signal E_4 corresponds to the density of the acid sample. Signals E_1, E_2 from analyzer 22 are applied to programmer 27, while signals E_3, E_4 are applied to acid strength signal means 35, which is hereinafter described in detail.

Programmer 27 controls the timing sequence of the development of set point pulse train E_{10} and signal E_{11} provided by set point signal means 28, which are used to control the set point of a conventional flow recorder controller 30, as hereinafter explained. Controller 30 operates a valve 32, to control the flow rate of the discharge acid in line 21, in accordance with a signal E_{12} from a conventional type sensor 33, corresponding to the flow rate of the discharge acid in line 21, and its set points. It should be noted that since the acid system is essentially a closed loop system, the acid flowing in line 21 corresponds to the fresh acid flowing in line 17 so that the amount of fresh acid being added to the system is actually controlled by controlling the discharge acid in line 21.

Programmer 27 provides a signal E_7, corresponding to the titration time ΔT of the acid sample, and pulse signals E_A through E_C to acid strength signal means 35. Acid strength signal means 35 is controlled by pulse signals E_A through E_C to provide a signal E_{14} corresponding to the average strength of the acid in accordance with signal E_4 from analyzer 22 and direct current voltages V_1 through V_4 and V_{24} from a direct current voltage source 37, as hereinafter explained. Signal E_{14} is applied to set point signal means 28 which also receives a signal E_{15}, corresponding to an anticipated required acid strength, from olefin signal means 36 as determined from the olefin and isoparaffin, as hereinafter explained. Set point signal means 28 is controlled by pulse signals E_B, E_D through E_H from programmer 27 to provide pulse train E_{10} and signal E_{11} to controller 30 in accordance with signals E_{14}, E_{15} and direct current voltages V_5 through V_9 from source 37. Set point signal means 28 also provides signal E_{16} to programmer 27 as hereinafter explained. Each pulse in pulse train E_{10} changes the set point of controller 30, while signal E_{11} controls the direction of the change of the set point. Pulse train E_{10} has no pulses when the set point of controller 30 is not required to be changed.

When the discharge acid flow rate in line 21 is changed, the acid level in settler 12 changes accordingly. A level sensor 40 provides a signal corresponding to the acid level to a conventional type level recorder controller 42. Controller 42 provides a signal to a valve 45 in line 17 corresponding to the difference between the level signal from sensor 40 and the position of controller 42 set point which corresponds to a predetermined acid level for settler 12. Valve 45 controls the flow rate of the fresh acid in line 17 to restore the acid level in settler 12 to its predetermined level.

When the acid strength is to be increased, the flow rate of the discharge acid is increased, by an appropriate adjustment of the set point in controller 30, causing the acid level in settler 12 to decrease. Controller 42 operates valve 45 to increase the fresh acid flow rate thereby increasing the acid in settler 12 to the predetermined acid level. The increase in the fresh acid flow rate increases the strength of the acid in the system.

Similarly when the acid strength is to be decreased, the discharge acid flow rate is decreased causing the acid level in settler 12 to increase. The increase in the acid level causes a decrease in the fresh acid flow rate to decrease the acid in settler 12 to the predetermined acid level. The decrease in the fresh acid flow rate decreases the strength of the acid in the system.

Olefin signal means 36 provides signal E_{15} to set point signal means 28 in accordance with a signal E_{17} from chromatograph means 38, corresponding to the constituents of the charge olefin, a signal E_{18} from a conventional sensor 40 corresponding to the flow rate of the charge olefin in line 6, direct current voltages V_{10} through V_{15}, V_{25} and V_{26} from source 37, and pulse signals E_B, E_I through E_U from programmer 27, as hereinafter explained.

Chromatograph means 38 also provides a pulse train E_{17A} to programmer 27. The pulses in pulse train 17A coincide with the peaks of signal E_{17}.

Referring to FIG. 3, programmer 27 includes an on-off switch 101 which receives a direct current voltage V_{16} from source 37. Switch 101 controls the operation of the control system. When activated, switch 101 applies voltage V_{16} to an inverter 103 and to an AND gate 106. Inverter 103 inverts voltage V_{16} to reset a flip-flop 104 to a clear state. Reset pulse E_6 occurring at the end of each cycle of operation triggers flip-flop 104 to a set state in which it remains until again being reset by the closing of switch 101. In changing from the clear state to the set state, a $\overline{Q}$ output of flip-flop 104 triggers a monostable multivibrator 105. Multivibrator 105 when triggered provides pulse signal E_T.

Pulse train E_{17A} from chromatograph means 38 is applied to AND gate 106 which controls the development of pulse signals E_I through E_R. AND gate 106 is fully enabled by voltage V_{16} and a high level direct current output from a logic decoder 108. When enabled, pulse train E_{17A} passes through AND gate 106 into a conventional counter 110 which counts the pulses in signal E_{17A} corresponding to the different peaks in signal E_{17}. Logic decoder 108 decodes the count in counter 110 to provide a plurality of outputs to monostable multivibrators 114. Logic decoder 108 may be of the type that includes AND gates connected to each stage of counter 110 in a manner so that each AND gate provides an output for a different count in counter 110. Upon reaching a count of 10, the direct current output provided by logic decoder 108 to AND gate 106 goes to a low level thereby disabling AND gate 106 to block pulse train E_{17A} to prevent further counting by counter 110.

Monostable multivibrators 114 represent a plurality of monostable multivibrators, each monostable multivibrator is connected to a different AND gate in decoder 108 and is triggered by its output to provide a pulse signal. Monostable multivibrators 114 provide a plurality of pulse signals E_I through E_R which coincide with the peaks of signal E_{17} corresponding to the various constituents of the charge olefin as determined by chromatograph means 38. FIG. 2C shows pulse E_I

while FIG. 2D shows pulse E_R. It should be noted that there is only one break associated with pulse E_R. This is because pulse E_I preceded pulse E_R in time and in this particular example, pulse E_R is used to start the timing sequence and is therefore time related to the pulses shown in FIGS. 2F through 2M.

Pulse signal E_R from monostable multivibrators 114 triggers yet another monostable multivibrator 116 which acts as a time delay and provides a pulse to a flip-flop 117. The trailing edge of the pulse from multivibrator 116 triggers flip-flop 117 to its set state. The Q and $\overline{Q}$ outputs of a flip-flop are high level and low level direct current voltages, respectively, when the flip-flop is in a set state. The levels of the Q and $\overline{Q}$ outputs are reversed when the flip-flop is in a clear state. Flip-flop 117 provides its Q output as signal E_A, shown in FIG. 2E, to acid strength signal means 35 and to an AND gate 118 partially enabling AND gate 118. The end of titration signal E_2 triggers a flip-flop 132 to a set state causing flip-flop 132 to provide a high level direct current output to AND gate 118 thereby enabling AND gate 118. AND gate 118 controls the development of pulse signals E_B, E_D, E_E, E_F, E_H, E_S and E_U so that they only occur after the acid strength analysis and the charge olefin analysis have been completed.

When fully enabled, AND gate 118 passes timing pulses from a clock 120 to a conventional counter 124. A logic decoder 125 decodes the count in counter 124 to provide a plurality of triggering inputs to a plurality of monostable multivibrators shown as monostable multivibrators 127. The decoder is arranged so that there is a time differential between the next to last count provided and the last count provided. Monostable multivibrators 127 provide signals E_D, E_S, E_U, E_E, E_F, E_H and E_B as shown in FIGS. 2F through 2L, respectively. The time differential previously referred to occurs between signals E_H and E_B and should be of a sufficient duration to allow the set point in flow recorder control 30 to be moved through its entire range although usually it is not necessary to do so.

Upon termination of pulse train E_{10}, set point signal means 28 provides a signal E_{16} to a flip-flop 134 triggering flip-flop to its set state. The $\overline{Q}$ output of flip-flop 134 enables AND gate 135 when flip-flop 134 is in a clear state and disables AND gate 135 when flip-flop 134 is in a set state. When enabled, AND gate 135 effectively passes timing pulses from a clock 137 as signal E_G and blocks the timing pulses when disabled. Pulse signal E_H from multivibrators 127 triggers flip-flop 134 to a clear state so that the $\overline{Q}$ output from flip-flop 134 enables AND gate 135.

The ΔT signal E_7 is developed by a flip-flop 140, a clock 141, an AND gate 142, monostable multivibrators 144 and 145, a counter 148, a storage register 150 and a digital-to-analog converter 151. The start of titration signal E_1 from acid strength analyzer 22 triggers flip-flop 140 to a set state. The Q output of flip-flop 140 enables AND gate 142 causing it to pass timing pulses to counter 148. Counter 148 counts the timing pulses passed by AND gate 142. The end of titration signal E_2 triggers flip-flop 140 to a clear state causing the Q output to disable AND gate 140. When disabled, AND gate 142 blocks the timing pulses from clock 141 so that the count in counter 148 corresponds to the time interval between signals E_1, E_2 which is the titration time ΔT.

The change in the $\overline{Q}$ output of flip-flop 140 due to signal E_2 triggering flip-flop 140 to the clear state triggers time delay multivibrator 144 causing it to provide a pulse. The trailing edge of the pulse from multivibrator 144 triggers multivibrator 145 so that multivibrator 145 provides a pulse after counter 148 has completed a count. The pulse from multivibrator 145 controls storage register 150 to accept and store the count from counter 148. Digital-to-analog converter 151 converts the count stored in register 150 to signal E_7.

Pulse signal E_B from monostable multivibrators 127 also triggers a delay monostable multivibrator 155 which provides a pulse to another monostable multivibrator 156 whose trailing edge triggers monostable multivibrator 156 causing it to provide reset pulse E_6, shown in FIG. 2M. Reset pulse E_6 is provided to chromatograph means 28, set point signal means 28, to counters 110, 124 and 148, storage register 150, flip-flops 117, 104 and 132 resetting flip-flops 117 and 132 to the clear state to recycle the control operation.

Referring to FIG. 4, there is shown in detail set point signal means 28 which effectively combines signal E_{14}, corresponding to feedback information pertaining to the acid strength, with signal E_{15}, corresponding to the anticipated required acid strength, to provide pulse train E_{10} and signal E_{11} for changing the set point of flow recorder controller 30 as needed. Pulse train E_{10} and signal E_{11} are provided in accordance with the following equation:

1. $SP_n = SP_{n-1} + G_4\,(G_1\,F_n + G_2\,F_{n-1} + G_3|F_n|F_n) + SP_{n-1}\,(U_n)$

where SP_n is the set point value for the current cycle, SP_{n-1} is the set point value for the next previous cycle, F_n is an error between the average acid strength and the desired acid strength for the current cycle, F_{n-1} is the error for the next previous cycle, U_n is the anticipated required acid strength for the current cycle, and G_1 through G_4 are constants having the following values: 3.1, −3.0, 1.0 and 2.0, respectively.

A sample and hold circuit 201 is controlled by pulse signal E_D from programmer 27 to sample and hold direct current voltage V_5 corresponding to a desired acid strength. Subtracting means 204 subtracts the acid strength signal E_{14} from signal means 35 from the output of sample and hold circuit 201 to provide an error signal to another sample and hold circuit 205. Sample and hold circuit 205 is controlled by pulse signal E_E from programmer 27 and provides an output corresponding to the term F_n in equation 1.

Absolute value circuit 207 provides a signal corresponding to the absolute value of output F_n from sample and hold circuit 205. Absolute value circuit 207 may be a squaring circuit, which squares the output from sample and hold circuit 205, and a square root circuit for taking the square root of the output from the squaring circuit to provide the absolute value signal $|F_n|$. The absolute value signal $|F_n|$ is multiplied by the F_n signal from sample and hold circuit 205 by a multiplier 209. The product signal from multiplier 209 is multiplied with direct current voltage V_6, corresponding to the G_3 term in equation 1, by a multiplier 210.

The output from a sample and hold circuit 206, corresponding to the term F_{n-1}, is multiplied with a direct current voltage V_7, corresponding to the term G_2 in equation 1, by a multiplier 214. Sample and hold circuit 206 is controlled by pulse signal E_B to accept and store the F_n signal from sample and hold circuit **205** so that it may be used as the F_{n-1} signal during the next cycle.

A multiplier **217** multiplies the F_n signal from sample and hold circuit **205** with direct current voltage V_8 corresponding to the term G_1 in equation 1. Summing means **218** sums the product signals from multipliers **210**, **214** and **217** to provide a sum signal to another multiplier **220**.

Multiplier **220** multiplies the sum signal with direct current voltage V_9, corresponding to the term G_4 in equation 1, to provide an output that corresponds to $G_4(G_1F_n+G_2F_{n-1}+G_3|F_n|F_n)$.

Summing means **225** sums the output from multiplier **220** with a signal, corresponding to the term SP_{n-1} in equation 1, from a sample and hold circuit **226** and a signal from a multiplier **227** which corresponds to the term $SP_{n-1}(U_n)$. Summing means **225** provides a sum signal, which corresponds to the term SP_n, to sample and hold circuit **230** which is controlled by pulse signal E_F from programmer **27**.

The SP_{n-1} and SP_n outputs from sample and hold circuits **226** and **230**, respectively, are compared with each other by a comparator **244** to provide signal E_{11}. When the output from sample and hold circuit **226** is greater than the output from sample and hold circuit **230**, signal E_{11} from comparator **244** is of one level to control the direction of change of the set point in flow recorder controller **30** so that the change, if any, will be in the one direction. When the output from sample and hold circuit **226** is equal to or less than the output from sample and hold circuit **230**, signal E_{11} from comparator **244** is of another level so that the set point in flow recorder controller **30** may be changed in an opposite direction.

Subtracting means **245** subtracts the SP_{n-1} output from sample and hold circuit **226** from the SP_n output provided by sample and hold circuit **230** to provide an error signal, corresponding to the change in set point, to an analog-to-digital converter **248**, which converts the error signal to a digital signal. Pulse signal E_H from programmer **27** controls a conventional type countdown counter **250** to enter the digital signal from converter **248**. Counting pulses E_G from programmer **27** enter countdown counter **250** causing counter **250** to count down. Counting pulses E_G are also provided as pulse train E_{10}. Upon reaching a count of zero, a logic decoder **251** provides signal E_{16} to programmer **27**, which terminates counting pulses E_G, as heretofore explained, so that the number of pulses in signal E_{10} corresponds to the proper change in set point value.

Sample and hold circuit **226** is controlled by pulse signal E_B from programmer **27** to hold the SP_n signal from sample and hold circuit **230** so that it is available as the SP_{n-1} signal during the next cycle. The SP_{n-1} signal from sample and hold circuit **226** is multiplied with signal E_{15} from olefin signal means **36** by multiplier **227** to provide the $SP_{n-1}(U_n)$ signal.

Referring to FIG. **5**, acid strength signal means **35** essentially comprises two analog computers. One analog computer provides a signal corresponding to the acid strength AS in accordance with the following equations:

2. $AS=(VOL_c)(N_c)(MEQ_A)/W_A$

where VOL_c is the volume of caustic required by the titration of the acid sample, N_c is the normality of the caustic, MEQ_A is milliequivalent weight of the acid, and W_A is the weight of the acid. Equation 2 may be rewritten as:

3. $AS=(\Delta T)(FR_c)(N_c)(MEQ_A)/(D_A)(VOL_S)$

where ΔT is the titration time, FR_c is the flow rate of the caustic, D_A is the density of the acid and VOL_s is the volume of the acid sample. The analog computer for solving equation 3 includes sample and hold circuit **300**, multipliers **304** through **304C**, a divider **306** and an electronic switch **308**. Signal E_3 from analyzer **22** occurs when signal E_4 corresponds to the density D_A of the acid sample and controls sample and hold circuit **300** to hold signal E_4 at that time. The output of sample and hold circuit **300** is applied to multiplier **304** where it is multiplied with a direct current voltage V_1 which corresponds to the volume VOL_s of the acid sample. Multiplier **304** provides a signal corresponding to the denominator in equation 3.

Multiplier **304A** multiplies the ΔT signal E_7 from programmer **27** with the caustic flow rate voltage V_{24} from source **37** to provide a product signal corresponding to $(\Delta T)(FR_c)$. The product signal from multiplier **304A** is multiplied with direct current voltage V_2 corresponding to the normality of the caustic, which by way of example, may be 0.2 meq/ml, to provide a product signal to multiplier **304C** where it is multiplied with direct current voltage V_3. Direct current voltage V_3 corresponds to the milliequivalent weight MEQ_A of the acid which for purpose of illustration may be sulphuric acid H_2SO_4 whose milliequivalent weight is 0.04904 grams/meq.

The product signal from multiplier **304C** corresponds to the numerator in equation 3. Divider **306** divides the numerator signal from multiplier **304C** with the denominator signal from multiplier **304** to provide a signal, which corresponds to the term AS in equation 3, to electronic switch **308**. Electronic switch **308** is controlled by pulse signal E_A so as to pass the acid strength signal AS from divider **306** once every cycle.

The second analog computer in acid strength signal means **35** provides a signal in accordance with the following equation 4 and includes subtraction means **315**; sample and hold circuits **318**, **318A**; summing means **320** and a multiplier **325**:

4. $\overline{AS_n}=\overline{AS_{n-1}}+C_1(AS_n-\overline{AS_{n-1}})$

where $\overline{AS_n}$ is the average acid strength during the current cycle, $\overline{AS_{n-1}}$ is the acid strength during the next previous cycle, AS_n is an instantaneous acid strength obtained during the current cycle and C_1 is a constant having a value of 0.75. Subtracting means **315** subtracts an output from sample and hold circuit **318**, which corresponds to the term $\overline{AS_{n-1}}$ in equation 3, from the passed acid strength signal from switch **308** to provide a signal corresponding to the expression $(AS_n-\overline{AS_{n-1}})$. A multiplier **325** multiplies the signal from subtracting means **315** with a direct current voltage V_4 corresponding to the constant C_1 having a value of 0.75. The output from multiplier **325** is applied to summing means **320** along with the output from sample and hold circuit **318** to provide a signal corresponding to the average acid strength $\overline{AS_n}$ to sample and hold circuit **318A**. Pulse signal E_D controls sample and hold circuit **318A** to hold the $\overline{AS_n}$ signal to provide signal E_{14}. Sample and hold circuit **318** is controlled by pulse signal E_B from programmer **27** to store the $\overline{AS_n}$ signal from sample and hold circuit **318A** for use as the $\overline{AS_{n-1}}$ signal during the next subsequent cycle.

Referring to FIGS. **6A** and **6B**, the peaks of signal E_{17} from chromatograph means **38** correspond to the different constituents of the charge olefin in line **6**. Sample and hold circuits **400** through **400I** are controlled by pulse signals E_I through E_R to hold the different peaks of signal E_{17}. The following table relates a particular sample and hold circuit to a corresponding constituent.

Circuit	Constituent	Circuit	Constituent
400	Ethane	400E	Normal Pentane
400A	Propane	400F	Propylene
400B	Iso-Butane	400G	Butylene
400C	Normal Butane	400H	Pentylene
400D	Iso-Pentane	400I	All compounds with 6 or more carbon atoms

The output from sample and hold circuits **400** through **400I** are applied to multipliers **403** through **403I** where they are multiplied with voltages V_{10} through V_{10I}, respectively, corresponding to the various chromatograph means **38** scaling factors pertaining to the particular constituents. By way of example, the voltages V_{10} through V_{10I} may correspond to 0.02, 0.2, 1.0, 0.2, 0.15, 0.02, 0.2, 0.10, 0.02 and 0.10 volts, respectively. The product signals from multipliers **403** through **403I** are sampled and held by circuits **405** through **405I** respectively in response to pulse signal E_D from programmer **27**. Sample and hold circuits **405** through **405I** are used so that outputs corresponding to the various constituents of the charge olefin may be presented simultaneously to summing means **406**. Summing means **406** provides a normalizing signal.

Not all of the constituents in the charge olefin affect the acid strength. It has been determined that the propylene, butylene, pentylene and some compounds with six or more carbon atoms affect the acid strength. Therefore, the signals from sample and hold circuits **403F** through **403I**, corresponding to those constituents, are operated upon to provide signal E_{15}.

Dividers **410** through **410C** divide the signals corresponding to those four constituents from sample and hold circuits **405F** to **405I** with the normalizing signal from summing means **406**. The signals from dividers **410** through **410C** are sampled and held each period by sample and hold circuits **412** through **412C** in response to pulse signal E_S from programmer **27**.

Multipliers **415** through **415C**, summing means **416** and **425**, multipliers **418**, **422** and **423**, sample and hold circuits **420** through **420B**, and a divider **424** comprise an analog computer for solving the following equations:

5. $A = KR(C_1Q_1 + C_2Q_2 + C_3Q_3 + C_4Q_4)$

where A is the load value on the acid system, K is a constant having a value of 1.0, R is the flow rate of the charge olefin, C_1 through C_4 are constants corresponding to the ratio of pounds of acid consumed per gallon of olefin for the acid consuming constituents and Q_1 through Q_4 are percentages of the acid consuming constituents in the charge olefin.

6. $U_n = P_3/A_o\,(P_1A_n + P_2A_{n-1})$

where U_n is the anticipated required acid strength during the current cycle, A_o is an initial load value on the acid system, while A_n and A_{n-1} are the load values for the current cycle and the next previous cycle, respectively, and P_1, P_2 and P_3 are dynamic constants of the system having the following values: 1.0, −1.0 and 1.0, respectively.

Multipliers **415** through **415C** multiply the outputs from sample and hold circuits **412** through **412C** with direct current voltages V_{12} through V_{12C} corresponding to the constants C_1 through C_4 in equation 5. Summing means **416** sums the outputs from multipliers **415** through **415C** to provide a sum signal which is multiplied by the charge olefin flow rate signal E_{18}, from sensor **40**, by multiplier **418** to provide a signal to a multiplier **419**. Multiplier **419** multiplies the signal from multiplier **418** with voltage V_{25}, which corresponds to the term K in equation 5, to provide a signal corresponding to the term A in equation 5.

Sample and hold circuit **420** is controlled by pulse signal E_T from programmer **27** which occurs early in the processing to hold the signal from multiplier **418** as the A_o signal. Divider **424** divides direct current voltage V_{14}, which corresponds to the term P_3 in equation 6, with the output from sample and hold circuit **420** to provide a signal corresponding to P_3/A_o.

Sample and hold circuit **420A** is controlled each cycle by pulse signal E_U from programmer **27** to sample and hold the output from multiplier **419** thereby providing a signal to a multiplier **421** corresponding to the term A_n in equation 6. Multiplier **421** multiplies the signal from circuit **420** with direct current voltage V_{26}, which corresponds to the constant P_1 in equation 6, to provide an output to summing means **425**. Sample and hold circuit **420B** is controlled by pulse signal E_B from programmer **27** at the end of each cycle, to sample and hold the output from multiplier **419** to provide a signal for the next subsequent cycle corresponding to A_{n-1}. The signal from sample and hold circuit **420B** is multiplied with direct current voltage V_{15} corresponding to the term P_2. Summing means **425** sums the output from multiplier **421** with the product signal from multiplier **422** to provide a signal, corresponding to the bracketed portion of equation 6, which is multiplied with the signal from divider **424** by multiplier **423** to provide signal E_{15}.

Although the system of the present invention has been shown as using analog computers, it may be used with a digital computer. Set point signal means **28**, acid strength signal means **35** and olefin signal means **36** are replaced by the digital computer. Conventional analog-to-digital converting techniques are used along with sample and hold circuits. Some of the sample and hold circuits are controlled by programmer **27** to hold the peaks of signal E_{17} as is done with the analog computers. Another sample and hold circuit is controlled by signal E_2 from acid strength analyzer **22** to hold the density signal E_4. The output of the sample and hold circuits and signals E_5 and E_{18} are converted to digital signals.

The system of the present invention as heretofore described provides a rapid response control system for controlling the acid strength in an alkylation unit. Measurements of the acid strength are combined with the measurements of the olefin composition and flow rate to provide a control signal for controlling the strength of the acid in the alkylation unit. The system of the present invention, as heretofore described, provides a signal corresponding to the strength of the acid in the alkylation unit and another signal corresponding to an anticipated required acid strength as determined in accordance with a quantity of acid consuming constituents of olefin entering the alkylation unit.

What is claimed is:

1. A system for controlling the strength of an acid in an alkylation unit wherein an isoparaffin is reacted with olefin in the presence of the acid to provide an acid-hydrocarbon mixture to a settler where the hydrocarbon is separated from the acid to provide a hydrocarbon product and a portion of the acid is recycled while the remaining acid is discharged from the alkylation unit and wherein fresh acid is added to the recycled acid to replace the discharged acid to affect the strength of the acid, comprising means for controlling the strength of the acid in the alkylation unit in accordance with a control signal, means for determining the strength of the acid and providing a signal corresponding thereto, means for determining the composition of the olefin and providing corresponding signals, means for sensing a condition of the olefin and providing a signal corresponding thereto, means for providing a reference signal corresponding to a desired acid strength, a circuit connected to the acid strength determining means and to the reference signal means for providing an error signal in accordance with the difference between the acid strength signal and the reference signal, and means for providing the control signal to the control means in accordance with the error signal and the signals corresponding to the composition and condition of the olefin.

2. A method for controlling the strength of an acid in an alkylation unit wherein an isoparaffin is reacted with olefin in the presence of the acid to provide an acid hydrocarbon mixture to a settler where the hydrocarbon is separated from the acid to provide a hydrocarbon product and a portion of the acid is recycled while the remaining acid is discharged from the alkylation unit, and wherein fresh acid is added to the recycled acid to replace the discharged acid to affect the strength of the acid, which comprises controlling the strength of the acid in the alkylation unit in accordance with a control signal, determining the strength of the acid in the processing unit and providing a signal corresponding thereto, sensing the quantity and composition of the olefin entering the alkylation unit, providing signals corresponding to sensed quantity and composition of the olefin, providing a reference signal corresponding to a desired acid strength providing an error signal in accordance with the difference between the acid strength signal and the reference signal, and providing a control signal in accordance with the error signal and the signals corresponding to the composition and quantity of the olefin.

3. A control system as described in claim 1 further comprising programming means connected to the determining means and to the control signal means for starting and stopping the operation of the control system and for periodically recycling the operation of the control system.

4. A control system as described in claim 3 in which the acid strength determining means includes acid strength analyzing means controlled by the programming means for periodically sampling the acid and titrating the sample acid with a caustic entering the analyzing means and providing signals corresponding to the elapsed time ΔT required for titration, and to the density D_A of the acid; and means for providing a signal corresponding to the flow rate F_C of the caustic entering the analyzing means and providing a signal corresponding thereto.

5. A control system as described in claim 4 in which the acid strength determining means also provides a signal corresponding to the average acid strength $\overline{AS_n}$ for the current cycle of operation as the acid strength signal in accordance with the following equations:

$$AS=(\Delta T)(F_c(N_c)(MEQ_A)/(VOL_S)(D_A)$$

$$\overline{AS_n}=\overline{AS_{n-1}}+C_5(AS_n-\overline{AS_{n-1}})$$

where AS is the instantaneous acid strength, N_c is the normality of the caustic, MEQ_A is the milliequivalent weight of the acid, and VOL_S is the volume of the acid sample, $\overline{AS_{n-1}}$ is the acid strength for the previous cycle, AS_n is the instantaneous acid strength during the current cycle, and C_5 is a constant having the following value: 0.75.

6. A control system as described in claim 5 in which the composition signal means includes chromatograph means sampling the olefin and providing a signal corresponding to constituents of the charge olefin, as the composition signal, and the sensed condition of the olefin is the sensed flow rate of the olefin.

7. A control system as described in claim 6 in which the control signal means includes means for providing a signal corresponding to the instantaneous acid consumption A due to the acid consuming constituents of the olefin, and means connected to the constituents signal means for providing a signal corresponding to an anticipated required acid strength U_n for the current cycle of operation in accordance with the following equations:

$$A=K\,R(C_1\,Q_1+C_2\,Q_2+C_3\,Q_3+C_4\,Q_4),\text{ and}$$

$$U_n=P_3/A_o\,(P_1\,A_n+P_2\,A_{n-1})$$

where K is a constant corresponding to volume of hydrocarbon product obtained from a unit volume of olefin, R is the flow rate of the olefin, C_1, C_2, C_3 and C_4 are pounds of acid per gallon of product produced for corresponding constituents of the olefin, Q_1, Q_2, Q_3 and Q_4 are ratios of the acid consuming constituents to the whole olefin, A_o is the acid consumption a short time after the start of operation of the control method, A_n is the acid consumption during the current cycle, A_{n-1} is the acid consumption during the previous cycle, and P_1, P_2 and P_3 are constants pertaining to the dynamic characteristics of the control system.

8. A control system as described in claim 7 in which the control means includes a valve through which the discharge acid flows and the acid strength is controlled by controlling the flow rate of the discharge acid, a sensor sensing the flow rate of the discharge acid and providing a signal corresponding thereto, and the control signal means includes a flow controller, having a set point whose position corresponds to a flow rate, connected to the discharge acid flow rate sensor and providing the control signal to the valve in accordance with a difference between the flow rate determined by the position of the flow controller's set point and the flow rate signal from the discharge acid flow rate sensor, and means connected to the flow controller, to the anticipated required acid strength signal means, to the

reference signal means and to the average acid strength signal means for providing a direction signal and a pulse train, each pulse in the pulse train changing the position of the set point in the flow controller by a predetermined amount in a direction determined by the direction signal, in accordance with the following equation:

$SP_n = SP_{n-1} + G_4(G_1F_{n-1} + GF_{n-2} + G_3|F_n|F_n) + SP_{n-1}(U_n)$,

where SP_n is the number of pulses in the pulse train during the current cycle, SP_{n-1} is the number of pulses in the pulse train for the previous cycle, F_n is a difference between the desired acid strength, and the average acid strength for the current cycle, F_n is the absolute value of F_n, F_{n-1} is a difference between the desired acid strength and the average acid strength for the previous cycle, and G_1, G_2 and G_3 are dynamic constants of the control system.

9. A method as described in claim **2** in which the steps are repeated periodically.

10. A method as described in claim **9** in which the acid strength determining step includes sampling the acid in the processing unit, titrating the sample acid with a steady flow of a caustic, and the acid strength signal step includes providing a signal corresponding to the titration time ΔT of the sample acid, a signal corresponding to the flow rate F_c of the caustic, and a signal corresponding to the density D_A of the acid sample, and providing the acid strength signal, which corresponds to an average acid strength $\overline{AS}$ for the current cycle, in accordance with the ΔT, F_C and D_A signals and following equations:

$AS = (\Delta T)(F_C)(N_C)(MEQ_A)/(D_A)(VOL_S)$

and

$\overline{AS}_n = \overline{AS}_{n-1} + C_5(AS_n - \overline{AS}_{n-1})$

where AS is the instantaneous acid strength, N_c is the normality of the caustic, MEQ_A is the milliequivalent weight of the acid, VOL_S is the volume of the acid sample, $\overline{AS}_{n-1}$ is the average acid strength for the next previous cycle, AS_n is an instantaneous acid strength occurring during the current cycle, and C_5 is a constant having the following value: 0.75.

11. A method as described in claim **10** in which the olefin quantity and composition step includes sensing the quantities of acid consuming constituents of the olefin entering the processing unit during each cycle, and providing signals corresponding to the quantities of acid consuming constituents of the olefin.

12. A method as described in claim **11** in the control signal step includes providing a signal corresponding to an anticipated required acid strength U_n for the current cycle in accordance with the acid consuming constituents signal and the following equation:

$A = KR(C_1Q_1 + C_2Q_2 + C_3Q_3 + C_4Q_4)$

and

$U_n = P_3/A_o\,(P_1A_n + P_2A_{n-1})$

where A is the instantaneous acid consumption due to the acid consuming constituents of the olefin, K is a constant corresponding to volume of bycarbon product obtained from a unit volume of olefin, R is the flow rate of the olefin, C_1, C_2, C_3 and C_4 are pounds of acid per gallon of product produced for corresponding constituents of the olefin, Q_1, Q_2, Q_3 and Q_4 are ratios of the acid consuming constituents to the whole olefin, A_o is the acid consumption a short time after the start of operation of the control method, A_n is the acid consumption during the current cycle, A_{n-1} is the acid consumption during the previous cycle, and P_1, P_2 and P_3 are relating to the dynamic constants of the control method.

13. A method as described in claim **12** in which the acid strength is controlled by controlling the flow rate of the discharge acid with a value responsive to the control signal, and the control signal is provided by a flow controller having set points in accordance with a difference between a signal corresponding to the flow rate of the discharge acid and the position of set points corresponding to a flow rate of the discharge acid, and the control signal step includes providing a reference signal corresponding to a desired acid strength, providing a direction signal and a pulse train to the flow controller, each pulse in the pulse train changes the position of the set points a predetermined amount in a direction controlled by the direction signal, in accordance with the average acid strength signal, the reference signal and the anticipated required acid strength signal and the following equation:

$SP_n = SP_{n-1} + G_4(G_1F_n + G_2F_{n-1} + G_3|F_n|F_n) + SP_{n-1}(U_n)$

where SP_n corresponds to the number of pulses in the pulse train for the current cycle, SP_{n-1} corresponds to the number of pulses in the pulse train for the next previous cycle, F_n corresponds to the difference between the reference signal and the average acid strength signal for the current cycle, F_n is the absolute value of F_n, F_{n-1} is the difference between the reference signal and the average acid strength signal for the next previous cycle.

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