United States Patent [19]

Sweeney, Jr.

[11] **3,778,603**

[45] **Dec. 11, 1973**

[54] **MEANS AND METHOD FOR ACHIEVING AN OPTIMUM OPERATING CONDITION FOR AN ALKYLATION UNIT**

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

[22] Filed: **May 26, 1972**

[21] Appl. No.: **257,408**

[52] **U.S. Cl.**........ **235/151.12,** 208/133, 208/DIG. 1, 260/683.59, 235/150.1

[51] **Int. Cl.**.... **G06f 15/46,** G06g 7/58, G05b 13/02

[58] **Field of Search**..................... 235/151.12, 150.1

[56] **References Cited**

UNITED STATES PATENTS

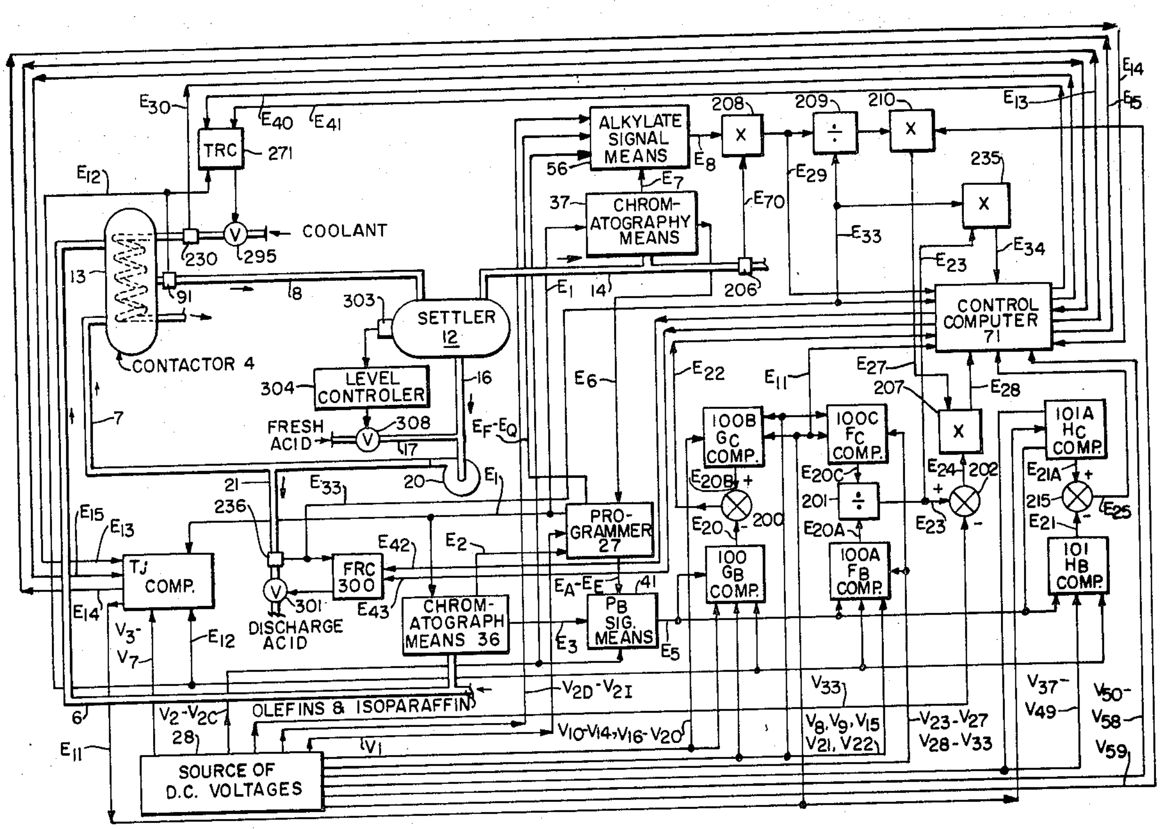
3,458,691	7/1969	Boyd, Jr.	235/151.12
3,602,701	8/1971	Boyd, Jr.	235/150.1
3,002,818	10/1961	Berger	235/151.12

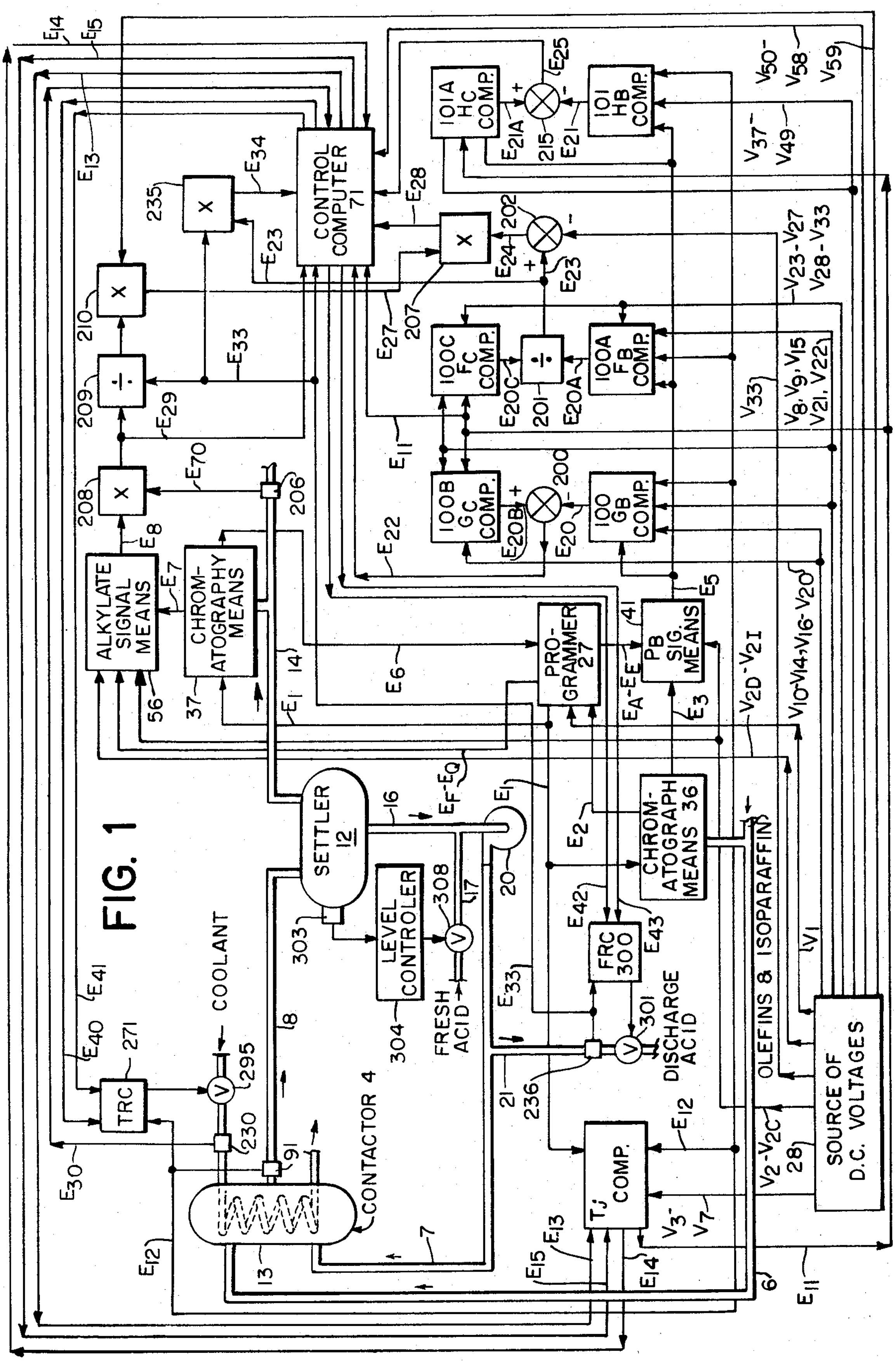
Primary Examiner—Eugene G. Botz
Attorney—Thomas H. Whaley et al.

[57] **ABSTRACT**

A system controls the temperature at which olefins are contacted with an isoparaffin in the presence of acid in an alkylation unit, and the flow rate of acid entering or leaving the alkylation unit. The system senses conditions of a hydrocarbon product, which results when the acid is removed from a hydrocarbon-acid mixture after the contacting process, the contact temperature, a condition relating to the contact acid and the olefin composition. The system includes a source providing signals corresponding to the economic values related to the octane rating of alkylate, which is produced from the hydrocarbon product, to the acid consumption and to the cost of controlling the contact temperature. The system uses the signals corresponding to the sensed conditions and the economic value signals to develop control signals for apparatus that control the contact temperature and the acid flow rate.

12 Claims, 6 Drawing Figures

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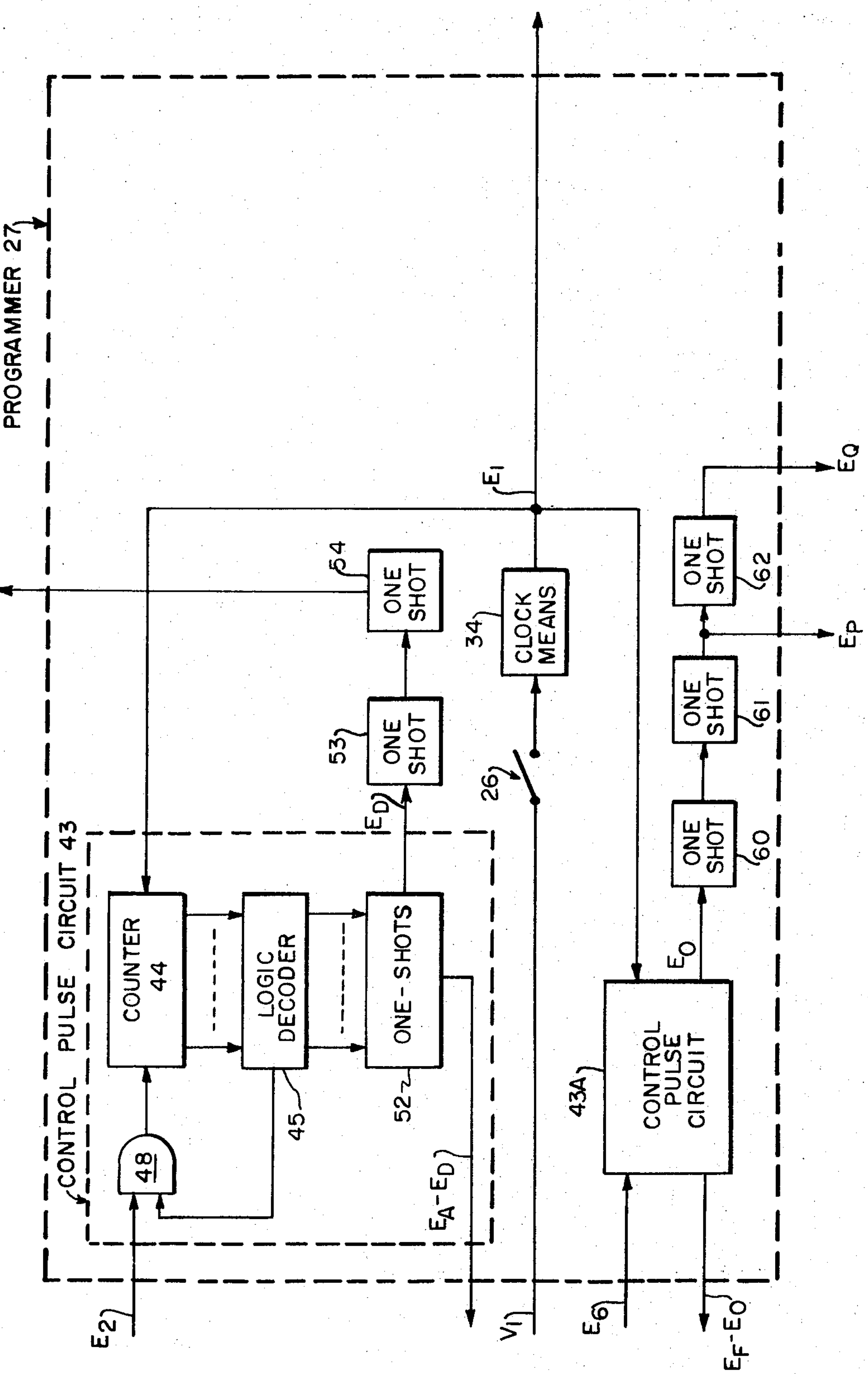
ALKYLATE SIGNAL MEANS
CHROMATOGRAPHY MEANS
PROGRAMMER 27
PB SIG. MEANS
CHROMATOGRAPH MEANS 36
SETTLER 12
LEVEL CONTROLER
FRC 300
TRC
COOLANT
CONTACTOR 4
FRESH ACID
DISCHARGE ACID
OLEFINS & ISOPARAFFIN
T_J COMP.
SOURCE OF D.C. VOLTAGES
100 GB COMP.
100B GC COMP.
100C FC COMP.
100A FB COMP.
101A HC COMP.
101 HB COMP.

FIG. 1

FIG. 2


PROGRAMMER 27
CONTROL PULSE CIRCUIT 43
COUNTER 44
LOGIC DECODER
ONE-SHOTS
48
45
52
53
54
ONE SHOT
ONE SHOT
E_E
E_D
E_A-E_D
E_2
E_1
CLOCK MEANS
34
26
V_1
CONTROL PULSE CIRCUIT
43A
E_6
E_F-E_O
E_O
ONE SHOT
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ONE SHOT
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61
62
E_P
E_Q

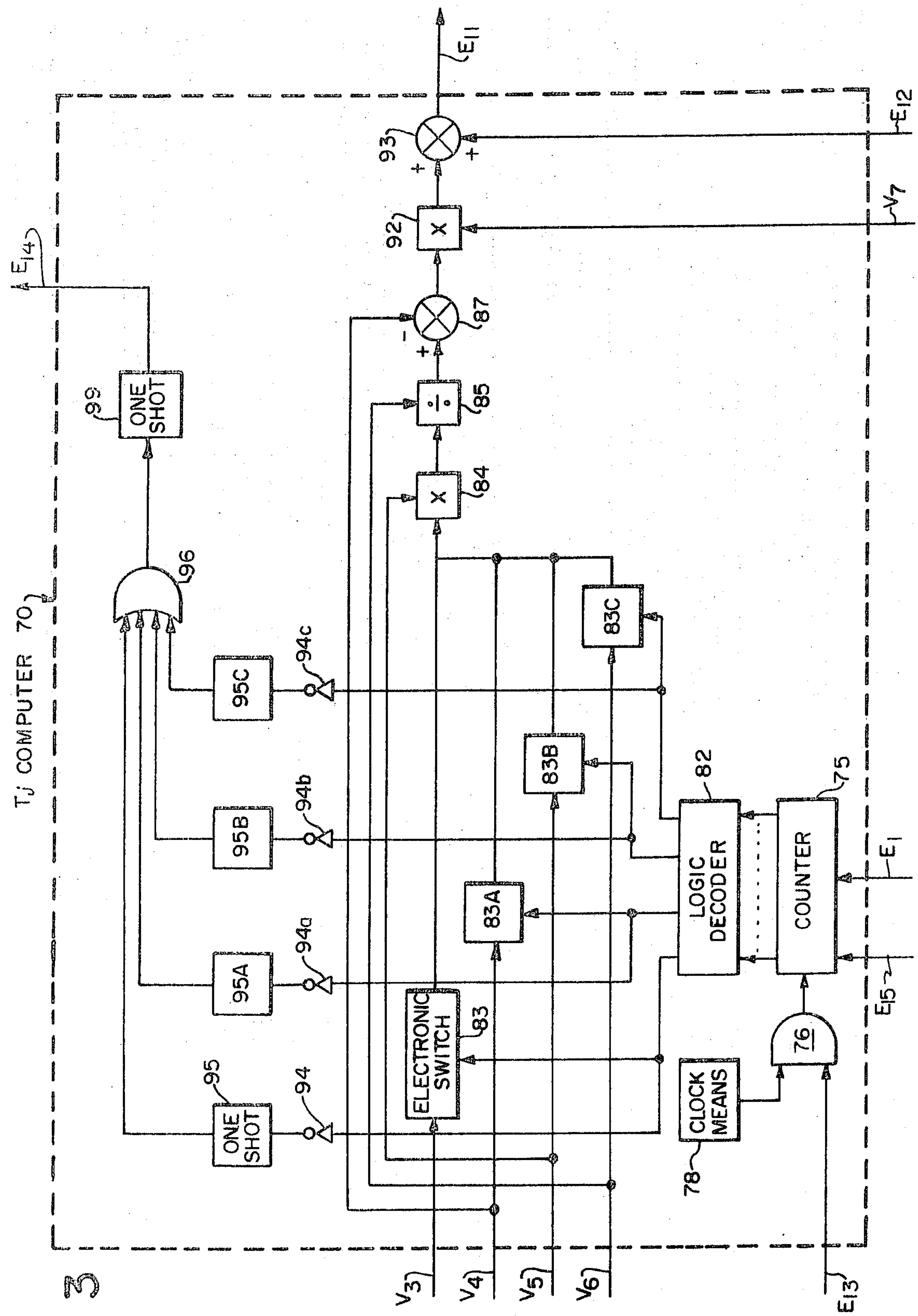

Tj COMPUTER 70
ONE SHOT
ELECTRONIC SWITCH
LOGIC DECODER
COUNTER
CLOCK MEANS
83A
83B
83C
95A
95B
95C
E11
E12
E13
E14
E15
E1
V3
V4
V5
V6
V7

FIG. 3

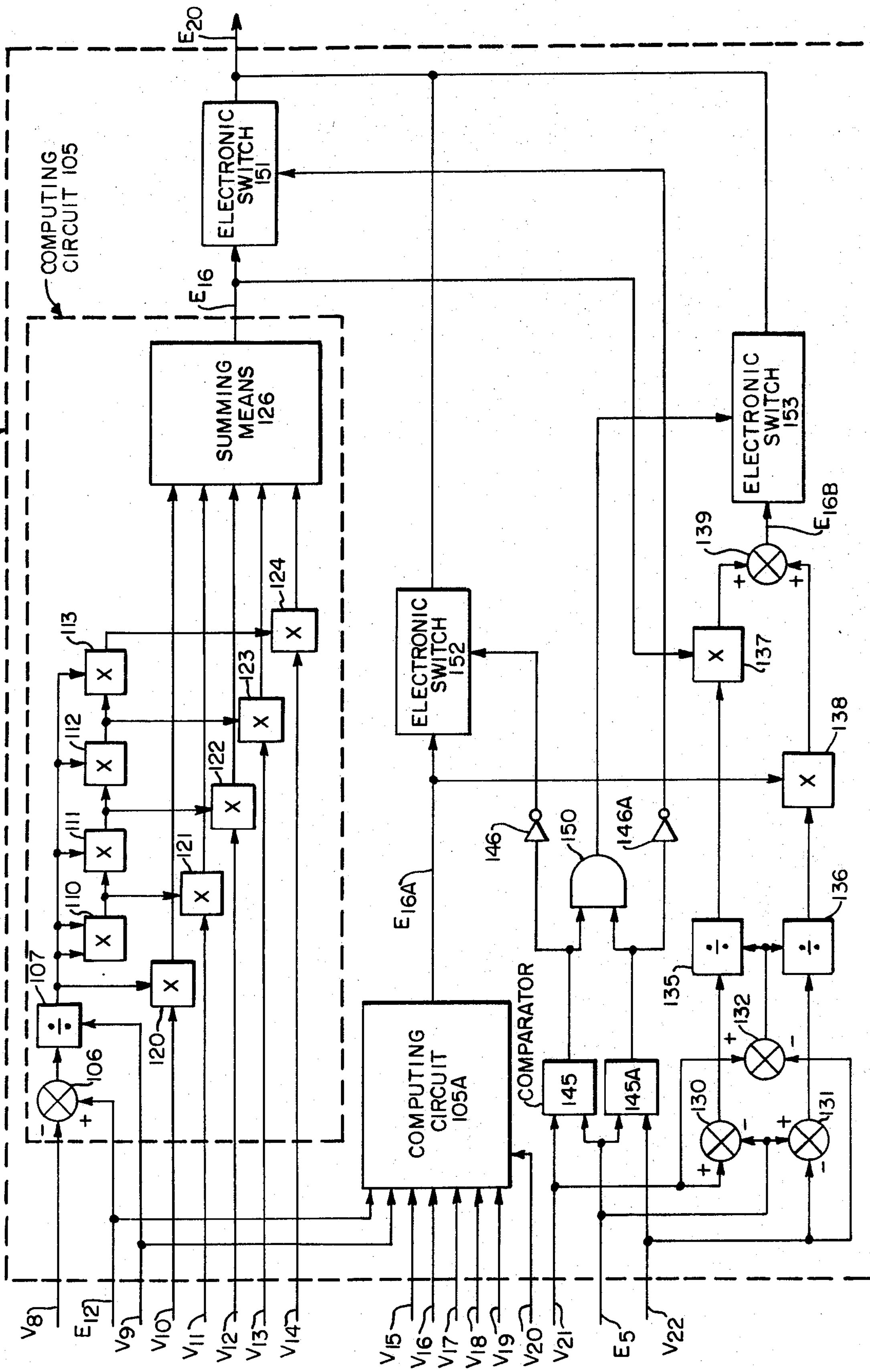

E20
ELECTRONIC SWITCH 151
COMPUTING CIRCUIT 105
E16
SUMMING MEANS 126
GB COMPUTER 100
ELECTRONIC SWITCH 153
E16B
ELECTRONIC SWITCH 152
E16A
COMPUTING CIRCUIT 105A
COMPARATOR
145
145A
V8
E12
V9
V10
V11
V12
V13
V14
V15
V16
V17
V18
V19
V20
V21
E5
V22

FIG. 4

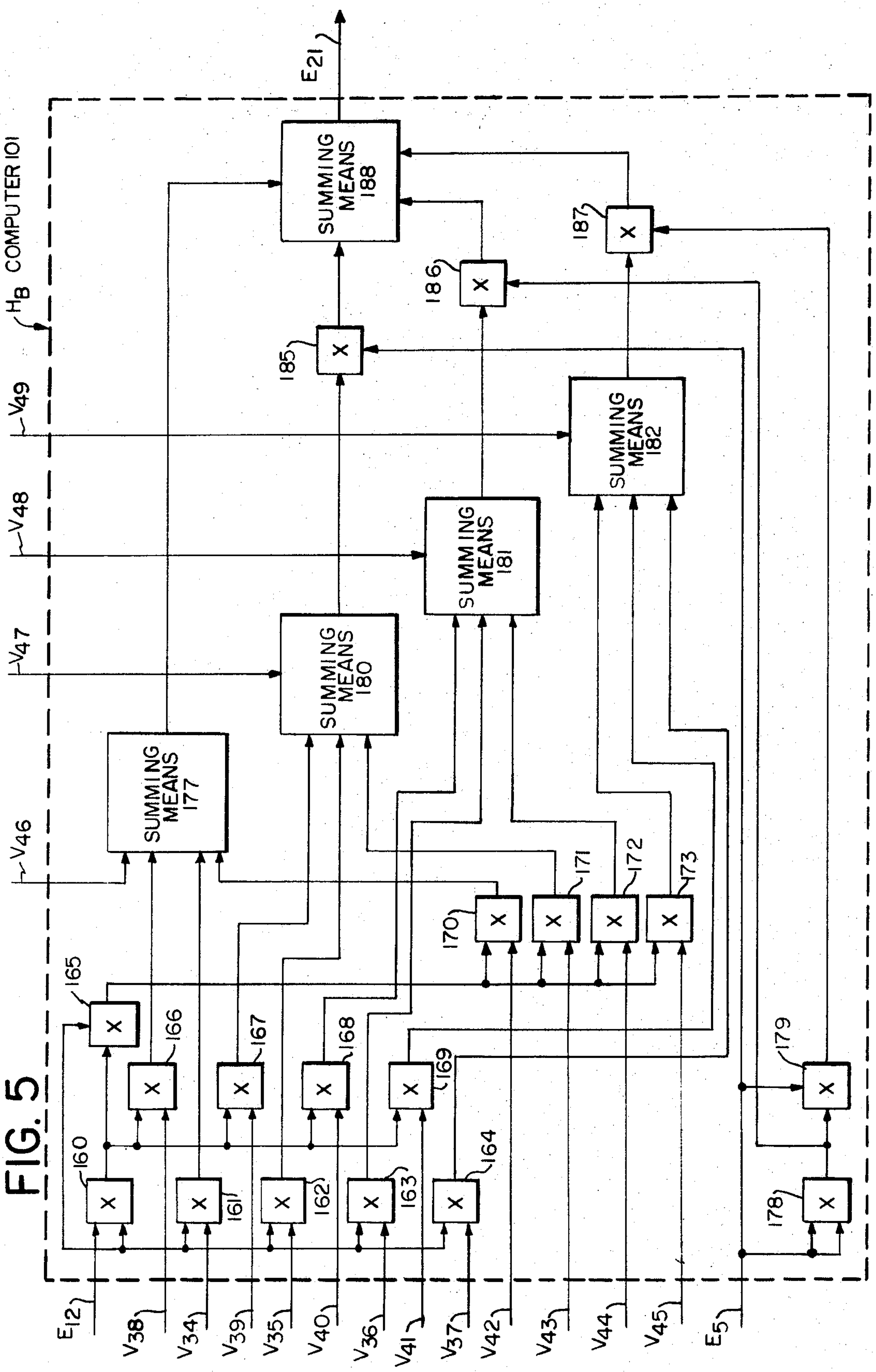
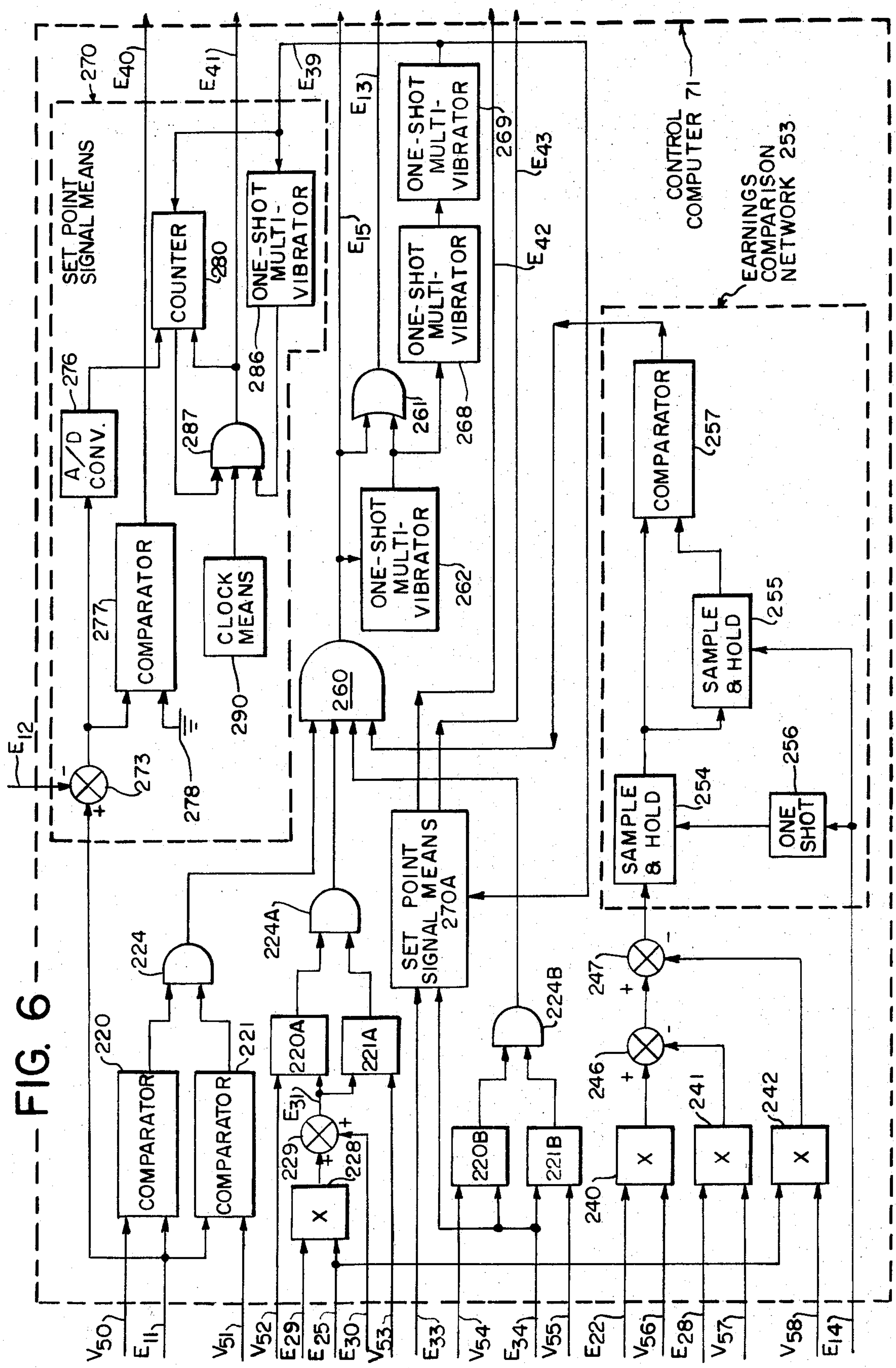

E21
H_B COMPUTER 101
SUMMING MEANS 188
SUMMING MEANS 177
SUMMING MEANS 180
SUMMING MEANS 181
SUMMING MEANS 182
V46
V47
V48
V49
E12
V38
V34
V39
V35
V40
V36
V41
V37
V42
V43
V44
V45
E5

FIG. 5

FIG. 6


CONTROL COMPUTER 71
SET POINT SIGNAL MEANS
270
COUNTER
280
ONE-SHOT MULTI-VIBRATOR
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A/D CONV.
COMPARATOR
277
CLOCK MEANS
290
273
278
220
221
224
224A
220A
221A
229
228
260
ONE-SHOT MULTI-VIBRATOR
262
261
268
269
SET POINT SIGNAL MEANS 270A
220B
221B
224B
EARNINGS COMPARISON NETWORK 253
COMPARATOR
257
SAMPLE & HOLD
255
254
ONE SHOT
256
246
247
240
241
242
E_{40}
E_{41}
E_{39}
E_{13}
E_{15}
E_{42}
E_{43}
E_{12}
E_{31}
V_{50} E_{11} V_{51} V_{52} E_{29} E_{25} E_{30} V_{53} E_{33} V_{54} E_{34} V_{55} E_{22} V_{56} E_{28} V_{57} V_{58} E_{14}

MEANS AND METHOD FOR ACHIEVING AN OPTIMUM OPERATING CONDITION FOR AN ALKYLATION UNIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to control systems in general and, more particularly, to a control system for controlling an alkylation unit to achieve an optimum condition.

2. Description of the Prior Art

Heretofore control systems such as disclosed in U.S. applications Ser. Nos. 169,385 and 169,443, now U.S. Pat. No. 3,729,629, both of which are assigned to Texaco Inc., assignee of the present invention, controlled an alkylation unit to achieve a more rapid response in controlling the acid strength to changes in the composition of the olefin and isoparaffin stream or in the process itself. Neither of the disclosed systems dealt with the problem of achieving an optimum control system for an alkylation unit. Nor is it obvious from the information disclosed in those applications how one would go about achieving an optimum operating condition for an alkylation unit.

Another control system disclosed in U.S. application Ser. No. 118,374, now U.S. Pat. No. 3,720,730, Inc., assignee of the present invention, concerns the problem of reducing the stabilizing time required for an alkylation unit where there are several acid settlers being used simultaneously. The last mentioned application does not concern itself with achieving an optimum condition for an alkylation unit.

SUMMARY OF THE INVENTION

A system controls an alkylation unit in such a manner so as to achieve an optimum operating condition for the alkylation unit. The alkylation unit includes a contactor wherein an olefin-isoparaffin mixture is contacted with acid at a temperature controlled by a utility. The contactor provides an acid-hydrocarbon mixture to a settler which separates the acid from a hydrocarbon product. The hydrocarbon product includes alkylate. A portion of the separated acid is discharged from the alkylation unit while the remaining separated acid is fed back to the contactor. Fresh acid is added to the feedback acid to replace the discharged acid. The contacting temperature, the operating rate of the utility, a condition related to the strength of the contact acid and a condition of the alkylate are sensed by sensing circuits which provide corresponding signals. A signal source provides signals corresponding to economic values related to the octane rating of the alkylate, to the acid consumption by the alkylation unit and to the utility. A control network provides control signals in accordance with the signals from the sensing circuits and from the signal source. At least one control signal is used to control the contacting temperature while another control signal is used to control either the acid entering the alkylation unit or the acid being discharged from the alkylation unit.

The objects and advantages of the invention will appear hereinafter from 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** includes a simplified block diagram of a control system, constructed in accordance with the present invention, for controlling an alkylation unit, which is also partially shown in schematic form, providing an alkylate product for further processing.

FIGS. **2, 3, 4, 5** and **6** are detailed block diagrams of the programmer, the T_j computer, G_B computer, H_B computer and the control computer, respectively, 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 at a predetermined temperature and in the presence of a catalyst, such as sulfuric acid and which is hereinafter referred to as the reaction 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 butylenes, propylene or a mixture of butylenes and propylene, while the isoparaffin may be isobutane. The control system shown in FIG. **1** controls the reaction temperature and the flow rate of discharge acid leaving the alkylation unit to achieve an optimum operating condition. The flow rate of fresh acid entering the alkylation unit may be controlled instead of the discharge acid.

The olefins and isoparaffin enter a contactor **4** by way of a line **6**, where the olefins and isoparaffin are contacted with the reaction 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.** The reaction temperature is controlled by coolant passing through a coil **13** inside contactor **4.** Settler **12** separates the hydrocarbon product from the reaction acid. The hydrocarbon product, which includes alkylate, is removed through a line **14** for further processing while the reaction 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 reaction acid strength. A pump **20** pumps the reaction acid from line **16** into line **7.** A portion of the reaction 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.

In order that an optimum operating condition, such as the contactor temperature, be determined, it is necessary that a differential earnings E be determined in accordance with the following equation:

1. $E = (\Delta Q)(W_Q)-(\Delta A)(W_A)-(\Delta U_1)(W_{U1}) \dots (\Delta U_n)(W_{Un})$,

where ΔQ is the differential octane rating of the alkylate product resulting from a change in the contactor's temperature, W_Q is the incremental worth of a unit change in octane rating, ΔA is the differential acid consumption resulting from a change in the contactor's temperature, W_A is the cost of acid, ΔU_1 through ΔU_n are differential utilities requirements for utilities **1** through n resulting from a change in the contactor's temperature, W_{U1} through W_{Un} are the cost of utilities **1** through n. For purpose of illustration, one utility will be hereinafter described and that utility concerns the coolant passing through coil **13.** Therefore, equation 1 may be written as:

2. $E = (\Delta Q)(W_Q) - (\Delta A)(W_A) - (\Delta U)(W_U)$

The terms W_Q, W_A and W_U are predetermined economic values for the octane rating, the acid and the utility, while ΔQ, ΔA and ΔU are determined as follows:

3. $\Delta Q = G_C - G_B$

where G_B is a calculated quantity based on sensed conditions such as the sensed contactor temperature T_B and the ratio P_B of propylene to olefins in line **6,** while G_C is the same type of quantity calculated at a contactor temperature other than the sensed temperature and for the existing propylene to olefin ratio. The quantities G_B and G_C may be calculated from the following equations 4 through 6 by substituting G_B or G_C for G_L, G_U or G_{L-U}.

4. $G_L = a_1\,[(T-T_1)/100] + a_2\,[(T-T_1)/100]^2 + a_3\,[T-T_1/100]^3 + a_4\,[T-T_1/100]^4 + a_5\,[(T-T_1)/100]^5$

5. $G_U = b_1\,[(T-T_2)/100] + b_2\,[(T-T_2)/100]^2 + b_3\,[(T-T_2)/100]^3 + b_4\,[(T-T_2)/100]^4 + b_5\,[(T-T_2)/100]^5$

6. $G_{L-U} = [(P_U-P_B)/(P_U-P_L)]\ G_L + [(P_B-P_L)/(P_U-P_L)]\ G_U$

where T may be the sensed temperature T_B or a calculated temperature T_j, T_1 is a first reference temperature which, by way of example, may be 45°F and T_2 is a higher reference temperature which for purposes of illustration may be 55°F. The selection of which equation to use in calculating G_C and G_B depends on the ratio of the propylene to olefins in line **6.** When the actual ratio P_B is below a predetermined ratio P_L, equation 4 is used. When the ratio P_B is above another predetermined ratio P_U, equation 5 is used. When the ratio P_B is greater than P_L but less than P_U, equation 6 is used. By way of example, P_L may be 0.35 while P_U may be 0.60. The following Table I shows values for a_1 through a_5 and b_1 through b_5 which have been determined for an existing alkylation unit.

TABLE I

a_1	−2.17592	b_1	−4.7
a_2	−14.668939	b_2	−5.855239
a_3	−37.631287	b_3	0.0
a_4	−29.920927	b_4	−9.427409
a_5	0.0	b_5	0.0

The differential acid consumption ΔA is determined from equation 7.

7. $\Delta A = A_B\,(F_B/F_C) - 1$

where A_B is the existing acid consumption, F_B is a quantity calculated at the existing contactor temperature and the existing propylene ratio, while F_C is a similar quantity calculated at any other contactor temperature and the existing propylene ratio. The existing acid consumption A_B is obtained from the following equation 8:

8. $A_B = \alpha\ R_{DB}/R_K$

where R_{DB} is a sensed discharge acid flow rate, R_K is the alkylate rate and α is a constant to convert the discharge acid rate from barrels per hour to tons per hour and by way of example may be 0.3213.

The calculated acid consumption A_C for a current calculation step is:

9. $A_C = A_B + \Delta A$

Equation 9 may be rewritten as:

10. $A_C = A_B + A_B\,(F_B/F_C) - 1$

which simplifies to

11. $A_C = A_B\,(F_B/F_C)$

Using equation 8, which is applicable for A_C by substituting R_{DC} for R_{DB}, the calculated discharge acid flow rate R_{DC} may be solved to yield equation 12.

12. $R_{DC} = R_{DB}\,(F_B/F_C)$

The alkylate product rate R_K is obtained from equation 13.

13. $R_K = V_K R_C$

where V_K is the volume fraction of alkylate product in the crude alkylate stream, R_C is the crude alkylate flow rate. The quantities F_B and F_C are obtained from equations 14, 15 and 16 by substituting the sensed temperature T_B for T when the quantity F_B is desired and the calculate temperature T_j when the quantity F_C is desired.

14. $F_L = 1.0 + c_1[(T-T_1)/100] + c_2[(T-T_1)/100]^2 + c_3[(T-T_1)/100]^3 + c_4[(T-T_1)/100]^4 + c_5[(T-T_1)/100]^5$

15. $F_U = 1.0 + d_1[(T-T_2)/100] + d_2[(T-T_2)/100]^2 + d_3[(T-T_2)/100]^3 + d_4[(T-T_2)/100]^4 + d_5[(T-T_2)/100]^5$

16. $F_{L-U} = [(P_U-P_B)/(P_U-P_L)]\ F_L + [(P_B-P_L)/(P_U-P_L)]\ F_U$

Equation 14 is used when the ratio P_B is less than the reference ratio P_L, equation 15 is used when the ratio P_B is greater than the reference ratio P_U and equation 16 is used when the ratio P_B is equal to or greater than the ratio P_L but less than or equal to ratio P_U. Table II relates specific values for the terms c_1 through c_5 and d_1 through d_5 in equations 14 and 15 for a particular alkylation unit.

TABLE II

TERM	VALUE	TERM	VALUE
c_1	−2.901263	d_1	−7.719104
c_2	1.3076425	d_2	29.247134
c_3	0.0	d_3	0.0
c_4	0.0	d_4	−211.32222
c_5	0.0	d_5	0.0

The differential utility rate ΔU is determined from equation 17.

17. $\Delta U = H_C - H_B$

where H_B is a quantity calculated at the existing contactor temperature and the existing propylene ratio P_B and H_C is a similar quantity calculated at any other contactor temperature and the existing propylene ratio P_B. The quantities H_B and H_C are calculated in accordance with equation 18.

18. $H = e_1 + e_2T + e_3T^2 + e_4T^3 + (e_5 + e_6T + e_7T^2 + e_8T^3)P_B + (e_9 + e_{10}T + e_{11}T^2 + e_{12}T^3)P_B^2 + (e_{13} + e_{14}T + e_{15}T^2 + e_{16}T^3)P_B^3$

where the sensed temperature T_B is substituted for T in the equation when the quantity H_B is desired and a calculated temperature T_j is substituted for T when the quantity H_C is desired.

The following table contains specific values for the co-efficients e_1 through e_{16} in equation 18 as determined for a particular alkylation unit.

TABLE III

e_1	−6.005131	e_7	0.0011537	e_{12}	0.0
e_2	0.26122	e_8	0.0	e_{13}	0.0
e_3	−0.002753	e_9	5.82	e_{14}	1.5
e_4	0.0	e_{10}	−0.1538	e_{15}	0.0
e_5	−2.1067	e_{11}	0.0	e_{16}	0.0
e_6	0.0				

The calculated utility rate R_{UC}, which in this case is the coolant flow rate, is determined from equation 19.

19. $R_{UC} = R_{UB} + (\Delta U)(R_K)$
where R_{UB} is the sensed utility rate which happens, in this case, to be the sensed coolant flow rate.

The control system as hereinafter described calculates the differential earnings for selected temperatures and when the differential earnings decreased or an operating parameter exceeds a constraint limit, the controls system returns to the next previous selected temperature and changes the contactor **4** temperature and the discharge acid flow rate accordingly to obtain an optimum operating condition. The selected temperatures are determined in accordance with the following equation 20.

20. $T_j = T_B + [(2j)/J-1](\Delta T_M)$
where J is any positive integer, j is a selected integer from zero to J and ΔT_M is the maximum allowable change in the contactor temperature.

Referring to FIGS. **1** and **2**, programmer **27** receives a voltage V_1 from a source **28** of direct current voltages. An operator initiates the optimizing control by closing switch **26** to apply voltage V_1 to clock means **34.** Switch **26** may be an on-off toggle switch. Clock means **34** provides pulses E_1 at a repetition rate which corresponds to a periodic initiation of an operation sequence. Pulse E_1 resets chromatograph means **36** and **37.**

Chromatograph means **36** samples the olefin and isoparaffin stream in line **6** and provides a pulse signal E_2 to programmer **27** and a continuous signal E_3 to P_B signal means **41.** The peaks of signal E_3 correspond to the concentrations of the constituents of the olefins and isoparaffin stream in line **6.**

Reset pulse E_1 is also applied to control pulse circuit **43** to reset a counter **44.** With counter **44** at a zero count, a logic decoder **45** provides a high level direct current voltage to an AND gate **48** which also receives signals E_2 from chromatograph means **36.** The pulses pass through the enabled AND gate **48** and are counted by counter **44.** Logic decoder **45** decodes the count in counter **44** to provide a plurality of outputs to a plurality of one shot multivibrators **52.** Each multivibrator of multivibrators **52** is triggered by a different output from logic decoder **45** and provides a control pulse coinciding with a different peak of signal E_3. Multivibrators **52** provide control pulses E_A through E_D which is shown as being on one line. Pulse E_D triggers another one shot multivibrator **53** which provides a time delay pulse whose width is of sufficient duration to allow calculations to be made by P_B signal means **41.** The delay pulse from multivibrator **53** triggers another multivibrator **54** which provides control pulse E_E. Programmer **27** provides control pulses E_A through E_E to P_B signal means **41.**

Signal means **41** provides a signal E_5 corresponding to the ratio P_B of propylene in line **6** to the olefins in line **6.** Signal means **41** is similar to the olefin signal means disclosed and described in a U.S. application Ser. No. 228,826 filed on Feb. 24, 1972. The aforementioned application is assigned to Texaco Inc., assignee of the present invention. In the aforementioned application, signal E_{10} corresponds to signal E_3 in the present application while control pulses E_A through E_E have the same function as described in the aforementioned application. Signal means **41** also receives scaling voltages V_2 through V_{2C} from source **28,** which corresponds to the scaling voltages V_5 through V_{5C} in the aforementioned application. The output from the olefin signal means represents a ratio having a range from 0 to 100, P_B signal means **41** is modified, so that E_5 corresponds to a range of 0 to 1, in a manner which is obvious to one skilled in the art.

Chromatograph means **37** samples the hydrocarbon product stream in line **14** and provides a pulse signal E_6 to a programmer **27** and a signal E_7 to alkylate signal means **56** receiving direct current voltages V_2 through V_{21} from source **28** and control pulses E_F through E_Q from programmer **27.** The peaks of signal E_7 correspond to the concentrations of different constituents of the stream in line **14.** Each pulse in pulse signal E_6 coincides with a different peak of signal E_7. Alkylate signal means **56** is controlled by pulse signals E_F through E_Q to provide a signal E_8 corresponding to the concentration of alkylate in the stream in line **14.** Alkylate signal means **56** is similar to the signal means desribed in U.S. application Ser. No. 169,443 filed Aug. 5, 1971 and assigned to Texaco Inc., assignee of the present invention, except that signal E_8 corresponds to a normalized concentration constituent with six or more carbon atoms. Alkylate signal means **56** samples and holds the peaks of signal E_7 corresponding to the concentrations of propane, isobutane, n-butane, pentanes, and all compound with six or more carbon atoms. Alkylate signal means **56** normalizes the determined concentration of compounds with six or more carbon atoms by summing all of the sampled peaks of signal E_7 and dividing into the sampled peak of signal E_7 corresponding to the concentration of the compounds of six or more carbon atoms, to provide signal E_8.

Pulse signal E_6 is applied to a control pulse circuit **43A,** which is similar in operation to control pulse circuit **43,** which provides control pulses E_F through E_0. Pulse E_0 is also applied to a delay one shot multivibrator **60** which provides a delay pulse of sufficient duration to allow alkylate signal means **56** to make the necessary calculations. The pulse from multivibrator **60** triggers another one shot multivibrator **61** which provides control pulse E_P.

Pulse E_P triggers yet another one shot multivibrator **62** to provide control pulse E_Q.

A T_j computer **70** provides a signal E_{11} corresponding to a calculated temperature T_j in accordance with signals E_{12}, E_{13} and E_{15}, direct current voltages V_3 through V_7, pulse E_1 and equation **20.**

Referring now to FIG. **3,** pulse E_1 resets a counter **75** in T_j computer **70.** Counter **75** is a conventional up-down counter. Signal E_{13} from a control computer **71** enables an AND gate **76** to pass timing pulses from clock means **78** to counter **75.** Counter **75** counts the timing pulses passed by AND gate **76.** The count in counter **75** is decoded by a logic decoder **82** which provides a plurality of outputs corresponding to the count in counter **75.** By way of example, one output from logic decoder **82** will be at a high level for a particular count in counter **75** and at a low level when that count is not in counter **75.** Thus when counter **75** reaches a first predetermined count, an output from count **75** is applied to an electronic switch **83** goes to a high level rendering switch **83** conductive to passed voltage V_3. When the output from counter **75** is at a low level, switch **83** is rendered non-conductive to block voltage V_3. Voltage V_3 corresponds to a value of 0.0 for the term j in equation 20. Similarly switches **83A, 83B** and **83C** receive direct current voltages V_4, V_5 and V_6

corresponding to values 1.0, 2.0 and 3.0, respectively; for the term j in equation 20.

It should be noted that if there are more values desired for the term j, more switches need to be connected to logic decoder **82.** It can be readily seen that in effect counter 75 and logic decoder **82** control switches **83** through **83C** so that the different voltages may be used in equation **20** for different values of j to determine the T_j temperature. A voltage passed by a switch **83, 83A, 83B** or **83C** is applied to a multiplier **84** receiving voltage V_5 to provide a signal, corresponding to the term $2j$, to a divider **85** which also receives voltage V_6 which corresponds to the term J in this instance. Divider **85** provides a signal corresponding to $2j/J$. Subtracting means **87** subtracts voltage V_4 from the output from divider **85** to provide a signal to a multiplier **92** corresponding to the term $[(2j/J) - 1]$ in equation 20. Multiplier **92** multiplies the signal from subtracting means **87** with voltage V_7 corresponding to a maximum allowable temperature change ($\Delta\ T_M$). The output from multiplier **92** is summed with signal E_{12} by summing means **93** to provide signal E_{11}. Signal E_{12} corresponds to the temperature T_B of the acid hydrocarbon mixture leaving contactor **4** by a sensor **91** in line **8.**

The outputs from logic decoder **82** are inverted by plurality of inverters **94** through **94C** and are applied to corresponding time delay one shot multivibrators **94** through **95C**, respectively. When an output from decoder **82** goes to a high level in response to a particular count in counter **75**, an inverter **94, 94A, 94B** or **94C** inverts the output to a low level thereby triggering a corresponding multivibrator **95, 95A, 95B** or **95C**, respectively. A pulse from the triggered one shot multivibrator **95, 95A, 95B** or **95C** passes through an OR gate **96** and the trailing edge of the passed pulse triggers another one shot multivibrator **99** causing it to provide a sampling pulse E_{14}. The pulse width of the pulses provided by multivibrators **95** through **95C** are of such a duration as to allow the various computers to make the calculations based on the new T_j temperature before sampling and holding is performed.

In operation, signal E_{13} is at a high level unless a certain predetermined condition exists. For example, if the earnings decrease or the constraint on an operating parameter is exceeded at the new calculated operating condition, then E_{13} goes to a low level. However, since the new calculated operating condition is an undesirable condition, E_{13} remains at a high level for a period of time before changing to a low level to allow one more timing pulse from clock means **78** to pass through AND gate **76.** Counting direction signal E_{15} changes immediately from a high level to a low level so that the last pulse passed by AND gate **76** causes the count in counter **75** to be reduced by one. The net result is that the control system is returned to its next previous calculation step which is the most desirable operating condition.

The T_B temperature signal E_{12} from sensor **91** is also applied to a G_B computer **100**, to an F_B computer **100A** and to a H_B computer **101** while T_j temperature signal E_{11} from T_j computer **70** is applied to a G_C computer **100B**, to an F_C computer **100C** and to an H_C computer **101A**. Computers **100A, 100B** and **100C** are similar to computer **100** except that computer **100A** differs from computer **100** in receiving different direct current voltages so it can solve equations 14, 15 and 16, while computer **100** solves equations 4, 5 and 6. Computers **100B, 100C** differ from computer **100** and **100A**, respectively, in that they use the T_j temperature instead of the sensed temperature T_B in their calculations. Therefore, it is necessary only to explain the operation of computer **100.**

Referring to FIG. **4,** there is shown the G_B computer **100** which includes computing circuit **105.** Circuit **105** receives signal E_{12} and direct current voltages V_8 through V_{14}, which correspond to the lower reference temperature T_1, the constant of **100** and the coefficients a_1 through a_5, respectively, in equation 4. Computing circuit **105** includes subtracting means **106** which subtracts voltage V_8 from signal E_{12} to provide a signal to a divider **107** receiving voltage V_9. Divider **107** provides a signal corresponding to the term $[(T_B-T_1)/100]$. The signal from divider **107** is effectively squared by a multiplier **110** to provide a signal corresponding to the $[(T_B-T_1)/100]^2$ which is applied to series connected multipliers **111** through **113.** Multipliers **111, 112** and **113** provide outputs corresponding to the quantities $[(T_B-T_1)/100]^3$, $[(T_B-T_1)/100]^4$ and $[(T_B-T_1)/100]^5$, respectively. A plurality of multipliers **120** through **124** multiply the outputs from divider **107** and multipliers **110** through **113,** respectively, with voltages V_{10} through V_{14}, respectively. The outputs from multipliers **120** through **124** are summed by summing means **126** to provide a signal E_{16} corresponding to the term G_L in equation **4.**

Another computer circuit **105A** receives signal E_{12} and direct current voltages V_9 and V_{15} through V_{20}. Voltages V_{16} through V_{20} correspond to the coefficients b_1 through b_5 in equation 5. Computer circuit **105A** operates in a similar manner as computer circuit **105,** except that voltages V_{15} and V_{16} through V_{20} replace voltages V_8 and V_{10} through V_{14}, respectively, to provide a signal E_{16A} which corresponds to the term G_U in equation **5** for the condition that the propylene ratio is greater than the second predetermined reference ratio which by way of example may be 0.60.

Subtracting means **130, 131** and **132,** dividers **135** and **136,** multipliers **137** and **138** and summing means **139** cooperate to provide a signal E_{16B} corresponding to the term G_{L-U} in equation **6** for a propylene ratio that lies within the upper and lower propylene reference ratios in accordance with equation **6,** signals E_5, E_{16} and E_{16A} and direct current voltage V_{21} and V_{22} from source **28.** Voltages V_{21} and V_{22} correspond to the predetermined upper and lower propylene reference ratios, respectively. Subtracting means **130** subtracts signal E_5 from voltage V_{21} to provide a signal corresponding to the term (P_U-P_B) in equation 6, while subtracting means **131** subtracts voltage V_{22} from signal E_5 to provide a signal corresponding to the term (P_B-P_L). Subtracting means **132** subtracts voltage V_{22} from voltage V_{21} to provide a signal corresponding to the term (P_U-P_L) in equation 6. Divider **135** divides the signal from subtracting means **130** with the signal from subtracting means **132** to provide a signal, corresponding to the term $[(P_U-P_B)/(P_U-P_L)]$, which is multiplied with signal E_{16} by multiplier **137.** The output from multiplier **137** corresponds to the term $G_L[(P_U-P_B)/(P_U-P_L)]$ in equation 6. Similarly, divider **136** divides the signal from subtracting means **131** with the signal from subtracting means **132** to provide a signal which is multiplied with signal E_{16A} by multiplier **138.** Multiplier **138** provides a signal corresponding to the term

$G_U\,[(P_B-P_L)/(P_U-P_L)]$ to summing means **139**. Summing means **139** sums the signals from multipliers **137**, **138** to provide signal E_{16B}.

The proper G_B signal is selected by comparing signal E_5 with voltages V_{21}, V_{22}. The comparison is then used to control switching means to pass the selected G_B signal. The comparison is made by comparators **145** and **145A**, while the switching means include inverters **146** and **146A**, an AND gate **150** and electronic switches **153, 151** and **152.** Comparators **145, 145A** compare signal E_5 with voltages V_{21} and V_{22}, respectively. When the propylene ratio signal E_5 is more positive than voltages V_{21} and V_{22} comparators **145** and **145A** provide a low level and a high level output, respectively, to inverters **146, 146A**, respectively. The outputs from comparators **145, 145A** are also provided to AND gate **150.** The high output from comparator **145A** is inverted to a low level by inverter **146A** which disables electronic switch **151** so that switch **151** blocks signal E_{16}. Since the output from comparator **145** is at a low level it is inverted to a high level by inverter **146** to render electronic switch **152**, conductive so that switch **152** passes E_{16A} as the G_B signal E_{20}. The low output from comparator **145** disables AND gate **150** so that AND gate **150** provides a low output to render electronic switch **153** non-conductive thereby blocking signal E_{16B}.

For the condition when the propylene ratio is within the upper and lower limits, comparators **145, 145A** provide high level outputs which cause AND gate **150** to enable switch **153.** When enabled switch **153** passes signal E_{16B} as signal E_{20}. Inverters **146, 146A** invert the high level outputs from comparators **145** and **145A**, respectively, to low level voltages which render switches **152** and **151** non-conductive, respectively. Switches **151, 152** block signals E_{16} and E_{16A}, respectively.

For the condition when the propylene ratio is less than the lower limit, comparators **145, 145A** provide a high level and low level output, respectively. The high level output from comparator **145** is inverted by inverter **146** to render switch **152** non-conductive to block signal E_{16A}. The low level output from comparator **145A** disables AND gate **150** causing it to render electronic switch **153** non-conductive thereby blocking signal E_{16B}. The low level output from comparator **145A** is inverted to a high level by inverter **146A** which renders electronic switch **151** conductive to pass signal E_{16} as signal E_{20}.

Voltages V_8, V_9, V_{15}, V_{21} and V_{22} are provided by source **28** to computers **100A, 100B** and **100C**, while voltages V_{10} to V_{14} and V_{16} to V_{20} are also applied to computer **100B**, and voltages V_{23} through V_{27}, V_{28} through V_{33} are applied to computers **100A** and **100C**. In this regard, voltages V_{23} through V_{27} correspond to the coefficients c_1 through c_5 in equation **14**, voltages V_{28} through V_{32} correspond to the coefficients d_1 through d_5 in equation 15, while voltage V_{33} corresponds to the term 1.0 in equations 14 and 15. It should be noted that the term 1.0 in equations 14 and 15 is not present in equations 4 and 5. Computers **100A** and **100C** have computing circuits similar to computing circuit **105**, which sum voltage V_{33} with the signals from the multipliers as is done by summing means **126** with the outputs from multipliers **120** through **124** in computing circuit **105.**

Referring to FIG. **5**, signal E_{12} is provided to multipliers **160** through **165.** Multiplier **160** in H_B computer **101** effectively squares signal E_{12} to provide a signal corresponding to the term T_B^2 in equation 18 to multipliers **165** through **169.** It should be noted that since H_B computer **101** uses signal E_{12}, the T in equation 18, for purpose of evaluation, may be replaced by T_B. Multipliers **161** through **164** multiply signal E_{12} with direct current voltages V_{34} through V_{37}, from source **28**, which correspond to the coefficients e_2, e_6, e_{10} and e_{14} in equation 18, to provide outputs representative of the terms $e_2\,T_B$, $e_6\,T_B$, $e_{10}\,T_b$ and $e_{14}\,T_B$, respectively. Multipliers **166** through **169** multiply the output from multiplier **160** with direct current voltages V_{38} through V_{41} from source **28** which correspond to the coefficients e_3, e_7, e_{11} and e_{15} in equation 18 to provide outputs representative of the terms $e_3T_B^2$, $e_7T_B^2$, $e_{11}T_B^2$ and $e_{15}T_B^2$, respectively.

Multiplier **165** multiplies the output from multiplier **160** with signal E_{12} to provide an output corresponding to the term T_B^3 in equation 18. Multipliers **170** through **173** multiply the output from multiplier **165** with direct current voltages V_{42} through V_{45} from source **28** which correspond to the coefficients e_4, e_8, e_{12} and e_{16}, respectively, in equation 18 to provide outputs representative of the terms $e_4T_B^3$, $e_8T_B^3$, $e_{12}T_B^3$ and $e_{16}T_B^3$. Summing means **177** sums the outputs of multipliers **161, 166** and **170** with a direct current voltage V_{46} from source **28** which corresponds to the coefficient e_1 to provide a signal corresponding to the term $(e_1 + e_2T_B + e_3T_B^2 + e_4T_B^3)$.

A multiplier **178** effectively squares signal E_5 to provide a signal corresponding to the term P_B^2, while another multiplier **179** multiplies the signal from multiplier **178** with signal E_5 to provide a signal corresponding to the term P_B^3. Summing means **180** sums the outputs from multipliers **162, 167** and **171** with a direct current voltage V_{47} from source **28** corresponding to the coefficient e_5. The signal from summing means **180** is multiplied with signal E_5 by a multiplier **185** to provide a signal corresponding to the term $(e_5+e_6T_B+e_7T_B^2+e_8T_B^3)P_B$ in equation 18. Summing means **181** sums the outputs from multipliers **163, 168** and **172** with a direct current voltage V_{48} from source **28** corresponding to the coefficient e_9. A multiplier **186** multiplies the signal from summing means **181** with the output from multiplier **178** to provide a signal corresponding to the term $(e_9+e_{10}T_B+ e_{11}T_B^2+e_{12}T_B^3)P_B^2$ in equation 18. Summing means **182** sums the outputs from multipliers **164, 169** and **173** with a direct current voltage V_{49} from source **28** corresponding to the coefficient e_{13}. A multiplier **187** multiplies the signal from summing means **182** with the output from multiplier **179** to provide a signal which corresponds to the term $(e_{13}+e_{14}T_B+e_{15}T_B^2 +e_{16}T_B^3)P_B^3$ in equation 18. Summing means **188** sums the output from summing means **177** and multipliers **185, 186** and **187** to provide signal E_{21} corresponding to H_B.

H_C computer **101A** operates in a similar manner as H_B computer **101** except that computer **101A** uses the T_j signal E_{11} instead of the T_B signal E_{12}.

Referring to FIG. **1**, subtracting means **200** subtracts signal E_{20} provided by G_B computer **100** from signal E_{20B} provided by G_C computer **100B** to provide a signal E_{22} corresponding to the $\Delta\,Q$ term of equations 2 and 3. The signal from subtracting means **200** is applied to control computer **71.**

A divider **201** divides signal E_{20A} from F_B computer **100A** by signal E_{20C} from F_C computer **100C**. Subtracting means **202** subtracts direct current voltage V_{33} from source **28** from the output from divider **201** to provide a signal corresponding to the term $[(F_B/F_C) - 1]$ in equation **7.** A multiplier **207** multiplies the output from subtracting means **202** with a signal E_{27} which corresponds to the acid consumption A_B to provide a signal E_{28}, corresponding to the term ΔA in equations 2 and 7, to control computer **71.**

Signal E_{27} is developed in the following manner. A multiplier **208** multiplies the alkylate concentration signal E_8 from alkylate signal means **56** with a hydrocarbon flow rate signal E_{70} from a sensor **206** in line **14,** to provide a signal corresponding to the term R_K in accordance with equation 13. A flow rate sensor **236** senses the flow rate of the discharge acid in line **21** and provides a signal E_{33} corresponding to the sensed discharge acid flow rate R_{DB}. Signal E_{33} is divided into the signal from multiplier **208** by a divider **209** to provide a signal to another multiplier **210.** Multiplier **210** multiplies a signal provided by divider **209** with a direct voltage V_{59}, which corresponds to the constant α in equation 8, from source **28** to provide signal E_{27}.

Subtracting means **215** subtracts signal E_{21} provided by H_B computer **101** from signal E_{21A} provided by H_C computer **101A.** Subtracting means **215** provides an output E_{25}, corresponding to ΔU in equations **2** and **17,** to control computer **71.**

Referring to FIGS. **1** and **6,** control computer **71** controls the operation of the alkylation unit by determining four conditions: whether or not the trial temperature T_j exceeds predetermined temperature limits T_U and T_L, whether or not the calculated utility rate R_U exceeds predetermined utility rate limits R_{UU} and R_{UL}, whether or not the calculated discharge acid flow rate R_{DC} exceeds predetermined discharge acid flow rate limits R_{DU} and R_{DL}, and whether or not the calculated earnings for the current calculation step is greater than the earnings for the next previous calculation step. Control computer **71** controls the alkylation unit in accordance with signals E_{11}, E_{14}, E_{22}, E_{25}, E_{28}, E_{29}, E_{30}, E_{33} and E_{34} and direct current voltages V_{50} through V_{58} from source **28.**

Signal E_{11}, corresponding to the temperature T_j, is applied to comparators **220, 221** receiving the upper temperature limit T_U voltage V_{50} and the lower temperature limit T_L voltage V_{51}, respectively. Comparators **220, 221** provide a low level and a high level direct current output, respectively, when signal E_{11} is more positive than voltages V_{50}, V_{51}; high level outputs when signal E_{11} is more positive than voltage V_{51} but not more positive than voltage V_{50}; and a high level and a low level output, respectively, when signal E_{11} is not more positive than voltages V_{50}, V_{51}. An AND gate **224** provides a high level direct current output when comparators **220, 221** provide high level outputs and a low level output when either comparators **220** and **221,** or both comparators, provide a low level output. Thus, AND gate **224** provides a high level output when the calculated temperature T_j does not exceed the predetermined limits and a low level output when T_j does exceed a predetermined limit.

Signal E_{25} corresponding to the term (ΔU) in equations 2, 17 and 19 provided by subtracting means **215** is multiplied with the alkylate rate R_K output from multiplier **208** by a multiplier **228.** The output provided by multiplier **228** corresponds to the term $(\Delta U)(R_K)$ in equation 19. Summing means **229** sums a signal E_{30}, corresponding to the coolant flow rate, provided by a sensor **230,** with the output from multiplier **228** to provide a signal E_{31} corresponding to the term R_{UC} in equation 19.

Comparators **220A** and **221A** and an AND gate **224A** cooperate in a manner similar to the cooperation of comparators **220, 221** and AND gate **224** to make the determination as to whether or not the rate of the utility exceeds predetermined limits. Comparators **220A, 221A** compare signal E_{31} with direct current voltages V_{52} and V_{53} from source **28** corresponding to the predetermined upper and lower limits, respectively, for the utility rate R_{UU} and R_{UL}, respectively. AND gate **224A** provides a high level output when the utility rate R_U does not exceed the predetermined limits and a low level output when R_U exceeds a predetermined limit.

The calculated discharge acid flow rate is computed in accordance with equation **12.** A multiplier **235** multiplies a signal E_{33} corresponding to the discharge acid flow rate provided by a sensor **236** in line **21,** with signal E_{23} from divider **201** to provide a signal E_{34} corresponding to the calculated discharge acid flow rate R_{DC} in equation **12** for the current cal-culation step.

Comparators **220B** and **221B** cooperate with AND gate **224B,** in a manner similar to comparators **220, 221** and AND gate **224,** to determine whether the calculated discharge acid flow rate R_{DC} is within predetermined limits. Comparators **220B** and **221B** compare signal E_{34} with direct current voltages V_{54} and V_{55} corresponding to a predetermined upper flow rate limit R_{DU} and to a predetermined lower flow rate limit R_{DL}, respectively, for the discharge acid in line **21.** AND gate **224B** is controlled by comparators **220B** and **221B** to provide a high level output when the calculated discharge acid flow rate R_{DC} does not exceed predetermined limits defined by voltages V_{54}, V_{55} and a low level output when R_{DC} does exceed a predetermined limit.

Multipliers **240, 241** and **242** and subtracting means **246** and **247** compute the earnings in accordance with equation **2,** signals E_{22}, E_{25} and E_{28} and direct current voltages V_{56}, V_{57} and V_{58} from source **28.** Multipliers **240, 241** and **242** multiply signals E_{22}, E_{28} and E_{25}, respectively, with voltages V_{56}, V_{57} and V_{58}, respectively. Voltages V_{56}, V_{57} and V_{58} correspond to the terms W_Q, W_A, and W_u, respectively. Multipliers **240, 241** and **242** provide outputs corresponding to the terms $(\Delta Q)(W_Q)$, $(\Delta A)(W_A)$, and $(\Delta U)(W_U)$, respectively, in equation 2. Subtracting means **246** subtracts the output provided by multiplier **241** from the output provided by the multiplier **240** to provide an output to subtracting means **247.** Subtracting means **247** subtracts the output provided by multiplier **242** from the output provided by subtracting means **246** to provide an output to an earnings comparison network **253.**

Earnings comparison network **253** compares the earnings for the current calculation step with the earnings for the next previous calculation step and includes sample and hold circuits **254, 255,** a one-shot multivibrator **256** and a comparator **257.** The output from subtracting means **247** is applied to sample and hold circuit **254** while sampling pulse E_{14} from T_j computer **70** are applied to multivibrator **256** and to sample and hold circuit **255.** One shot multivibrator **256** provides a pulse output to sample and hold circuit **254** in response to the trailing edge of a pulse E_{14}. The sequence of sampling and holding is such that sample and hold circuit **255** holds the output from sample and hold circuit **254**. The output provided by sample and hold circuit **255** corresponds to the earnings for the next previous calculation step while the output from sample and hold circuit **254** corresponds to the earnings for the current calculation step. Comparator **257** compares the outputs from sample and hold circuits **254** and **255** and provides a high level direct current output when the output from sample and hold circuit **254** is more positive than the output from sample and hold circuit **255** and a low level output when the output from sample and hold circuit **254** is not more positive than the output from sample and hold circuit **255**. Thus comparator **257** provides a high level output when the current calculated earnings are greater than the earnings for the next previous calculation step, and provides a low level output when the current earnings are equal to or less than the next previous earnings. An AND gate **260** provides directional signal E_{15} at a high level when AND gates **224, 224A, 224B** and comparator **257** provide high level outputs and a low level output when one or more of the outputs from AND gates **224, 224A** and **224B** and comparator **257** is at a low level.

Signal E_{15} from AND gate **260** is applied to an OR gate **261** and to a one-shot multivibrator **262**. As each calculation satisfies all of the aforementioned conditions, signal E_{15} from AND gate **260** remains at a high level and passes through OR gate **261** to become signal E_{13}. During the course of a calculation if one of the limits is exceeded or the earnings does not increase, signal E_{15} from AND gate **260** goes to a low level and triggers one-shot multivibrator **262**. It would be expected that signal E_{13} would go to a low level when signal E_{15} did. However, if this was to occur, the control operation would remain in an undesirable state so that it is necessary to go back one calculation step. This is provided for by the pulse output from one-shot multivibrator **262** which passes through OR gate **261** to become signal E_{13} so that signal E_{13} remains at a high level for duration of the pulse from multivibrator **262** while signal E_{15} is at a low level. The duration of the pulse from one-shot multivibrator **262** is such that it enables one more pulse E_{15} from clock means **78** to pass through AND gate **76**. The low level signal E_{15} from AND gate **260** causes the counter to count down the last pulse passed by AND gate **76** resulting in all of the computers being returned to their next previous calculation step.

When the desired operating condition has been determined, control computer **70** implements the required changes. The pulse from multivibrator **262** which returns the control system to the next previous calculation step, triggers a one-shot multivibrator **268** causing it to provide a time delay pulse. The time delay is to allow time for all of the calculations of the next previous calculation step to be made. The trailing edge of the pulse from multivibrator **268** triggers another one shot multivibrator **269** causing it to provide an "enter" pulse E_{39} to set point signal means **270, 270A**. Set point signal means **270** also receives signals E_{11}, E_{12} and provides a directional signal E_{40} and a pulse signal E_{41} to a temperature recorder controller **271**. Signals E_{40}, E_{41} position the set point of controller **271** so as to control the temperature of contactor **4**. Subtracting means **273** in signal means **270** subtracts signal E_{12} from signal E_{11} to provide an output corresponding to the change in the contactor temperature required to achieve the desired operating condition. A comparator **277** compares the output from subtracting means **273** with a ground reference **278** to provide directional signal E_{40}. When the selected temperature, which is now temperature T_j, is less than the sensed temperature T_B, the output from subtracting means **273** is negative and hence is less positive than ground **278** causing comparator **277** to provide a low level direct current output as directional signal E_{40}. When the sensed temperature T_B is less than the selected temperature T_j, the output from subtracting means **273** is positive causing comparator **277** to provide a high level output as signal E_{40}.

A conventional type analog-to digital converter **276** converts the output from subtracting means **273** to digital signals which are applied to a count down counter **280**. The entry of digital signals into counter **280** is controlled by 'enter' pulse E_{39} from multivibrator **269** and presets counter **280** to the desired change in temperature.

The trailing edge of the 'enter' pulse E_{39} from multivibrator **269** triggers a multivibrator **286** which provides an enabling pulse to an AND gate **287**. AND gate **287** is connected to counter **280** in such a manner that counter **280** provides a low level direct current signal to AND gate **287** when the count in counter **280** is zero and a high level direct current signal when the count in counter **280** is not zero. Clock means **290** provides timing pulses to AND gate **287**. As a result of a count in counter **280** not being zero and the enabling pulse from multivibrator **286**, and timing pulses from clock means **290** pass through AND gate **287** to be counted down by counter **280** from the entered count. The timing pulses passed by AND gate **287** are also provided as pulse signal E_{41} to temperature recorder controller **271**. Each pulse in pulse signal E_{41} changes the position of the set point in temperature recorder controller **271** by a predetermined amount and in a direction in accordance with signal E_{40}. The set point changing process continues until a count of zero is reached by counter **280**, at which time counter **280** output to AND gate **287** goes to a low level thereby disabling AND gate **287**. When disabled, AND gate **287** blocks the timing pulses from clock means **290**. It is obvious that the duration of the enabling pulse from multivibrator **286** must be such to allow the largest anticipated count in counter **280** to be counted down to zero.

Temperature recorder controller **271** receives signal E_{12} from the temperature sensor **91** in line **8** and provides a signal to a valve **295** which controls the flow rate of the coolant flowing through coil **13**. Temperature recorder controller **271** controls valve **295** in accordance with signal E_{12} and the position of its set point so that the temperature of the acid-hydrocarbon mixture leaving contactor **4** will assume the desired temperature as represented by the position of temperature recorder controller **271** set point.

Set point signal means **270A** is similar in construction and operation to set point signal means **270** except that the sensed discharge acid flow rate signal E_{33} replaces signal E_{12} and the calculated discharge acid flow rate signal E_{34} replaces signal E_{11}. Set point signal means **270A** provides a directional signal E_{42} and a pulse signal E_{43}, instead of directional signal E_{40} and pulse signal E_{41}, respectively, to a flow recorder controller **300** which also receives signal E_{33}. Flow recorder controller **300** provides a signal to a valve **301** in line **21** which controls the flow rate of the discharge acid. Set point signal means **270**A is activated by 'enter' pulse E_{39} from one-shot multivibrator **269** to provide signals E_{42}, E_{43}. In response to signals E_{42} and E_{43} the set point of flow recorder controller **300** changes accordingly and provides a signal to valve **301** which corresponds to the difference between the sensed signal E_{33} and the position of set point causing valve **301** to increase or decrease the discharge acid flow rate in accordance with the position of the set point of flow recorder controller **300** so that the discharge acid flow rate is the desired discharge acid flow rate.

Since the acid strength changes when the contact temperature is changed, the discharge acid flow rate is changed to maintain the strength of the acid entering contactor **4.** In this regard, when the discharge acid flow rate is increased, the acid level in settler **12** would decrease. A level sensor **303** provides a signal to a level controller **304.** Level controller **304** provides a signal which corresponds to the difference between the sensed level and a predetermined level, to a valve **308** in line **17** in accordance with the signal from sensor **303** and the position of levelcontroller **304** set point. The signal from level controller **304** causes valve **308** to increase the fresh acid flow rate so as to increase the acid level in settler **12.** The increase in the fresh acid flow rate increases the strength of the acid entering contactor **4.** Similarly, a decrease in the discharge acid flow rate will result in a decreased acid strength.

The system of the present invention as heretofore described controls an alkylation unit to achieve an optimum operating condition for the alkylation unit. The discharge acid, the contactor's temperature and the alkylate product are monitored to determine values using equations heretofore described so that earnings may be determined. The control system uses a set of trial contactor temperatures and calculates the effect of a change in contactor's temperature on the earnings. The control system of the present invention as heretofore described controls an alkylation unit to achieve the optimum operating condition without exceeding a constraint value of an operating parameter.

What is claimed is:

1. A system for controlling an alkylation unit to achieve an optimum operating condition and said alkylation unit includes a contactor wherein an olefin-isoparaffin mixture is contacted with acid at a temperature controlled by utility means in accordance with a control signal and the contactor provides an acid-hydrocarbon mixture to a settler which separates the acid to provide a hydrocarbon product which include alkylate and acid, a portion of the separated acid is discharged while a portion of the separated acid is fed back to the contactor along with fresh acid entering the alkylation unit that is added to the feedback to replace the discharge acid, comprising means for sensing the contact temperature T_B and providing a signal corresponding thereto, means for sensing a utility rate and providing a signal corresponding thereto, means for sensing a condition related to the contact acid and providing a corresponding signal, means for sensing conditions of the hydrocarbon product and providing signals representative thereof, means for sensing the olefin and providing a signal representative thereof, means for providing signals corresponding to economic values W_Q, W_A and W_u related to the octane rating of the alkylate, to the acid consumption and to the utility, respectively, means for controlling the acid entering or leaving the alkylation unit in accordance with a control signal and means connected to all of the other means for providing the control signals to the acid control means and to the utility means in accordance with the signals from the sensing means and from the signal means so as to achieve a desired operating condition for the alkylation unit.

2. A system as described in claim **1** in which the utility means includes means for passing a coolant through the contactor so as to control the contact temperature.

3. A system as described in claim **2** in which the control signal means determines the effect that a change in the contact temperature would have on the earnings of the alkylation unit.

4. A system as described in claim **3** in which the control signal means includes first means connected to the temperature sensing means, to the olefin sensing means and to the hydrocarbon product sensing means for calculating values of factors G_B, F_B and H_B from the signals from the temperature sensing means, from the olefin sensing means and from the hydrocarbon product sensing means, means connected to the temperature sensing means for providing a signal, corresponding to a trial temperature T_j, in accordance with the sensed contact temperature T_B signal and the following equation:

1. $T_j - T_B + [(2j/J - 1\ )\ \Delta\ T_M$

where T_B is the sensed contacting temperature, J is any positive integer and j is iterativeely changed in value between 0 and J; in response to a command signal, second means connected to the trial temperature signal means, to the hydrocarbon product sensing means and to the olefin sensing means for calculating values of factors G_C, F_C and H_C in accordance with a trial temperature signal from the trial temperature signal means and the signals from the hydrocarbon product sensing means and from the olefin sensing means and providing signals corresponding thereto; means connected to the acid sensing means, to the hydrocarbon product sensing means and to the first and second calculating means for determining changes $\Delta\ Q$, $\Delta\ A$ and $\Delta\ U$ in the octane rating, the acid consumption and the utility rate, respectively, means connected to the change determining means and to the economic value signal means for determining the earnings for the alkylation unit for a current trial temperature and providing an earnings signal corresponding thereto for earnings control means connected to the earnings signal means and to the trial temperature signal means for providing a command signal to the trial temperature means causing the trial temperature means to iteratively change the trial temperature until the command signal is representative of a decrease in earnings and then to control the trial temperature signal means to the next previous trial temperature, and means connected to the earnings control means, to the utility means, to the acid control means, means for providing the control signals to the utility means and to the acid control means in response to the command signal from the earnings control means being representative of a decrease in earnings.

5. A system as described in claim **4** in which the olefin sensing means includes means for sensing concentrations of the different olefins and providing signals corresponding thereto, means connected to the olefin concentration sensing means for providing a signal corresponding to the ratio P_B of propylene to olefins; and the first and second calculating means includes G signal means connected to the temperature sensing means and to the trial temperature signal means, respectively, and receiving direct current voltages corresponding to reference temperatures T_1 and T_2 and predetermined coefficients a_1 through a_5 and b_1 through b_5 for providing signals corresponding to the quantities G_B and G_C in accordance with the following equations:

$G_L = a_1\ [(T-T_1/100] + a_2\ [(T-T_1/100]^2 + a_3\ [(T-T_1/100]^3 + a_4\ [(T-T_1)/100]^4 + a_5\ [(T-T_1)/100]^5$

$G_U = b_1\ [(T-T_2)/100] + b_2\ [(T-T_2)/100]^2 + b_3\ [(T-T_2)/100]^3$, and $+ b_4\ [(T-T_2)/100]^4 + b_5(T-T_2)/100]^5$

$G_{L-U} = [(P_U-P_B)/(P_U-P_L)]\ G_L + [(P_B-P_L)/(P_U-P_L)]\ G_U$

so that a signal G_B or G_C is provided in accordance with each equation by each G signal means using sensed temperature T_B for the term T to provide the G_B signal and the trial temperature T_j for the term T to provide the G_C signal, first switching means receiving direct current voltages corresponding to reference ratios P_U and P_L and connected to the P_B ratio signal means and to each G signal means for selecting the proper signal G_B or G_C in accordance with the ratio P_B signal and the P_U and P_L reference voltages so that the signals corresponding to the term G_L are provided as the G_B and G_C signals to the change determining means when the ratio P_B is more negative than the lower reference ratio P_L signal, and signals corresponding to the term G_U are provided as the G_B and G_C signals to the change determining means when the ratio signal P_B is more positive than the upper reference ratio P_U voltages, the signals corresponding to the term G_{U-L} are provided as the G_B and G_C signals to the determining means when the sensed ratio P_B signal is not more negative than the lower reference ratio P_L voltage nor more positive than the upper reference ratio P_U voltage; F signal means connected to the temperature sensing means and to the trial temperature signal means and receiving the direct current voltages corresponding to reference temperatures T_1 and T_2, a term of 1.0 and predetermined coefficients c_1 through c_5 and d_1 through d_5 for providing signals corresponding to quantities F_B and F_C in accordance with the following equations:

$F_L = 1.0 + c_1[(T-T_1)/100] + c_2\ [(T-T_1)/100]^2 + c_3[(T-T_1)/100]^3 + c_4[(T-T_1)/100] + c_5[(T-T_1/100]^5$

$F_U = 1.0 + d_1[(T-T_2)/100] + d_2[(T-T_2)/100]^2 + d_3[(T-T^2)/100\pi^3 + d_4](T-T_2)/100] + d_5[(T-T_2)/100]^5$

$F_{L-U} = [(P_U - P_B)/(P_U - P_L)]\ F_L + [(P_B - P_L)/(P - P_L)]\ F_U$

second switching means receiving the direct current voltages corresponding to the reference ratios P_U and P_L and connected to the P_B ratio signal means and to each F signal means for selecting the proper signal F_B or F_C in accordance with the P_B signal and the P_U and P_L reference voltages so that signals corresponding to the term F_L are provided as the F_B and F_C signals to the change determining means when the ratio P_B is more negative than the P_U reference voltage, signals corresponding to the term F_U are provided as the F_B and F_C signals to the change determining means when ratio P_B signal is more positive than reference ratio P_U voltage, and signals corresponding to the term F_{U-L} are provided as the F_B and F_C signals to the change determining means when the ratio P_B signal is not more negative than the reference ratio P_U voltage; and means connected to the temperature sensing means, to the trial temperature signal means and to the ratio P_B signal means and receiving direct current voltages corresponding to the coefficients e_1 through e_{16} for providing signals corresponding to the quantities H_B and H_C in accordance with the following equation:

$H = e_1 + e_2\ T + e_3\ T^2 + e_4\ T^3 + (e_5+e_6T+e_7T^2+e_8T^3)P_B + (e_9+e_{10}T+e_{11}T^2+e_{12}T^3)P_B^2 + (e_{13}+e_{14}T+e_{15}T^2+e_{16}T^3)P_B^3$

where the sensed temperature T_B is used for T to provide the signal H_B and the trial temperature T_j is used for T to provide the signal corresponding to the calculated quantity H_C.

6. A system as described in claim **4** in which the hydrocarbon product sensing means includes means for sensing the flow rate R_C of the hydrocarbon product and providing a signal corresponding thereto, means for sensing the alkylate content V_K of the hydrocarbon product and providing a corresponding signal, and means connected to the hydrocarbon product flow rate sensing means and to the alkylate content sensing means for providing a signal corresponding to the alkylate flow rate R_K in accordance with the following equation:

$R_K = V_K R_C$

and the acid sensing means includes means for sensing the flow rate R_{DB} of discharge acid and providing a signal corresponding thereto.

7. A system as described in claim **6** in which the change determining means includes means connected to the earnings signal means and to the first switching means for subtracting the G_B signal from the G_C signal to provide a signal to the earnings signal means, corresponding to the change in octane rate $\Delta\ Q$, means connected to the alkylate flow rate signal means and to the discharge acid flow rate sensing means and receiving a direct current voltage corresponding to a predetermined conversion factor α for providing a signal corresponding to the acid consumption A_B by the alkylation unit in accordance with the following equation:

$A_B = \alpha R_{DB}/R_K$

means receiving a direct current voltage corresponding to a term 1 in the next following equation and connected to the second switching means to the earnings signal means and to the acid consumption signal means for providing a signal corresponding to the differential acid consumption $\Delta\ A$ to the earnings signal means in accordance with the following equation:

$\Delta\ A = A_B[(F_B/F_C) - 1]$

and means connected to the H_B and H_C signal means and to the earnings signal means for subtracting the H_B signal from the H_C signal to provide a signal to the earnings signal means corresponding to the change $\Delta\ U$ in the utility rate.

8. A system as described in claim **7** in which the earnings signal means provides the earnings signal in accordance with the $\Delta\ Q, \Delta A, \Delta U, W_Q$, W_A and W_U signals and the following equation:

$E = (\Delta\ Q)(W_Q) - (\Delta\ A)(W_A) - (\Delta\ U\ )(W_U\ )$

where E is the earnings; and the earnings control means includes means connected to the earnings signal means for sampling and holding the earnings signal to provide a pair of signals, one signal corresponding to the earnings for a current trial temperature while the other signal corresponds to the earnings for a next previous trial temperature, comparing means connected to the sample and hold means and to the trial temperature signal means and responsive to the signals from the sample and hold means for providing a high level direct current signal as the command signal to the trial temperature signal means when the earnings for the current trial temperature is not less than the earnings for the next previous trial temperature and providing a low level direct current signal as the command signal to the trial temperature signal means when the earnings for the current trial temperature is less than the earnings for the next previous trial signal, and temperature control signal means connected to the first comparing means, to the trial temperature means and to the utility means for providing the signal corresponding to the next previous trial temperature as the temperature control signal in response to the command signal from the comparing means changing from a high level to a low level.

9. A system as described in claim **8** in which the earnings control means further comprises means connected to the ΔU signal means, to the discharge acid flow rate sensing means and to the alkylate flow rate signal means for providing a signal corresponding to a utility rate R_U in accordance with the $\Delta\ U$ signal, the R_{DB} signal and the R_K signal and the following equation:

$R_U = R_{DB} + (\Delta\ U)(R_K)$,

and means connected to the acid consumption A_B signal means, to the $\Delta\ A$ signal means and to the alkylate flow rate R_K signal means and receiving the direct current voltage corresponding to the conversion factor α for providing a signal corresponding to a calculated discharge acid flow rate R_{DC} in accordance with the $\Delta\ A$, A_B and R_K signals, the direct current voltage and the following equation:

$R_{DC} = (A_B + \Delta\ A)R_K/\alpha$,

and the comparing means is also connected to the R_U signal means and receiving direct current reference voltages corresponding to predetermined limits for the trial temperature T_j, for the utility rate R_U and for the calculated discharge acid flow rate R_{DC} and provides the high level signal to the temperature control signal means when the earnings for the current trial temperature is not less than the earnings for the next previous trial temperature, the trial temperature T_j does not exceed a predetermined limit, the utility rate R_U does not exceed a predetermined limit, and the calculated discharge acid flow rate R_{DC} does not exceed a predetermined limit, and providing the low level signal when the earnings for the current trial temperature is less than the earnings for the next previous trial temperature, the trial temperature T_j exceeds a predetermined limit, the utility rate R_U exceeds a predetermined limit, or the calculated discharge acid flow rate exceeds a predetermined limit.

10. A method for controlling an alkylation unit to achieve an optimum operating condition and said alkylation unit includes a contactor wherein an olefinisoparaffin mixture is contacted with acid at a temperature controlled by utility means and the contactor provides an acid-hydrocarbon mixture to a settler which separates the acid from the acid-hydrocarbon mixture to provide a hydrocarbon product, which includes alkylate and acid, a portion of the separated acid is discharged while a portion of the separated acid is fed back to the contactor along with fresh acid entering the alkylation unit that is added to feedback acid to replace the discharge acid, which comprises the following steps: sensing the contact temperature T_B, sensing a utility rate, sensing a condition related to the contact acid, sensing conditions to the hydrocarbon product, sensing conditions of the olefin, determining economic values related to the octane rating of the alkylate, to acid consumption and to the utility and controlling the acid entering the alkylation unit and the contact temperature in accordance with the sensed contact temperature, the sensed utility rate, the sensed condition related to the contact acid, the sensed condition of the hydrocarbon product and the sensed olefin conditions and the determined economic values, so as to achieve an optimum operating condition for the alkylation unit.

11. A method as described in claim **10** in which the contact temperature is controlled by passing a coolant through the contactor.

12. A method as described in claim **11** in which the controlling step includes determining the effect that a change in the contact temperature would have on the earnings of the alkylation unit.

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