

[54] **PROCESS CONTROL**

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Related U.S. Application Data

- [63] Continuation of Ser. No. 711,063, March 6, 1968, abandoned.
[52] **U.S. Cl.**..... **73/23.1, 23/255, 55/187, 235/151.35**
[51] **Int. Cl.**... **G01n 31/08, B01d 15/08, G06f 15/20**
[58] **Field of Search**..... **55/67, 197, 386; 73/23.1; 235/151.35**

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[57] **ABSTRACT**

A gas chromatographic system includes a chromatographic column, injection control and six fraction collectors. A thermal conductivity detector monitors the outlet conduit of the column and controls a strip chart recorder which includes a retransmitting potentiometer. Connected to the potentiometer are a peak-valley-slope signal generator and six set point signal generators. The system also includes a clock, six time comparators, an auxiliary timer and a twenty step deca-tron sequencer. A plug board permits selective interconnection of the signal generators, the time comparators, the timer and the sequencer for producing output signals to operate the injection control and the fraction collectors as a function of the output of the column as monitored by the detector.

8 Claims, 9 Drawing Figures

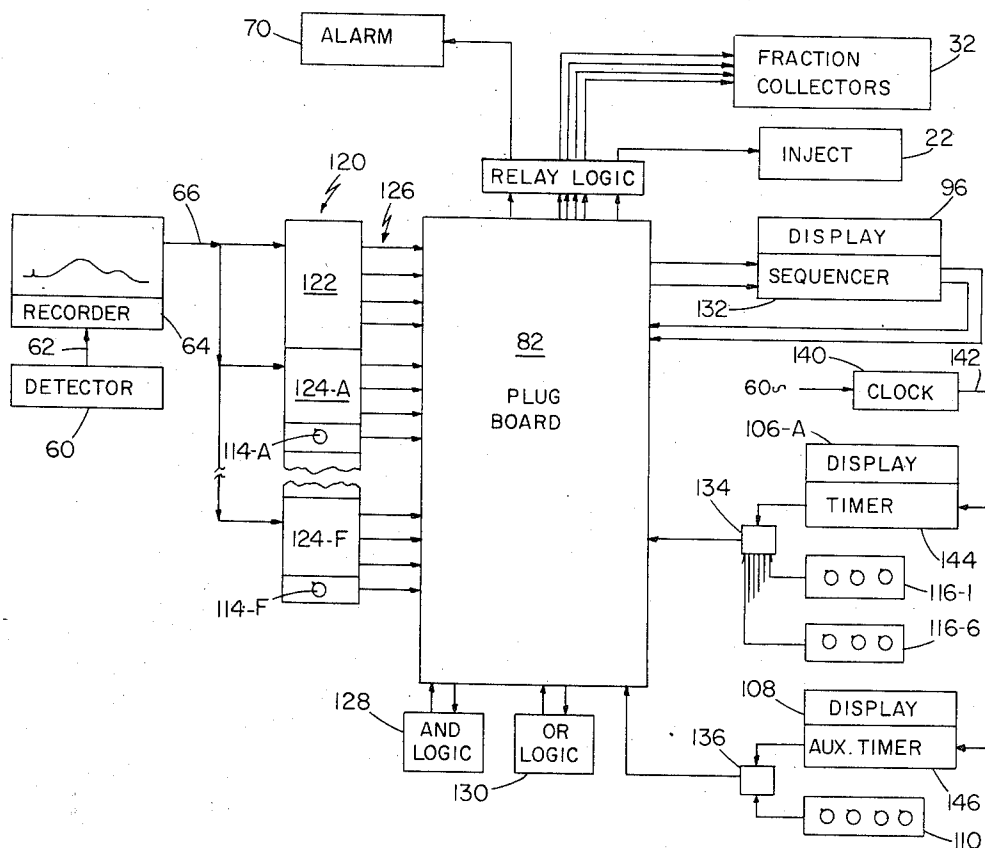


FIG 1

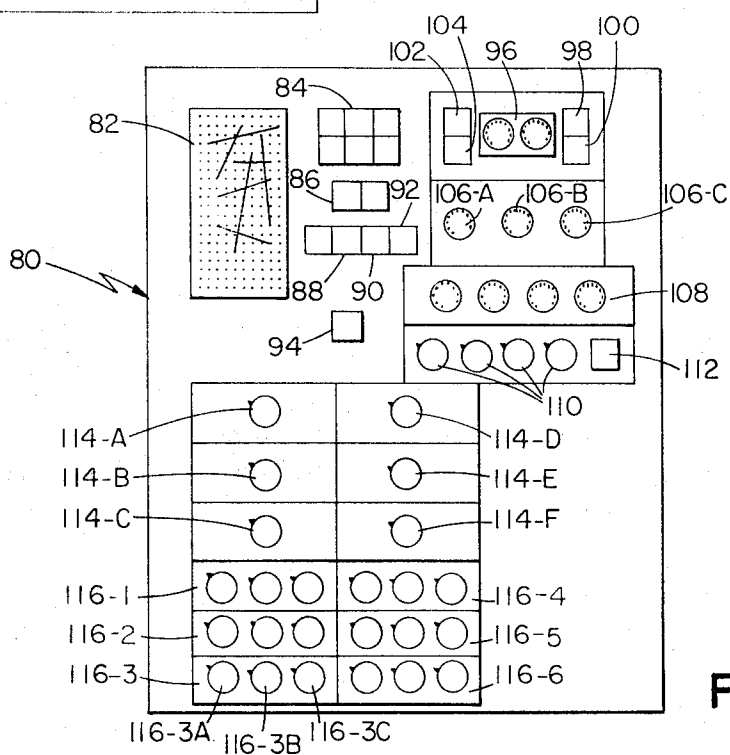
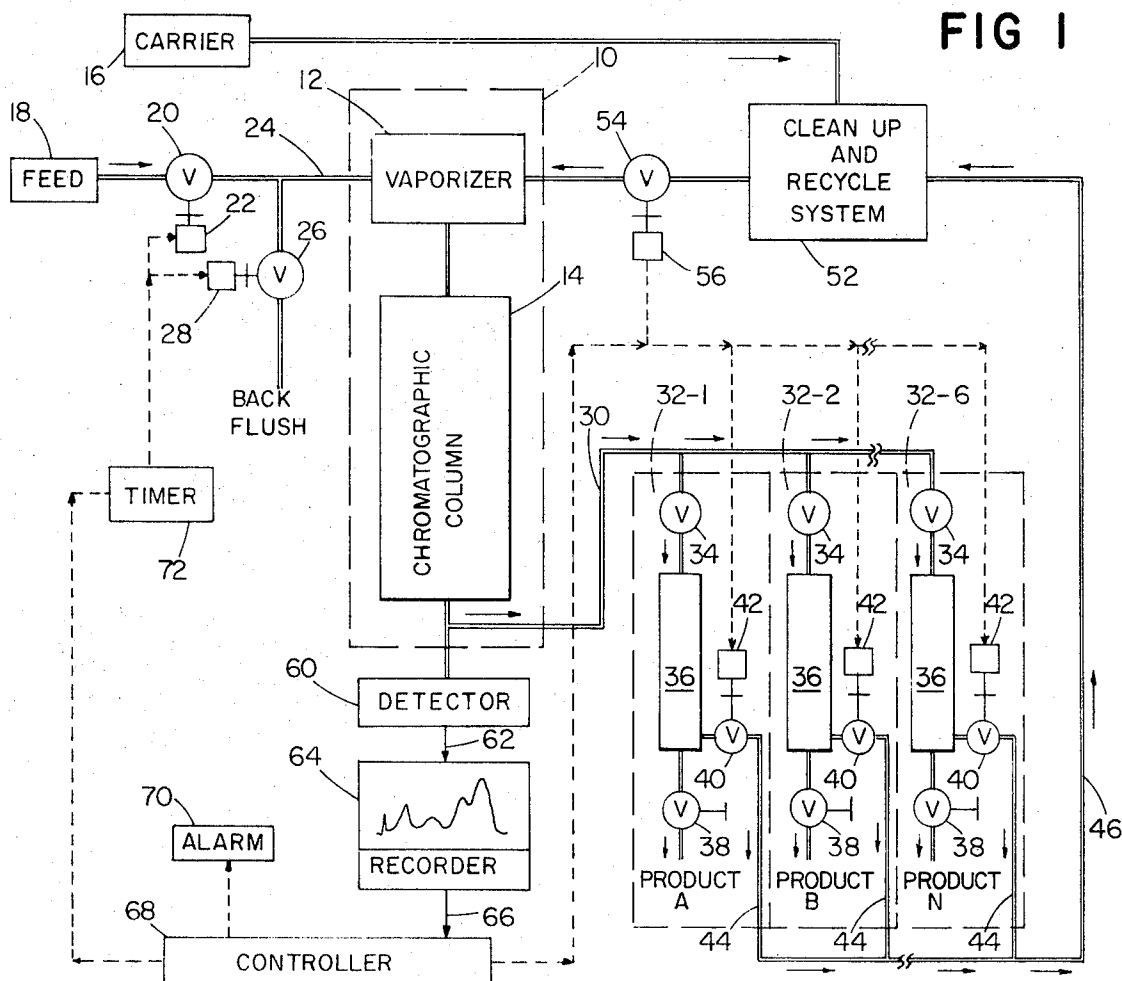


FIG 2

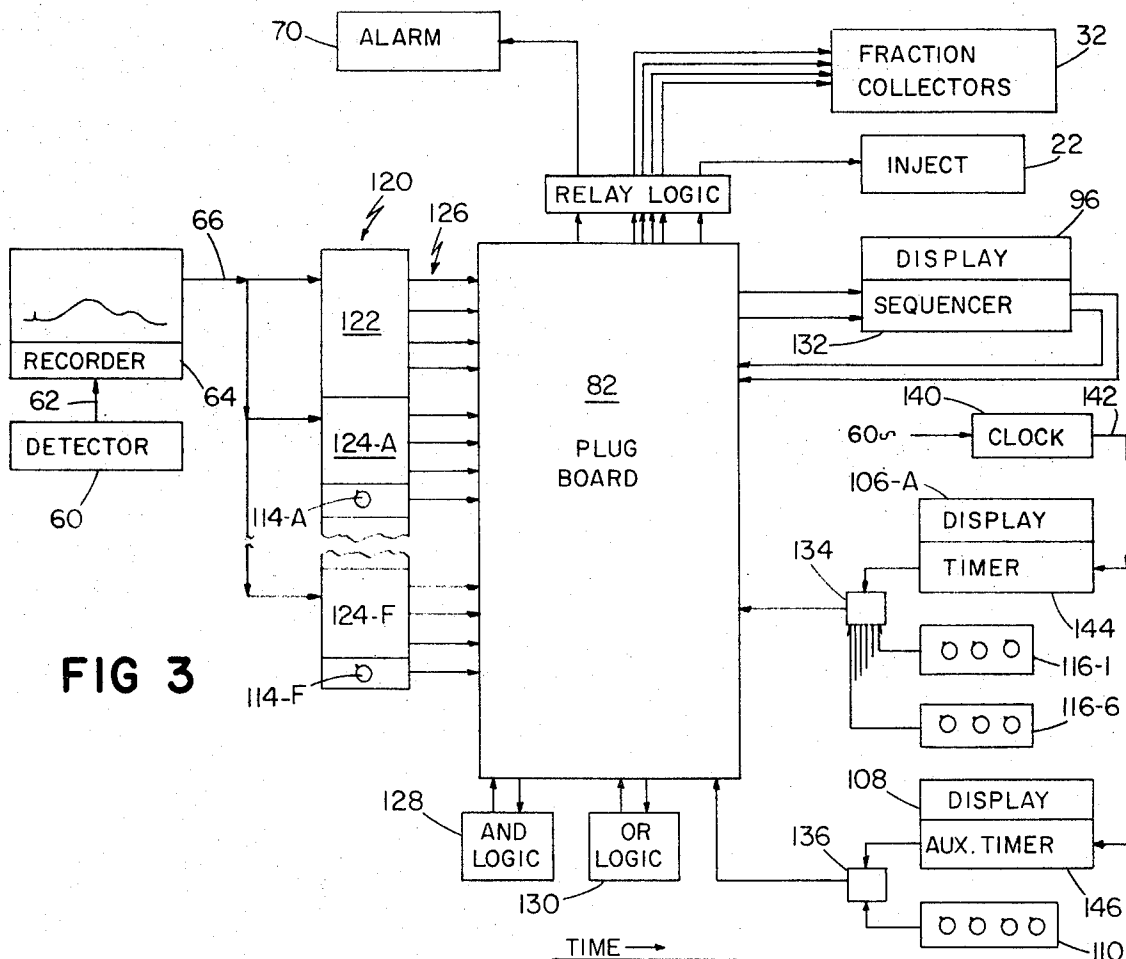


FIG 3

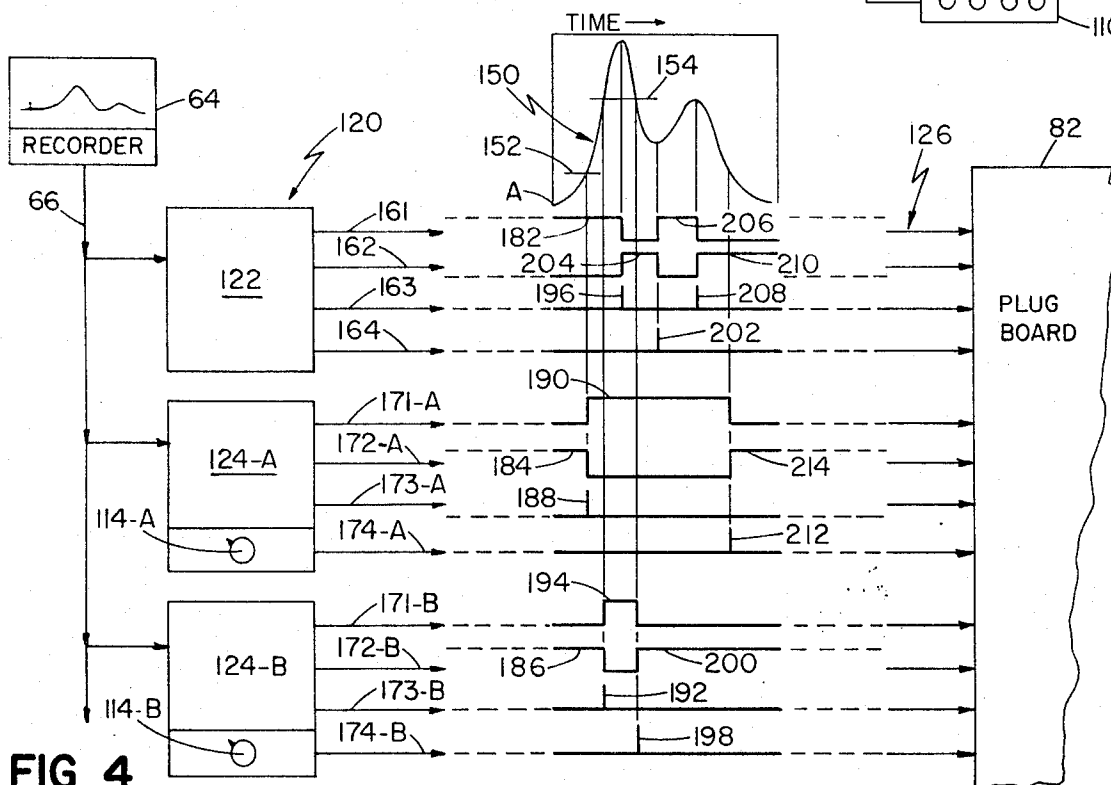


FIG 4

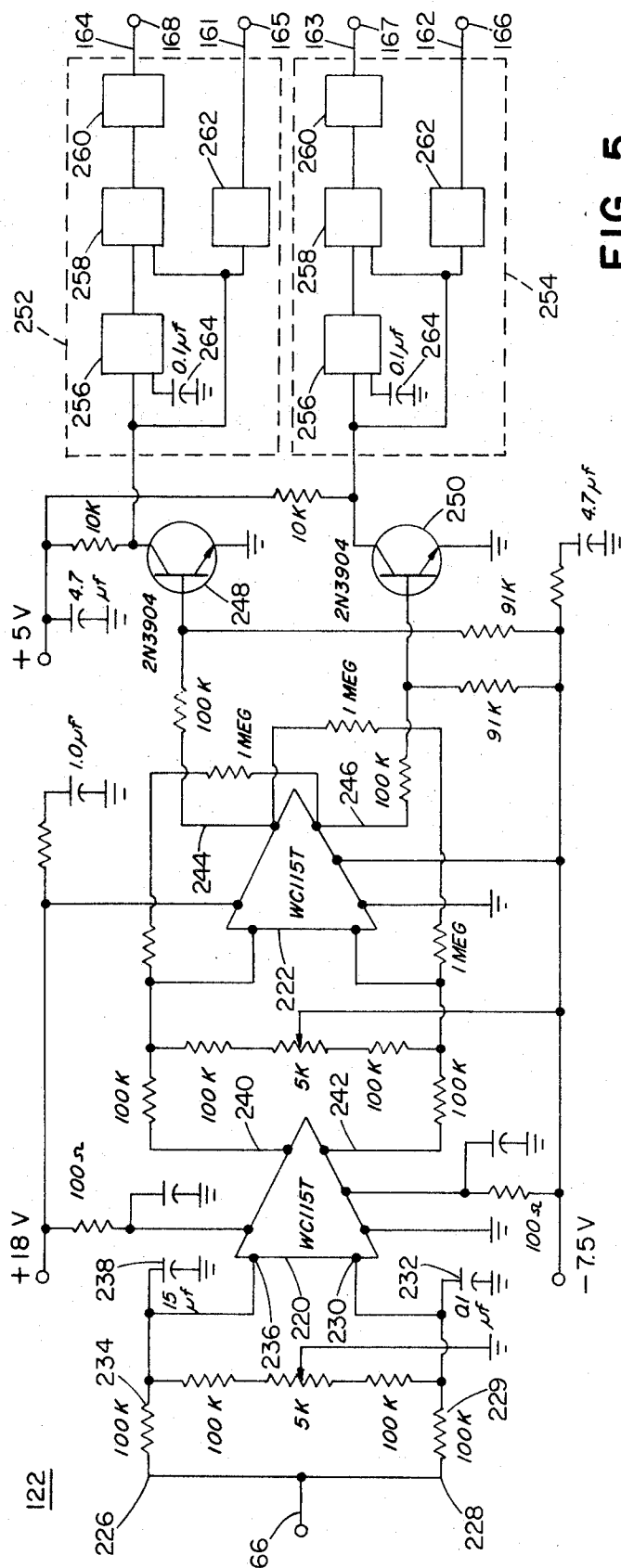


FIG 5

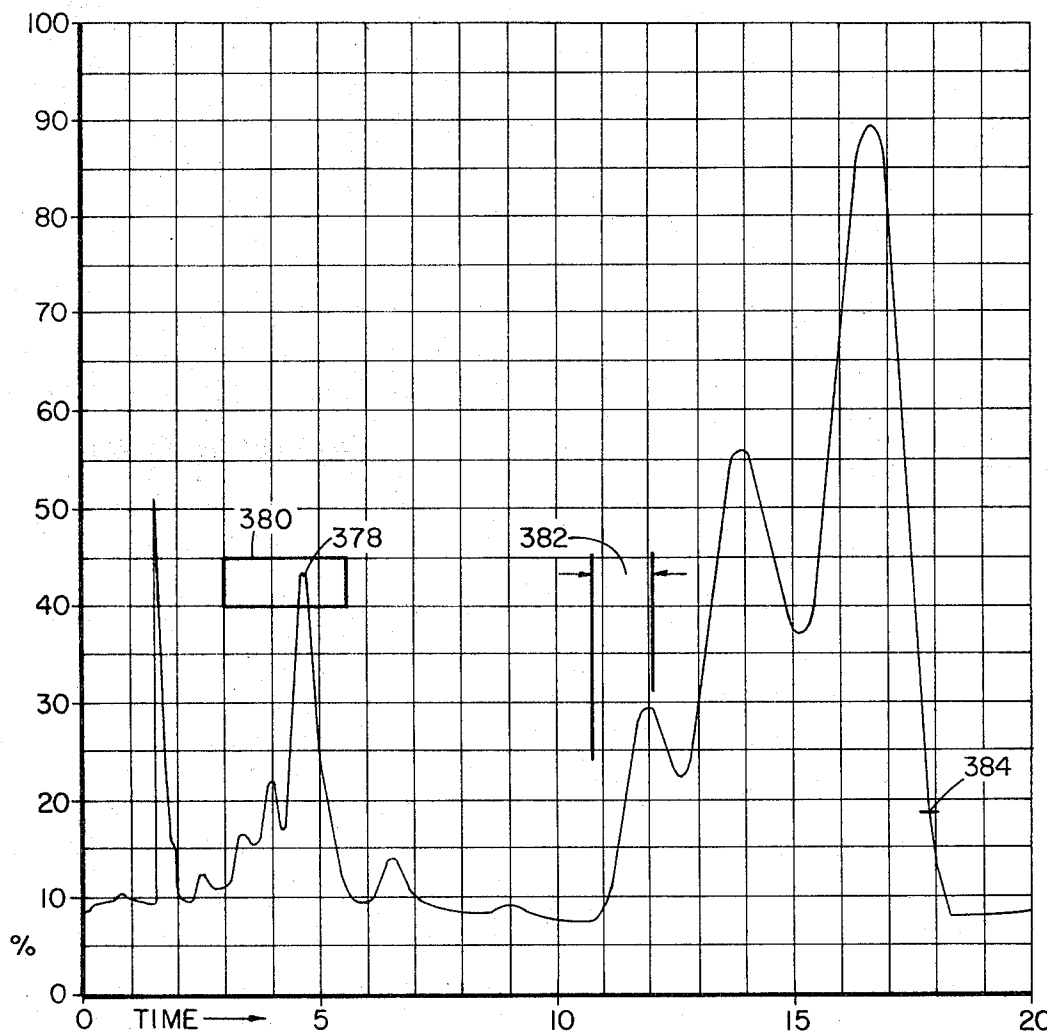


FIG 9

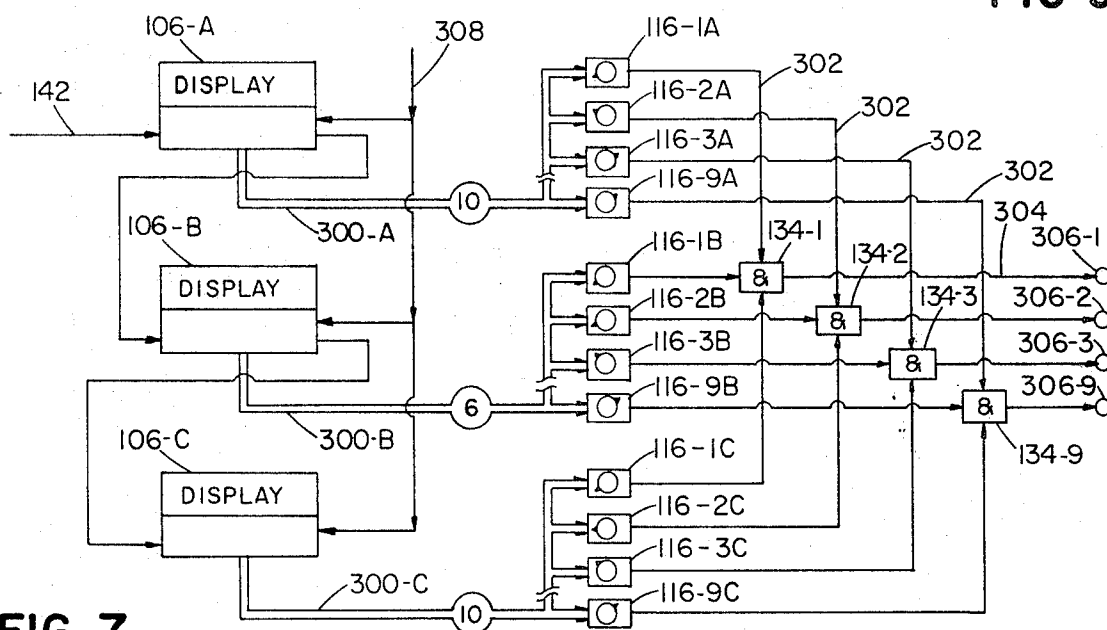


FIG 7

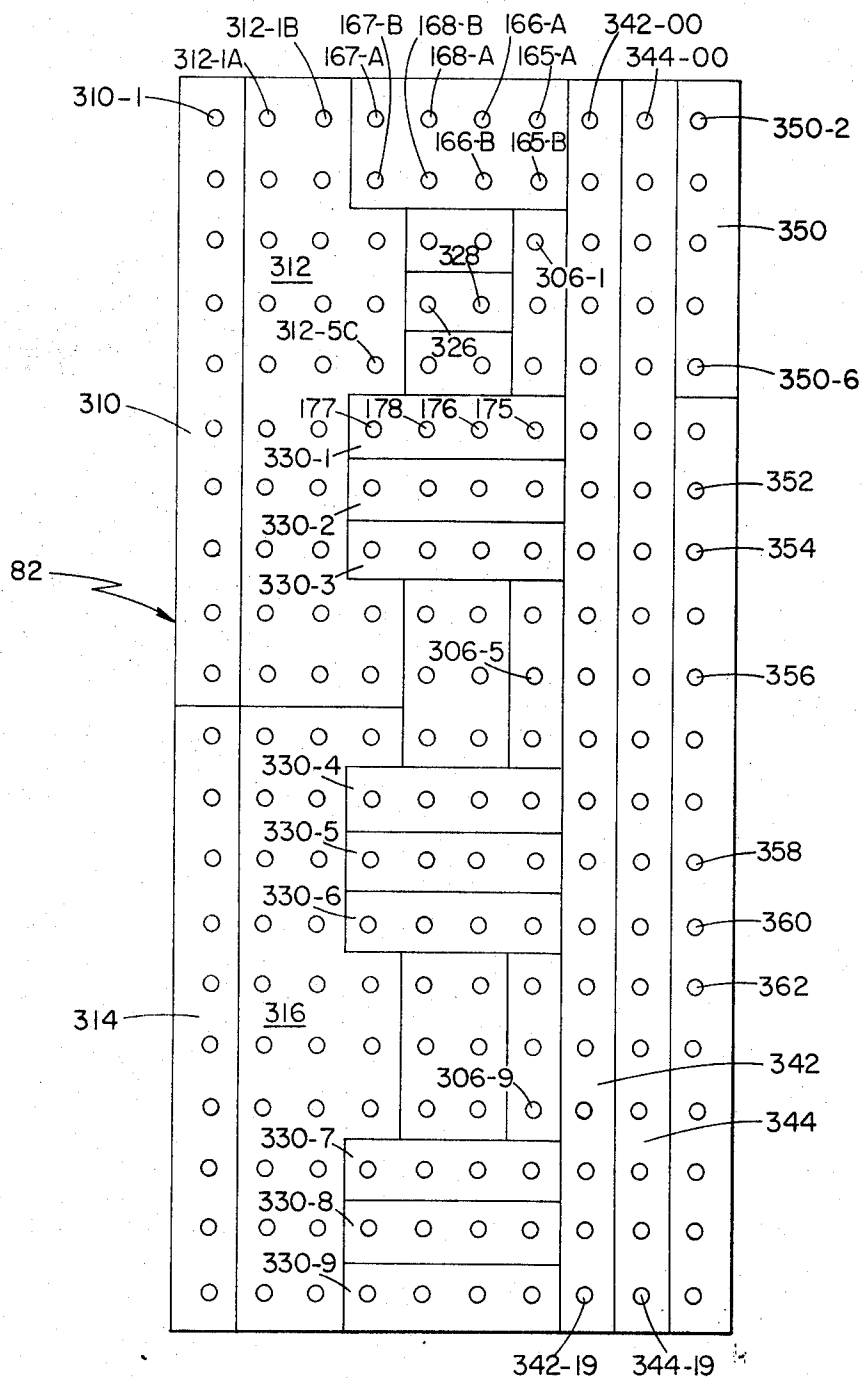


FIG 8

PROCESS CONTROL

This is a continuation, of application Ser. No. 711,063, filed Mar. 6, 1968, now abandoned.

SUMMARY OF INVENTION

This invention relates to control systems and more particularly to apparatus responsive to a process output signal for generating control signals for the control of the supervised process or related apparatus. The invention has particular applicability to chromatographic systems.

Chromatographic systems separate a gas or liquid sample into one or more chromatographic fractions, utilizing a repetitive process involving the sequential injection of the sample stream into a chromatographic column and the sequential elution of the chromatographic fractions from the column. Typically, an inert carrier fluid is employed to drive the sample stream through the column and a detecting device such as a thermal conductivity sensor or flame ionization device detects the chromatographic fractions emerging from the column.

In preparation or production scale chromatography, the series of eluted chromatographic fractions are detected and one or more of the desired fractions is collected, the fraction collection being controlled in response to the output signals from the detecting device. The output signal of the detecting device, however, is subject to a number of variables, including the temperature of the chromatographic column and the nature of the constituents of the sample stream being processed. On repetitive operations over a period of time, variations or abnormalities in the cyclic operation occur as a function of a number of conditions. In many prior art systems where the system was programmed to detect a particular peak in a sequential wave form output signal, a shift of this peak either in amplitude or in time often resulted in the collection of an undesired portion, the contamination of a previously collected portion, or failure to collect the desired portion. Also, where such control systems have been used to control the rate of injection of the sample stream into the column, such control systems were incapable of providing the maximum or optimum throughput of the sample stream.

Accordingly, it is a particular object of this invention to provide a novel and improved control system for chromatographic systems which permits improved control of the injection and fraction collection processes.

Another object of the invention is to provide novel and improved control apparatus responsive to a process output signal for generating signals for the control of that process or related apparatus.

A further object of the invention is to provide a novel and improved process control system that provides greater optimization of the cycle and throughput capabilities of the process.

Still another object of the invention is to provide a novel and versatile chromatographic control system capable of detecting and responding to variations and abnormalities in a repetitive operating cycle in a manner to prevent contamination of collected portions and to assure collection of desired fractions.

A further object of the invention is to provide a novel and improved control apparatus selectively responsive to time and amplitude functions of the output signal of the supervised system, which control system offers accuracy and efficiency over an extended operating pe-

riod while providing flexibility to the operator in the selection of time, amplitude and dynamic characteristics (such as slope) of the output signal of the system being supervised.

In accordance with the invention there is provided process control apparatus particularly useful with chromatographic apparatus, which includes circuitry for generating a plurality of digital signals representing different characteristics of the process analog signal, a plurality of timing devices for producing timing signals, an interval selector, and signal generating means for producing output signals for control purposes. The apparatus further includes a selective interconnection device for selectively interconnecting the digital process characteristic signals and the timing signals to control the interval selector in response to those signals through a series of process intervals in which a series of output signals are generated for the control of predetermined output devices as a function of the progress of the supervised process. The selective interconnection device includes receptacle means and a matrix of circuit completing elements adapted to be secured in the receptacle for interconnecting the digital characteristic signals, the timing signals, the interval selector and the output producing means so that a particular process control program may be selected by insertion of the circuit completing matrix into said receptacle means.

In a preferred embodiment, the process output characteristic signal generator produces digital signals indicative of peaks, valleys, and the rate of change of the analog process output. That signal generator, in a particular embodiment, employs a differential amplifier having an input network which applies the analog process output to both inputs of the differential amplifier, the application of the analog signal to one input of the amplifier being delayed relative to the application of that analog signal to the other input of the amplifier, and an output logic network responsive to the output of the differential amplifier for producing the peak, valley, and rate of change characteristic signals. The apparatus of that particular embodiment also includes a plurality of comparators for selecting particular set points such that digital characteristic signals indicative of the sensed magnitude of the process output are generated and interconnected with other digital signals in the control of the interval selector.

The apparatus of the invention permits versatile and comprehensive supervision of a process and is particularly adapted to processes where the analog output varies over wide ranges as in a chromatographic analysis in which components in a fluid stream are eluted sequentially.

Other objects, features and advantages of the invention will be seen as the following description of a particular embodiment progresses, in conjunction with the drawings, in which:

FIG. 1 is a schematic diagram of a gas chromatographic system employing process control apparatus constructed in accordance with the invention;

FIG. 2 is a diagrammatic view of the control panel of the process control apparatus employed in the system shown in FIG. 1;

FIG. 3 is a block diagram of components of the process control apparatus employed in the system shown in FIG. 1;

FIG. 4 is a diagram indicating the nature of control signals generated by apparatus shown in FIG. 3;

FIG. 5 is a schematic diagram of the slope-peak-valley detector circuitry employed in the apparatus shown in FIG. 4;

FIG. 6 is a schematic diagram of the set point comparator circuitry employed in the apparatus shown in FIG. 4;

FIG. 7 is a block diagram of the timer comparator logic employed in the apparatus shown in FIG. 3;

FIG. 8 is a view of the plug board employed in the apparatus shown in FIG. 3; and

FIG. 9 is a graph indicating a typical process control employing the apparatus shown in FIG. 3.

DESCRIPTION OF PARTICULAR EMBODIMENT

With reference to FIG. 1, the chromatographic system there illustrated comprises an oven 10 in which is mounted a vaporizer 12 and a chromatographic column 14 in the form of a bed of finely divided particles capable of effecting the chromatographic separation of a fluid stream into two or more components. A carrier from source 16 is introduced to the vaporizer 12 together with a sample from feed source 18 under the control of injection valve 20 (controlled by solenoid 22) for introduction of sample into the inlet column via conduit 24. A second valve 26 controlled by solenoid 28 permits back flush of the vaporizer when required.

At the outlet of the column the effluent is conducted over conduit 30 to fraction collectors 32. Each fraction collector includes a check valve 34, a drain outlet valve 38 and a flow valve 40 (controlled by solenoid 42). Each fraction collector outlet conduit 44 is connected via a common return conduit 46 to clean up and recycle system 52 which includes pressure regulators and a compressor. The carrier is returned to vaporizer 12 from system 52 via valve 54 that is controlled by solenoid 56.

A suitable detector 60 such as a thermal conductivity detector monitors the outlet conduit 30 of the chromatographic column 14. This detector produces output signal over line 62 to recorder 64 which is of the strip chart type. The recorder 64 includes a retransmitting potentiometer which applies a signal over line 66 to controller 68. Output signals from the controller are applied to alarm device 70; inject timer 72 (which controls solenoids 22 and 28); and process control solenoids 42 and 56.

Controller 68 includes a control panel 80, as indicated in FIG. 2, which includes a receptacle for a removable plug board 82; a set of six fraction collector indicator-controls 84; an inject indicator-control 86; an alarm indicator 88; an alarm silence control 90; a carrier gas indicator-control 92; and an on-off switch 94. In addition, there is provided a two-stage sequencer indicator 96 and four manual sequencer controls: an advance control 98; a sequencer hold control 100; and two sequencer reset controls 102 (go to 00) and 104 (go to 01). Below the sequencer control section is mounted a three-stage interval timer display 106 and a four-stage auxiliary timer display 108. Associated with the auxiliary timer display is a manual control 110 for providing a control setting for the auxiliary timer and a manual timer reset button 112. The lower part of the control panel 80 includes six set point indicator control 114 (with space for three more) and six interval timer

comparison controls 116 (also including space for three more).

With reference to FIG. 3, the output of detector 60 is applied to recorder 64 which recorder, on line 66 transmits an analog signal indicative of the position of the pen of the recorder to a pen position signal processing network 120 that includes a peak-valley-slope detector circuit 122 and six pen position comparator circuits 124. Each pen position comparator circuit also has an input from the corresponding set point selector unit 114. The outputs from the signal processing circuits are applied over lines 126 to the plug board 82. Other inputs to the plug board include AND logic units 128 (10 inputs); OR logic units 130 (10 inputs); sequencer 132 (20 inputs); interval timer comparators 134 (six inputs); and auxiliary timer comparator 136 (one input). Outputs from the plug board are applied to AND logic 128 (25 outputs), OR logic 130 (24 outputs), sequence 132 (20 outputs), fraction collectors 32 (five outputs), inject control 22, alarm 70, and miscellaneous additional control outputs.

The sequencer 132 includes two decatron display tubes 96 and is stepped through twenty positions (00-19). A sixty cycle signal is applied to clock 140 and that clock produces output pulses at one second intervals on line 142 for application to interval timer 144 and auxiliary timer 146, each of which has a decatron display 106, 108, respectively, coupled to it.

The nature of the output of the signal processing network 120 is indicated in FIG. 4. That circuitry includes a peak-valley-slope detector 122 and six pen position comparators 124 (only two of which are shown). A typical curve 150 having two set points 152 and 154, is indicated in FIG. 4. Comparator 124A is set to set point 152 and comparator 124B is set to set point 154. The peak-valley-slope detector 122 has four outputs 161-164, output 161 providing a positive signal when the pen is moving in an up direction; output line 162 providing a positive signal when the pen is moving in a downward direction; output 163 providing a positive output pulse when the pen has reached a peak; and output 164 providing a positive output pulse indicative of a valley. Each comparator 124 similarly has four outputs 171-174, output 171 providing a positive signal when the pen is above the selected set point level; line 172 providing a positive output when the pen is below the selected set point level; output 173 providing a positive pulse when the pen is passing the selected set point in the upward direction; and line 174 producing a positive output pulse when the pen is passing the selected set point in the downward direction.

With reference to the illustrative curve 150 and the selected set points 152 and 154, at point A the pen of recorder 64 is rising and circuit 122 produces a positive level 182 on line 161. As the pen is below both set points, there are positive outputs 184 on line 172A and 186 on line 172B. When the pen (curve 150) passes set point 152 a pulse 188 is applied to line 173A, signal 184 terminates and signal 190 appears on line 171A. The curve 150 next passes the second set point 154, producing a pulse 192 on line 173B, terminating the signal 186 on line 172B and providing signal 194 on line 171B. Curve 150 next goes through a peak and pulse signal 196 is provided on line 163. The curve continues to fall past set point 154 and a pulse 198 indicative of this is generated on line 174B. At the same time signal level 194 terminates and signal level 200 appears

on line 172B. Rather than continuing down past set point 152, the slope of the signal curve reverses, creating a valley which is signalled by pulse 202 on line 164. Signal 204 on line 162 also terminates and signal 206 appears on line 161. Before reaching set point 154 the curve reverses producing a peak which is signalled by pulse 208 on line 163, the termination of signal 206 on line 161 and the generation of signal 210 on line 162. Curve 150 then falls past the first set point (level 152) and as it passes that set point, pulse 212 is generated, level 190 is terminated and a new level 214 appears on line 172A.

The peak-valley-slope detector is shown in schematic form in FIG. 5. That circuit includes two integrated circuit amplifiers 220, 222, circuit 220 being connected as a differential amplifier and circuit 222 being connected as a flip flop circuit. The input signal from the chart recorder slide wire is applied over line 66 to input lines 226 and 228. The signal on line 228 is coupled by resistor 229 directly to amplifier input 230, capacitor 232 functioning as a noise suppressor. The signal on line 226 is coupled by resistor 234 to the second amplifier input 236, the application of that signal to the input being delayed by capacitor 238. Applied to the output lines 240, 242 is the amplified difference between the signals applied to input lines 230, 236 and that amplified difference signal is coupled to the flip flop circuit 222. Output line 244 of the flip flop is positive with respect to output line 246 when the analog signal on line 66 is going down, while output line 246 is positive with respect to line 244 when the analog signal on line 66 is rising. The flip flop output signals are coupled by amplifier transistors 248, 250 respectively, to logic circuits 252, 254 each of which includes NAND circuits 256, 258, 260 and 262, circuits 260 and 262 functioning as pulse amplifiers.

Thus the output signal from transistor amplifier 248 is coupled to output line 161 by NAND circuit 262. That output is also applied to one input of NAND circuit 258 and one input of NAND circuit 256. Capacitor 264 coupled to circuit 256 delays its output transition in response to conduction of transistor 248 for one hundred microseconds so that NAND circuit 258 has an output for that duration which output is inverted by pulse amplifier 260 and applied as a pulse on line 164 indicative of the transition from decreasing signal level to increasing signal level.

Logic circuit 254 operates in similar but reciprocal manner to produce a signal level indicative of negative slope on line 162 and a pulse on line 163 indicative of a peak.

A schematic diagram of the pen position comparator circuit 124 is shown in FIG. 6. The signal from the slide wire of the retransmitting potentiometer of recorder 64 is transferred over line 66. Each set point control knob 114 controls the position of the tap 270 of a corresponding potentiometer 272. The signals from the line 66 and tap 270 are applied over lines 274 and 276, respectively, to the integrated circuit amplifier 278 and from there to the flip flop circuit employing amplifier 280. That circuit produces output signal on line 282 to cause transistor 284 to conduct when the signal on line 66 is above the potential applied via tap 270; while an output signal on line 286 causes transistor 288 to conduct when the signal on line 66 is below the signal from tap 270. Logic circuits 290, 292, identical with logic circuits 252 and 254, generate in corresponding man-

ner signals on lines 171A-174A for application to plug board 82. Comparator circuits 124B-F cooperate with potentiometers 272B-F to produce the corresponding outputs on lines 171B-174F.

The interval timer-comparator circuitry is shown in block diagram form in FIG. 7. The signal from clock 140 (one cycle per second) is applied over line 142 to step a seconds decatron 106A through stages 0-9. The pulse transition from 9 to 0 steps a second seconds decatron 106B. Each transition from 5 to 0 of decatron 106B steps the minutes decatron 106C. The signals from each display section coupled over output lines 300. Connected to each output line 300 are six corresponding decade switch timer selectors 116 which connect one of the output lines in each group 300 to an output line 302 for application to AND circuit comparators 134. As indicated, selectors 116-1A, 116-1B and 116-1C are connected to AND circuit comparator 134-1. When signals are applied to all three inputs of the comparator, a signal is applied on output line 304 to the plug connection 306-1. The decatrons 106 are reset to 0 by a signal on line 308 in response to each stepping operation of the sequencer.

The layout of the plug board 82 is shown in FIG. 8. As there indicated, the output plug connections of the ten AND circuits 128 are provided in block 310 and the input plug connections for those AND circuits are provided in block 312 (there being five two input AND circuits and five three input AND circuits, (the first AND circuit having inputs 312-1A and 312-1B and output 310-1 for example). The OR logic 130 includes provision for ten OR circuits, the output plug connections being in section 314 and the input plug connections being in section 316 (there being four three input OR circuits and six two input OR circuits). The rising slope signal on line 161 has two plug connections 165A, 165B; the falling slope signal on line 162 has two plug connections 166A, 166B; the peak signal on line 163 has two plug connections 167A, 167B; and the valley signal on line 164 has two plug connections 168A, 168B. An input plug connection to the auxiliary timer 146 is provided at plug 326 and an output plug connection from the auxiliary timer is provided at plug 328. There is a set 330 of four plug positions for each pen comparator circuit 124 plug position 175 being connected to line 171 and indicating a signal above the set point; plug position 176 being connected to line 172 and indicating a pen position below the set point; plug position 177 being connected to line 173 indicating that the pin is passing the selected set point in the up direction; and plug position 178 being connected to line 176 and indicating that the pen position is passing the selected set point in the downward direction. There are also nine plug positions 306, one for each of the nine time comparators 134. The plug positions in columns 342 and 344 are sequencer input and output plug connections respectively, a signal applied to the input plug connection 342-92 causing the sequencer 132 to step to interval 3, for example, the sequencer in that interval continuously producing an output signal line 344-03. The plug positions in section 350 are connected via the relay logic to actuate fraction collector solenoids 42 (FIG. 1)—only five plug positions being provided as collector 32-1 is open for use unless another collector signal is being generated. Plug position 352 is connected to a sequencer reset (00) control; plug position 354 provides a signal to cause the se-

quencer 132 to go to 01; plug position 356 is connected to injector control solenoid 22; plug position 358 is connected to energize alarm 70; plug position 360 is connected to respond to an energized alarm and permits a particular action to be taken via a plug board connection when an alarm condition occurs; and plug position 362 is connected to the carrier gas control solenoid 56. Other plug connections are spares.

Through appropriate interconnection via the plug board 82 of the control components with the input signals from the detector 60, the output devices such as the fraction collectors 32 and the inject control 22 may be operated in the desired sequence to control a preparative gas chromatography separation process. These interconnections may be made through plug cords inserted in appropriate receptacles in the plug board, or through the use of a prewired plug inserted in the receptacle in the control panel. Other selective circuit interconnection devices such as a card inserted in a suitable receptacle may be used through appropriate modification of the selective interconnection device. A simple example of a desired separation performed by the apparatus is indicated in FIG. 9, a gas chromatographic separation of a terpene hydrocarbon from a natural terpenoid essential oil by passing of the essential oil in a helium carrier through the chromatographic column 14, that terpene hydrocarbon being eluted in interval 382 from about 10.8 minutes through 12.6 minutes of the 20 minute cycle with the essential oil injection occurring at zero time. The peak 378 that occurs between the fourth and fifth minutes in the graph (FIG. 9) is used as a control both of the amplitude and the time relations of the elution signal produced by detector 60. The parameters of the system are such that peak 378 should occur after three minutes but before five and a half minutes and should have an amplitude in that period of at least 40 percent but less than 45 percent. In other words, the peak should fall within the box 380. After the peak occurs a timing interval of 5 1/4 minutes is provided; increasing slope is then sensed and the terpene hydrocarbon is shunted to fraction collector 32-2 during the interval indicated at 382. At the end of interval 382 (10 seconds after the terpene hydrocarbon peak) the elutant is returned to the main collector system (fraction collector 32-1); relatively large signal outputs are produced until the elution cycle terminates as indicated by the detector signal falling below 18% of full scale (point 384). The following table indicates the sequence of control:

Sequencer Interval	Sequencer Interval Termination Signal	Fraction Collector	Other Control
01	3 minutes (timer 116-2)	1	inject at time 0
02	pen position above 40% (comparator 114-1)	1	if interval exceeds 2 1/2 minutes, go to 00 and alarm (timer 116-1)
03	pen position below 40% (comparator 114-1)	1 if pen	position exceeds 45% g. to 00 and alarm (comparator 114-3)
04	5 1/4 minutes (timer 116-3)	1	
05	detect rising slope	2	
06	detect peak	2	
07	10 seconds (timer 116-4)	2	
08	pen position	1	

09	below 18% (comparator 114-2)	1	g. to 01 in response to timer 116-5 output signal
5	2 minutes (timer 116-5)		

The plug board indicated in FIG. 8 could be wired as follows for this program:

	OUTPUT	INPUT
10	306-2 — 342-01 Timer(2m)	terminates Interval 01
	175(330-1) — 342-02 PP ₁ (40%)	terminates Interval 02
	176(330-1) — 342-03 PP ₁ (40%)	terminates Interval 03
	306-3 — 342-04 T ₃ (5 1/4m)	terminates Interval 04
	165A — 342-05 R Slope	terminates Interval 05
	167A — 342-06 Peak	terminates Interval 06
	306-4 — 342-07 T ₄ (10s)	terminates Interval 07
15	176(330-2) — 342-08 PP ₂ (18%)	terminates Interval 08
	306-5 — 342-09 T ₃ (2m)	terminates Interval 09
	344-01 — 356 Int 1	Inject
	344-02 — 312-1A Int 2	AND ₁
	344-03 — 312-3A Int 3	AND ₂
	344-06 — 316-1a Int 6	OR ₁
	344-07 — 316-1b Int 7	OR ₁
20	344-10 — 354 Int 10	Go to 01
	306-1 — 312-1b T ₁ (2 1/2m)	AND ₁
	167 — 312-3b Peak	AND ₂
	175(330-3) — 312-3c PP ₂ (45%)	AND ₃
	310-1 — 316-2A AND ₁	OR ₂
	310-3 — 316-2B AND ₂	OR ₂
25	214-2 — Branch OR ₂	Branch
	Branch cord — 358 Branch cord	cord
	360 — 362 Alarm	Carrier Gas off
	Branch — 352 Branch cord	Go to 00
	314-1 — 350-2 OR ₁	FC ₂

With reference to FIG. 9, the essential oil is injected into the carrier stream of helium at time 0 to interval 1. After about 1 1/2 minutes a peak is sensed by detector 60 which occurs at 50 percent of chart height. As the sequencer is in interval 01 under control of timer 2, no action is taken (sensing of a peak being operative to stop the sequencer only in interval 06 in this interconnection). A calibration check is run during intervals 02 and 03 with respect to the chart area 380. As indicated above, a peak should be detected within that area between 3 and 5 1/2 minutes, which peak is greater than 40 percent of chart height and less than 45 percent. If those criteria are detected in sequence in intervals 02 and 03, the sequencer 32 is stepped into interval 04. If those criteria had not been satisfied, the sequencer would have been reset to 00 (plug 352), an alarm would have been sounded (plug 358), and the carrier gas turned off (plug 362)—either in response to the sequencer not stepping into interval 03 by 5 1/2 minutes (timer comparator 116-1) or the recorder signal 66 exceeding 45 percent of chart width. Interval 04 is 5 minutes 15 seconds long which provides a timing period from the detected peak (which in the illustrated case occurred at 4 minutes 50 seconds) so that the sequencer steps into interval 05 at 10 minutes 5 seconds after injection (in response to timer comparator 116-3) thus avoiding response to variations in the recorder output over that interval. In interval 05 increasing slope is sensed (by sensor 122) and as soon as that characteristic is sensed, either immediately or after a time in interval 05, the sequencer 132 steps into interval 06 in which the effluent is channelled to fraction collector 32-2 by closing valve 40-1 and opening valve 40-2. The terpene hydrocarbon constituent now being eluted is collected through interval 06 until a peak is detected (sensor 122) in response to which the sequencer steps into interval 07 for 10 seconds (timer comparator 116-4) after which time collection of the

terpene hydrocarbon fraction in fraction collector 32-2 is terminated. As interval 08 commences, collection control returns to the main collector 32-1. Two large peaks are detected (one at 56 percent and one at 89 percent of chart width) but no action is taken until the recorder falls to a chart width of 18 percent at point 384 (detected by pen position comparator 124B) at which time the sequencer 132 steps into interval 09 for a 2 minute period (timer comparator 116-5) and then steps to interval 10 for immediate return to interval 1 and injection of another sample of essential oil into the chromatographic column 14.

The above is a simple example of the type of process control that may be performed with the invention. Many other and more complex types of control may be achieved with the disclosed embodiment. Also, other embodiments of the invention will be apparent to those skilled in the art. Therefore while a particular embodiment of the invention has been shown and described, it is not intended that the invention be limited to that disclosed embodiment or to details thereof and departures may be made therefrom within the spirit and scope of the invention as defined in the claims.

What is claimed is:

1. A process control apparatus for use with a chromatographic apparatus having:
 - a. a chromatographic column;
 - b. a detector connected to the column to sense the fluid stream eluted from the column and produce an analog output signal;
 - c. a source of carrier fluid;
 - d. injection control for periodically injecting a sample into said carrier fluid for flow through said column; and
 - e. a plurality of fraction collectors, the process control apparatus comprising:
 - i. means responsive to the analog output signal for generating a plurality of signals representing different characteristics of said analog signal;
 - ii. means to monitor the signal representing the different characteristics of said analog signals to determine if said signals fall within predetermined values at predetermined times during at least one step in a cycle;
 - iii. a plurality of timing devices for producing timing signals, the timing signals referenced to the initiation and duration of the steps of the cycle;
 - iv. an interval selector responsive to the output characteristic signals and the timing signals for producing a series of steps, the total of which comprises the entire cycle;
 - v. means for producing output signals to control the injection of the sample and the collection of the eluted stream; and
 - vi. means for selectively interconnecting said means for generating a plurality of signals, said means for monitoring the magnitude and time of occurrence of said plurality of signals, said plurality of timing devices, said interval selector,

and said means for producing control signals so that said interval selector is caused to step from at least one cycle interval to the next in response to a determination by said monitoring means that said output characteristic signals fall within said predetermined values and times during said at least one cycle interval and so that said control signal producing means is caused to produce signals for collection of the eluted stream components or for injection of subsequent samples also in response to said determination by said monitoring means.

2. The apparatus as claimed in claim 1 wherein said interconnecting means includes receptacle means and circuit controlling means releasably secured in said receptacle means, said receptacle means including a matrix of connection controls for interconnecting via said receptacle means said characteristic signals, said timing signals, said interval selector and said output producing means so that a particular process control program may be selected by insertion of said circuit controlling means into said receptacle means.

3. The apparatus as claimed in claim 2 wherein said receptacle means includes a plug board and said circuit controlling means includes a plurality of connector cords releasably secured in said plug board to define selectively the programmed process control interconnections.

4. The apparatus as claimed in claim 2 wherein said interval selector is a stepper device which selects intervals sequentially for the generation and control of said output signals for control purposes.

5. The apparatus as claimed in claim 4 wherein said matrix selective interconnection means includes means for providing signals terminating specific intervals, and said interval selector includes circuitry responsive only to the specific interval termination signal corresponding to that interval to step the selector to the next sequential interval.

6. The apparatus as claimed in claim 5 wherein said monitoring means includes an adjustable set point signal generator, and circuitry for producing output signals which includes means to indicate that the analog process signal is greater than the set point signal, the analog process signal is less than the set point signal and when the analog process and set point signals are equal, an indication of the direction of relative change of said set point and analog process signals.

7. The apparatus as claimed in claim 6 wherein said monitoring means includes a differential amplifier and a flip-flop circuit.

8. The apparatus as claimed in claim 7 wherein said matrix means for interconnecting said signals includes means for selectively producing an output signal in response to one of said timing and characteristic signals, a combination of said timing and characteristic signals, or a choice of said timing and characteristic signals.

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