Aug. 27, 1963 L. B. ROOF 3,101,606
PROGRAMMER FOR CHROMATOGRAPHY
Filed June 20, 1958 5 Sheets-Sheet 1

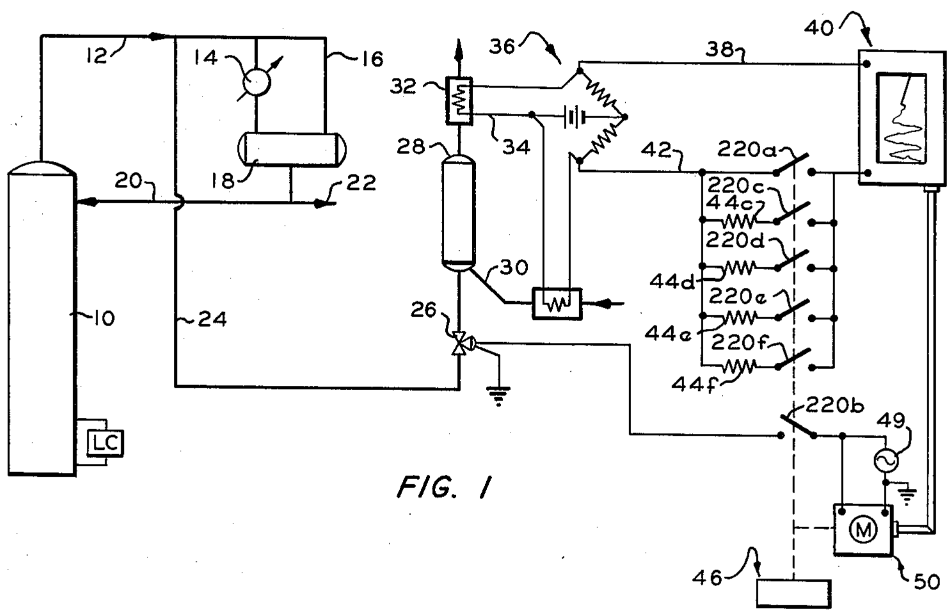


FIG. 1

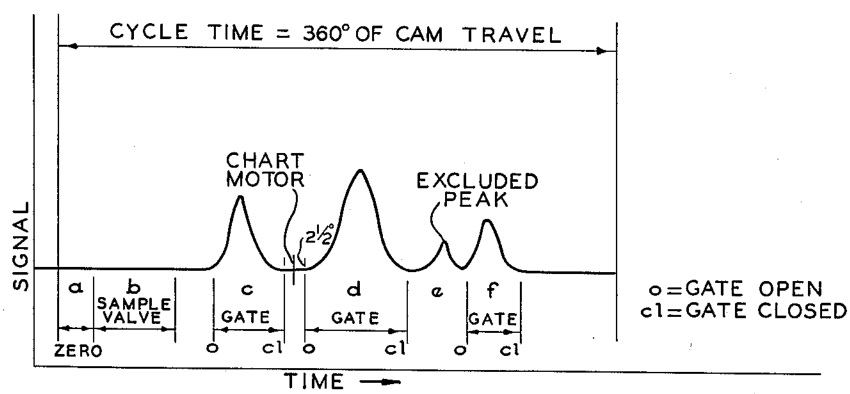


FIG. 2

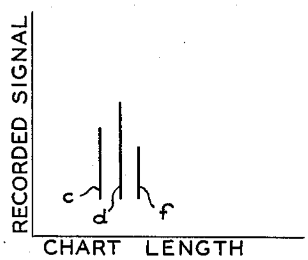


FIG. 3

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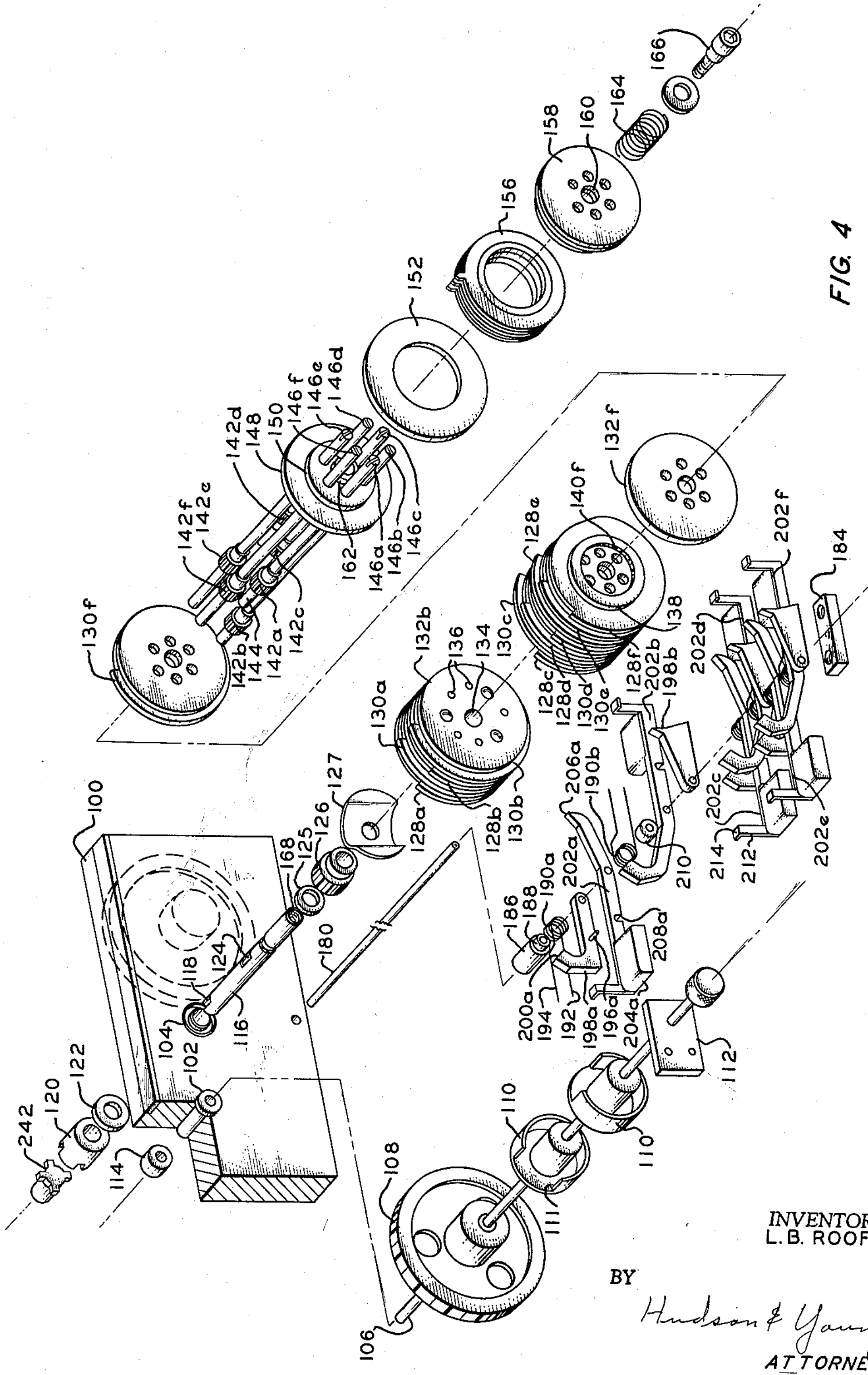


FIG. 4

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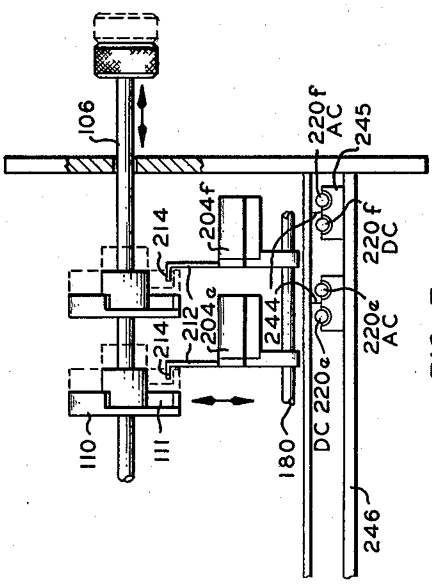


FIG. 7

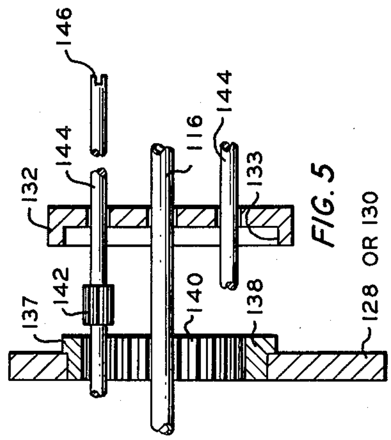


FIG. 5

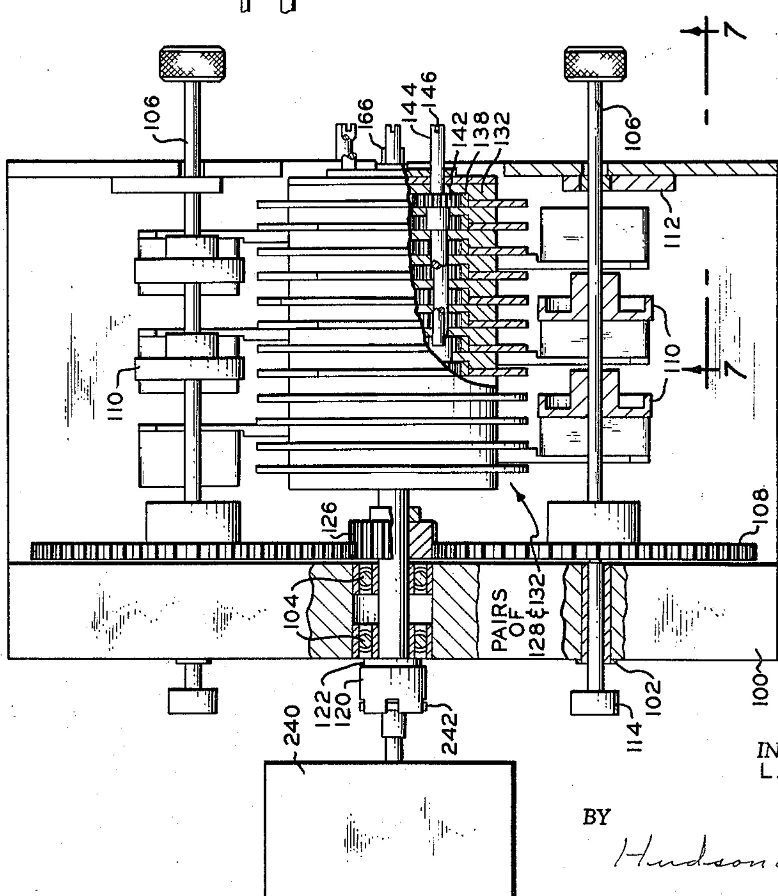


FIG. 6

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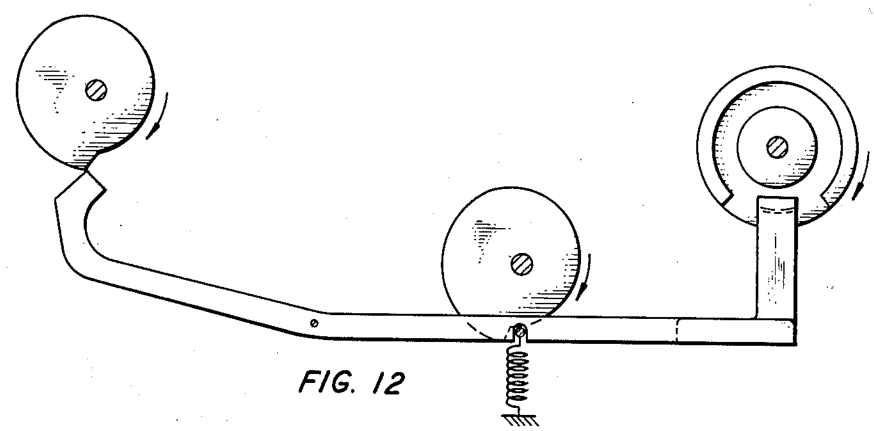

FIG. 12

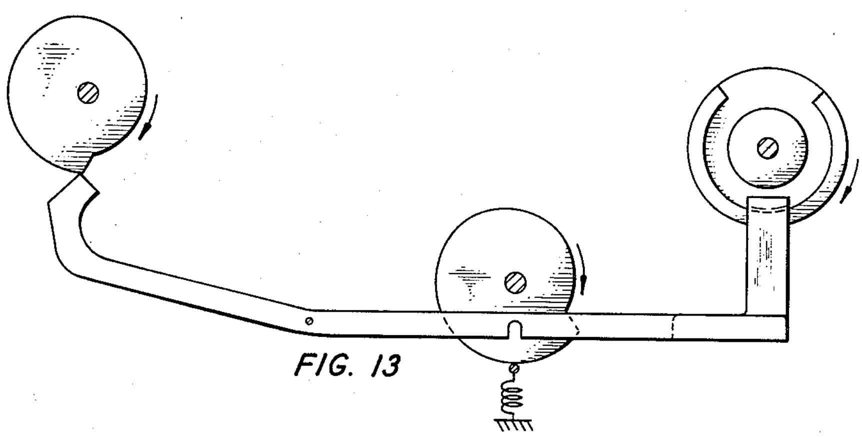

FIG. 13

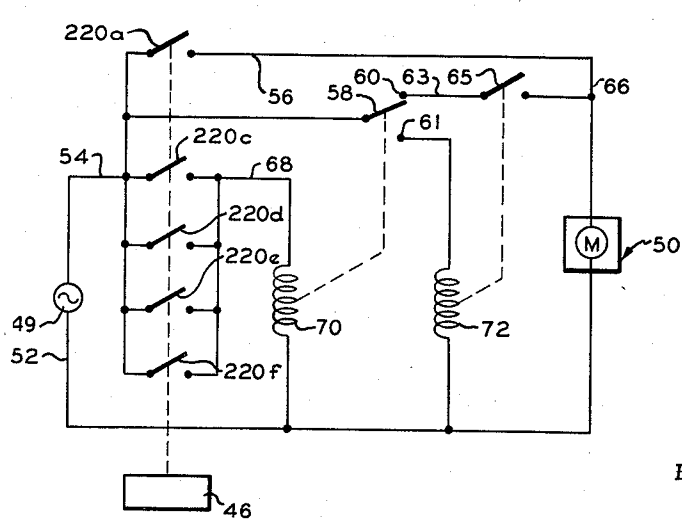


FIG. 8

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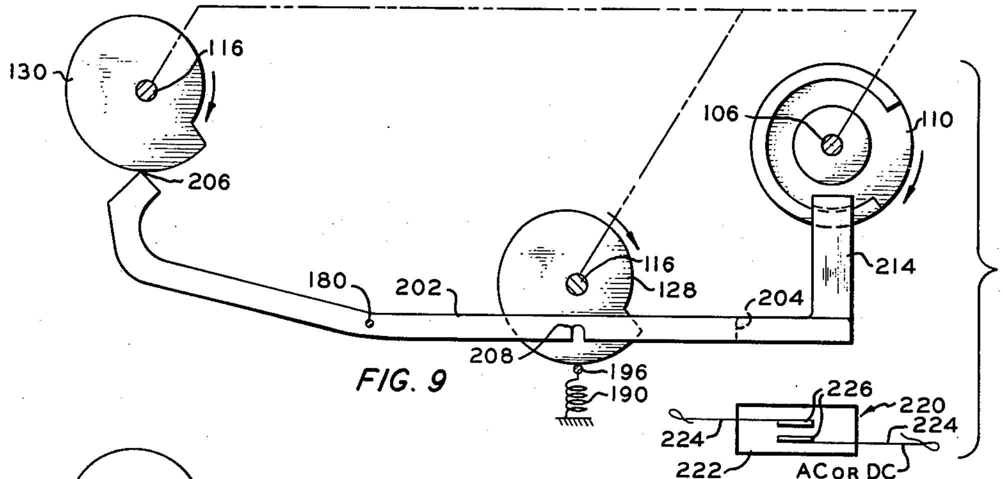


FIG. 9

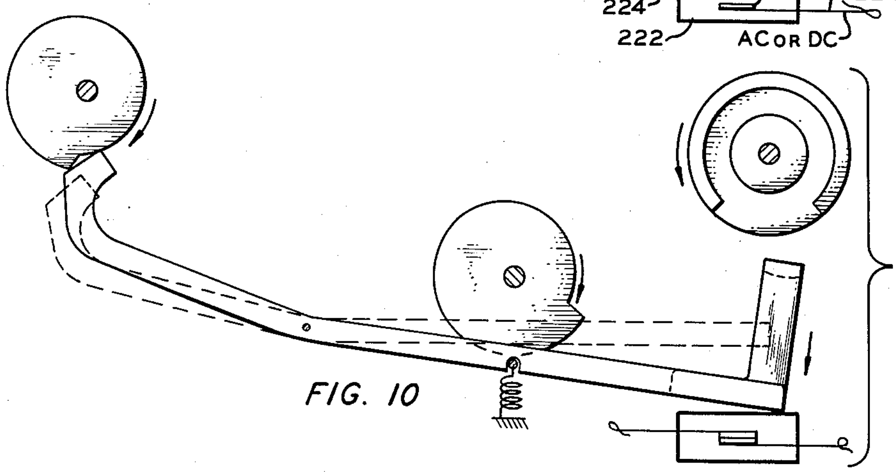

FIG. 10

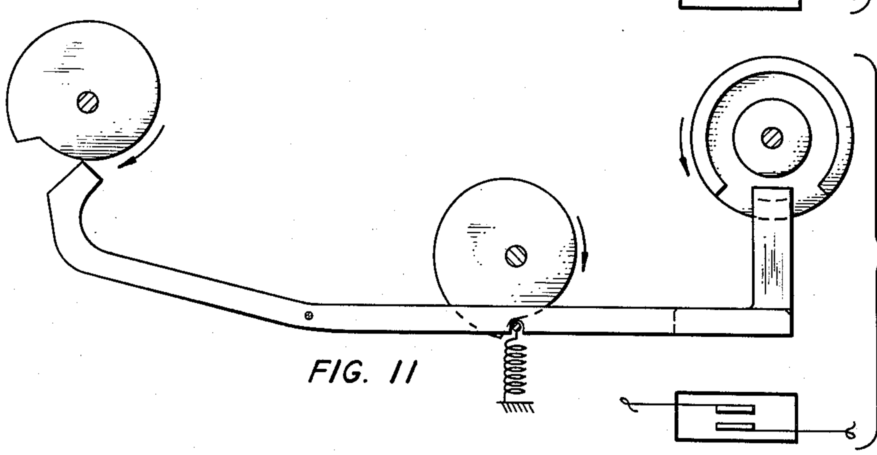

FIG. 11

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United States Patent Office

3,101,606

Patented Aug. 27, 1963



# 3,101,606
# PROGRAMMER FOR CHROMATOGRAPHY

Lewis B. Roof, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware

Filed June 20, 1958, Ser. No. 743,330
11 Claims. (Cl. 73—23)

This invention relates to a programming switch. In one specific aspect it relates to an improved programmer for use with a vapor phase chromatographic analyzer.

In vapor phase chromatography a measured sample is placed in a packed column. This sample is then eluted from the column by passing a carrier gas, such as helium, therethrough. The various gases that make up the sample will be eluted from the column by the carrier gas in a fixed order. Each of these gases has a different heat transfer characteristic and this phenomenon is used to determine which of the several gases is being eluted at a given time. When suitable measuring and control apparatus is associated with the packed column, a series of curves will be generated by a given sample of gas during its elution from the column. These curves consist of a series of peaks with each peak indicating a certain component, or in certain cases, two components. It is frequently desired to select only one or perhaps several, but not all, of the peaks for recording or control purposes.

A properly designed timing mechanism can program the events to permit this to take place. Programming is possible because with a given column and a given size of sample the substances in the sample will be eluted from the column in a known order covering, respectively, predetermined periods of time.

Occasionally the peaks generated on elution are quite close together when plotted on a time axis and the programmer must be capable of operating at a high speed in order to separate the two peaks. Frequently in chemical plant operation, especially where hydrocarbons are being analyzed, the danger of explosion is great and programming switches as well as other apparatus must be fire or explosion proof. Also, at times it is considered desirable to record the results of chromatographic analyses in a bar graph form by intermittently operating the recorder chart motor. Also, it is necessary to operate valves for sampling and for the carrier gas.

In present day chemical plant practice it is common to alter the plant operation to either accommodate substantially different feed stock or to produce different products. Sometimes the products, while having the major component the same, may have strict limitations on certain impurities therein to satisfy specifications. In order that such a plant be flexible, its entire analyzing and control system must, of course, be adjustable to the changes in feed stock or in product. This means, of course, that if an analyzer such as described above is used that it and the timing mechanism therefor must be adjustable to conform to the new conditions that are being measured. This is necessary because different components may be measured or the elution times and occurrences thereof may change upon new components appearing in the feed stock.

The instant invention comprises a timing switch which is suitable for connecting a measuring apparatus such as a Wheatstone bridge to a recorder at selected time intervals. These selected intervals are determined by the times at which elution peaks or curves will occur, and the programmer in its operation, will then permit the recording of only selected peaks, but not necessarily of all peaks. Furthermore, the recorder can be operated by the programmer of the instant invention to produce



analyses of compositions in a bar graph rather than in a peak or curve form. The programmer also has suitable mechanism for rendering it readily adjustable to accommodate changes in feed stock or in specifications of the product. High speed operation is achieved by providing one mechanism to electrically connect the Wheatstone bridge to a recorder and a separate mechanism to break such connection. The adjusting means provided are suitable for holding the adjusted portions of the apparatus in position.

Accordingly, it is an object of this invention to provide a programmer capable of higher speed operation than prior art devices. Another object of this invention is to provide a programmer having means therein for adjusting the timing. It is still another object of the instant invention to provide a programmer which is explosion proof and hence is suitable for use in chemical plants. Finally, it is an object of this invention to provide a programmer which is suitable for use with a chromatographic analyzer and which permits selecting which of various signals are to be recorded or otherwise used as for control purposes. Other objects and advantages will become apparent from the following disclosure.

In the drawings:

FIGURE 1 demonstrates the position of a programmer when used in a chromatographic analyzer circuit;

FIGURE 2 represents the time sequence of events when peaks are generated on a continuously moving chart;

FIGURE 3 represents bar graphs produced by an intermittently moving chart;

FIGURE 4 is an exploded view of the programmer mechanism;

FIGURE 5 is a cross-section of the cam adjusting mechanism;

FIGURE 6 is a plan view of the assembled programmer of FIGURE 4;

FIGURE 7 is a cross-section through 7—7 of FIGURE 6;

FIGURE 8 is a wiring diagram for the delay relay feature;

FIGURES 9–13 are schematic diagrams demonstrating the cooperation of the programmer elements.

Referring now to FIGURE 1 there is shown a conventional fractionating column **10** having an overhead product line **12** leading through a condenser **14** and a condenser by-pass line **16** to an accumulator **18**. A reflux line **20** returns a proportion of the liquid from the accumulator to the column. A liquid overhead product line **22** delivers the product for storage or further processing. The pumps, valves, and their associated controls have been eliminated in this sketch for clarity.

A sample line **24**, having a sampling valve **26** disposed therein, is connected to a chromatographic column **28**. The column is supplied with carrier gas through a line or conduit **30**. The eluted gas from the column passes to a sample cell **32** in which is disposed a thermistor **34**. The thermistor **34** comprises a branch of the Wheatstone bridge **36**. The bridge is connected through leads **38** and **42** to a recorder **40**.

The lead **42** is connected through a series of parallel switch circuits to the recorder **40**. As shown in the drawing, the switches **220***a, c, d, e,* and *f* are those in parallel. The latter four of the switches have attenuator pots **44***c, d, e,* and *f* disposed in their circuits. A switch **220***b* provides power from source **49** to operate the sampling valve **26** responsive to actuation by the programmer. The switches are associated with a delay relay circuit **50** which is likewise operated by the programmer to operate the chart motor sequentially to produce bar graphs as will hereinafter be described. The structure of these switches is discussed below with respect to FIGURE 9. The detail of the delay relay, which in actuality is built into the programmer 46, will be hereinafter discussed with respect to FIGURE 8.

Referring now to FIGURE 2, there is shown a series of peaks such as is generated on a continuously operating recorder when the connection between the bridge and recorder is continuous. A complete cycle of events is shown in FIGURE 2: this cycle comprises zeroing the Wheatstone bridge, taking a measured sample of the gas to be analyzed, and selectively recording the peaks and operating the chart motor upon cutting off of the peak.

In FIGURES 2 and 3 the peaks numbered *c, d, e,* and *f* correspond to those which may be selectively passed by the switches having the same alphabetical numbers in FIGURE 1. FIGURE 3 demonstrates the results obtained when the timer is adjusted to pass only three of these peaks. The term "gate" as used in FIGURE 2 denotes the time during which a peak may be read. When the gate opens, one of the switches 220 is closed; when the gate closes, switches 220 are open, i.e., in the position shown in FIGURE 1. As will be hereinafter described, the signal is passed by making a contact, recording the peak and then breaking a contact. FIGURE 3 represents the bar graph which would be produced by adjusting the programmer 46 to pass only the peaks *c, d,* and *f* and to intermittently operate the chart motor in the recorder.

Referring now to FIGURE 4, there is shown a bearing block 100 having mounted therein bearings 102 and 104. 102 is preferably a journal bearing while 104 is preferably a roller, needle or ball bearing. In the bearing 102 is mounted a shaft 106. This shaft has a timing gear 108 mounted thereon and also has mounted thereon a plurality of flanged detent cams 110 with a portion 111 cut out of the flange. At the other end of the shaft 106 from the bearing 102 is disposed another bearing in the block 112. The detent cam and the timing gear are each held in place by set screws on the shaft 106. The collar 114 is disposed on the opposite side of the block 100 from the timing gear and is fixed to the shaft 106 by a set screw in order to retain the shaft in position longitudinally.

In the bearing 104 is mounted a cam shaft 116 having a flatted surface 118 on whch is mounted a splined coupling 120 (as best seen in FIGURE 6). A washer 122 serves to space the coupling from the back side of the bearing or pillow block. Another flatted surface 124 is provided on the shaft for receiving a timing gear 126. The timing gear and the coupling are held in place by set screws. A washer 125 serves to separate the front edge of the bearing 104 from the timing gear 126. Disposed next to the timing gear on the cam shaft is a spring 127 for holding the various discs hereinafter described in position next to each other. These discs are not fixed to the cam shaft by set screws or the like, but rely on the frictional engagement provided by the spring to keep them positionally related on the shaft. Disposed along the shaft 116 between the spring 127 and the outboard end of the shaft are a plurality of pairs of cams 128 and 130. The pairs are denoted by the letters *a* through *f*, respectively. With each cam is associated a mounting disc 132 which is used to connect the cam to the cam shaft in such a manner that timing adjustments can be made, as will be hereinafter described with respect to FIGURE 5. Each of these mounting discs has a hole 134 therein for receiving the shaft 116 and also has a plurality of holes 136 corresponding to the total number of cams 128 and 130.

As shown in FIGURE 5, each and every cam 128, 130 has pressed thereinto a bushing 138 having along the internal periphery a series of gear teeth 140. In order that each cam be independently adjustable relative to all other cams, a pinion 142 may be provided for each internal gear 140 and is mounted on a shaft 144 which passes through the holes 136 in the manner shown in FIGURE 5. Alternatively, only one of the paired cams 128, 130 need have a pinion 142, if complete independent adjustability can be sacrificed. The ends of the respective shafts 142 are fitted with means for manually rotating them, such as screwdriver slots 146. Knobs could also be used, but the design shown is more compact. Figure 4 shows the exploded view of the pinion and shaft arrangement for one-half the cams, the remainder being omitted for sake of clarity.

At the outboard end of the shaft 116 is mounted a disc 148 fashioned similarly to the mounting discs 132. However, this disc differs in that it has a collar 150 thereon which passes through a face plate 152 (for carrying indicia, is desired). Outboard of 152, but disposed along the shaft and preferably disposed on the collar 150, may be mounted index markers 156 to cooperate with indicia marked on the member 152. A disc 158, having a hole 160, designed to receive the collar 162 on the disc 148 is mounted outboard of the index markers 156. A spring 164 biases the disc 158 up against the mounting member 152. The spring is compressed by a bolt 166 which screws into a threaded end of the shaft 168. The indicia, face plate, and elements cooperating therewith could be omitted, if desired, as long as bolt 166 or other longitudinal positioning means are provided.

A shaft 180 is fixed in the block 100 at one end and rests on a block 184 at the other end thereof. A spacer 186, having a spring collar 188 thereon, fits on one end of the shaft to separate the lever mechanism hereinafter discussed from the bearing block and timing gears. A spring 190*a* is mounted on the collar 188. The spring has arms 192 and 194 which are compressed between the base plate, not shown, and the pin 196*a* which is mounted on a lever 198*a* that is rotatably mounted on the shaft 180. The lever 198*a* has a cam follower surface 200*a* that engages the cam surface on the cam 128*a*. Adjacent the lever 198*a* on the shaft is another lever 202*a* having a magnet 204*a* mounted at one end thereof. At the opposite end is a cam follower surface 206*a* which engages the cam 128*a*. Between the fulcrum provided by the shaft and the magnet is disposed a notch 208*a* in which the pin 196*a* may fit. The same assembly is repeated in like elements *b* through *f* for a plurality of times continuing down the shaft to the block 184. There are right and left hand assemblies of the levers 198 and 202. The operation of these will be explained thereinafter with respect to FIGURES 9 through 13. The other springs 190 are mounted on collars 210. These collars also serve to space the pairs of levers. Although not shown (for the sake of clarity) on all embodiments of the lever 202, each of them has a detent finger 212 with a surface 214 for engaging the detent cams 110 which are described below with respect to FIGURE 13.

Referring now to FIGURE 5, there is shown in cross-section the manner in which the cams 128 and 130 are mounted to the shaft 116 in such a manner that they can be rotated with respect to both the shaft and each other for purposes of adjusting the "gate," i.e., the length of time that the magnet 204 will be in operative condition as shown in FIGURE 10, or for adjusting to the position of FIGURE 12 to prevent passing of a signal. In essence, FIGURE 5 shows the mounting disc 132 to be in engagement with the shaft 116 and that the cam discs 128 or 130 are supported from the mounting disc 132. Of course, if desired, the mounting disc 132 could be keyed to the shaft 116 to prevent slippage with respect thereto. A key, square shaft, or set screw could all be considered as equivalent for this purpose. Because of the low torque involved in this system it has not been found necessary to do this, friction aided by the biasing forces of springs 128 and 164 being sufficient to hold the parts in position. As shown in FIGURE 5, the cam 128 (or 130, as the case may be) has a bushing 138 press-fitted thereinto with a shoulder 137 thereon. This shoulder engages the internal portion of a flange 133 that is part of the mounting disc 132. When the parts are properly assembled, the shoulder does engage the flange and the pinion 142 meshes with the gear teeth 140. Other shafts 144 pass through the disc and through the aperture provided by the bushing 138. When adjustment of the timing is desired a screw driver can be inserted in the slot 146 to turn the shaft 144 and thereby to rotate the cam 128 or 132 in the flange 133 and with respect to the shaft. Although the pinions 142 aid in holding the cams in their respective adjusted positions, the aforementioned frictional engagement has been found sufficient to do so. Hence, only one pinion need be provided for each pair of cams, if desired.

Variations in this structure would include mounting one of the cam discs 128 or 130 without the bushing 138 therein. This would require, of course, either fixing the cam disc to the shaft by a spider or providing a central structure analogous to that of the mounting disc 132. Another variation would be to make mounting disc 132 integral with one of the cams. Both of these variations then require only one pinion 142 and only one shaft 144, but are permissible only when some sacrifice in independent adjustability of the cams is permissible. The end result of all these structures is to permit one cam to be moved relative to the other and to the shaft without having to disassemble the entire cam shaft. The advantage to the illustrated structure is that the cam discs may all be of like structure, hence be interchangeable, as may be the mounting discs.

Referring now to FIGURE 6, there is shown an assembly of the mechanism illustrated in FIGURE 4. The part numbers are the same. It may readily be seen that the construction provides a compact and rugged unit. FIGURE 6 also shows a synchronous motor 240 having on its drive shaft a splined coupling 242 which engages the coupling 120 to provide a constant speed to the cams that are mounted on the shaft 116. It should also be noted that the diameter of the timing gear 108 is four times that of the timing gear 126 in order that the detent cams operate only once out of every four revolutions. In accordance with this design it is necessary that the cut-out portion 111 on the detent cams be 90 degrees. Of course, different ratios and cutouts can be made according to the ratio of operation desired. It should also be noticed that the shaft 106 is positioned for longitudinal movement as well as rotary movement in the bearing 102. This permits engaging and disengaging the detent fingers 212 by merely pushing the shaft 106 toward the rear. Two shafts 106 are shown in order that detent cams may be provided to all cams, both the left and right-hand pairs.

The motor 240 acts as a counter-weight about the bearing 104 and serves to balance the effect of the cams and other mechanism on the other side of the bearing. This permits a cantilever construction going from the bearing 104 to the outboard end of the shaft 116 and eliminates the necessity for an outboard bearing.

FIGURE 7 is a section through 7—7 of FIGURE 6. FIGURE 7 illustrates the cooperative positions of the detent finger 214 and the detent cam 110. It also illustrates the position in the programmer of the reed switches 220 which are described in greater detail below in reference to FIGURE 9. These reed switches are placed in cradles 245 which are in turn mounted on a base 246. In the switches shown there are two reed switches actuated by each magnet. One of these is for carrying direct current (D.C.) in the circuit shown in FIGURE 1; the other is for carrying alternating current (A.C.) in the circuit shown in FIGURE 2. A shield 244 is interposed between them to prevent the A.C. from effecting the D.C. The pairs of switches are both simultaneously actuated when their respective magnets 204 fall down into actuating position as shown in FIGURE 7. These switches may be the Revere Glaswitch described in Engineering Bulletin No. 1057, by Revere Corporation of America, Wallingford, Connecticut, or their equivalent.



The details of the delay relay for the chart motor are shown in FIGURE 8. The power source 49 (FIGURE 1) is connected through lead 52 to a recorder chart motor which is part of the recorder 40. Another lead 54 connects the other side of the source 49 to the parallel circuits, each containing one of the switches 220*a, c, d, e,* and *f*. The *a* switch (for zeroing) is connected by a lead 56 to switch 58. The switch 58 is a double throw switch having the contacts 60 and 61. The contact 60 is connected by a lead 63 to a switch 65. The switch 65 is connected by a lead 66 to the recording chart motor. The switches *c* through *f* are connected by a lead 68 to a solenoid 70 which actuates the switch 58. The other side of 70 is connected to the lead 52. The contact 61 is connected through a delay relay solenoid 72 to the lead 52. This may be a thermal delay switch, such as the Amperite Thermostatic Delay Relay sold by Amperite Company, Inc., 56 Broadway, New York 12, New York.

Referring now to FIGURE 9, there is shown schematically the mechanism of the elements mounted on the shafts 106, 116, and 180. In addition, there is shown the structure a preferred type of magnetic switch 220, which is used for the switches of FIGURES 1 and 2. In this switch there are two flexible magnetic elements 224 which close their contacts 226 when subjected to a magnetic field as from a magnet 204. These contacts are enclosed in a sealed container 222. One, two or more of these switches can be actuated by the magnet 204 when it is moved into proximity to them.

The operation of the programmer in conjunction with a system such as shown in FIGURE 1 will now be explained by referring to FIGURES 9–13. The motor 240 is started and operated at synchonous speed driving the cams on shaft 116. As shown in FIGURE 2, the first operation necessary in a cycle is to zero the Wheatstone bridge 36 to correct for any drift that may have occurred due to aging of the thermistor or other measuring element 32.

FIGURE 9 shows the position of the elements before any of the switches close to permit a signal to pass between the bridge and the recorder as shown in FIGURE 1. For the sake of clarity the cams 128 and 132 are shown on separate shafts. The synchronous motor drives the shaft 116 and brings the cam 130 to a position such that the cam follower surface 206 of the member 202 moves upward sharply to the position shown in FIGURE 10. This is because the magnet 204 comprises a weight at the opposite end of the lever and gravity causes the opposite end to drop. When the lever assumes the position shown in FIGURE 10 the pin 196 is then in an operative position with respect to the lever 202, but is prevented from operating by the cam 128 which acts against the bias of spring 190. In order for the lever to drop, as aforesaid, the detent cam 110 must rotate to the position shown in FIGURE 10 so that the flange cut-out 111 permits the finger 214 to fall free of the cam permitting the downward movement of the right end of lever 202.

The cams 130 and 128 are positioned on shaft 116 with respect to each other so that the lever 202 will retain the position shown in FIGURE 10 for a predetermined period of time. When the lever 202 has dropped, the contacts 226 of the switch close to thereby "open the gate" as discussed with respect to FIGURE 2. The next event is "closing the gate," i.e., breaking this contact.

To close the gate, the cam 128 moves to the position shown in FIGURE 11, whereupon the pin 196 moves sharply upward under the bias of spring 190, carrying with it the lever 202. This also returns the finger 214 to a position where it can be again engaged by the flange of detent cam 110. This upward movement causes the contacts 226 to open by removing them from the field of magnet 204.

When the above events have taken place on the "*a*" cam and lever group, the bridge is zeroed. The next event is to operate the sample valve **26** by a like sequence on the "*b*" group. The peaks are then read by causing the *c*, *d*, *e*, and *f* groups operate, respectively, in their proper sequence. The entire cycle is then repeated.

Where it is desired to produce a bar graph (FIGURE 3) instead of peaks (FIGURE 2) it is necessary to intermittently operate the recorder chart motor by means such as the delay circuit of FIGURE 8. The operation of this circuit follows:

Simultaneously with the actuation of the switches **220***c* through *f* in FIGURE 1 (i.e., the "peak" recording switches), an alternating current is applied to the recorder chart motor by the circuit of FIGURE 8. The switches in FIGURE 8 are those denoted in FIGURE 7 as **220**. Using the switch number **220***c* of FIGURE 8 as an example, it is closed when a magnet moves to the position of FIGURE 10 and current is admitted through a solenoid **70** which closes the contact at **61** admitting current to the delay relay solenoid **72**. For a portion of the time that the signal is being sent from the bridge to the recorder, the switch **65** remains open, but upon heating of the solenoid **72** by the current therethrough this switch **65** closes. This has no effect on the recorder chart motor at this time because the switch **58** is not in contact with **60**. However, this contact is made upon the cam **130** moving the magnet away from the reed switch **220** and thereby causing the contact to be broken at **61** and to be made at **60**. This then admits current to the recorder chart motor unit such time as the delay relay **72** opens the switch **65**. The effect of this structure is to permit the recorder chart motor to operate immediately upon the closing of the gate as shown in FIGURE 3. A short period of time after the chart motor stops (in the preferred embodiment being 2½ degrees of cam shaft rotation when the chart speed is 60 inches per hour) the circuit is ready for the next peak which is recorded in the same manner as described above with respect to the peak lettered *c*. Subsequent operations merely repeat the operation of the respective levers **202** and **198** (*d* through *f*) by their respective cams **128** and **130**.

FIGURE 12 shows how the relative positions cams **128** and **130** when adjusted with respect to each other so that a particular signal will not pass between the bridge and the recorder. For example, this could be done to cut out peak *e* by adjusting cams **128***e* and **132***e*. What is done in FIGURE 12 is to adjust the relative positions of the cams by turning a proper one of the shafts **146** (there being but one shaft for the pair of cams **128***e* and **132***e*) to cause one of the cams to rotate relative to the other. When properly positioned the cam **128***e* is then positioned so that it will move the pin **196***e* into engagement with lever **202***e* before the cam **130***e* can actuate the lever. This, of course, prevents the lever from dropping and from actuating the switch **220**. In the cycle shown in FIGURE 2, this adjustment would be made on the "*e*" group.

FIGURE 13 shows how the detent cam operates to prevent the lever **202** from actuating the switch **220** when it drops. It must be remembered that the detent cams **110** turn at only a fraction of the speed of cams **130** and **128**, for example, at one-fourth of the speed. This, in turn, means that only one time out of every four will the switch **220** be actuated and, insofar as the recorded signal is concerned, it means that only one sample out of every four will have a particular component registered on the recorder. As shown in FIGURE 11, the detent cam engages the finger **214** so that when cam **130** moves to the operating position for the lever **202** the magnet **204** cannot drop. It should be noted in this feature that the relative positions of the cams can remain the same as is necessary to provide proper timed and programmed switch actuation as described in FIGURES 9 through 11. However, the detent cam here prevents the signal from passing only a certain proportion of the time. This is in contrast to FIGURE 12 where no signal at all can be passed when the cams are adjusted relative to each other.



It should now be apparent that the instant invention involves an apparatus for programming which is rugged, compact, and which has further advantages of being adjustable without disassembly and permits a high speed operation. High speed is possible because separate cams are used for actuating and disengaging the magnet from the switch **220**. This permits setting the actuating or notched portions of the cams very close together for close timing without creating problems in cam contour, follower inertia, and so forth. The cams are of a structure permitting interchangeability, base of assembly, and hence are suitable for mass production.

Although a specific example has been given wherein one selected peak is excluded, it should be obvious that the instant device can be adjusted to record all peaks. Also, in the example given, a column has been used that has a constant flow of carrier gas therethrough, thus not necessitating use of a carrier gas valve. If desired, of course, such a valve may be employed. Moreover, although a device has been disclosed wherein one element (**202**) operates responsive to the force of gravity, it is permissible to modify the design to permit this element to be urged by other means, e.g., under the bias of a spring.

The instant switch provides a fireproof or explosion proof structure and is safe for use in hazardous locations. Although demonstrated by way of example to be suitable for use with chromatographic analyzers the use of this switch is not limited thereto but is suitable for use in any place where a programming switch of high speed with explosion proof characteristics and adjustability is desired. By the unique arrangement of multiple switches (best seen in FIGURE 7) a simultaneous actuation of a plurality of circuits can be achieved with only one cam and lever group.

I claim as my invention:

1. A timing switch comprising a first shaft, a first lever pivotally mounted by its central portion on said first shaft, a first cam follower surface disposed on one end of said first lever, a magnet disposed on the opposite end of said first lever, a second lever having a second cam follower surface thereon, said second lever being pivotally mounted on said shaft thereby to dispose said second cam follower surface on the opposite side of the shaft from said first cam follower surface, a pin projecting from said second lever to engage said first lever at a point between said first shaft and said magnet, a spring engaging said second lever and biasing it upwardly; a second shaft mounted above said first shaft, first and second adjustable cams adjacent each other disposed along said second shaft, said first and second adjustable cams engaging, respectively, said first and second cam follower surfaces; each of said adjustable cams including a cam disc having a circular central opening concentric with said second shaft, internal gear teeth peripherally disposed in said opening, an annular shoulder surrounding said opening and protruding from one side of said cam disc, mounting disc engaging said second shaft and having a peripheral flange concentric therewith, said annular shoulder on said cam disc rotatably engaging the internal surface of said first mounting disc flange; a first pinion engaging a portion of said internal gear teeth in said first cam disc; a third shaft on which said first pinion is mounted; said mounting disc for said second adjustable cam having holes therein through which said third shaft passes; said first mounting disc having a hole therein through which said third shaft passes; a fourth shaft, a detent disc having a discontinuous peripheral flange protruding from one side thereof, said detent disc being fixedly mounted on said fourth shaft; a finger protruding upwardly from the magnet end of said first lever, a surface on said finger for engaging said discontinuous peripheral flange on said detent disc; a

bearing block in which one end of each of said second and fourth shafts is rotatably mounted; a rotary motor connected to one end of said second shaft; gears on said second and fourth shafts, said gears engaging each other, and said fourth shaft gear being of larger diameter than said second shaft gear.

2. A timing switch comprising a first shaft, a first cam disc surrounding a portion of said first shaft and having a circular opening therethrough, internal gear teeth around the circumference of said opening, a circular shoulder surrounding said opening, a second shaft, a pinion mounted on said second shaft and meshing with said internal gear teeth, a mounting disc having a circular flange, a hole through said mounting disc, said second shaft passing through and being rotatably supported in said hole, said cam disc shoulder being surrounded by and rotatably supported by said mounting disc flange, said mounting disc being mounted on said first shaft, a second cam disc, a second mounting disc, said second cam disc and mounting disc engaging each other in the same manner as said first cam disc and mounting disc, said second mounting disc being mounted on said first shaft, a first degree lever of rigid material, a weight comprising a magnet disposed at one end of said lever, a cam follower surface disposed at the other end of said lever, a pin disposed to engage said lever at a point in the path of motion of said lever, a spring urging said pin toward said lever, said cam follower surface engaging said first cam disc, said second cam disc engaging means for preventing the movement of said pin toward said lever until a predetermined event has occurred.

3. The apparatus of claim 2 further including a magnetically responsive switch disposed for engagement with the field of said magnet when said lever is engaged by said pin before said predetermined event occurs.

4. The apparatus of claim 2 further comprising means for permitting said lever to drop only once in a preselected number of revolutions of said first shaft.

5. The apparatus of claim 4 wherein said means comprises a shaft, a circular disc, a discontinuous flange on the circumference of said disc, a finger on the magnet end of said lever, a portion of said finger protruding therefrom and position for engagement with the internal portion of said flange.

6. A timing switch comprising a first shaft; a first rigid member rotatably mounted on said shaft for arcuate motion thereabout; a magnet on one end of said member; a cam follower surface on the other end of said member; said shaft engaging said member at a central portion of the latter; a second rigid member mounted adjacent said first rigid member on said shaft and extending toward said magnet; a pin mounted on said second member and protruding toward said first member to engage the latter at a point in the path of motion thereof; a spring biasing said second member towards said first member; a cam follower surface on said second member; a second shaft; first and second adjustable cams disposed along said second shaft, each of said adjustable cam discs including a cam disc having a circular opening therethrough, an internal gear disposed within said opening, a circular shoulder surrounding said opening, another shaft, a pinion mounted on said another shaft and meshing with said internal gear, a mounting disc having a circular flange, a hole through said mounting disc, said another shaft passing through and being rotatably supported in said hole, said shoulder being surrounded by and rotatably supported by said flange, and said mounting disc being supported on said second shaft; said first adjustable cam engaging said first cam follower surface; and said second adjustable cam engaging said second cam follower surface on said second member.

7. The apparatus of claim 6 further comprising a detent means that includes a fourth shaft; means for linking said fourth shaft to said first shaft; a disc mounted on said fourth shaft; a discontinuous cam surface surrounding a



portion of said disc; a finger engaging said cam surface; said finger being attached to the magnet end of said first rigid member.

8. The apparatus of claim 7 further comprising means for mounting said fourth shaft for selective reciprocable movement longitudinally thereof and for rotary movement.

9. The combination comprising a chromatographic column; a sample cell connected to said column; a Wheatstone bridge having one branch disposed in said sample cell, a pair of output terminals on said bridge; means for indicating and recording in bar graph form selected signals appearing at said output terminals that further comprise means for connecting said output terminals to said means for indicating including a plurality of parallel-connected attenuators each said attenuator having an individual switch in series therewith, and a programmer for actuating said individual switches in a predetermined sequence that comprises for each said individual switch a first means for actuating said switch, second means for returning said first means to a non-actuating position thereby deactuating the switch, third means for connecting said first and second means to a source of power, and fourth means to selectively adjust said first means with respect to said second and third means, a chart motor connected to said means for indicating and recording, and a delay relay means actuated in response to said second means for actuating said chart motor.

10. A timing switch comprising a first shaft, a cam, means for supporting said cam on said shaft and for rotating said cam with said shaft, means for adjusting said cam by rotating it relative to said shaft, a second cam, a second means for supporting said second cam on said first shaft and rotating it therewith, a fulcrum, means for pivoting a magnet about said fulcrum along an arcuate path responsive to said first cam, means to engage said means for pivoting when the latter is at a first terminal point of its arcuate path, means to bias said means to engage toward the other terminal point of the arcuate path, means responsive to said cam to actuate said means to bias, and means for permitting said magnet to pivot through its arcuate path only once in a preselected number of revolutions of said shaft, said means for permitting comprising a shaft, a circular disc having a discontinuous flange on its periphery, said disc being concentrically mounted on said shaft, a finger on said magnet hand of said means for pivoting, and a portion of said finger protruding therefrom in position for engaging the internal portion of said flange.

11. The combination comprising a chromatographic column; a sample cell connected to said column; a Wheatstone bridge having one branch disposed in said sample cell; a pair of output terminals on said bridge; means for indicating and recording in bar graph form selected signals appearing at said output terminals; means for connecting said output terminals to said means for indicating including a plurality of parallel-connected attenuators, each said attenuator having an individual switch in series therewith; and a programmer for actuating said individual switches in a predetermined sequence comprising a switch-actuating member for each said switch; a pair of actuating devices for each said member, one device of each of said pairs actuating said member of a corresponding switch to cause said switch to close, a second device of each of said pairs actuating said member to cause said corresponding switch to open independently of said first device, actuating device adjusting means for adjusting the angular position of each of said devices independently to vary the angular relationship between said devices and between said devices and driving means therefor; a chart motor connected to said means for indicating and recording; and a delay relay means actuated in response to said one device of each of said pairs to deenergize said chart motor and to energize said chart motor for a predetermined period of time when each of said switches is opened.

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