United States Patent

[11] **3,615,239**

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[54] **AUTOMATED ANALYZER AND PROGRAMMER THEREFOR**
19 Claims, 12 Drawing Figs.

[52] **U.S. Cl.** .... **23/259,** 23/253 R, 141/130, 200/38
[51] **Int. Cl.** **B01l 9/06,** B01l 11/00, G01n 1/10
[50] **Field of Search** .... 23/259, 253, 230 A; 141/130

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ABSTRACT: An apparatus especially suited for use in automated chemical analysis wherein the operations of delivering fluids to sample tubes and of extracting fluids from such tubes are programmed by mechanical-electrical programming means. Such programming means includes a plurality of rotatable elements each equipped with a multiplicity of spring fingers. Each rotatable element corresponds with the treatment means at a sample tube treatment station and each of the multiple fingers is representative of a single sample tube advanced through such treatment stations. The fingers are adapted to sweep over contacts representative of the stopping stations of the sample tubes and when a selected tube reaches its particular treatment station a finger of the rotatable member corresponding with the treatment means at that station makes electrical contact to produce a signal which energizes such treatment means. The apparatus also includes means for shifting the spring fingers between operative and inoperative positions and for synchronizing the operation of the programming means with other components of the analyzer.

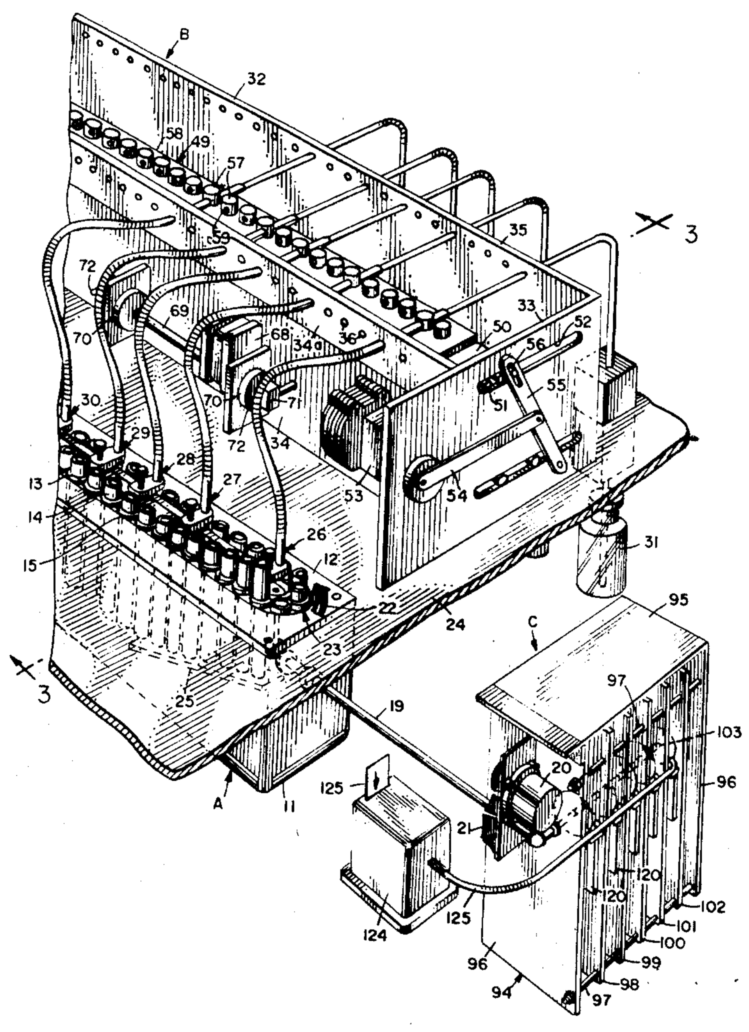
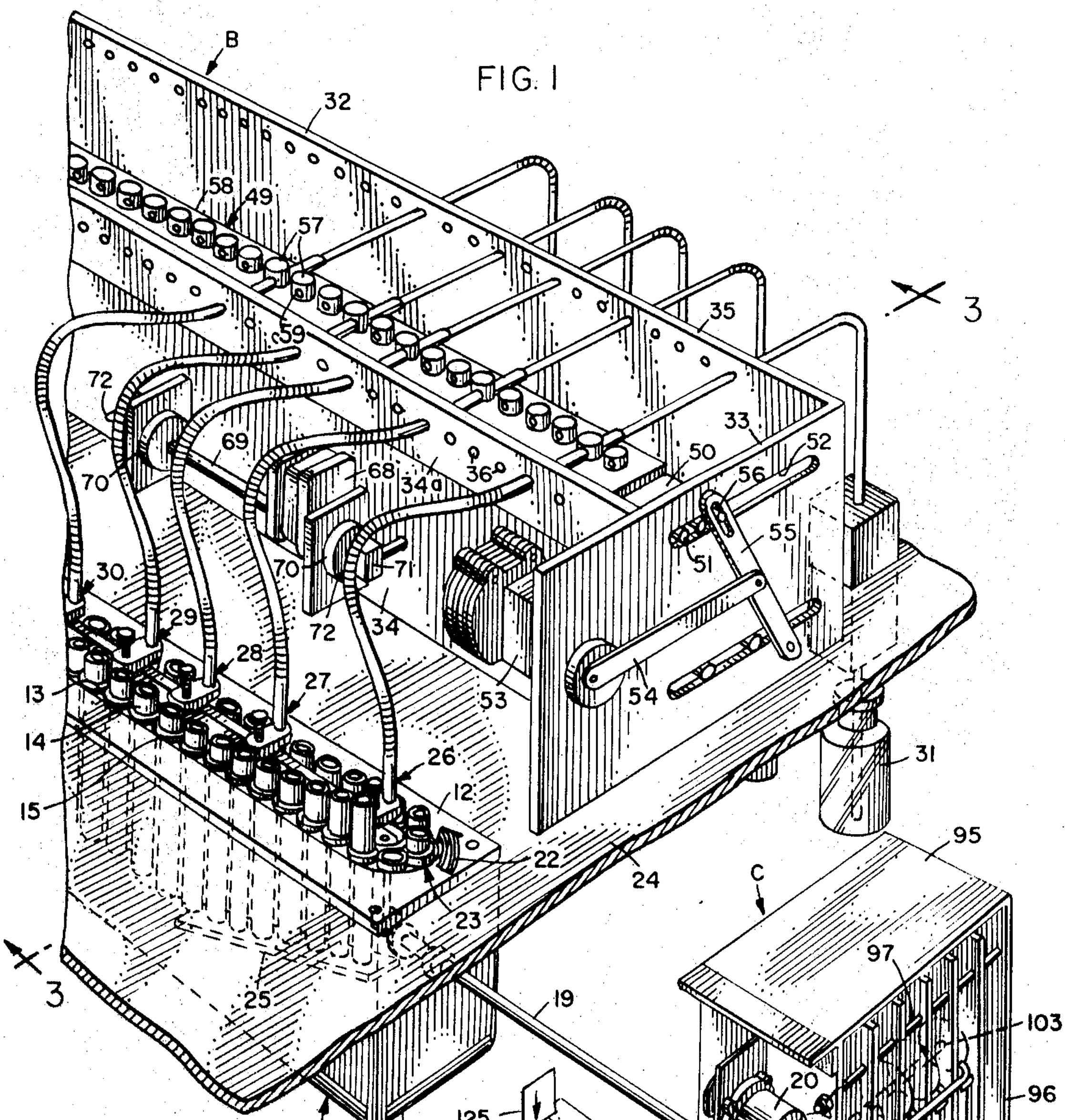


FIG. 1



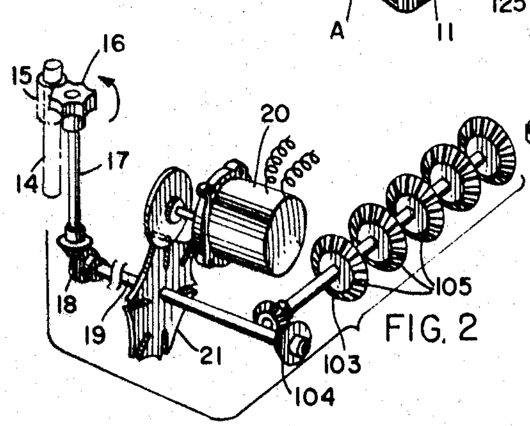


FIG. 2

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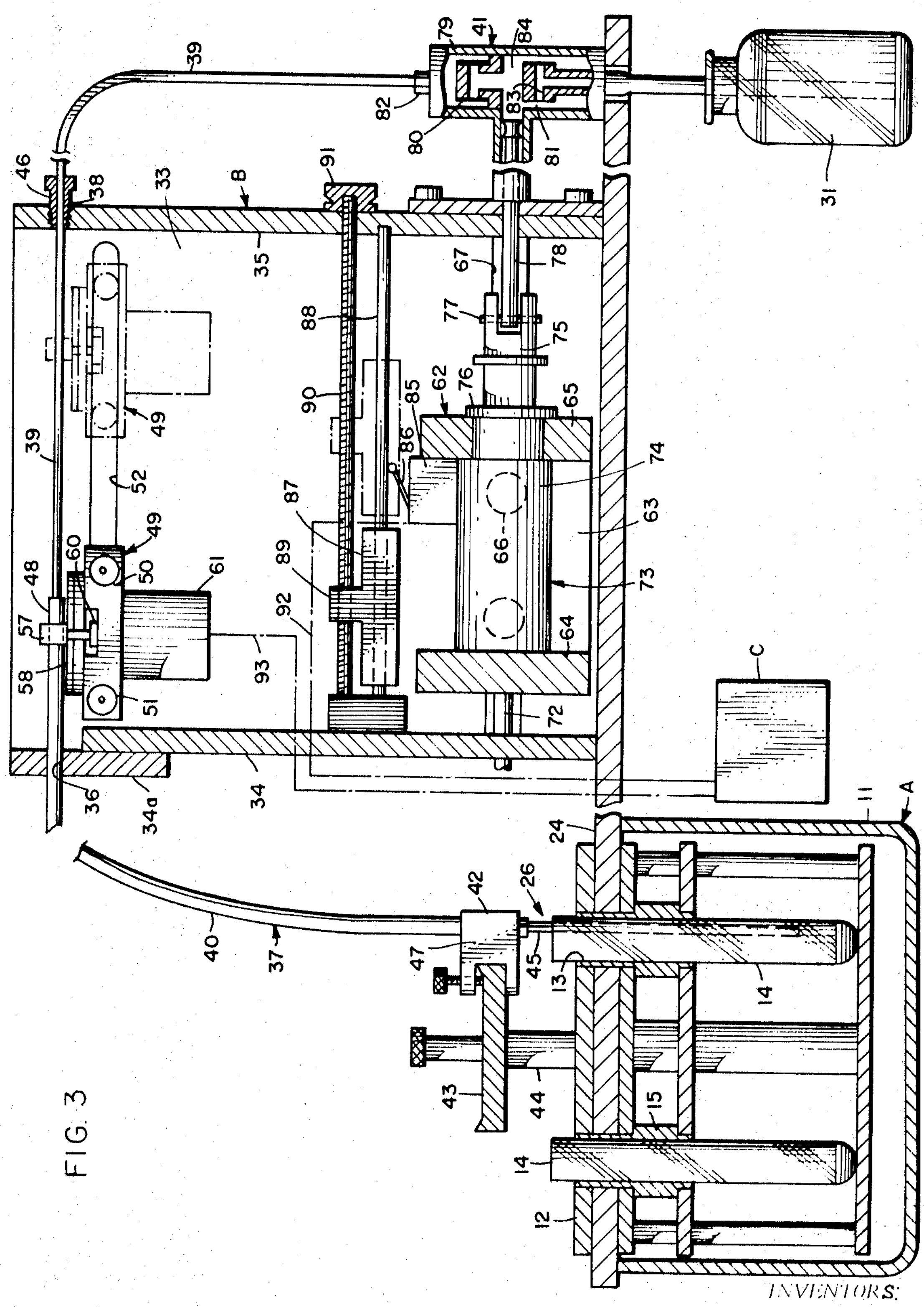

FIG. 3

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FIG. 4

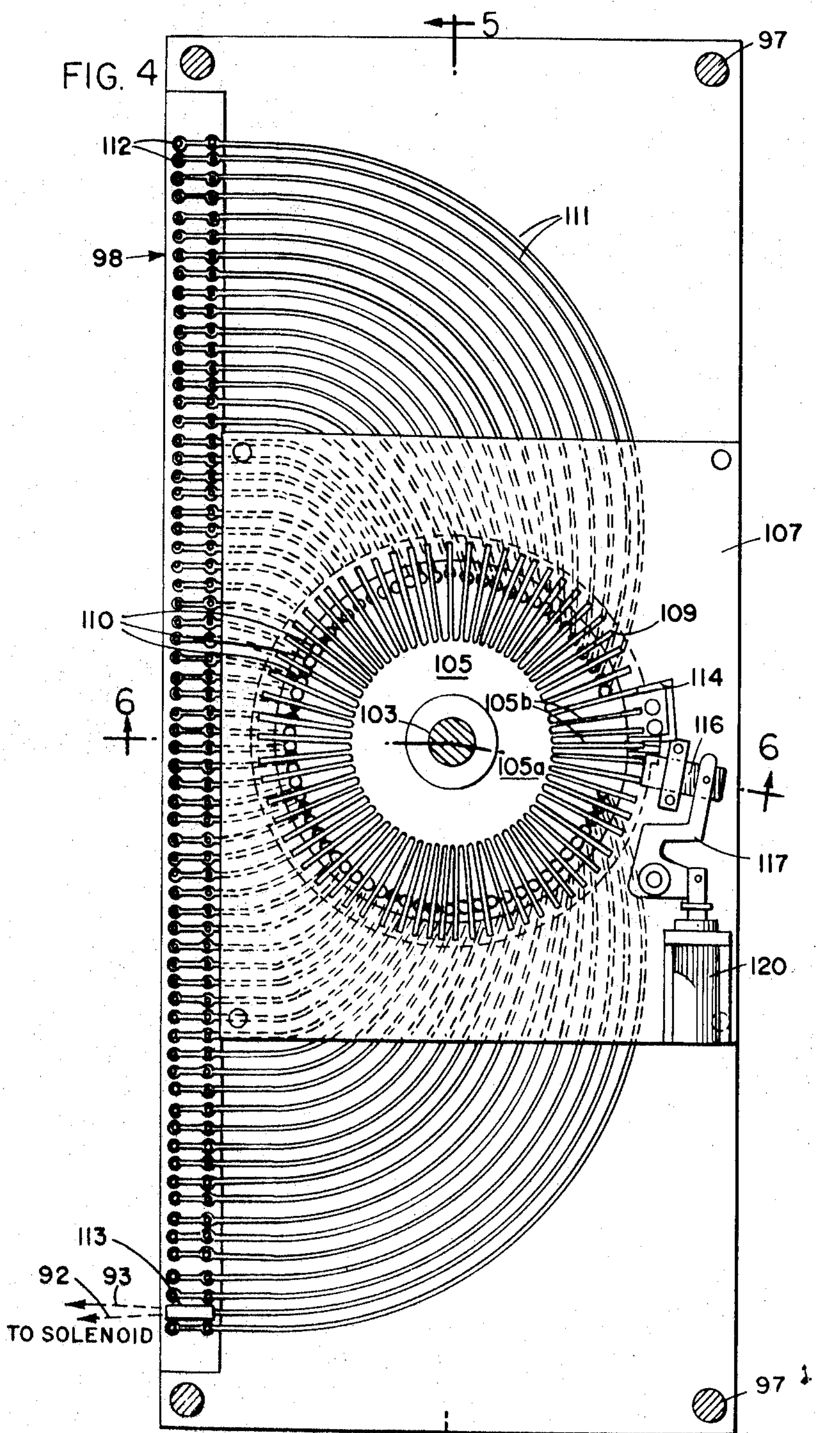
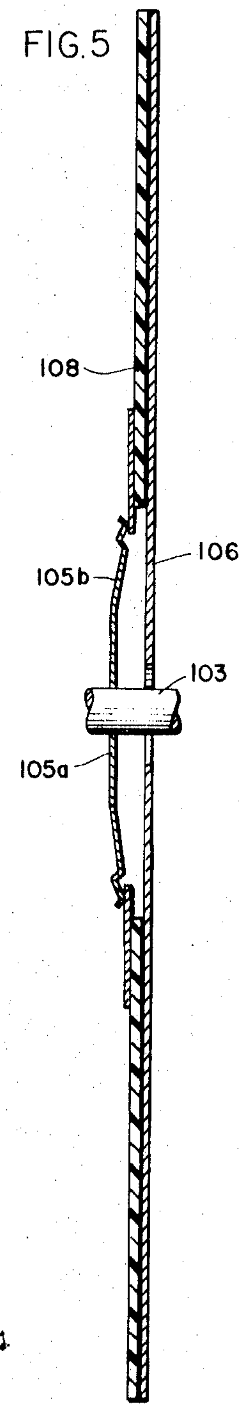


FIG. 5



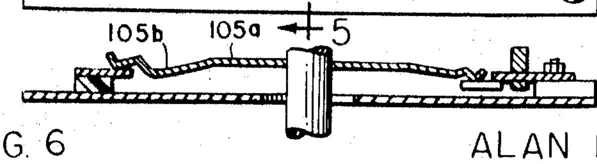


FIG. 6

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FIG. 7

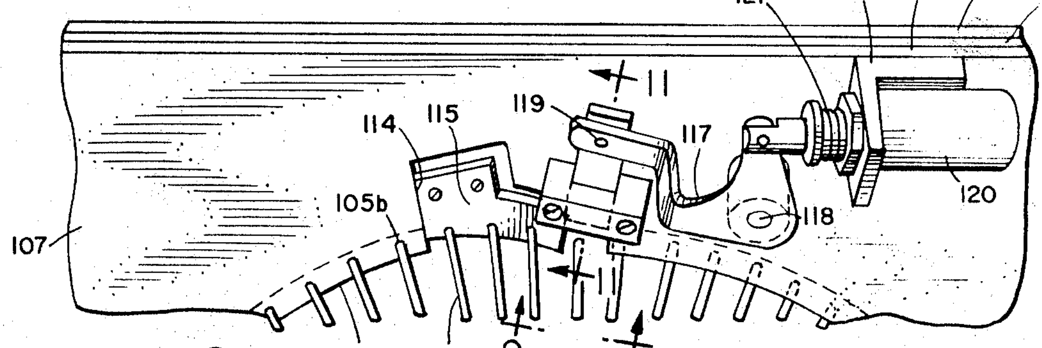


FIG. 8

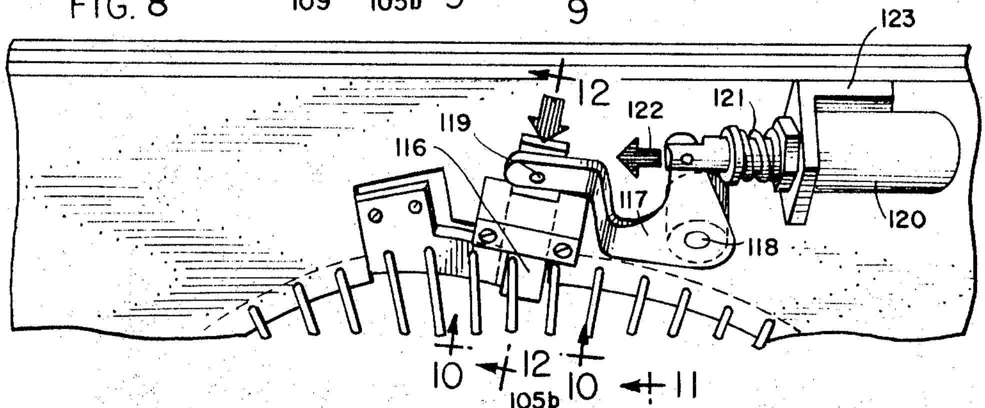


FIG. 9

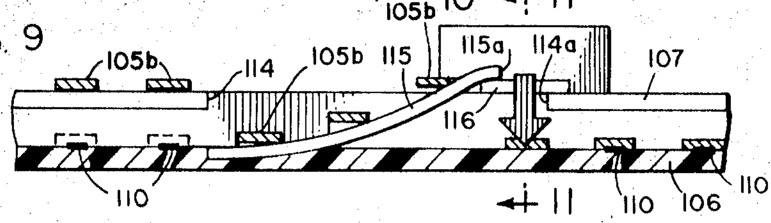


FIG. 10

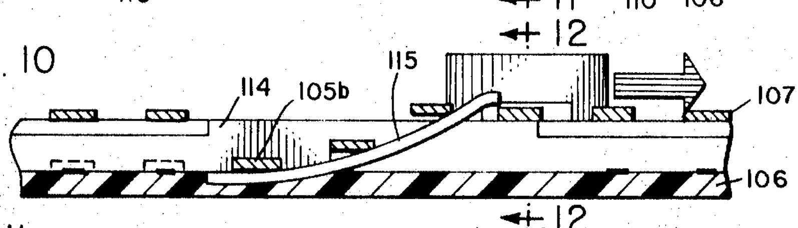


FIG. 11

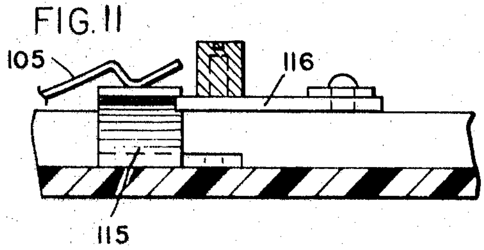
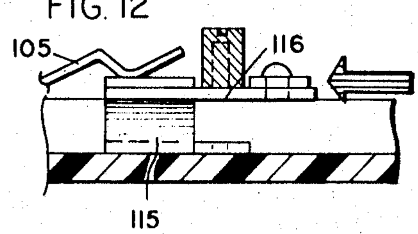


FIG. 12



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AUTOMATED ANALYZER AND PROGRAMMER THEREFOR

OTHER APPLICATIONS

Reference will be made as the specification proceeds to copending applications Ser. No. 688,144, filed Dec. 5, 1967, now U.S. Pat. No. 3,511,613 and Ser. No. 656,218, filed July 26, 1967, and now abandoned.

BACKGROUND

While delivery systems for automatic chemical analysis equipment have been known in the past, such systems have been relatively complex in structure and operation and, partly by reason of such complexity, have been subject to malfunctioning and, in general, have been troublesome and expensive to maintain in operation. It will be appreciated that any such malfunctioning may have serious consequences since such automatic chemical analysis equipment is intended for use in performing diagnostic tests on body fluids in clinical laboratories.

Speed in running such diagnostic tests is also of considerable importance because the treatment given patients may depend on the outcome of such tests. While there are a number of different diagnostic tests that may be run in such equipment, present machines have a major shortcoming in their ability to perform only a single type of diagnostic test at one time. Because of the time and effort required to "set up" such a machine for running any given test, it is common laboratory practice to delay the running of a test until a substantial number of samples requiring the same test are accumulated or, alternatively, to forego use of the automatic equipment in favor of manual testing procedures where there are only a limited number of samples requiring the same test procedure. The unfortunate result may be that tests which are urgently required for early diagnosis and treatment may either be delayed for efficient use of the automatic analysis equipment or may be run manually without the benefit of the high degree of accuracy and control inherent in the operation of automatic equipment.

SUMMARY

The apparatus of the present invention is intended for use in automatic analysis equipment wherein a substantial number of different diagnostic tests may be performed simultaneously. Sample tubes containing samples of body fluids to be tested are placed in a transporter which may be of the type disclosed in copending application Ser. No. 688,144, filed Dec. 5, 1967, and such tubes are advanced intermittently or incrementally through a series of treatment stations. For any given diagnostic test there are one or more stopping stations of the series where a selected treatment fluid must be delivered to the sample tubes in which such test is to be performed. Different diagnostic tests require the addition or withdrawal of fluid from other sample tubes at other stopping stations. Whenever the series of sample tubes is stopped, a pumping stroke is executed by a pumping arm or carriage of the apparatus and each tube requiring the addition or extraction of fluid at that moment is automatically subject to such treatment.

Although the carriage executes a pumping stroke during the interval when the series of samples tubes is stopped, actual pumping action does not occur unless means for operatively coupling the carriage to the selected fluid pumps has been activated. In the form of the apparatus disclosed, such coupling means constitutes a plurality of solenoids, one for each fluid pump. If at the time the carriage executes its "pumping" stroke one or more of the solenoids is energized then the pumps associated with those solenoids will deliver (or withdraw) fluid from certain of the momentarily stopped sample tubes. Therefore, where such apparatus is equipped with a multiplicity of pumps, certain pumps being arranged to deliver to withdraw fluids for certain diagnostic tests and other pumps for other tests, each specific pump will be operated during cyclical movement of the carriage only if the solenoid associated with that pump is energized so that fluid is introduced or withdrawn from a given tube of the series at the proper moment. By suitable programming resulting in the energization of the various solenoids at the proper moments, a multiplicity of different diagnostic tests may be carried out simultaneously in the series of sample tubes.

The programming means is primarily mechanical in construction and is relatively simple in structure and operation. Because of its relative simplicity and mechanical nature, it is found to be highly reliable in operation, in an area where dependability is essential. Furthermore, it is constructed in modular form, each module being representative of a single test or operation to be performed by the analyzer. Therefore, where the number of diagnostic tests to be performed by the analyzer is to be increased at some later date after installation of such a unit, it is a relatively simple matter to add a further module for programming the analyzer to perform the additional test.

While the programmer may have other uses, it is particularly suitable for use in conjunction with the delivery and transport systems of an automatic analyzer. Each module of the programmer includes a disklike rotatable member having a plurality of radially extending spring fingers. Such member, as well as the members of adjacent modules, is rotated by a shaft synchronized with the operation of a transport unit which advances sample tubes from a loading station to a plurality of treatment stations. Adjacent to the rotatable member of each module is a plate having a multiplicity of electrical contacts arranged in a circumferential series and adapted to be engaged by the spring fingers of the rotatable member. However, such fingers are normally held out of contact with such plate and any selected finger of the series is allowed to make initial contact with the plate only at one point or position where a retractable panel is located. Such panel is retracted when a sample tube is introduced at the loading station of the transporter and the single finger permitted by the retraction of the panel to flex into contact with the plate thereafter represents the newly introduced sample tube for one complete sweep of the rotatable member. As the released finger travels over the plate in synchronization with the movement of the corresponding sample tube it approaches a contact element which is representative of the treatment means at the station where treatment of the corresponding sample tube is to be performed. Contact between the spring finger and the contact element causes an electrical signal to be transmitted to such treatment means with the result that fluid is delivered to the sample tube, or is removed from such tube, or the sample is subjected to some other appropriate treatment at such station. The same plate may be provided with additional contacts to be engaged in succession by the spring finger to initiate further treatment operations on the same sample when the sample tube arrives at subsequent treatment stations.

If a number of samples requiring the same treatment for the same diagnostic test are present in the transporter at the same time, then a corresponding number of spring fingers of a single rotatable member will be advanced over the contact plate, each finger being representative of one of the samples and serving to actuate the treatment means at the appropriate treatment stations when the corresponding tube reaches such stations. However, as already mentioned, the programmer includes a plurality of modules, each being representative of the treatment required for a different diagnostic test. Thus, successive tubes advanced by the transporter may require different treatment and, in such cases, the treatment for the respective tubes is controlled by different modules of the programming means.

The means for delivering or withdrawing fluid from the sample tubes comprises a plurality of extensible delivery tubes, each delivery tube consisting of a pair of telescoping tubes formed of flexible plastic or other flexible material. The inner tube of each concentric tube assembly extends from a fluid pump to a treatment station of the transporter assembly, the

end of the inner tube at the treatment station normally being maintained in position above the sample-carrying tubes advancing intermittently therebeneath. When fluid is to be added or withdrawn from any given sample tube, the innermost plastic tube of a concentric pair is projected downwardly into the sample tube prior to commencement of the pumping stroke. It has been found that the inner tube may be extended most effectively by shifting the outer tube to remove slack only from the outer tube. As a result, the free end of the inner plastic tube is extended without buckling of either tube and dips into the preselected sample tube to deliver or withdraw fluid therefrom. Since fluid extracted from the sample tube is withdrawn from adjacent the bottom thereof an ample supply of fluid is assured; conversely, since fluid delivered to the sample tube is discharged adjacent the lower end thereof a thorough mixing of sample and treatment fluid is achieved.

DRAWINGS

FIG. 1 is a fragmentary and partly schematic perspective view of certain major components of an automatic analyzer, including the programming means therefor;

FIG. 2 is a perspective view showing certain components of the transporter, programmer, and drive means extracted from the view of FIG. 1 for clarity of illustration;

FIG. 3 is an enlarged vertical sectional view, shown partially diagrammatically, and taken along line 3—3 of FIG. 1;

FIG. 4 is an enlarged side elevational view of a single module of the programmer;

FIG. 5 is a sectional view taken along line 5—5 of FIG. 4;

FIG. 6 is a sectional view taken along line 6—6 of FIG. 4;

FIG. 7 is a perspective view showing a portion of a module and illustrating the means for transferring or diverting spring fingers into contact with the contact plate;

FIG. 8 is a perspective view similar to FIG. 7 but illustrating the transfer means in its normal extended position;

FIG. 9 is an enlarged sectional view taken along line 9—9 of FIG. 7;

FIG. 10 is a sectional view taken along line 10—10 of FIG. 8;

FIG. 11 is a fragmentary sectional view taken along line 11—11 of FIG. 9;

FIG. 12 is a sectional view along line 12—12 of FIG. 10.

DESCRIPTION

Referring to FIG. 1, three basic components of an automatic analyzer are illustrated: transporter unit A, delivery unit or system B, and programming means C.

The transporter A is similar in construction and operation to the unit disclosed in copending application Ser. No. 688,144, filed Dec. 5, 1967. In brief, the transporter consists essentially of a casing **11** having a top plate **12** defining an endless channel **13** along which a multiplicity of sample tubes or containers **14** are advanced in single file. Each tube is slidably carried in a sleeve **15** and the sleeves are driven along the channel by a sprocket **16** carried by a shaft **17** (FIG. 2). The shaft is operatively connected by gears **18** to a drive shaft **19** which is rotated and stopped intermittently and at regular intervals by motor **20** and Geneva transmission **21**. Thus, the sample tubes **14** are advanced periodically in the direction of arrow **22** from a starting point or loading position indicated generally at **23** (FIG. 1). As the motor **20** operates, each tube is advanced into the position occupied by the preceding tube and is then stopped for a predetermined interval during which the operations of the delivery system B may be performed.

It will be observed that plate **12** is disposed upon a platform or table surface **24** and that the upstanding sample tubes **14** normally project a slight distance above the top surface of the plate. Each tube of the series travels no more than one complete trip or revolution along channel **13**. Tubes containing fresh samples are inserted into the channel by an operator, or by some suitable mechanical means, at the loading station **23** and are thereafter intermittently advanced through one or more treatment stations until they have made the full circuit, ride upwardly upon ramp **25**, and are finally discharged into a waste receptacle (not shown) beneath surface **24**.

Each sample tube placed into the transporter may contain a serum sample or a sample of some other body fluid to be subjected to automatic analytical testing. While a wide variety of tests may be performed, in general such tests require the addition of one or more reagents to the sample, a mixing of the reagents and the sample fluid, a period of incubation during which the test reaction may occur, and a final photometric analysis of the reaction mixture. In the apparatus disclosed, five treatment stations **26–30** are indicated although a greater or smaller number may be provided depending on the number and type of different diagnostic tests to be performed. At each of these stations **26–30** a predetermined quantity of a test reagent may be introduced into selected sample tubes from a suitable source of supply, one such source for station **26** being indicated schematically at **31**. Alternatively, the treatment occurring at one or more of such treatment stations may involve an operation other than the addition of a reagent; for example, in one of such stations, such as station **30**, a portion of the fluid contained in each sample tube may be withdrawn and delivered to a photometer or other testing device for analysis.

The delivery system B is most clearly illustrated in FIGS. **1** and **3** and comprises a frame **32** having upstanding side, front, and backwalls **33**, **34**, and **35**, respectively. The upper portion **34a** of wall **34** has a series of openings **36** through which flexible tubular conduits **37** extend. Similarly, rear wall **35** is provided with openings **38** which are aligned with openings **36** so that conduits or tubes passing through such aligned openings are disposed in parallel relation with each other.

Each conduit **37** consists of an inner tube **39** and an outer tube or sheath **40**. The inner tube **39** is in direct communication with a source of fluid supply **31** with a pump **41** interposed along the line for directing the flow of fluid therethrough. Tube **39** extends through the aligned openings **36** and **38** and then curves downwardly towards treatment station **26** and fitting **42**. The fitting is in the form of a C clamp and is held by screw **43** in any desired position along plate member **43** which is in turn supported by posts **44** above the top plate **12** of the transporter. The parts are constructed and arranged so that in the normal position of tube **39** its free end **45** will be disposed directly above a sample tube **14** when such tube is stopped at delivery station **26**.

Opening **38** in rear wall **35** may be threaded to receive a fitting or plug **46** for anchoring tube **39** against sliding movement with respect to the rear wall. It will be observed that the stretch of tubing between the rear and front walls is substantially straight and extends horizontally, whereas the section of tubing **37** in front of wall **34** is arcuate or curved and, in general, has a substantial amount of slack. As will become apparent hereinafter, the amount of slack depends on the proximity of the delivery unit B and transporter A; the greater distance between such units, the less slack is necessary.

Sheath **40** has one end secured within opening **47** of fitting **42**. The sheath curves upwardly and rearwardly, passing through opening **36** in front panel **34a** (in which it is slidable), and has its rear end **48** terminating at a point between the front and rear walls of the frame.

Directly beneath the parallel stretches of tubes extending between the front and backwalls is a laterally extending carriage **49** which consists in part of a horizontal bar **50** having rollers **51** at its ends which are received in horizontal slots **52** in side walls **33**. The carriage is therefore mounted for movement between the forward position illustrated in FIGS. **1** and **3** and the rearward position indicated in broken lines in FIG. **3**. Reciprocatory forward and rearward motion of the conduit-extending carriage is achieved by motor **53**, crank **54**, and link **55**, the latter being operatively connected to the carriage by pin **56** projecting from one end of the carriage through slot **52** (FIG. **1**).

As shown in FIG. **1**, a plurality of tube gripping members **57** project upwardly through openings in top plate **58** of the carriage. Each cylindrical upstanding gripping member has a transverse opening 59 therethrough, such opening being in alignment with a pair of corresponding openings 36 and 38 in the front and rear walls of the frame. Each sheath 40 has its rear portion 48 extending through one of such openings 59. Each opening flares outwardly at opposite ends and even at its smallest inner diameter is substantially larger than the outside diameter of the sheath. Consequently, when the gripping member is in the position shown in solid lines in FIG. 2, forward and rearward movement of the carriage will have no effect on the position of conduit 37.

Each gripping member 57 is connected to a plunger 60 of an encased solenoid 61 and, when such solenoid is energized, the gripping member is pulled downwardly to grip the sheath 40 between the upper arc of aperture 59 and the top surface of carriage plate 58. When the rear portion of the sheath is so gripped and the reciprocable carriage is then shifted rearwardly into the broken line position illustrated in FIG. 3, the sheath is pulled rearwardly through the front plate opening 36 to reduce the slack in the arcuate front section of conduit 37 to the extent permitted by the rearward travel of the carriage. Since the gripping member grips only the sheath 40 and not the inner tube 39, the length of the inner tube in front of wall 34 remains the same. However, with the slack largely removed from the arcuate section 37, the free end 45 of the inner tube 39 is extended or projected downwardly a distance equal to the extent of rearward travel of the carriage. As a result, the free end 45 of the inner tube dips downwardly into a sample tube 14 as indicated in broken lines in FIG. 3.

It has been found that the above action occurs smoothly and without buckling of the concentric tubes. For reasons which may not be fully understood at the present time, extension of the inner tube is readily accomplished without buckling when the sheath is retracted in the manner described, whereas a definite tendency towards buckling would occur should the sheath be held stationary and the clamping and extending forces be applied directly to the inner tube to thrust that tube through the sheath into an extended position.

Tube 39 and sheath 40 are both formed from flexible material, preferably a plastic material such as polyvinyl chloride. It is to be understood that any of a wide variety of materials having the desired properties of flexibility, durability, and resistance to chemical activity may be used.

Beneath carriage 49 is a second carriage 62 having sidewalls 63, front wall 64, and rear wall 65 (FIG. 3). Rollers 66 mounted upon the sidewalls 63 are received in horizontal channels or recesses 67 in the sidewalls of the frame and guide the lower carriage for horizontal reciprocatory movement.

The carriage is shifted forwardly and rearwardly by a motor 68 mounted on front wall 34 (FIG. 1) and operatively connected by shaft 69, desmodromic cams 70, riders 71, and connecting rods 72 to the front wall 64 of the carriage.

Carriage 62 supports a plurality of electromagnet assemblies 73, each such assembly comprising a solenoid element 74 and a core element or plunger 75. The electromagnet assemblies are arranged in parallel side-by-side relation with the solenoid casing of each assembly being secured to rear wall 65 of the carriage by nut 76. Since the assemblies are disposed in side-by-side relation, only one such assembly is visible in the sectional view of FIG. 3; however, it is to be understood that a plurality of identical assemblies are concealed from view by the one illustrated. Since the structure and operation of the multiple assemblies are the same, only one such assembly will be described herein.

The plunger 75 of each solenoid assembly is connected by a pin 77 to the piston shaft 78 of pump assembly 41. While any suitable pump may be used, a pump of the type disclosed in copending application Ser. No. 656,218, filed July 26, 1967, and now abandoned, is particularly effective and is shown in simplified form in FIG. 3. As there shown, the pump assembly 41 comprises a housing 79 containing a pair of unidirectional valves 80 and 81. Each of the valves consists of a sleeve of resilient stretchable material such s rubber, the respective sleeves 80 and 81 covering valve ports 82 and 83. When piston 78 executes its intake stroke, sleeve 81 flexes or stretches to permit the flow of fluid from the supply source 31 into piston chamber 84, and when the piston executes its discharge stroke valve sleeve 80 similarly expands to permit the flow of fluid from the piston chamber towards the sample tube 14 through flexible plastic tube 39. Reverse flow through each of the unidirectional valves is prevented because the valve sleeves fit snugly against the ports and an increase of fluid pressure in a reverse direction only causes such sleeves to seal more tightly.

While motor 68 reciprocates pump carriage 62 at regularly timed intervals corresponding with the intermittent operation of the transport, such movement of the carriage does not necessarily result in operation of pump assemblies 41. The solenoid plunger 75 of each electromagnet assembly is freely slidable in solenoid casing 74 and unless the solenoid is energized movement of the carriage and the solenoid casing mounted thereon is unaccompanied by movement of the plunger. However, when the solenoid is energized, then the solenoid and its plunger are locked against independent relative movement and reciprocation of the carriage will result in corresponding reciprocation of the plunger and the pump piston connected thereto. Hence, each of the plural pump assemblies 41 is operated only when the pump carriage reciprocates and when the particular solenoid associated with that pump is energized.

Control over the amount of fluid delivered or withdrawn through the operation of each pump assembly 41 is achieved by microswitches 85 mounted upon carriage wall 65 adjacent each electromagnet assembly 73. The contact arm 86 of each microswitch is positioned to engage an adjustable contact member or block 87 disposed directly above each electromagnet assembly and in the path of movement of the microswitch arm. The contact member is slidably carried upon a horizontal rod 88 and an upstanding portion 89 of he member threadedly receives a parallel threaded adjustment rod 90. The adjustment rod is equipped with knob 91 so that upon rotation of the knob the member 87 may be shifted between the solid and broken line positions illustrated in FIG. 3. Engagement between the arm 86 of the microswitch and the adjustable member 87 closes the contacts of the switch; when the arm is in the raised position illustrated in FIG. 3 the flow of current to the solenoid is interrupted. It is believed apparent that if adjustment member 87 is shifted into the broken-line position so that solenoid 74 will be energized at the commencement of a cycle of operation of the pump carriage 62, then piston 78 will be shifted to the left to execute its full intake and discharge strokes. However, if the contact member 87 is shifted to the left, then the carriage 62 will move forwardly a selected distance before the microswitch is closed and, consequently, before the solenoid is energized and the intake stroke is commenced. Thereafter, when the carriage executes its return stroke to pump fluid from pump 41 into tube 39, the solenoid will be deenergized as soon as the arm of the microswitch clears contact element 87. Therefore, by adjusting the position of contact member 87 the amount of fluid delivered by each pump 41 and conduit 37 to a sample tube 14 may be easily and accurately controlled.

Primary control over energization of each solenoid 74 of a pump assembly and each solenoid 61 of a tube extension-retraction assembly is achieved by programming means C. Such programming means is diagrammatically illustrated in FIG. 3 and is shown to be connected by leads or signal lines 92 and 93 to solenoids 74 and 61. It is to be understood that the program or control means is similarly electrically connected to the respective solenoids of the delivery system B for each of the treatment stations 26–30 and that the apparatus of the delivery unit B responsible for delivering (or extracting) fluid at each of such stations constitutes treatment means for the samples carried by the transporter.

The programmer C comprises a casing 94 having a top panel 95 and end panels 96 connected by bolts 97. Between the end panels 96 are a plurality of programming modules or devices **98–102**, each of said modules being substantially identical and, as shown in FIG. **1**, being arranged in spaced parallel relation. Any number of such modules may be provided depending on the size of the analyzer and, in particular, upon the number of different treatment procedures to be performed thereby.

A shaft **103** extends through all of the modules and is journaled in end plates **96**. As shown most clearly in FIG. **2**, shaft **103** is operatively connected by gears **104** to drive shaft **19**; therefore, rotation of the shaft **103** is synchronized with the operation of the transporter as well as with the operation of delivery system B. Mounted on shaft **103** are a plurality of disks or rotatable members **105**, one such member being provided for each module **98–102**. Referring to FIG. **4**, it will be seen that each member **105** has a hub portion **105*a*** and a multiplicity of radially extending spring fingers **105*b***. The number of spring fingers corresponds directly with the number of sample tubes capable of being carried by the transporter; therefore, while a total of **66** spring fingers are illustrated in FIG. **4**, it will be understood that a greater or smaller number may be provided depending upon the capacity of the transporter and the size of the analyzer as a whole.

It will be observed that the spring fingers are equally spaced and are of equal length. As viewed in side elevation, each of the fingers slopes away from the plane of the hub with which is it integrally formed. The tension of the flexible fingers tends to urge them into engagement with a contact plate or member **106** which extends normal to the axis of shaft **103**. However, such fingers are normally held away from contact with plate **106** by a second plate **107** which is parallel with the first plate and spaced therefrom by an insulating spacer **108**. It will be observed that plate **107** has an opening **109** concentric with rotatable member **105** but slightly smaller than the diameter of spring fingers **105*b***. Consequently, in their normal condition, such fingers ride upon plate **107** about the edge of opening **109** and are prevented from engaging contact plate **106**.

The ends of the spring fingers **105*b*** may be bent as shown most clearly in FIGS. **5** and **6** so that slightly rounded or curved surface portions of the fingers engage the plates to reduce wear of the fingers, to insure a smooth operation, and to achieve proper electrical contact as will be described hereinafter.

Like spacer **108**, contact plate **106** is formed of plastic or other suitable electrical insulating material. However, applied to the surface of plate **106** which faces the spring fingers is a circumferential series of metallic contacts **110**. In the illustration given, a total of 60 such contacts are provided, each contact representing or corresponding with a possible location of a treatment station along transporter A. Conductive lines or stripes of metal lead from each of the contacts **110** to a series of plug-in connectors **112** disposed along one edge of the plate or card **106**. Thus, if module **98** shown in FIG. **4** were to control treatment occurring at station **26** in FIGS. **1** and **3**, then a suitable mating connector **113** would be plugged into the second pair of contacts (counting from the bottom of the plate because of clockwise rotation of the rotatable member **105**) and the signal lines **92** and **93** would lead from connector **113** to solenoids **74** and **93** as indicated in FIG. **3**.

Opening **109** in second plate **107** is generally circular in configuration except for a recess **114** along an edge portion of the opening. When the spring fingers **105*b*** of the rotatable member reach recess **114** they are no longer supported by the second plate **107** and, because of their tension, such fingers spring in a direction towards plate **106** as soon as they reach the recess. Direct contact between the fingers and plate **106** at that point is prevented, however, by a ramp **115** which is secured to contact plate **106** and which slopes away from that plate to a point above the level of second plate **107** (FIGS. **7–10**). As a result, spring fingers **105** which have advanced to the point where they are no longer supported by plate **108** and therefore drop into recess **114** engage ramp **115** and ride upwardly along the ramp to a point above the level of plate **107**.

Between the upper end **115*a*** of the ramp and the adjacent edge **114*a*** of plate **107** is a transfer opening of greater width than each of the spring fingers **105*b***. Such opening is normally closed by a retractable panel **116** which serves as a slidable trap door between the two levels defined by the surfaces of plates **106** and **107**. When the panel is extended, as illustrated in FIGS. **8**, **10** and **12**, spring fingers riding upwardly upon ramp **115** engage the panel and then pass on to the surface of second plate **107**. However, when the panel **116** is retracted, as illustrated in FIGS. **7**, **9** and **11**, a finger clearing the upper end of the ramp is free to drop downwardly (by reason of the tension in the spring finger) into engagement with the surface of contact plate **106**. A finger which has dropped through the opening remains in contact with plate **106**, and successively engages electrical contacts **110**, until it has traveled substantially an entire revolution, at which time it again engages ramp **115** and rides upwardly along that ramp to the opening normally closed by the retractable panel **116**. The positions of such fingers upon the surface of plate **106** as they approach the ramp are indicated by broken lines in FIGS. **9** and **10**.

In the illustration given, the means for retracting panel **116** comprises a crank or lever **117** which is pivotally connected to plates **106–108** by pin **118** and which has one end connected to the retractable panel at **119** and its opposite end connected to the plunger of a solenoid unit **120**. Any suitable means may be provided for biasing the panel into a normally closed or extended position; in the embodiment illustrated, a compression spring **121** urges the plunger of the solenoid in the direction indicated by arrow **122** (FIG. **8**) to maintain the panel in its extended position unless the solenoid is energized. As shown, the solenoid unit is secured to plates **106–108** by a bracket **123**.

Any of a variety of means may be utilized for selectively energizing the solenoids of the respective programming modules. FIG. **1** schematically illustrates a card reader **124** which may be connected by a bundle of signal lines **125** to each of the several solenoids and which will energize one of such solenoids when a card **125** is inserted into the reader. Alternatively, the means for energizing the respective solenoids **120** might comprise a control panel having a series of control buttons, one for energizing each respective solenoid. Whatever the case, suitable means are provided for energizing the solenoid of a program module corresponding with a treatment procedure to be applied to a sample introduced into loading station **23** of the transporter. Such energizing of the solenoid will cause a spring finger to drop into engagement with the contact plate of the selected program module and such spring finger will thereafter advance from contact to contact in timed relation with the movement of the corresponding sample tube from stopping station to stopping station. When the spring finger engages a contact **110** which is electrically connected to the pumping and tube-extending solenoids for a given treatment station, such solenoids will be energized and the sample at that station will be so treated.

To illustrate the operation more specifically, it will be observed in FIG. **1** that treatment station **26** is two stopping positions beyond loading station **23**. If a sample inserted into the transport at the loading station is deemed to require the treatment available at station **26**, then at the time the sample is loaded the solenoid **120** for programming module **98** is energized and a spring finger drops into a first position in engagement with contact plate **106**. The sample tube and the corresponding spring finger then advance incrementally and in timed relation. When the finger has reached a second position in engagement with the contact element **110** in circuit (by means of leads **92** and **93**) with the solenoids **61** and **74** of treatment station **26**, the sample will be at that station ready to receive the selected treatment. Energization of solenoid **61** coupled with reciprocation of carriage **49** causes tube **39** to project downwardly into the sample tube, and energization of solenoid **74** results in a pumping action which supplies fluid to the sample tube or extracts fluid therefrom. Thereafter, the conduit is withdrawn from the sample tube and the tube along the circuit of the transport for subsequent treatment only at those stations programmed at the time the tube was inserted into the transporter at the loading station.

It is believed apparent from the foregoing that the programmer may have utility in programming operations which differ considerably from the treatment operations disclosed herein. While an embodiment of the invention has been disclosed in considerable detail for purposes of illustration, it will be understood by those skilled in the art that many of such details may be varied considerably without departing from the spirit and scope of the invention.

We claim:

1. In combination, transport means for conveying a sample from a loading station to a treatment station, treatment means for treating a sample at said treatment station upon receiving an electrical signal, and a programmer comprising a member mounted on a rotatable shaft and provided with at least one radially extending finger, a contact member having a surface normal to said shaft and adapted to be engaged by said finger, said finger being movable along said surface upon rotation of said shaft from a first position corresponding with the introduction of a sample at said loading station to a second position corresponding with the arrival of said sample at said treatment station, electrical contact means on said surface engageable by said finger at said second position for producing an electrical signal upon contact by said finger, means for transmitting said signal to said treatment means, and driving means for driving said transport means and said shaft in timed relation so that the interval for conveying said sample from said loading station to said treatment station is the same as for moving said finger from said first position to said second position.

2. The structure of claim 1 in which said rotatable member is provided with a plurality of said radially extending fingers, means for normally maintaining said fingers spaced from the surface of said contact member and out of engagement with said contact means, and means for selectively directing any one of said fingers at said first position into engagement with said surface when a sample is introduced into said loading station.

3. The structure of claim 2 in which said fingers are flexible and are formed of electrically conductive material, said fingers when in contact with said surface being flexed and engaging said surface under tension created by such flexure.

4. The structure of claim 2 in which said driving means operates intermittently to drive and stop said transport means and said shaft at regularly timed intervals, said treatment station comprising a stopping station at which said treatment means is located.

5. The structure of claim 2 in which there are a plurality of additional treatment stations in spaced series with respect to said first-mentioned treatment station, additional treatment means at said additional stations substantially identical with said first-mentioned treatment means but adapted to perform individually distinctive treatment to a sample, said transport means being adapted to convey a series of samples in succession through said plurality of treatment stations, and a control unit comprising said programmer and a plurality of additional and substantially identical programmers each corresponding with one of said treatment means and each having electrical contact means engageable by a spring finger in said second position wherein the interval for moving said finger of each programmer from said first position to said second position is the same as the interval for conveying a sample from said loading station to the treatment station of the treatment means corresponding with each said programmer.

6. The structure of claim 5 in which said samples are fluid and are contained in open-topped sample tubes, said treatment means including a plurality of pumps and conduits for delivering fluid to or extracting fluid from selected sample tubes, said driving means operating intermittently to drive and stop said transport means and said tubes at regularly timed intervals, said treatment stations comprising stopping stations for said tubes where fluid is delivered to or extracted therefrom.

7. The structure of claim 6 in which said conduits are partially supported by a reciprocable carriage equipped with a plurality of solenoid-actuated conduit gripping devices, each of said conduits being extensible and retractable and being adapted to be extended into and retracted from a sample tube at a treatment station when the solenoid-actuated gripping device associated therewith is energized during reciprocation of said carriage, and power means for reciprocating said carriage in timed relation with the intermittent drive of said transport means, whereby, a conduit is extended into a sample tube at a treatment station only if the solenoid gripping device therefor is energized by a signal produced by engagement between a finger and the electrical contact means of the programmer corresponding with such treatment station.

8. The structure of claim 6 in which said treatment means includes a reciprocable pump carriage supporting a plurality of electromagnets each connected to a one of said pumps, each of said pumps being operated by reciprocation of said pump carriage only if the particular electromagnet associated therewith is energized, and power means for reciprocating said pump carriage in timed relation with the intermittent drive of said transport means, whereby, a pump is actuated to deliver fluid to or extract fluid from a sample tube at a treatment station only if the electromagnet therefor is energized by a signal produced by engagement between a finger and the electrical contact means of the programmer corresponding with such treatment station.

9. In combination, a transporter for conveying sample tubes in succession from a loading station through a series of treatment stations, electrically actuated treatment units for selectively treating samples in said tubes at said treatment stations, the sample treatment at each of said stations being different than at the other of such stations, and programming means for automatically actuating certain of the treatment units when a tube reaches the appropriate treatment station in accordance with a selection made upon introducing such tube at said loading station, said programming means consisting of a plurality of programming devices each corresponding with and energizing certain of said treatment units, each programming device comprising:

a. a rotatable member having a plurality of radially extending fingers,

b. a plate having a surface parallel with said rotatable member and adapted to be engaged by said fingers,

c. each of said fingers being movable upon rotation of said member between a first position upon said plate corresponding with the introduction of a sample tube at said loading station and a plurality of additional circumferentially spaced positions corresponding with the arrival of the same sample tube at subsequent treatment stations,

d. electrical contacts at each of said additional positions engageable by said fingers for producing electrical signals for activating the treatment means associated with said programming device,

e. means for normally maintaining said fingers spaced from said plate and from the electrical contacts provided thereon,

f. transfer means for selectively shifting any one of said fingers into contact with said plate at said first position when a sample requiring the treatment associated with said program device is introduced into said loading station,

g. means for withdrawing a finger from contact with said plate after said finger has traveled substantially a full revolution from said first position,

and driving means for driving said transporter and for simultaneously rotating all of said rotatable members of said programming devices in timed relation with said transporter so that the intervals for conveying any given sample tube from said loading station to the required treatment stations are the same as for advancing a finger of the corresponding programming device from said first position to the respective additional contact positions.

10. The structure of claim 9 in which said rotatable member comprises a hub portion mounted on a shaft provided by said driving means, said fingers being formed of flexible material and being flexed and tensioned when in contact with said surface.

11. The structure of claim 10 in which said means for normally maintaining said fingers spaced from said plate comprises a second plate upon which the ends of said fingers normally ride, said second plate being insulated from said first plate and having an opening therein smaller in diameter than the diameter of the fingers of said member.

12. The structure of claim 11 in which said second plate has a recess communicating with said opening and extending radially outwardly therefrom at a point overlying said first position of said first-mentioned plate, whereby, a spring finger entering said recess will be released from contact with said second plate and will flex into contact with said first plate at said first position.

13. The structure of claim 12 in which said transfer means comprises a retractable panel normally extending over said recess and preventing spring fingers riding upon said second plate from flexing into contact with said first plate.

14. The structure of claim 13 in which a solenoid-operated lever is connected to said panel for selectively retracting the same to permit a spring finger engaging said panel to flex through said recess into engagement with said first plate at said first position.

15. The structure of claim 13 in which said first panel is provided with a ramp adjacent said first position for returning spring fingers which have executed substantially a full revolution in contact with said first plate back into riding surface engagement upon said second plate.

16. The structure of claim 9 in which said driving means operates intermittently to drive and stop said transport means and said rotatable members at regularly timed intervals.

17. The structure of claim 9 in which said treatment means includes a plurality of pumps and conduits for delivering fluid to or extracting fluid from selected sample tubes, said driving means operating intermittently to drive and stop said transport means and said tubes at regularly timed intervals, said treatment stations comprising stopping stations for said tubes where fluid is delivered to or extracted therefrom.

18. The structure of claim 17 in which said conduits are partially supported by a reciprocable carriage equipped with a plurality of solenoid-actuated conduit gripping members, each of said conduits being extensible and retractable and being adapted to be extended into and retracted from sample tubes at a treatment station when the solenoid-actuated gripping member associated therewith is energized during a reciprocatory stroke of said carriage, and power means for reciprocating said carriage in timed relation with the intermittent drive of said transporter, whereby, a conduit is extended into a sample tube at a treatment station only if the solenoid gripping member therefor is energized by a signal produced by engagement between a finger and the electrical contact of the programming device corresponding with such treatment station.

19. The structure of claim 17 in which said treatment units comprise a reciprocable pump carriage supporting a plurality of electromagnets each connected to one of said pumps, each of said pumps being operated by reciprocation of said pump carriage only if the particular electromagnet associated therewith is energized, and power means for reciprocating said pump carriage in timed relation with the intermittent drive of said transporter, whereby, a pump is actuated to deliver fluid to or extract fluid from a sample tube at a treatment station only if the electromagnet therefor is energized by a signal produced by engagement between a finger and an electrical contact of the programming device corresponding with such treatment station.