United States Patent [19]

Downing et al.

[11] **3,753,657**

[45] **Aug. 21, 1973**

[54] **AUTOMATIC TEST TUBE TRANSPORTER AND SAMPLE DISPENSER HAVING SOLID STATE CONTROLS**

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[73] Assignee: **Micromedic Systems, Inc.**, Philadelphia, Pa.

[22] Filed: **June 11, 1971**

[21] Appl. No.: **152,189**

[52] **U.S. Cl.** .... **23/253 R**, 23/259, 73/425.6, 141/130

[51] **Int. Cl.** **G01n 21/00**

[58] **Field of Search** 23/230, 253, 292, 23/259; 141/130

[56] **References Cited**

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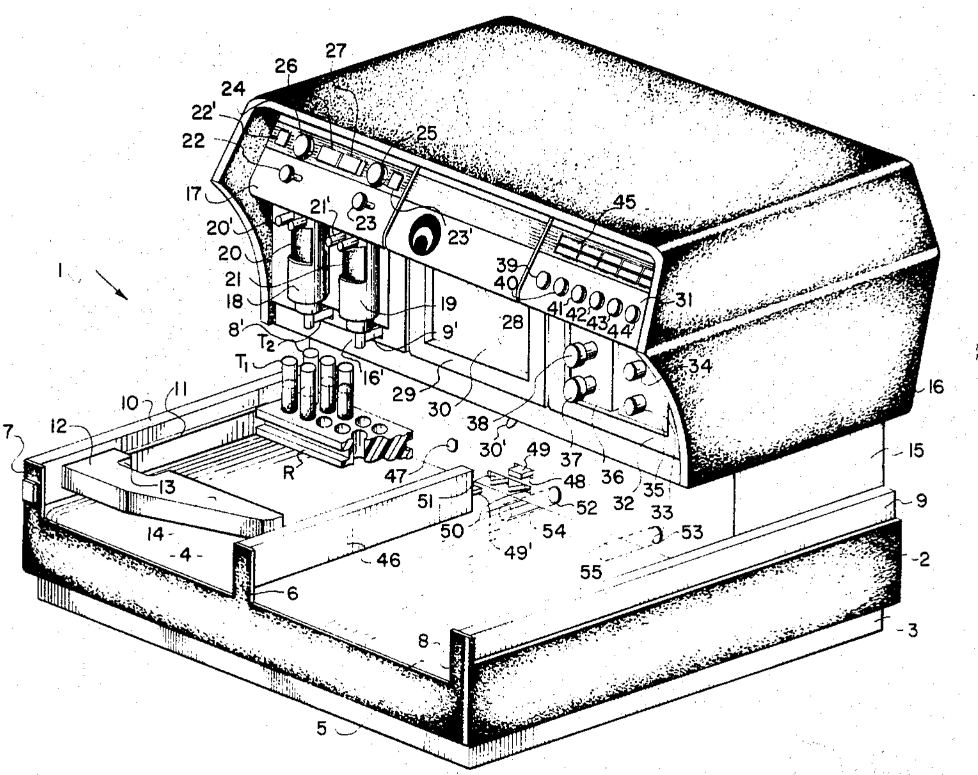
Primary Examiner—Morris O. Wolk
Assistant Examiner—R. E. Serwin
Attorney—Gerry J. Elman et al.

[57] **ABSTRACT**

An automatically controlled test tube transporter apparatus which advances a test tube rack containing two rows of receptacles for test tubes under a vertically movable aspirating and dispensing tip or nozzle which is adapted to move down into adjacent tubes and aspirate or discharge depending on the test to be performed. The tip is operationally in communication with a twin pipette metering and dispensing apparatus which includes a linearly adjustable eccentric mechanism which drives the pipette pistons with a motion of adjustable sinusoidal amplitude. The apparatus includes a solid state control circuit which includes a binary shift register. The pipettes may be adjusted to either work in parallel or alternating strokes. An automatic tip wiping mechanism, controlled by the operation of the tip, is provided to insure precision in the processing. The apparatus is adapted to be set for continuous operation or for individual test tube processing cycle operation. Empty racks can be advanced without engaging the tip and pump apparatus. The pipetting mechanism may be operated separately without the operation of the transporting mechanism. A malfunction and alarm logic circuit gives a warning in case of certain malfunctions and stops the apparatus.

48 Claims, 36 Drawing Figures



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22 Sheets-Sheet 1

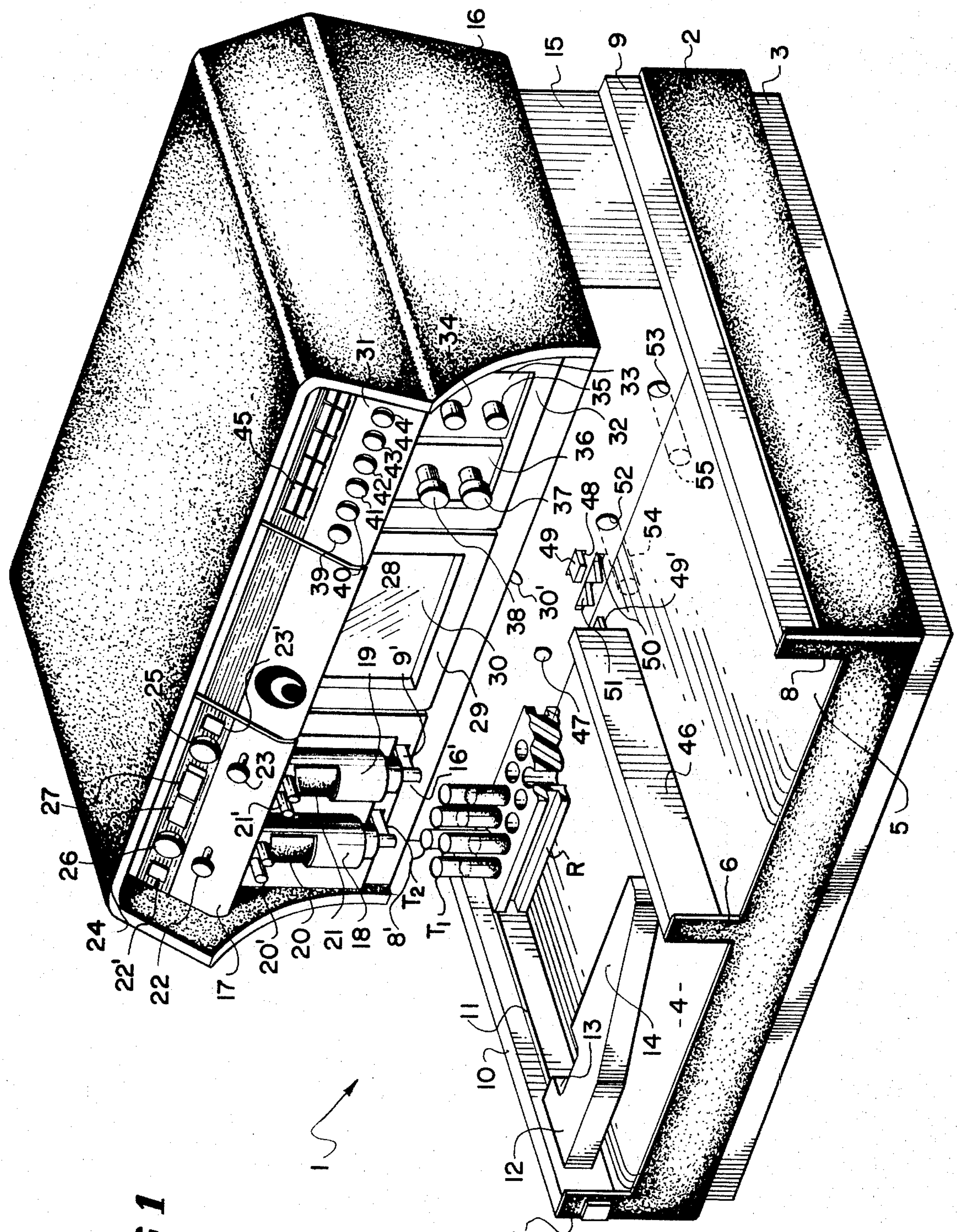


FIG 1

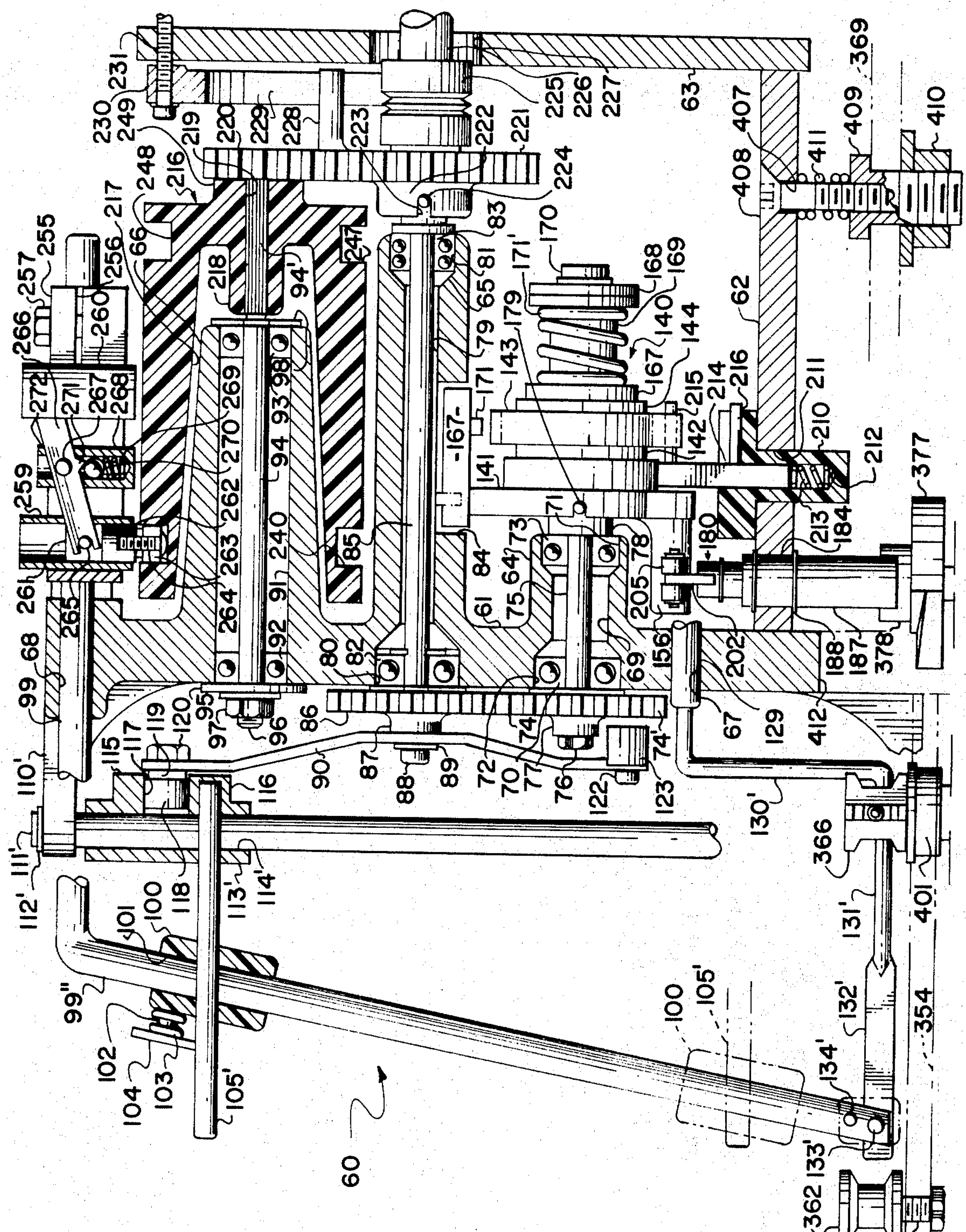
INVENTOR

HARVEY T. DOWNING

CHARLES V. LAWSON, BYRON E. STURGIS

BY

ATTORNEYS



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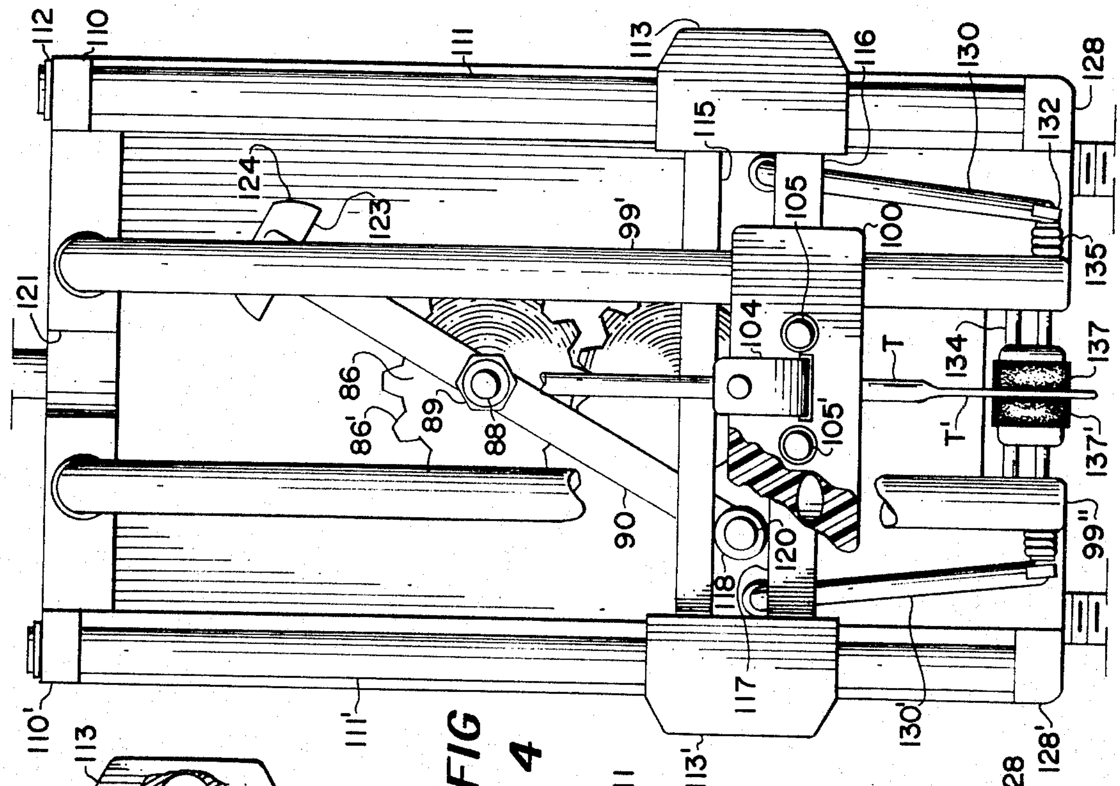

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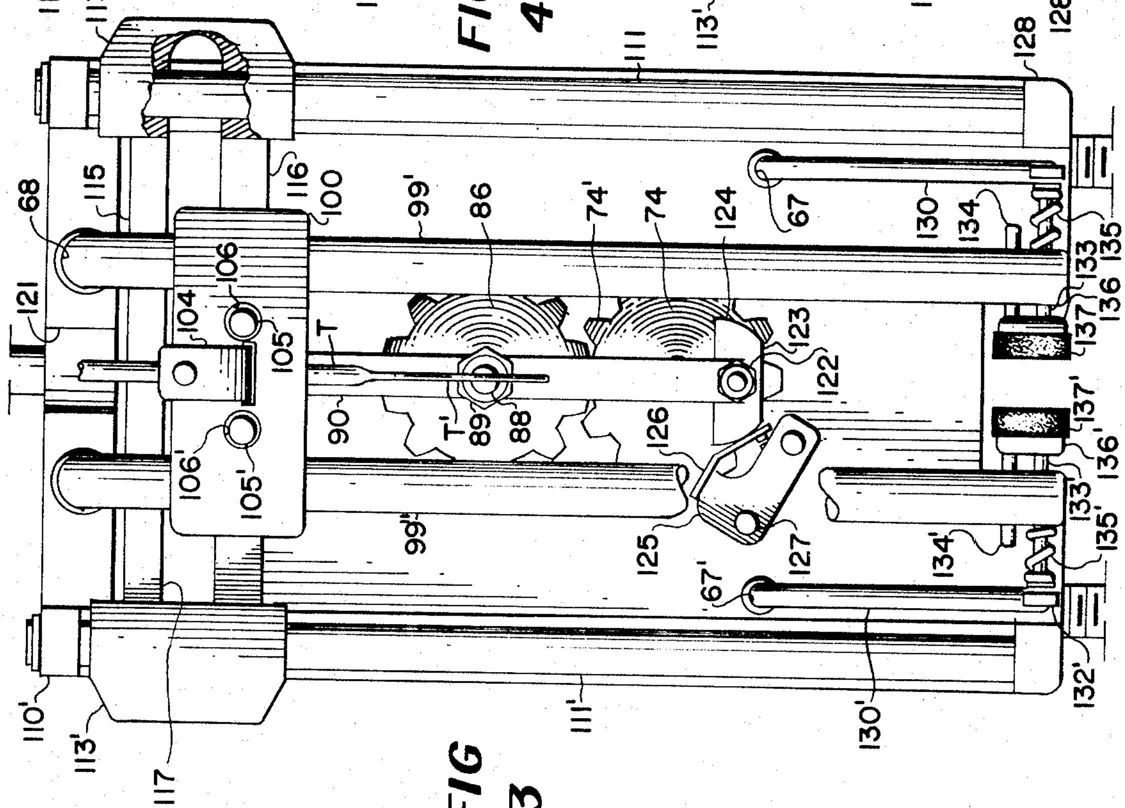

FIG 3

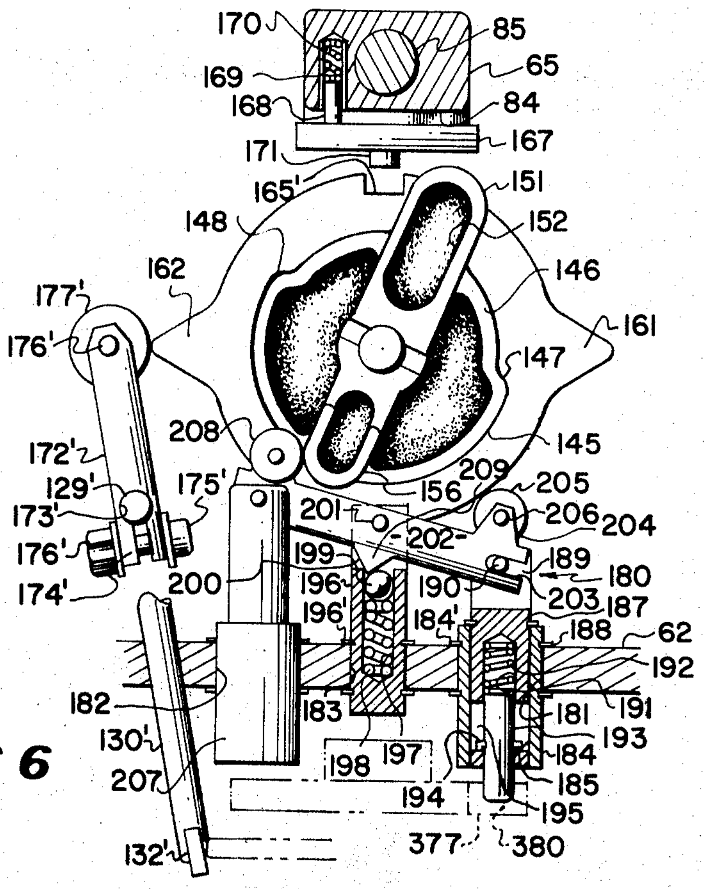
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FIG 6

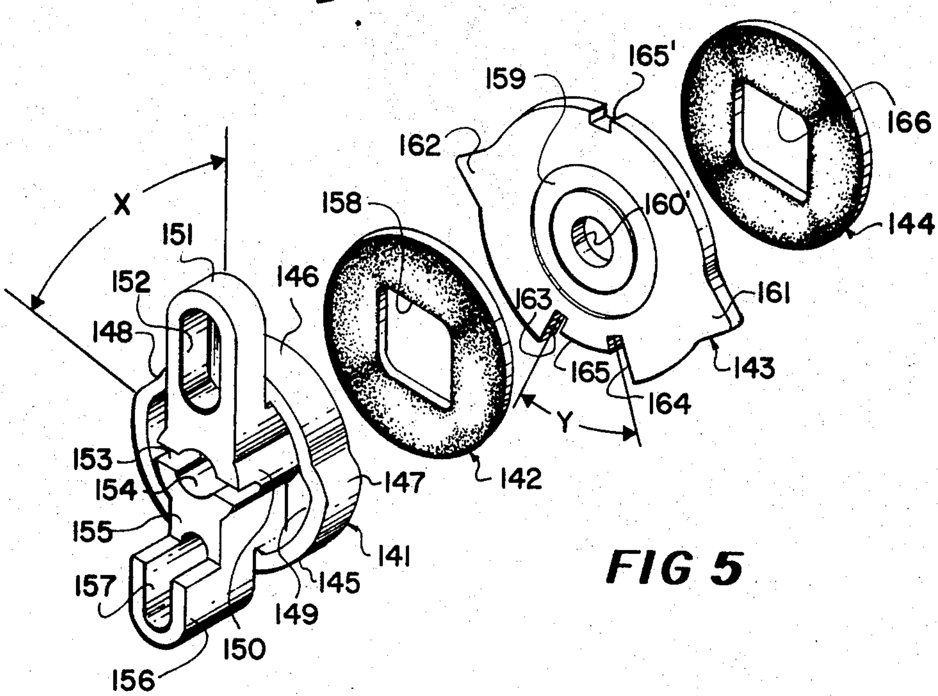
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FIG 5

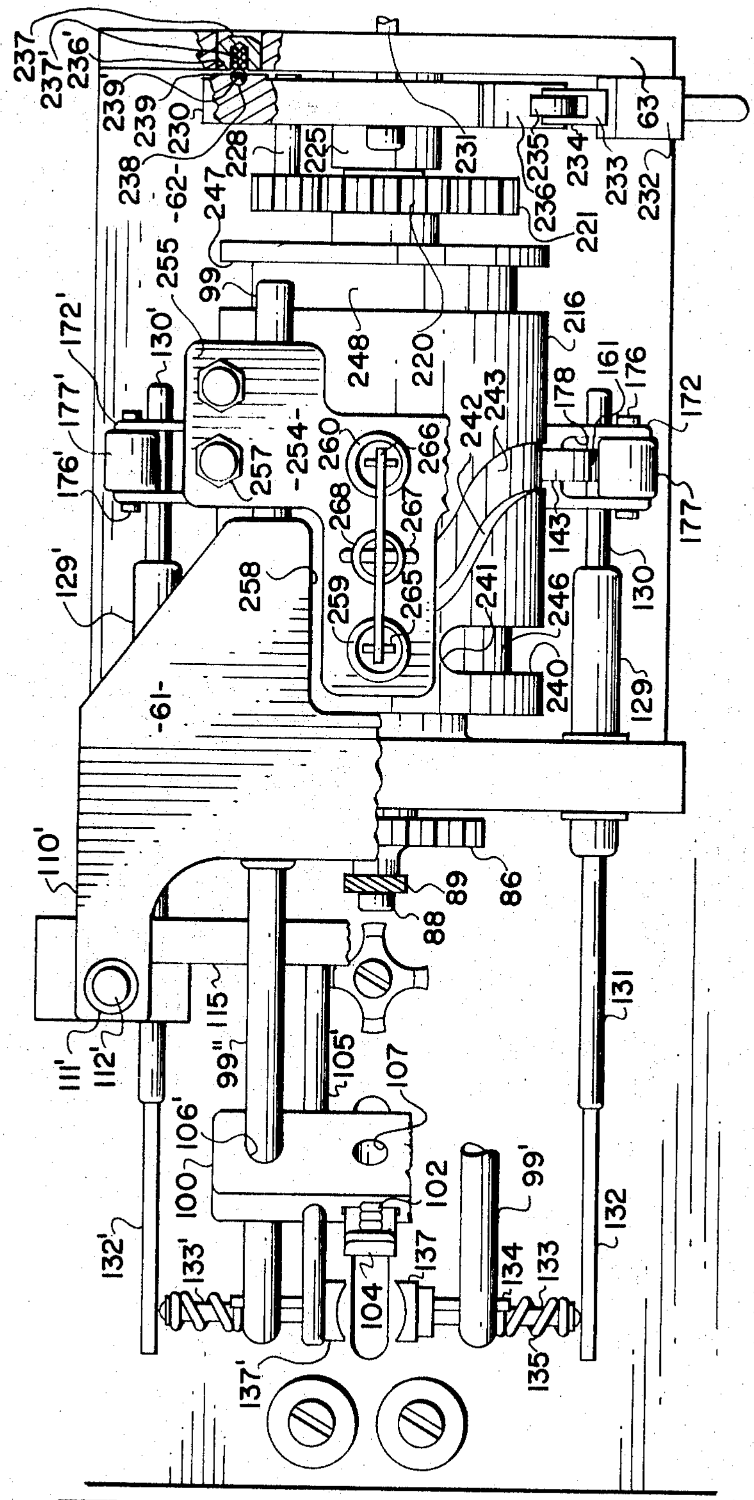
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FIG 7

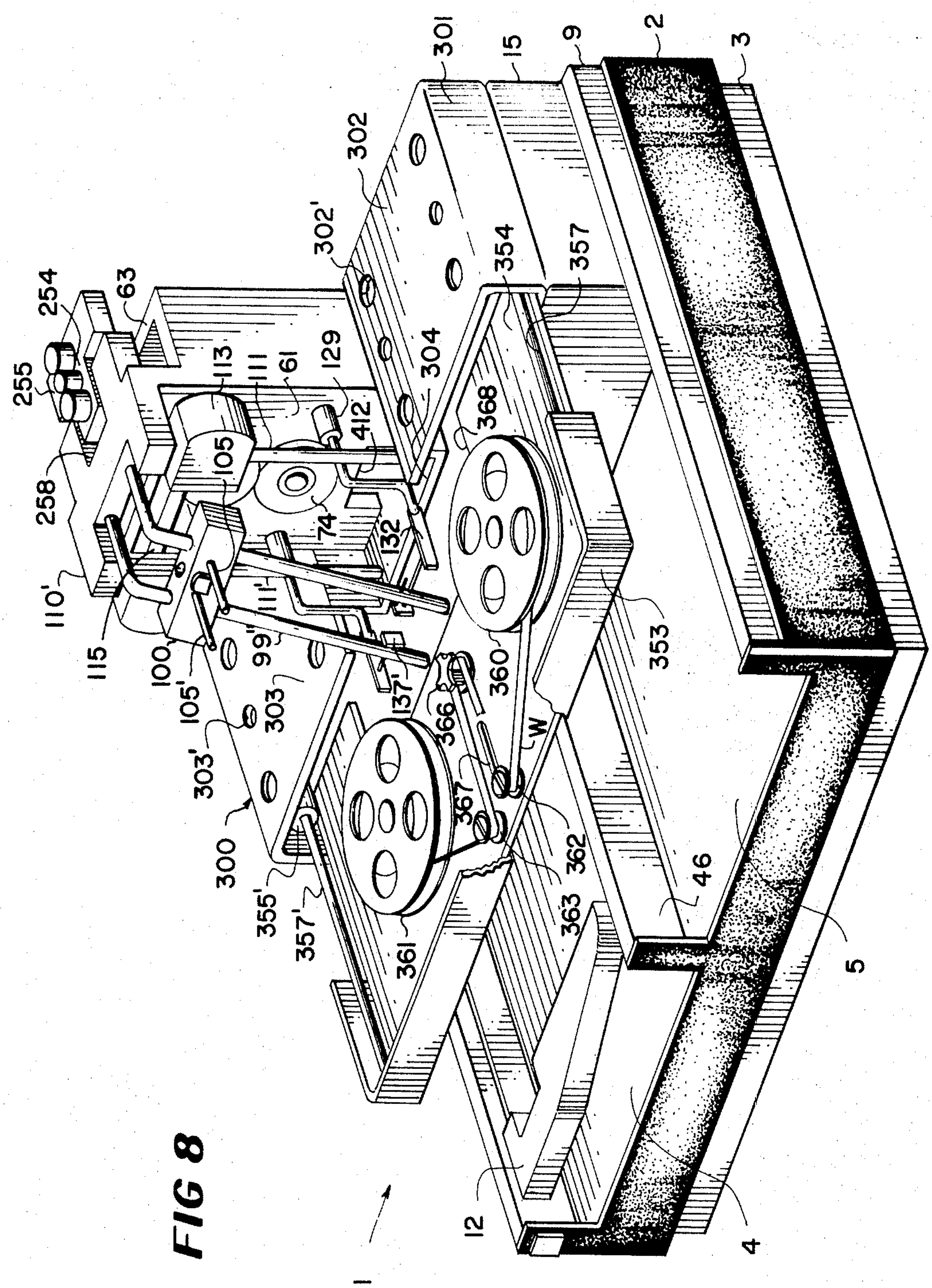

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FIG 8

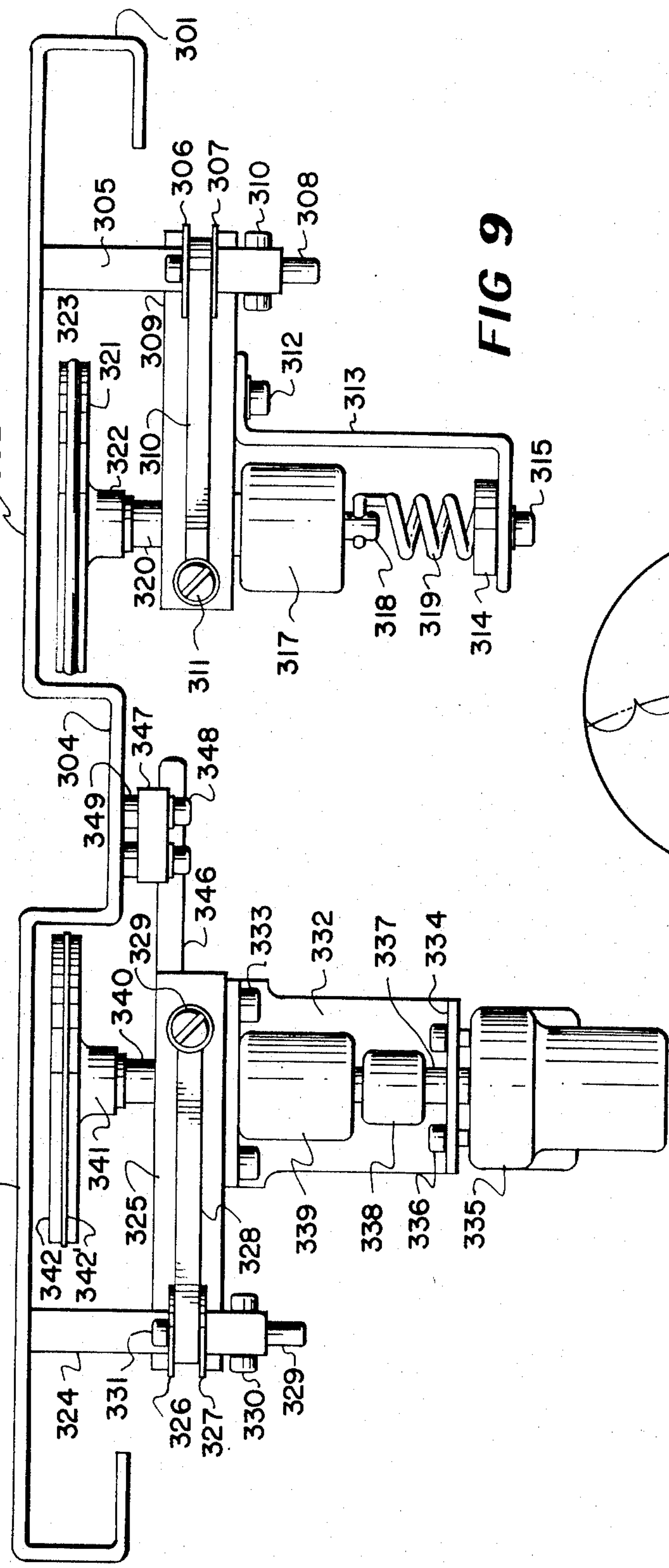
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FIG 9

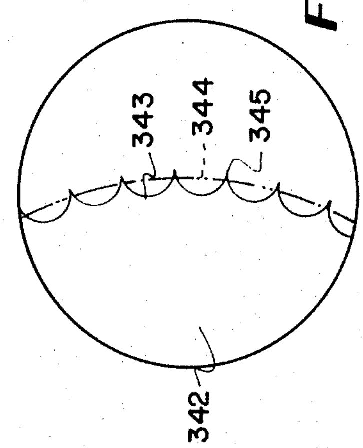
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FIG 11

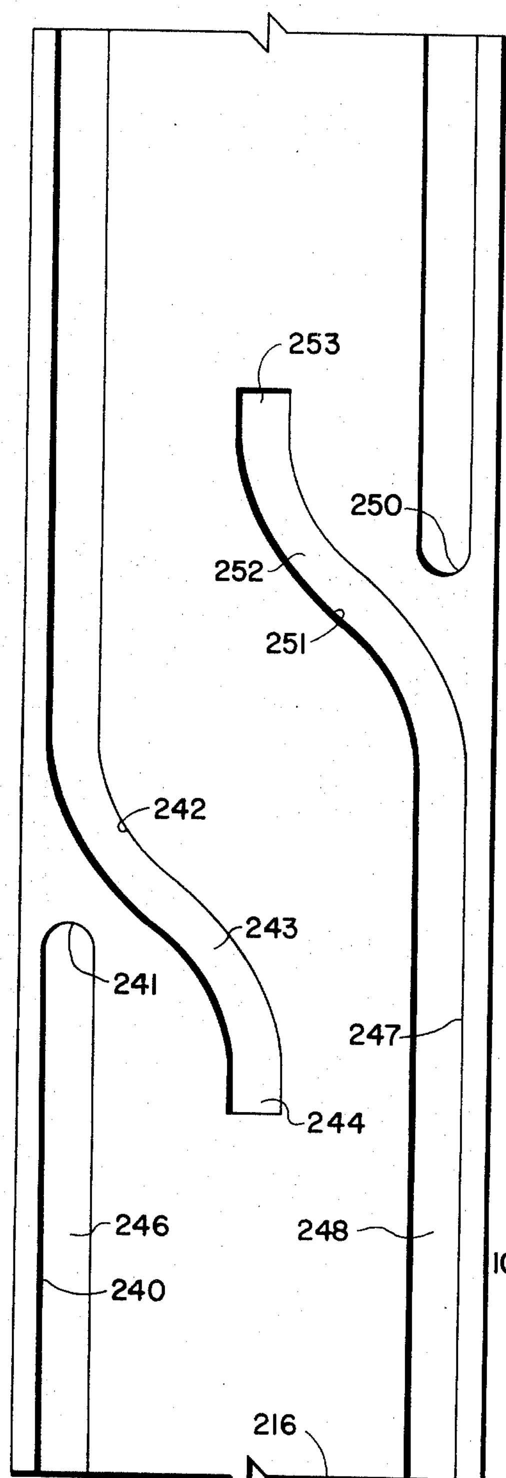

FIG 10a

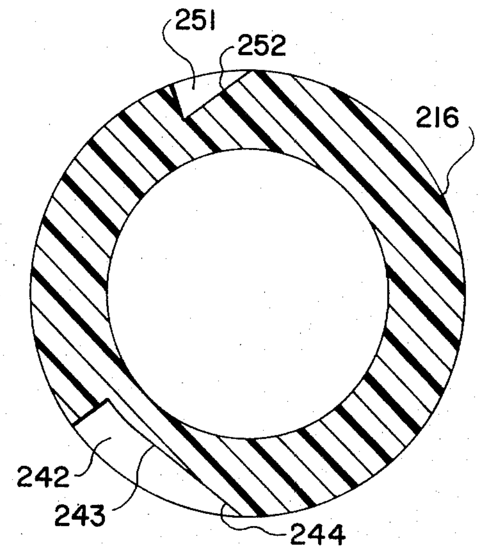

FIG 10b

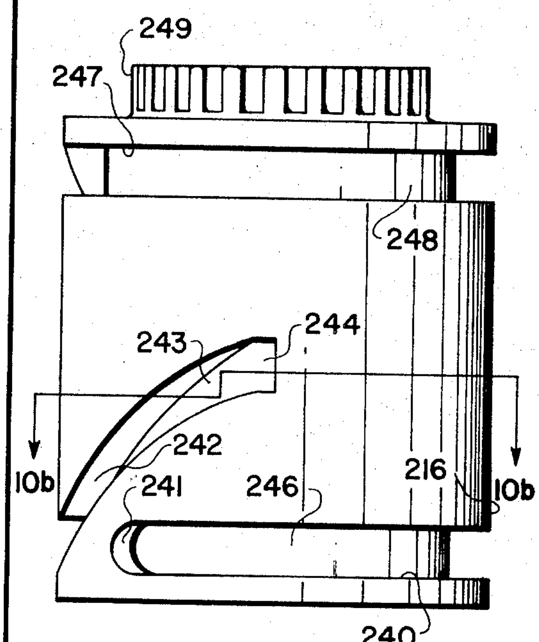

FIG 10c

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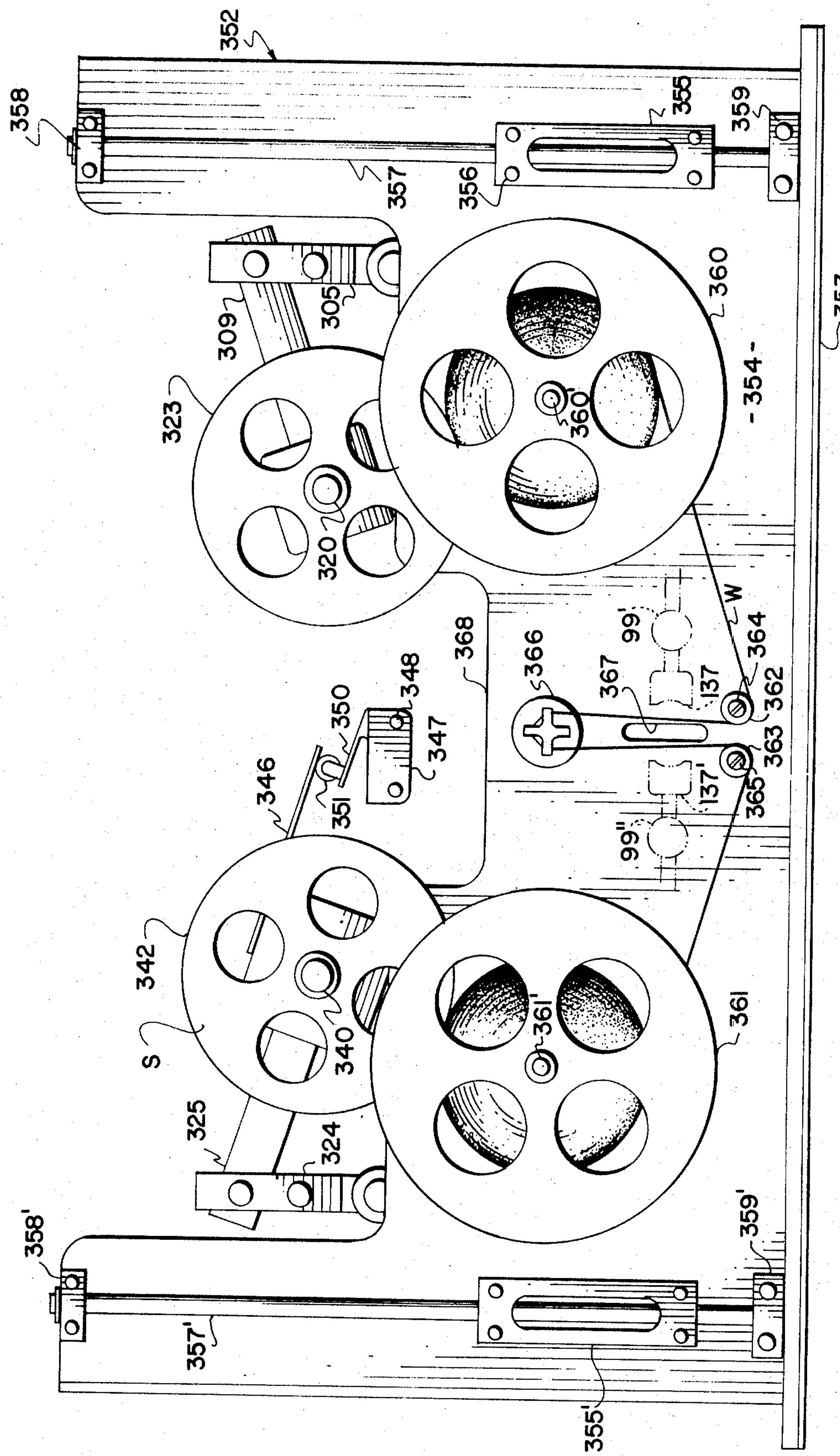
22 Sheets-Sheet 9



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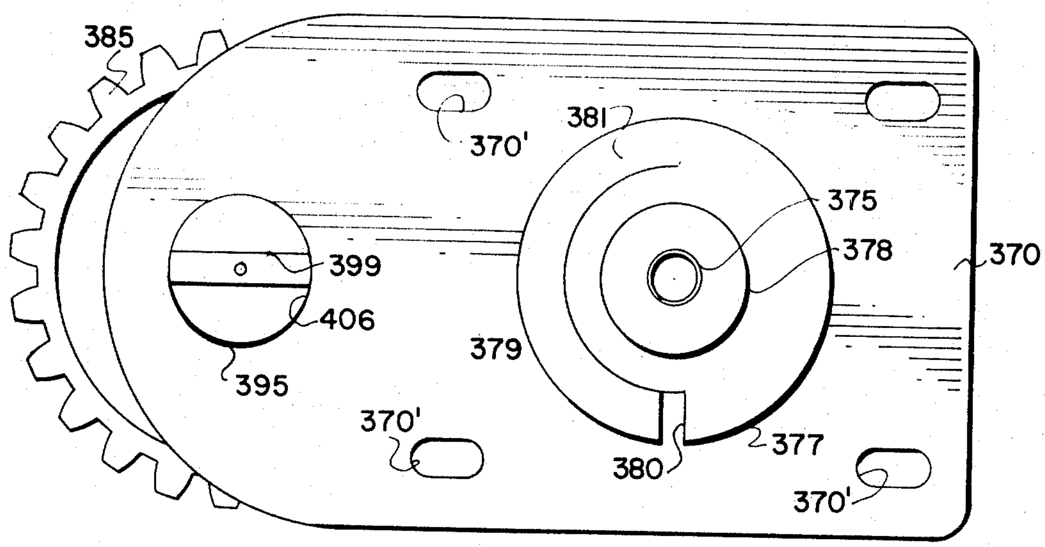
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FIG 14

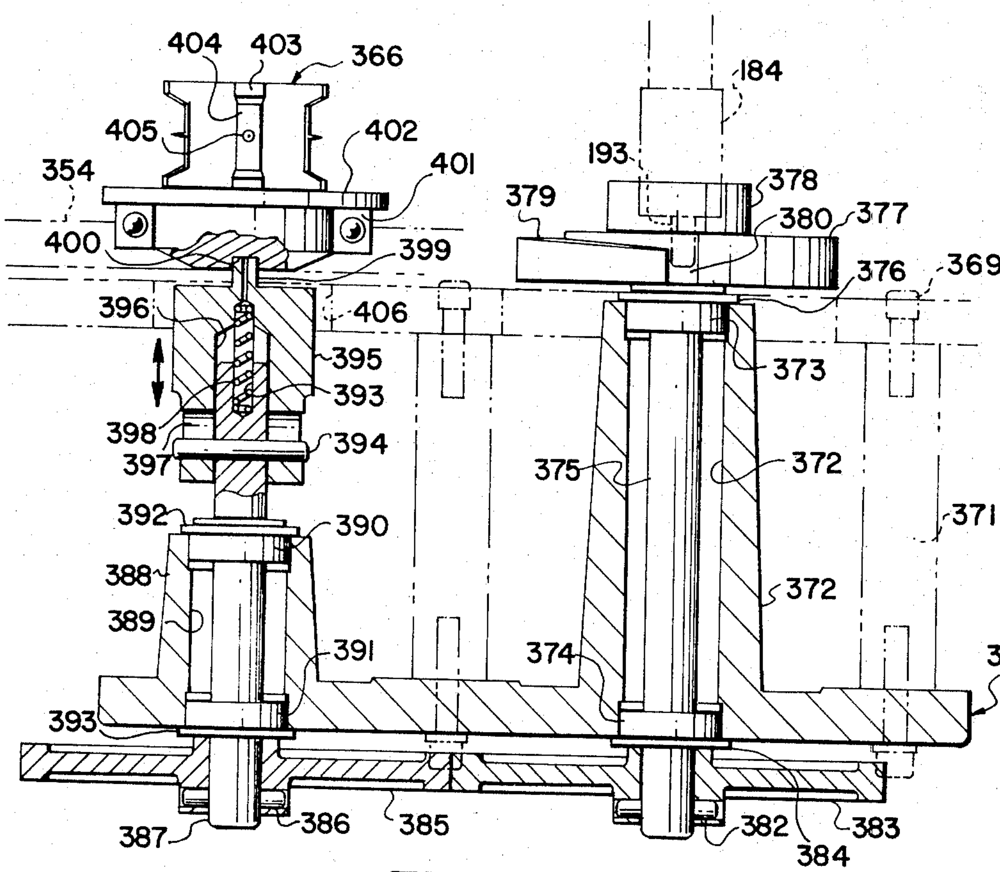
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FIG 13

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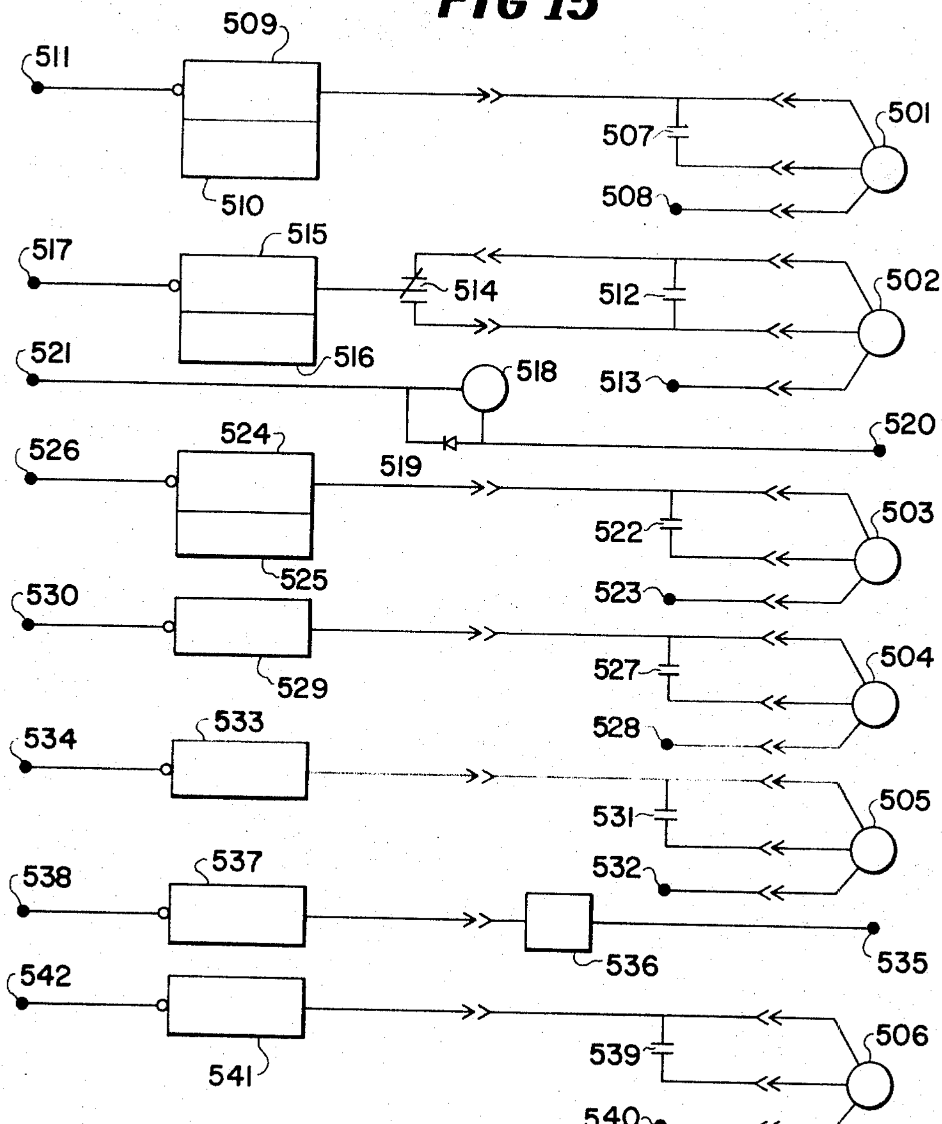
22 Sheets-Sheet 11

FIG 15



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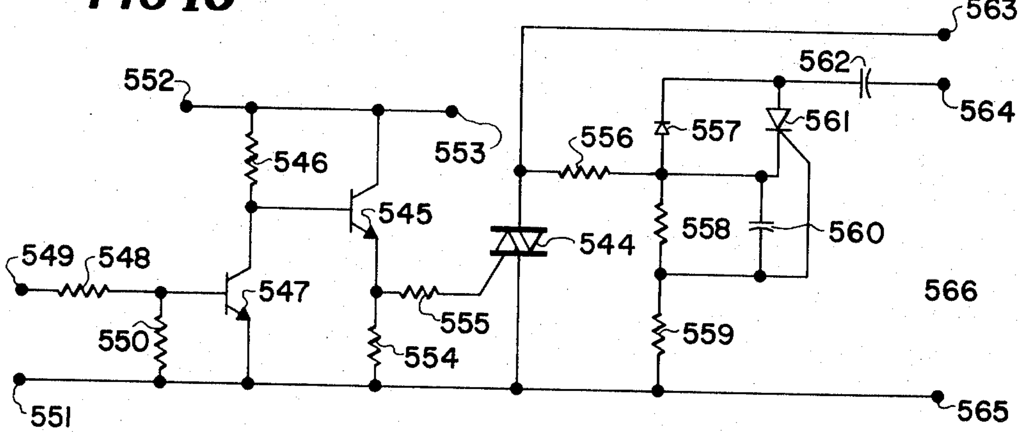

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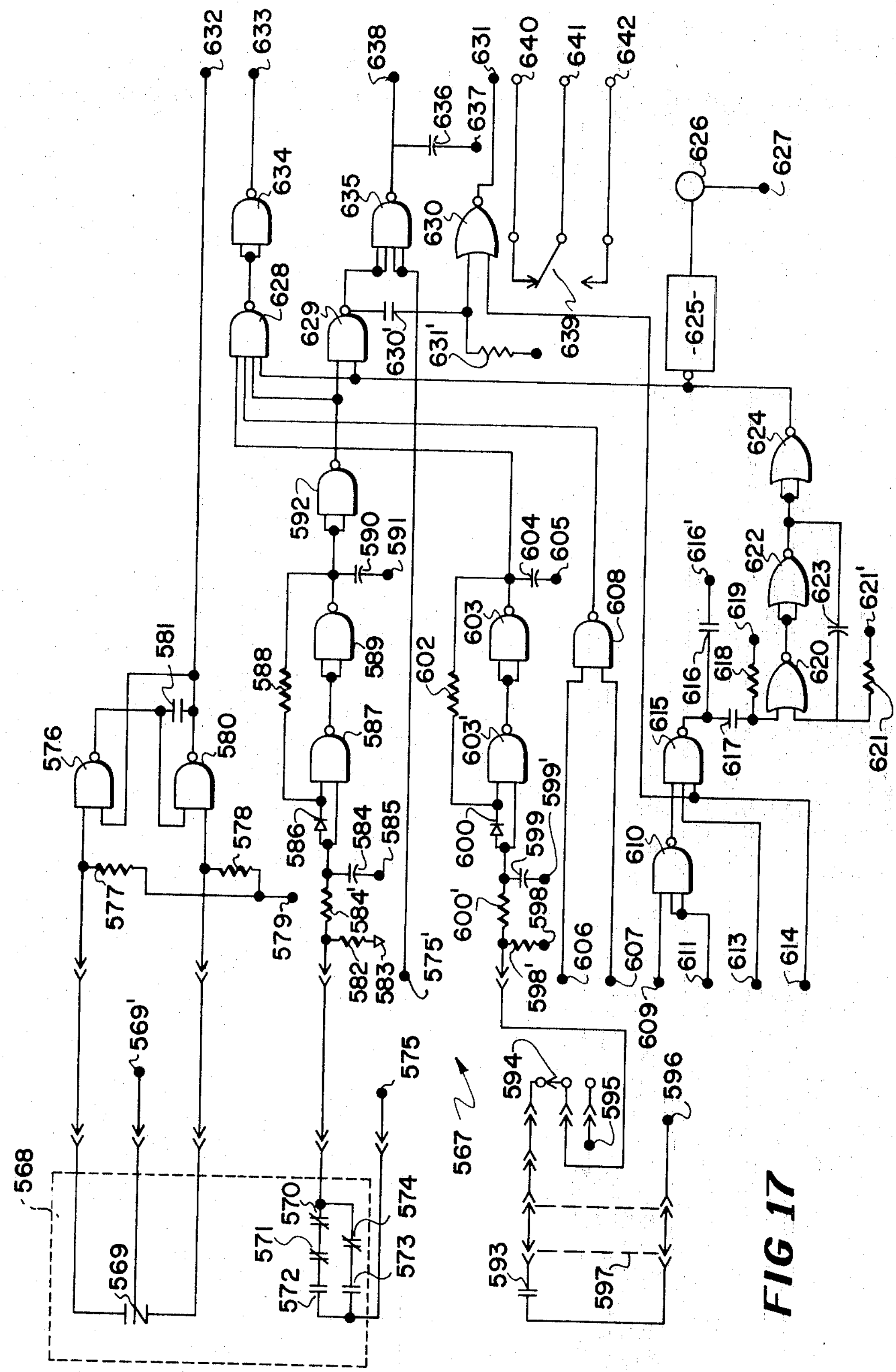

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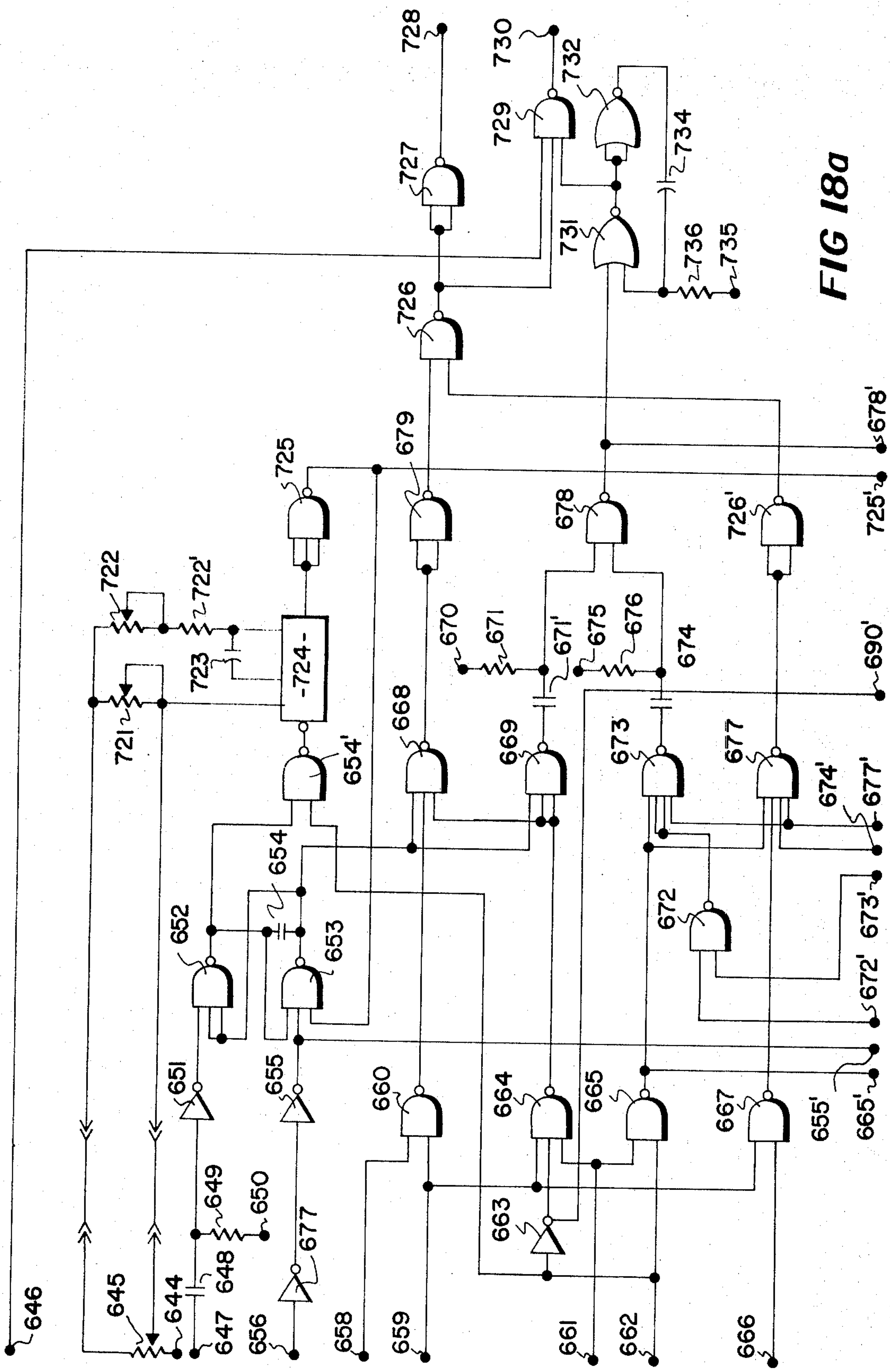

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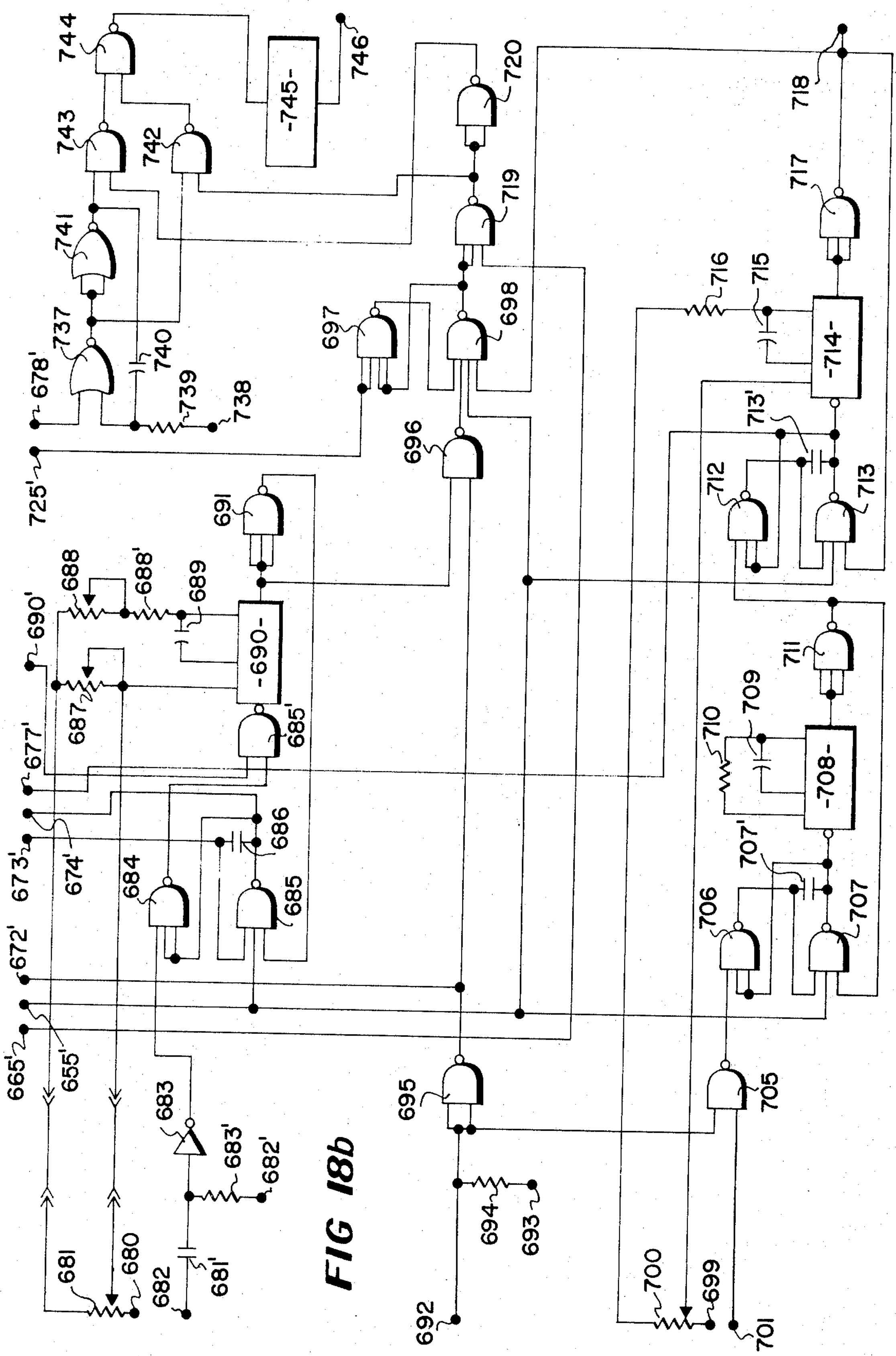
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FIG 18b

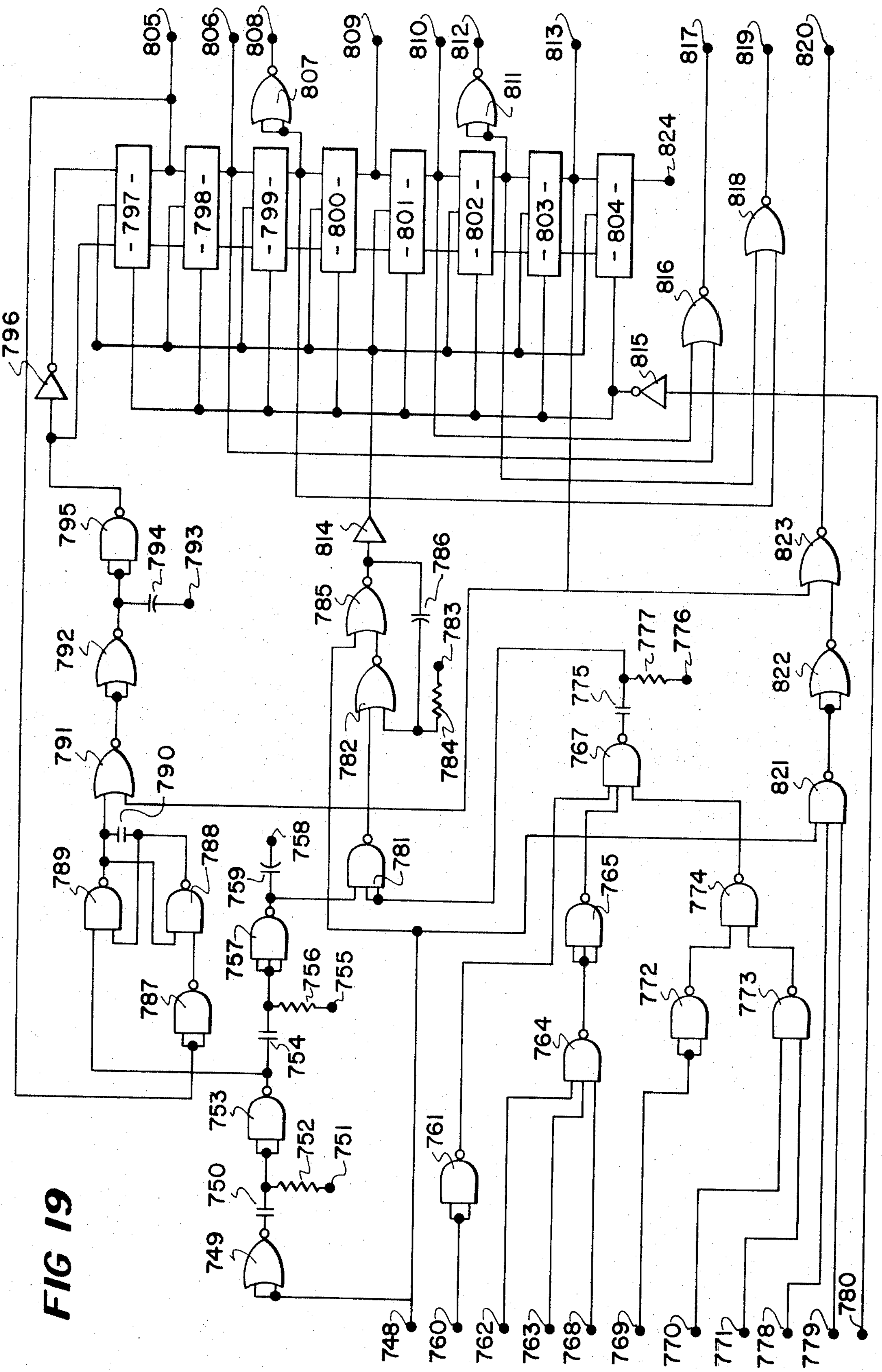
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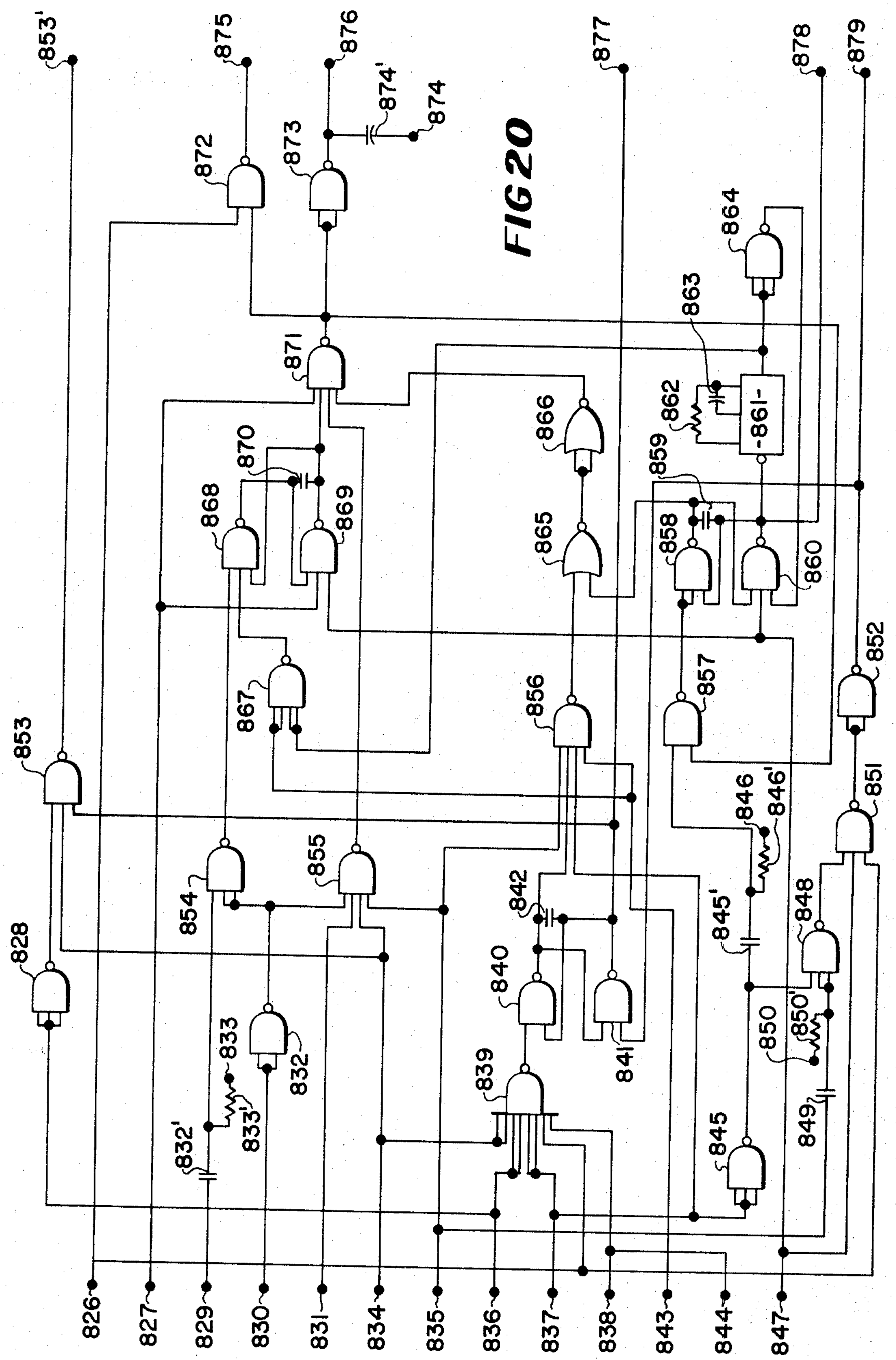
FIG 19



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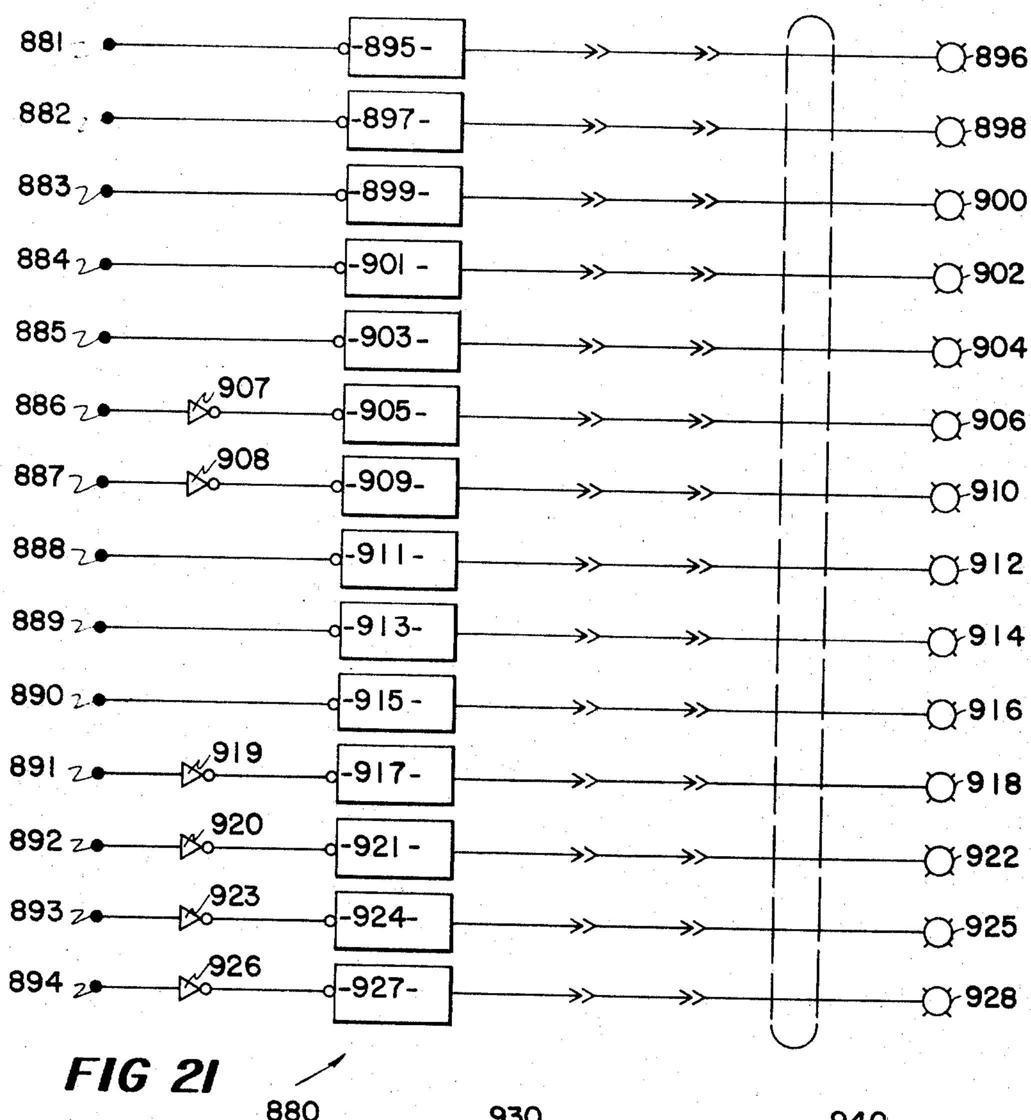
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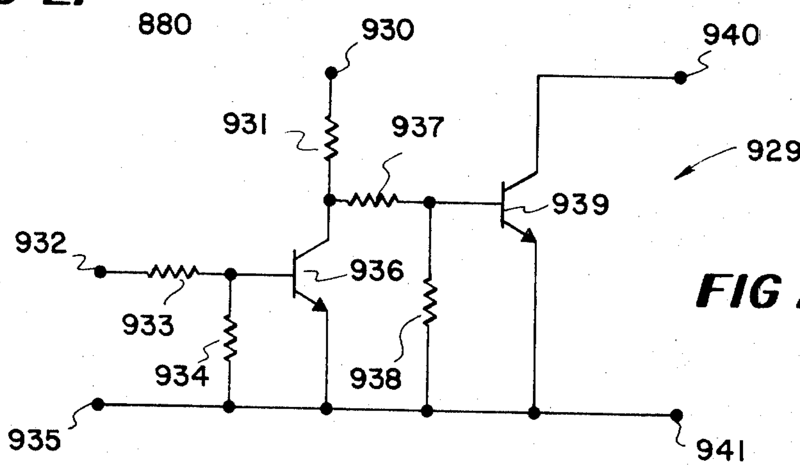
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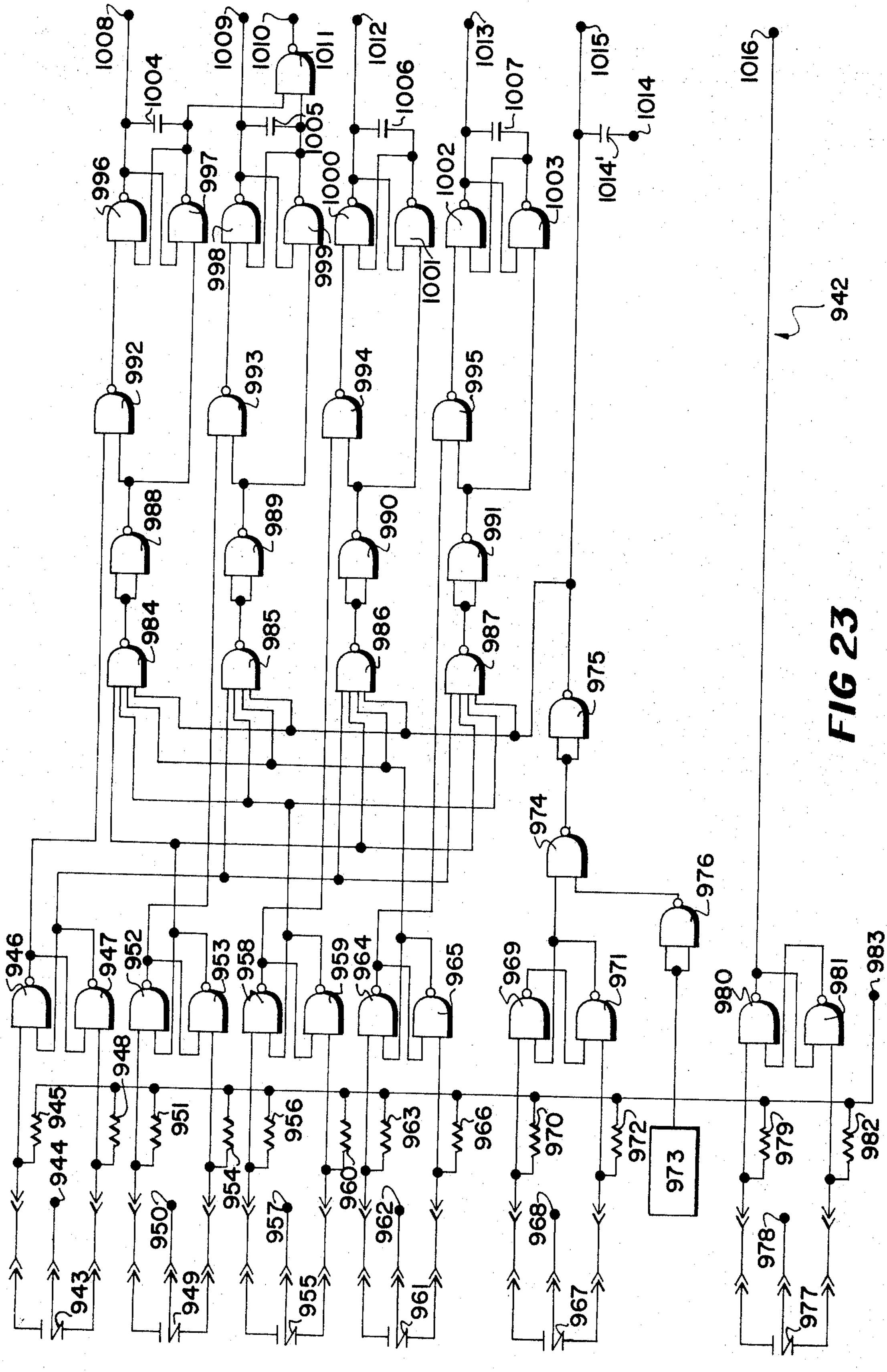

FIG 23

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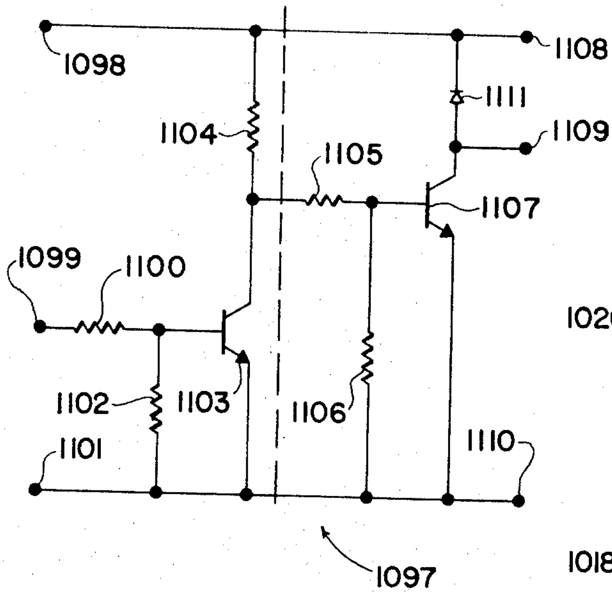

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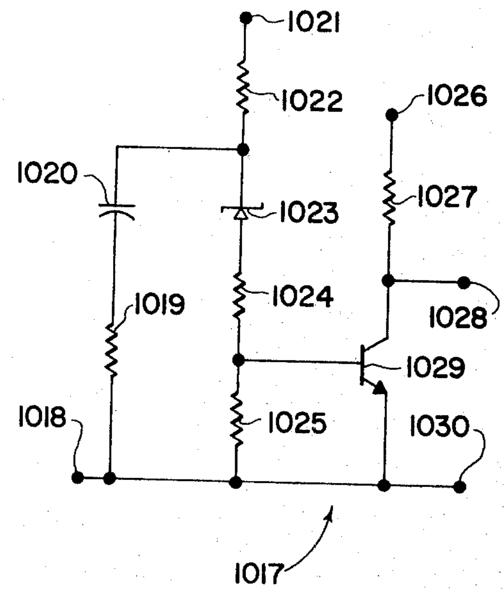


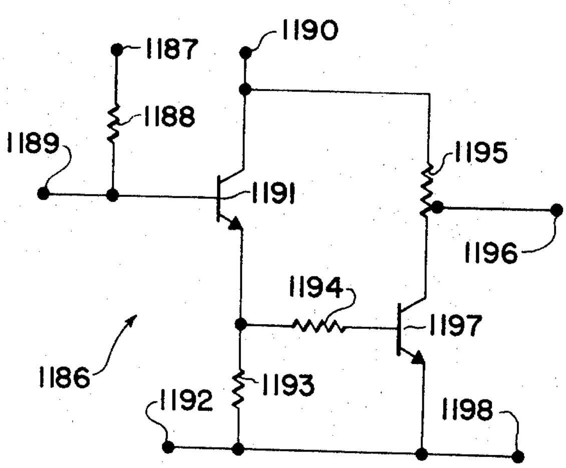
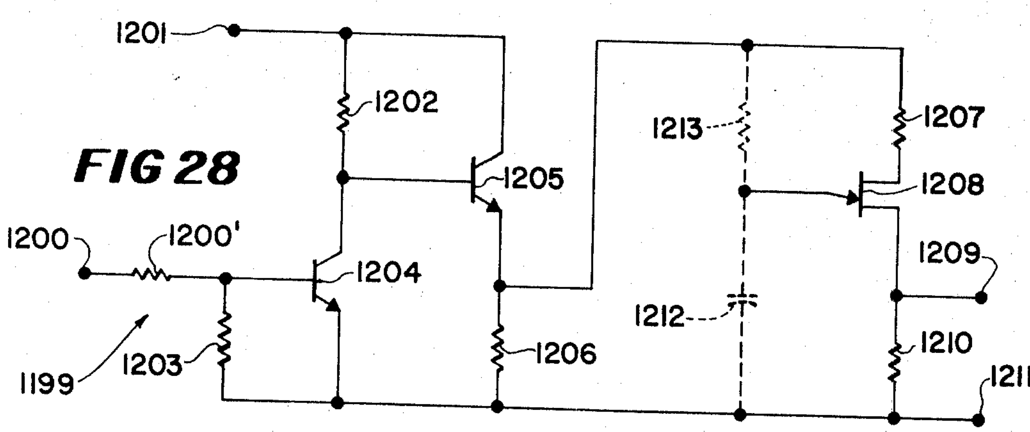


FIG 27

FIG 28



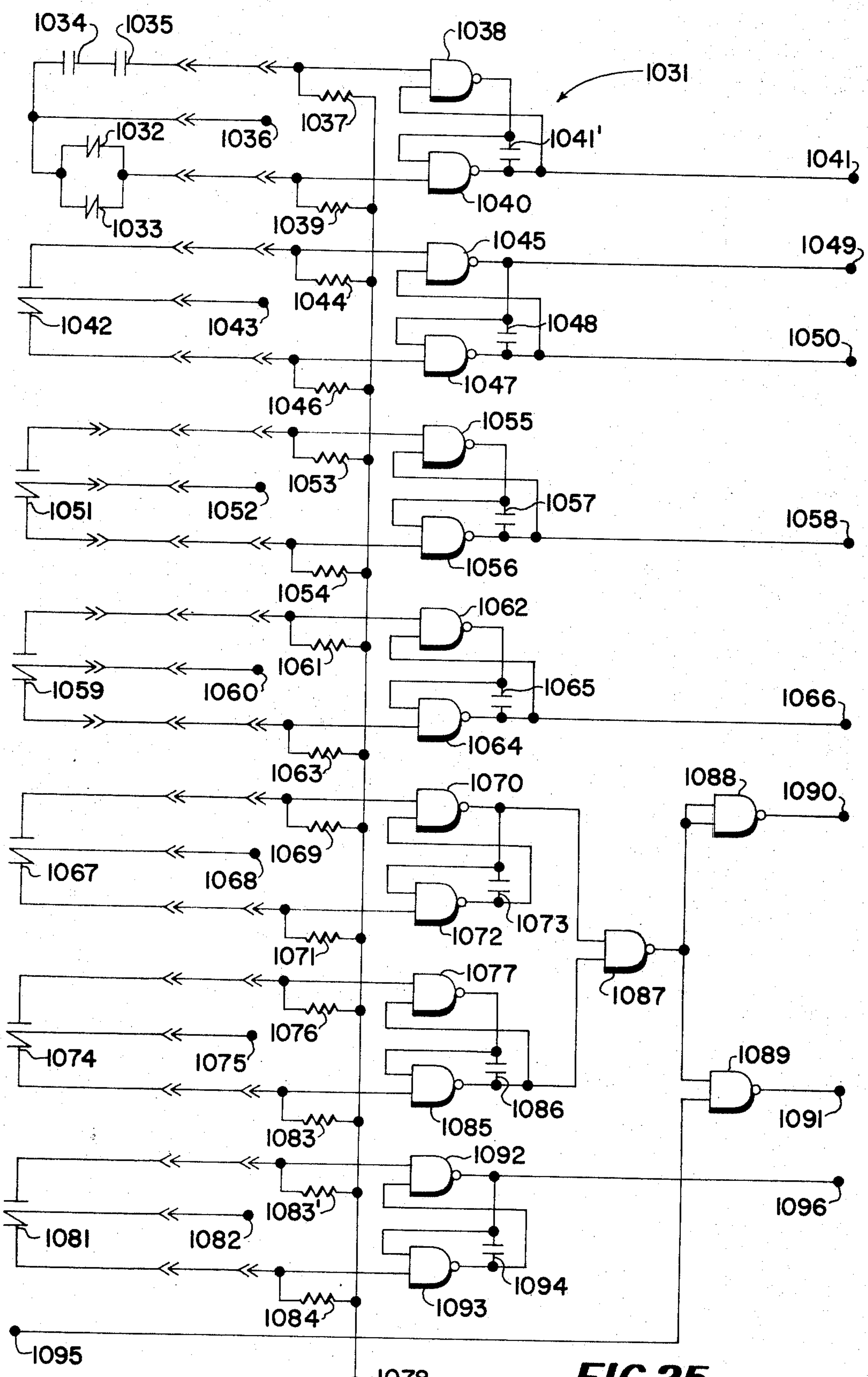

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FIG 25

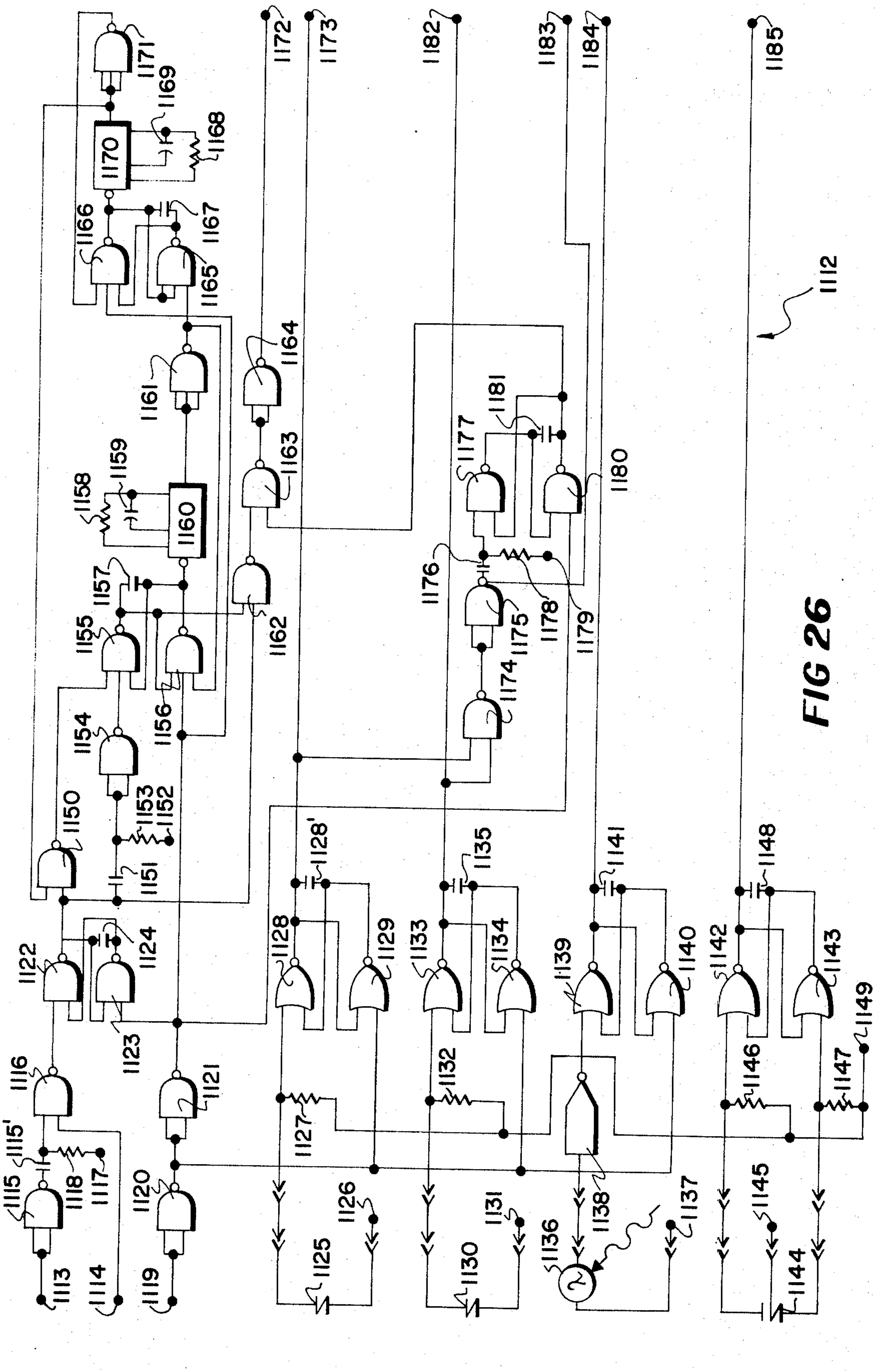
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FIG 26

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22 Sheets-Sheet 22

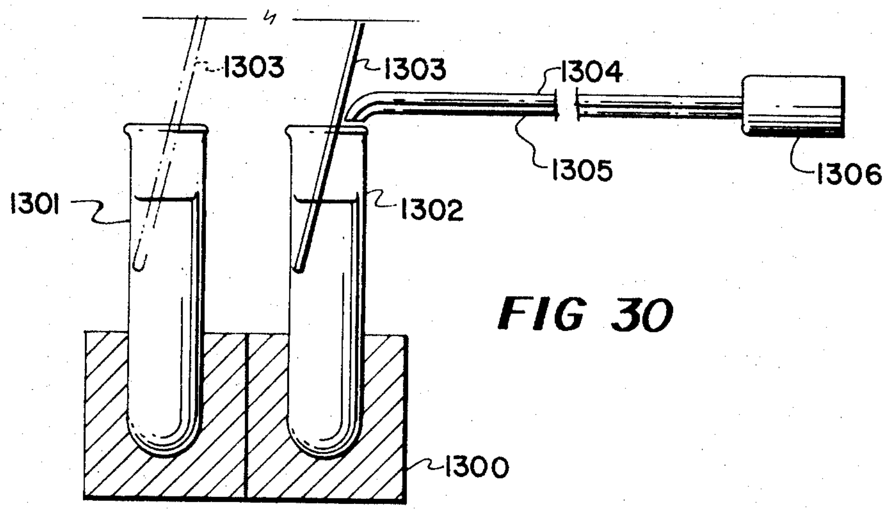

FIG 30

FIG 32

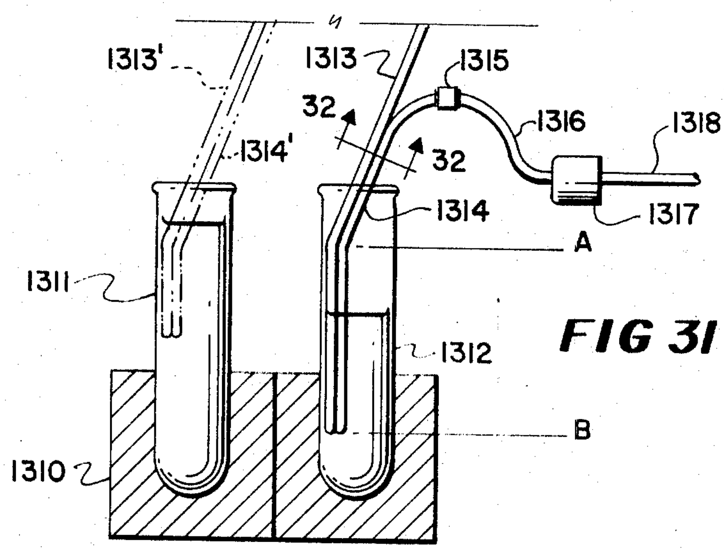

FIG 31

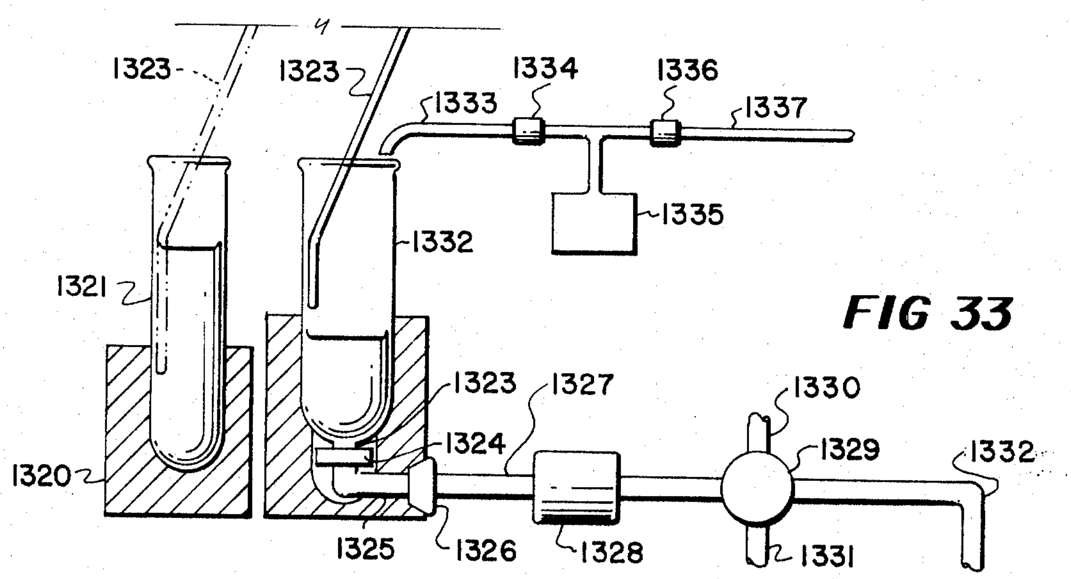

FIG 33

AUTOMATIC TEST TUBE TRANSPORTER AND SAMPLE DISPENSER HAVING SOLID STATE CONTROLS

DESCRIPTION OF THE INVENTION

This invention is directed to an automatically controlled transporter apparatus for sequentially performing aspirating and/or dispensing functions on a plurality of test tube pairs containing liquid samples and reagents. It entails drawing off, through a conduit, a volumetrically metered, freely adjustable, quantity of liquid and for performing further functions on this metered quantity through another conduit.

A major problem in the past in analytical testing of large numbers of sample liquids, such as blood, has been the large amount of time consumed in individually processing each sample-containing tube. For instance, where a tube having a sample liquid therein has to have reagent added thereto in order for certain tests to be performed and analytical conclusions drawn, there are the problems of adding exactly the right amount of reagent, handling the sample tube so as not to spill or splash any sample liquid and the placing of the sample tube in upright position in a rack. In addition, the time consumed by such individual handling results in a serious time delay in hospitals and private analytical laboratories in getting the analysis results back to the physicians or, in the case of non-medical testing, the party requesting the analysis.

Thee same problems occur in performing other types of laboratory analysis. While metering and dispensing apparatus to perform this function are known, they are mainly used in test laboratories, e.g., biochemical and clinical laboratories, and are intended either to deliver a predetermined volume of a liquid to be analyzed (i.e., operating as a metering apparatus), or to deliver successively several metered quantities, all of identical volume, of the same liquid (i.e., operating as a dispensing apparatus), or else to deliver simultaneously both a volumetrically predetermined metered quantity of a liquid to be analyzed and a metered quantity, also volumetrically predetermined but not necessarily of same volume as the liquid to be analyzed, of a diluting liquid or of a reagent (i.e., operating as a diluting apparatus). The use of these apparatuses is becoming widespread as the demand for large volume testing increases. However, the known apparatuses are often of low accuracy, inasmuch as the volumetric quantities they meter lack accuracy and are not readily reproducible, particularly when these volumetric quantities are small.

This defect in the known devices is largely due to the fact that, in these known forms of apparatus, adjustment of the metered quantity is not "digitalized." I.e., adjustment is continuous and such adjustment is often affected by errors in the reading of scales, these being human errors attributable to distraction, inattention or tiredness on the part of the operators. Moreover, the known forms of metering apparatus operate in a rather brutal way. First, an abrupt suction action occurs, then an abrupt stoppage of the suction action and finally an abrupt discharge of the metered quantity of liquid that has been sucked in. This often results in cavitation or breaks in the columns of liquid (hydraulic hammering effects) or in the formation of drops, both being a source of material errors also occurring in manual handling of the samples. The only way known to reduce the extent of the errors with these known forms of metering and dispensing apparatus is by having them handle relatively large quantities of liquid. This, of course, is a major drawback when it is required to carry out a large number of different tests on a liquid from one source since, in order to do this, a corresponding number of samples is usually required of the liquid and this means that quite a sizable starting quantity will be needed. The only way in which this need for sizable starting quantity of the liquid can be avoided is to reduce to the greatest possible extent the volume of each sample.

Another problem in analysis has been the handling, of the sample after it has been added to a reagent and before a separate function is to be performed. I.e., the devices available have not been sophisticated or flexible enough to coordinate several analytical steps on the sample or sample and reagent.

Therefore, it is desirable to minimize all possible causes for inaccuracy in metering. This is particularly important in haematology where it is often desired to carry out a large number of tests without having to draw off large quantities of blood from the patients. One of the most relevant examples is in pediatric haemotology.

According to the present invention, there is provided a solid state controlled apparatus which includes an advancement mechanism which moves the racks under a movable tip or nozzle which is actuated by a grooved cam arrangement which lowers it into first one tube and then the adjacent tube. After aspirating or dispensing the tip is withdrawn and simultaneously wiped clean by a wiper mechanism controlled by the tip. An ejector mechanism which ejects the processed racks is also part of the apparatus.

The apparatus includes a pipette unit having a pair of pumps, each with a suction and forcing piston, pumpable during a suction stroke to draw off a predetermined volume and a switching valve associated with said pump and able cyclically to pass from one condition in which it causes said pump to communicate with one conduit to a second condition in which it causes the pump to communicate with another conduit. The pipette unit also includes a drive mechanism able to cause said valve to pass from one condition to the other and able cyclically to actuate said pump by imparting to the reciprocating movement of the piston a substantially sinusoidal action, said mechanism being adapted so that the suction strokes of the pump occur when the valve is in said one condition and that the forcing strokes of the pump occur when the valve is in said other condition and so that each suction and forcing stroke may be followed by an idling pause during which the valve passes from one condition to another. Also featured is an adjustment means for selectively adjusting the volume of said metered quantity of varying the length of the stroke of the pump piston and display means for displaying to the outside a number indicative of said volume.

The apparatus also has a novel cam and toggle arrangement for controlling the movement of the tip in a vertical direction in and out of adjacent tubes in a test tube rack. The distance the tip moves into each tube is controlled by the duration of the drive motor for the tip. A second and/or third fixed tips may also be used in conjunction with a movable tip to discharge reagents into the back tube in a test tube rack. Also, an auxiliary pipette unit may also be used in conjunction with the pipette unit furnished with the transporter. The auxiliary pipette discharges through one or two fixed tips. The apparatus is designed to be connected to a flame photometer or other auxiliary equipment for direct analysis of the diluted or reacted sample in the rear test tube.

A novel wiper mechanism is provided for wiping the tip as it moves upwardly out of the tube after having either dispensed or aspirated within the tube. A pair of reels, one a supply reel for a wiping tape and the other a take-up reel, are mounted on a slidable tray or drawer which may be pulled out from the apparatus to replace the tape supply and/or take-up reel.

Accordingly, it is an object of this invention to provide an improved sample moving and testing apparatus for use in analyzing sample liquids carried by test tubes mounted in a rack.

It is a further object of this invention to provide an improved dispensing and aspirating tip advance and retraction mechanism.

It is a further object of this invention to provide a novel test tube transporter and sample aspirator and dispensing mechanism for use in conjunction with various tests run on the samples contained in the test tubes.

It is a still further object of this invention to provide an improved tip wiper mechanism for use in a test tube transporter and sample dispensing apparatus.

Another object of this invention is to provide an automatic test tube transporter and sample dispenser apparatus having a novel solid state control system which minimizes operator involvement and maximizes flexibility of the apparatus in performing various analytical functions upon samples carried in test tubes.

Another object of the invention is to provide a novel test tube transporter and sample dispenser apparatus which may operate continuously upon a plurality of test tube samples in parallel rows within a single test tube rack or in a pair of test tube racks or may be manually operated upon each tube or pair of tubes.

It is a further object of this invention to provide a novel test tube sample transporter and dispensing apparatus which may be used in conjunction with auxiliary pipettes or external control units.

It is a still further object of this invention to provide a novel test tube transporter and sample dispenser apparatus having a solid state control system which includes a binary shift register.

These and other objects of this invention will become apparent when reference is had to the following specification and the accompanying drawings in which:

FIG. **1** is a perspective view of the transporter showing the working surface, the control and pipette modules and the movable tip module;

FIG. **2** is a side view of the tip module, partially in section, showing the various interrelationships between the tip moving mechanism and the tip wiper mechanism;

FIGS. **3** and **4** are front views of the tip module with the case removed, showing the tip guide mechanism when the tip is in retracted and down positions, respectively;

FIG. **5** is an exploded view of the cam and cam clutch driving assembly for the tip wiper mechanism;

FIG. **6** is a partial front view of the wiper cam assembly showing the interrelationship between the cam, the cam clutch, the wiper toggle mechanism and the follower;

FIG. **7** is a top view with parts broken away and in section of the tip module shown in FIG. **2**;

FIG. **8** is a perspective view of the apparatus similar to FIG. **1**, but showing the wiper tray pulled forward and with the pipette and electronic control modules removed and the casing off the tip module;

FIG. **9** is a front view of the supply reel subassembly showing the supply spindle and take-up spindle;

FIG. **10***a* is a two-dimensional plot of the grooves in the cylindrical tip cam;

FIG. **10***b* is a cross-section taken along lines **10***b*—**10***b* of FIG. **10***c*;

FIG. **10***c* is a side view of the cylindrical tip cam;

FIG. **11** is a partial planar view showing the teeth in the take-up spindle shown in FIG. **9**;

FIG. **12** is a plan view of the wiper tray showing the interrelation of the supply and take-up reels with the supply and take-up spindles;

FIG. **13** is a side view with parts in section of the transmission means for the wiper tape spool;

FIG. **14** is a plan view of the device shown in FIG. **13**;

FIG. **15** is a schematic view of the A.C. motor driver circuitry;

FIG. **16** is a schematic view of the driver and breaking circuit typically used in FIG. **15**;

FIG. **17** is a schematic view of the pipette logic circuitry;

FIG. **18***a* is a partial schematic view of the tip motor logic circuitry;

FIG. **18***b* is a schematic view of the remaining tip motor logic circuitry and has matching leads with FIG. **18***a*;

FIG. **19** is a schematic view of the shift register and logic circuitry;

FIG. **20** is a schematic view of the advance and start logic circuitry;

FIG. **21** is a schematic view of the lamp driver circuitry;

FIG. **22** is a schematic view of a typical lamp driver circuit used in FIG. **21**;

FIG. **23** is a schematic view of the manual switch buffers and logic circuitry;

FIG. **24** is a schematic view of the power-up reset used in the circuitry shown in FIG. **23**;

FIG. **25** is a schematic view of the automatic switch buffers and logic circuitry;

FIG. **26** is a schematic view of the malfunction and alarm logic circuitry;

FIG. **27** is a schematic view of the interface circuit used in FIG. **26**;

FIG. **28** is a schematic view of a typical timer circuit used in the circuitry shown in FIG. **26**;

FIG. **29** is a schematic view of the relay driver circuitry used in FIG. **17**;

FIG. **30** is a diagrammatic view of a sampling and dispensing operation;

FIG. **31** is a diagrammatic view of a sampling and dispensing operation using a double bore tip;

FIG. **32** is a cross-sectional view taken along lines **32**—**32** in FIG. **31**;

FIG. **33** is a diagrammatic view showing an alternative sampling and dispensing arrangement.

The apparatus is provided with three modules; the pipette, electronic and tip modules. Controls on the pipette and electronic modules enable an operator to adapt the apparatus to perform many and various analytical operations and functions.

The general operating function of the transporter is determined by positions of an auxiliary pipette switch and an external control switch on the function control panel in the electronic modular unit. Details of the operation may vary according to the operator set-up; for instance, in the manifolding of pipettes. There are four basic switch combinations; both OFF, either one ON, and both ON.

In the basic operation function, i.e., with the auxiliary pipette and external control switches OFF, the function control option instituting operations in the following arrangements:

1. a sample in the front tube row diluted with a sample reagent into the back tube row;
2. a reagent dispensed in each tube row; or
3. one or two reagents dispensed in the back tube row only.

With the auxiliary pipette switch ON and the external control switch OFF, the function control option provides for the use of an auxiliary dispensing pipette in conjunction with the apparatus. Basically, this application entails the preparation of a sample in the front tube row diluted with a first reagent from the transporter pipette and further with second and third reagents from the auxiliary pipette. The transporter pipette will be manifolded in the conventional way through a single or double-bore tip moved by the tip mechanism. The auxiliary pipette uses one or two fixed tips mounted over the tubes in the rear row. Discharge from the pipette tips is adapted to occur simultaneously. The auxiliary pipette may use one or two pumps in the pipette module as required by the particular application. The fixed position auxiliary tip will not touch the wall of the test tube during the operation soc that dispensed volumes should be relatively large to minimize break-off reproducibility errors.

With the auxiliary pipette switch OFF and the external control ON, the function control option provides for applications requiring supply of diluted samples to a readout instrument. An interface unit is then provided to adapt perspective readout instruments to the apparatus. In this operation, the tip module is provided with a twin tip in the tip mechanism. In the alternative, special configurations may be provided for other readout instruments to provide minimum sample carry-over and rapid sample feed to the instrument. In this adaptation, the rear tubes in the rack are omitted and a fixed cup is installed on the transporter. The transporter has a single movable tip for sample and diluent.

With the auxiliary pipette switch ON and the external control switch ON, the operation is similar to the one just described except that it allows for the introduction of one or two additional reagents through the fixed tips in the latter part of the analytical sequence.

This device is an improvement over the apparatus shown and disclosed in copending application Ser. No. 126,782, filed Mar. 22, 1971, entitled AUTOMATIC TEST TUBE TRANSPORTER AND SAMPLE DISPENSER. The improvement over the apparatus described in the copending application consists of the electronic solid state controls and a re-designed tip mechanism. The new tip mechanism facilitates many other analytical operations. The pipette unit used in said copending application is identical with the pipette unit, including the pumps and motion converting means used in this application.

Since the pipette units used in both the apparatus of the copending application and the pipette unit used in the instant device are identical, the contents of said copending application are hereby incorporated by reference in their entirety.

The structure and operation of the pipette module is described on pages 22 to 36 of said copending application. The details, including the drawings, are not included as a part of this case but the unit is identical. Generally, the apparatus is a two-piston sinusoidal stroke metering and dispensing device. A motor drives a motion converting mechanism through a gear box. The motion converting mechanism comprises a cylindrical housing having a hollow cylindrical insert member adapted to be rotated therewithin. Said member is driven by said gear box. There are two parallel juxtapositioned longitudinal slots or slideways in the inner surface of said tubular member. A second insert member is located within said tubular member and locked against rotation therewithin. The second insert member, however, is mounted for longitudinal sliding within said tubular member and its position relative to said first rotatable insert member is adjustable by means of a screw adjustment shaft. The first rotatable insert member has a pair of longitudinally extending slideways which carry one end of a crank mechanism. The other end of the mechanism is fixed within a jeweled bearing within said second nonrotatable insert member. The crank mechanism includes a shaft connecting said insert members with a bearing connected thereto. A slide block rides on the outside of said tubular member and is connected to said bearing. As the first insert member rotates, the crank and crank pin describe an arc and the motion is transmitted to the bearing and slide block on the tubular member housing. Thus, the slide block reciprocates vertically as the first insert member rotates. The slide block is connected to a crank bar, one end of which is fixed to said tubular housing and the other end is fixed to the lower driving portion of the pump piston located within said pipette unit. The motion converting means thereby converts rotary motion into sinusoidal reciprocal motion which is transmitted to the pump pistons at the end of the crank bar.

The pumps which make up part of the pipette unit are positive displacement type pumps having a cylinder, a constant diameter piston, the driving end of which is connected to the stroke bar of the motion converting means and a valve switching mechanism. There are two port bores connected to each pump, there being two pumps, and the valves are adapted either to switch from one port bore to another between each stroke, whether positive or negative, of said crank bar, or to remain in position. The valve itself has a cylindrical member located within the cylinder housing of each pump and has a V-shaped connecting channel which alternately connects each port bore with the interior of said cylinder when the valve is rotatably reciprocated. A priming means is provided on each pump. The piston is easily removed from the pumps of varying volume.

The gear box is adapted to drive a valve switching mechanism which converts the rotary motion of the gears to longitudinal reciprocating motion. At the pumped end of the valve switching mechanism are reciprocally rotatable driving pins. The driving pins may be placed in one of two positions, the first position being a driving position in which the pin is operatively connected to the pump valve whereupon the valve will switch from one port to another and the second being in a position in which the pin is disconnected from the valve and the valve remains in a preselect position, thereby maintaining only one port in connection with the cylinder. The driving gears for the valve switching mechanism have relieved areas thereon whereby after said valves are switched, no motion takes place while the piston is stroked either negatively or positively.

Thus, the pipette pumps can be operated in several fashions, the first being where the valves switch in both pumps between pumping strokes, the second being where neither valve changes ports during the pumping strokes, the third where one valve remains in a predetermined position and the second valve switches between piston strokes. Also the pistons may be stroked in the same direction simultaneously or may, through changing the relative gear positions, be alternately stroked or be simultaneously stroked in opposite directions. Thus, a great variety of dispensing and sampling operations are possible with the pipette unit.

The pipette unit also has counters located thereon which are operatively connected to the main threaded shafts for adjusting the stroke of the pump pistons. These counters are used to indicate to the operator the amount of stroke and consequently, the particular volume of each pump during that operation.

The pipette unit has a RUN switch and a SET switch thereon which, when both are depressed, provide power to the tip and wiper mechanism. The operation of the pipette unit and its components actuates several switches within the electronic solid state control system. The RUN and SET swtiches are shown in FIG. **17**, the pipette logic circuitry diagram. Also shown in that diagram are switches **569, 570** and **571.** They are, respectively, a pipette limit position switch, a pipette left position limit switch, and a pipette limit right position switch. Also in the drawing is switch **574** which is a pipette limit set position switch. The operation of these contact switches will be described later herein.

TIP MECHANISM

Referring now to FIG. **1,** there is shown the transporter apparatus generally designated as **1.** It consists of a base unit **2** having a supporting structure **3.** A planar surface **4** is located on top of base portion **2** and has an exit surface **5** separated therefrom by base unit projection **6** and dividing bar **46.** A pair of other base portion projections **7** and **8** act together with border strips **9** and **10** to provide an alignment guidance for the test tube racks. Member **10** contains a slot **11** therein in which rides rack guide arm **12.** Arm **12** is tapered as at **14** and has a relieved area as at **13** by which an operator may grasp the arm to retract it when placing racks into the transporter. The member **10** and arm **12** and its accompanying drive mechanism form the contents of a separate application and is not described in detail in this specification.

The racks such as R are placed on surface **4** and contain adjacent rows of tubes such as T_1 and T_2. Usually, the sample to be tested, whether it be blood, urine, or some other substance, is placed in the row containing tube T_1 and a reagent to be reacted with said sample is placed in the row containing tube T_2.

A raised portion of the transporter, **15,** houses a rack-advancement mechanism, not shown in detail but generally similar to the rack-advancement mechanism shown and described in said earlier copending application. The rack-advancement mechanism has teeth, such as **51,** which project outwardly through a slot **50** is the housing. The housing also contains a rack sense contact **47** which tells the electronic logic of the transporter when a rack is in place and is ready for processing. Also located alongside the path of rack R in front of the housing is a tube sensing switch, such as **49,** which projects through a slot **48** within housing **15,** and **49'** projecting from the end of bar **46.** The sensing switches **49** and **49'** are not shown in detail but may be simply a spring-loaded slide switch or a microswitch. A rack-ejector mechanism is also located within housing **15** but is not described in detail. Instead of using flipper arms, as used in said earlier copending application, the mechanism is adapted to drive push rods, **54** and **55,** shown in phantom, through cylindrical apertures **52** and **53** in said housing to eject racks along the surface **5** once processing on the tubes contained therein has been completed.

The main console containing cabinet **16** is supported on housing **15** and contains a pipette module unit identical with the one shown and described in said earlier copending application. The unit contains pumps **18** and **19** having windows **20** and **21** cut therein respectively. The windows are for viewing the liquid within the cylinder chambers, the chambers preferably being made of glass or clear plastic. The pumps have ports, such as **20'** and **21'**, located thereon and are used as previously described in this application and described in detail in said earlier copending application. The pistons (not shown) contained within the pumps are connected to stroke bars such as **8'** and **9'** which, in turn, are connected to motion converting means within the pipette module.

A SET switch **26** and a RUN switch **27** are located on said pipette control panel and are used to set both the pipette module and electronic control module into operation. Control knobs **25** and **26** are used by the operator to set the stroke adjustment or, in other words, the length of said stroke which each pump will incur. Counters **22'** and **23'** are adjacent the control knobs to indicate to the operator the present setting of the stroke length. Thus, the operator can quickly determine the volumetric capacity of each pump during the processing of the samples.

Located adjacent the pipette module is the tip housing module **28.** It consists of a frame **29** having a window **30** therein through which the tip may be viewed or, in the alternative, the panel **30** may be non-transparent.

Located on the other side of the tip module is the electronic control module **32.** It has an upper control face **31** which contains the major mode switches. It contains automatic mode switch **39,** manual mode switch **40,** advance mode switch **41,** pipette mode switch **42,** reset switch **43** and start switch **44.** These switches are shown designated by different numerals on FIG. **23,** the manual switch buffer and logic circuitry. Located directly above said switches is a lamp display console **45** which includes the following lamps to indicate the following conditions: open tray; advance jam; tip wiper; eject; pump sequence; tip down front; pipette; tip down back; tip up; advance; automatic; manual; advance and pipette.

Located underneath said major control switches on panel **33** are the auxiliary pipette switch **34** and the external control switch 35. Adjacent said switches on panel 36 are front stroke adjustment knob 38 and back stroke adjustment knob 37. The latter two knobs control the depth to which the transporter tip moves into tubes such as T_1 and T_2.

All three module units are supported on a support member 16'. Located on the underside (not shown) of member 16' is a fixed auxiliary pipette tip member 30'. As previously stated, the tip module unit and the electronic control unit will be described in detail whereas the pipette module unit, being identical with that disclosed in said earlier copending application will not be described nor shown in detail.

Referring now to FIG. 2, there is shown in section, the tip module unit 60 the major components of which are tip holder, guide mechanism, and guide driving means. During the description of the structure and operation of this portion of the apparatus, reference may be had to FIGS. 3, 4, 5, 6, 7, 8, 10*a*, 10*b*, and 10*c*.

A front mounting casting 61 supports most of the major components of the mechanism. It is connected, in any suitable fashion, to a base plate member 62 which, in turn, is connected to a rear plate 63 to form the supporting structure for the entire mechanism. Casting 61 has a plurality of projections 64, 65, and 66 on the rear face thereof. It also has a pair of bores 67 therein each of which receives a bushing 129. Another pair of bores 68 are in the top of said casting and each receives the forwardly extending portion 99 of a tip guide rod. Projection 64 has a bore 69 located therein with counterbored sections 71 and 72. Located within said counterbored areas are bearings 70 and 73. The bearings support a wiper cam shaft 75 therein. One end of said wiper cam shaft has a gear 74 thereon having teeth 74' and a flanged portion 77. A nut 76 secures said gear to the end of said cam shaft 75.

Gear 74 is in operative drive action with a gear 86. Gear 86 has a flange portion thereon and a machine screw 88 secures gear 86 through lock washer 89 to the drive shaft 85. Drive shaft 85 is located within a bore 79 in projection 65. Bore 79 has counterbored areas at the end thereof such as 80 and 81 in which are located journal bearings 82 and 83 which support shaft 85 for rotation. Mounted for rotation with gear 86 on its flange portion 87 is a crank 90. Crank 90 is best seen in FIGS. 3 and 4.

A bore 91 in projection 66 has a pair of journal bearings 92 and 93 therein which support a cylinder cam shaft 94 for rotation therein. On one end of cylinder cam shaft 94 is a washer 98 and a splined section 94'. Splined section 94' carries cylindrical cam 216 thereon for rotation therewith. The opposite end of shaft 94 is threaded as at 96 which receives a nut 97 and washer 95 to lock the shaft in projection 66 against longitudinal movement therein.

The upper end of crank 90 has a circular cam follower 118 mounted thereon by spacer 119 in machine screw 120. Follower 118 is adapted to ride in a longitudinal slot 117 in a cam follower guide member 113'. Cam follower guide member has projecting portions 115 and 116 which together form slot 117. The opposite ends of member 113' are vertically bored as at 114' in FIG. 2 so as to receive a pair of guide rods 111 and 111'. The tops of guide rods 111 and 111' are secured by locking washers or members 112'. They are secured to projecting tab portions such as 110'. Tab portions 110' are extensions of front castings 61.

The lower end of crank 90 (as seen in FIG. 2) has a top dead-center cam 123 secured thereto by machine screw 122. The configuration of cam 123 can be seen in FIGS. 3 and 4. Cam 123 has rounded surfaces such as 124 which are adapted to engage the actuator arm 126 of a microswitch 125. Microswitch 125 is secured to the device in any suitable manner, such as by pins 127.

The guide rods 111 and 111' support a cross slide (or cross-head) having opposed sections 113 and 113' for sliding movement thereon. As seen in FIG. 3, the cross slides have projecting transverse portions 115 and 116 connecting the two together. The guide bars 99' and 99'' project outwardly from the top of casting 61 and are angled downwardly. They support a tip holder 100 for up and down sliding movement thereon. Tip holder 100 has a pair of bores, such as 101, as shown in FIG. 2 which receive the guide bars. Tip holder 100 has an aperture (not shown) for receiving the tip T, as shown in FIG. 3. A latch member 104 is supported on a shaft 102 and is biased inwardly by spring 103 to hold the tip T in position. The tip holder also has bores 106 and 106' for receiving a pair of stabilizing rods 105 and 105'. Stabilizing rods are received, at their end portions, in projection member 116 of the cross slide. As shown in FIG. 3, the tip T has a reduced diameter portion T' which is the maximum portion which is wiped.

The ends of guide bars 99' and 99'' are received in a cam block 254 as shown in FIG. 7. Cam block 254 has a pair of tab portions, such as 255, which are split as at 256 to receive a machine screw 257 for locking the cam block 254 in position on bars 99' and 99''. The upper portion of casting 61 is cut away as at 258 to accommodate longitudinal movement of cam block 254. Located within cam block 254 is a "toggle" mechanism comprising a snap-action lever 266 and a pair of guide cylinders 259 and 260. Located within member 254 between the cylinders is a fixed cylinder 268 having a transverse bore receiving for rotative movement therein a pin member 267 which is secured to lever 266. The upper portion of cylinder 268 is slotted as at 272 to allow lever 266 to reciprocally rotate therein. Located within cylinder 268 is a compression spring 269 which urges a ball 270 upwardly against a downwardly directed pointed projection or tab 271 on lever 266 which causes the lever 266 to snap from one position to the other when the lever 266 is moved clockwise from the position shown in FIG. 2 till the point of 271 passes over to the other side of ball 270. Since both cylinders 259 and 260 are identical, only one will be described. Guide cylinder 259 has a plunger 262 located therein with the upper portion cut away as at 261. The upper portion of 262 supports a pin 265 which is received within a notch on the end of lever 266. The other end of lever 266 has an identical notch. A cam follower 263 is secured to plunger 262 by means of a machine screw 264. Cam follower 263 is adapted to ride in grooves such as 240 in cylindrical cam 216. Cylindrical cam 216 has the hub portion 218 which extends inwardly therein to cover the splined portion 94' of shaft 94. The interior of cam 216 is cut away as at 217 to accommodate projection 66 on casting 61.

Referring now to FIGS. 10*a*, 10*b*, and 10*c*, the cam 216 will be described. FIG. 10*a* shows a development of the grooves within the cam. In other words, FIG. 10*a* is representative of the circumference of cam 216 in a two-dimensional plane. The cam contains two grooves, namely groove **246** and groove **248**, which have side walls **240** and **247**, respectively. The grooves are essentially linear and have rounded terminal portions **241** and **250**, respectively. Groove **248** has a curved wall **242** at the opposite end thereof and has a portion which tapers upwardly as at **243** so as to provide a more shallow groove. The tapered portion **243** terminates at **244**. Groove **248** has a curved wall section **251** which forms a portion of an upwardly tapered groove portion **252** which terminates at **253**. The cam is shown in side view in FIG. **10***c* and the view shows that groove **240** is initially deep and then rises as at **243** to planar section **244**. FIG. **10***b* shows a cross-sectional view of the cam taken along lines **10***b*–**10***b* of FIG. **10***c* and shows the general cross-sectional configuration of the grooves at the tapered or upwardly slanted groove portions. As shown in FIG. **10***c*, the cam has a gear **249** mounted on one end portion thereof, In the alternative, referring back to FIG. **2**, a gear **220** may be provided on the end of splined shaft **94'** which fits within a bore **219** in cam **216**. In either construction, the gear is adapted to mesh with a gear **221** which is operatively connected to drive shaft **85**. Gear **221** has a flange portion **222** with a slot **223** therein. An extension of drive shaft **85** contains a roll pin **224** which engages within slot **223** to lock the gear and drive shaft against relative rotation. Gear **221** is connected to a coupling member **225** which in turn is connected to the main drive shaft **226** which projects through an aperture **227** in rear plate **63**.

A machine screw **231** mounts a camming plate **230** to rear plate **63**. Cam plate **230**, although not shown in front view configuration, is a generally U-shaped member having two extending arm portions such as **229**. Mounted on gear **221** for rotation therewith is an actuator bar **228**. As gear **221** rotates, actuator bar **228** describes an arc which eventually forces it to abut one of the depending portions, such as **229**, of member **230**. Such an action forces member **230** to rotate on screw **231** and, as shown in FIG. **7**, member **230** has a camming surface on one upper corner thereof such as **236**. The camming surface **236** is adapted to engage a microswitch roller **235** which is supported between arms such as **234** of a switch actuator **233**. The switch actuator **233** extends from a microswitch **232** and when actuated gives enabling signals to the solid state control logic.

Referring again to FIG. **7**, the member **230** is shown to have a flange portion **236** with a semicircular recess **239'** therein. Rear plate **63** has a bore therein which supports an insert member **237**. Insert member **237** has a bore therein which supports a helical compression spring **237'**. Spring **237'** biases a ball **238** into engagement with the aperture **239'** in the rear of member **230**. The compression spring and ball maintain member **230** in actuated position until the actuator bar **228** rotates around in a reverse direction and engages the other leg from the one previously engaged. In other words, this prevents the member **230** from assuming normal position before the actuator bar has again made contact. Thus, it is seen that the member **230** has two positions.

Referring again to FIG. **2**, the wiper cam shaft **75** is connected via an extension **78** to an extension portion **170**. Mounted on shaft extension portion **170** is the cam and cam clutch assembly for operating the wiping mechanism.

TIP WIPER ASSEMBLY

Referring now to FIG. **8**, there is shown the tip wiper bars and the wiping tape assembly tray. The wiping assembly is controlled by the cam and cam clutch wiping assembly **140**. Assembly **140** is shown in detail in FIGS. **5** and **6**. It consists of a cam member **145** having a large-diameter peripheral camming surface **141** and a small-diameter camming surface **146**. The cam surfaces are merged smoothly as at **147** and **148**. The cam is preferably made of nylon and has a projecting cam portion **151** having a rounded surface at one end thereof the center of which is recessed as at **152**. Extending downwardly away from portion **151** is portion **156**. Portion **156** is a camming surface having a recessed center area **157** and a main body section **155**. The cam **145** itself is relieved as at **149**. A bore **154** is provided for locking onto the cam shaft and a keyway **153** is provided to lock the cam against rotation relative to the cam shaft. The angle X is one-half of the distance of camming surface **146** and is preferably about 770°. Member **142** and member **144** are clutch washers having square apertures **158** and **166**, respectively, therein. Received between the cam washers is the cam clutch plate **143**. The clutch plate **143** is generally circular having a reduced-thickness portion **159** and a central bore **160'** therein. A pair of ears **161** and **162** are located 180° apart on the cam plate. A notch **165'** is located approximately midway between the ears and a second notch consisting of deep notches **163** and **164** and projecting tab portion **165** is located 180' opposite from notch **165'**. Angle Y, shown in FIG. **5**, is preferably approximately 38'.

Referring now to FIG. **6**, the cam assembly is shown assembled together with its "toggle" or snap-action mechanism and wiper bars. The Snap-action assembly for the wiper mechanism is shown designated generally as **180**. The mechanism is shown in side view in FIG. **2**. Snap-action assembly **180** has a pair of guide cylinders **207** and **184**. Since both the guide cylinders are identical, only one will be described in detail. Cylinder **184** is maintained in place by retaining rings **188** and **184'**. Mounted for vertical sliding movement within cylinder **184** is insert member **187**. Insert member **187** has a slot **189** and a pin **190** extends transversely through the slot into the adjacent portions of **187**. Member **187** is relieved as at **191** to receive a helical compression spring **192**. A vertical slot **195** is cut in the wall of cylinder **187** and a plunger **193**, having a pin **194**, is adapted to ride within aperture **191** of member **187**. Pin **194** rides within slot **195** and defines the limit of travel of plunger **193**. Cylinder **184** is mounted in an aperture **181** of base plate **62**.

Mounted between cylinders **184** and **207** is a cylinder **196**. Maintaining rings, such as **196'**, maintain **196** in place on plate member **62**. Cylinder **196** has an aperture **197** therein which receives a helical spring **198** which, in turn, biases a ball bearing member **199** upwardly. Cylinder **196** is relieved at its upper extremity to define a notch having a pin **201** extending thereacross into the adjacent walls or prongs of **196**. A snapsection lever **202** is mounted for reciprocal pivotal movement on pin **201**. A pointed projecting tab **209** is adapted to engage either side of ball **199** and thus produce a snap-action as lever **202** is reciprocated. The ends of lever **202** have notches such as **203** which engage pins **190** mounted on the relieved areas of the insert members **187**. A pair of tab portions such as **204** project upwardly from the top surface of lever **202** and have pins such as **206** to secure rollers **205** and **208** in place. Rollers **205** and **208** are adapted to engage camming portion **156** of cam **145**.

Plunger pin **193** is adapted to ride on a twist disc **377** and engage in a slot **380** thereon. The operation of the twist disc will be described later herein.

Referring now to FIG. **2**, there is shown beneath cam assembly **140** a cam follower barrel **210**. The barrel is preferably made of plastic and has an aperture **212** therein. Aperture **212** receives a helical spring and a follower member **214**. Follower member **214** has two longitudinally spaced and parallel extending arms **215** and **216**. Arm **216** is adapted to ride in a notched area **214** of follower barrel **210**. Member **215** is adapted to ride on the lower surface of tab portion **165** of clutch plate **143**. At either limit of its travel, it snaps into notches **163** or **164**, depending on the direction of rotation.

In projection **65** of casting **61** is a plate follower **167**. Plate follower **167** is engaged by the top of camming portion **151** and has a stud **171** adapted to engage in notch **165'** of clutch plate **143**. A pin **168** (FIG. **6**) extends from the opposite side of plate follower **167** into an aperture **169** in projection **65**. A helical spring **170** maintains the plate follower in a downwardly biased condition, thereby allowing the stud **171** to snap into notch **165'**.

Ears **161** and **162** on clutch plate **143** are adapted to engage a pair of rollers **177** and **177'** which control the operation of the wipers. Referring to FIG. **6**, roller **177'** is shown attached by pin **176'** to wiper crank **172'**. Wiper crank **172'** has an aperture **173'** therein which receives one end of wiper bar **129'**. The end of wiper crank **172'** is split to provide grapsing portions such as **174'** and has apertures therein to allow for a machine screw **175'** and nut **176'** to securely fasten the wiper crank to the wiper bar.

Wiper bars **131** and **131'** are shown extending from the main portion of the apparatus outwardly in FIGS. **2** and **7**. They have a bent portion such as **130'** and a flattened end potrion such as **132** and **132'**. The end of each guide rod **99'** and **99''** has a pair of holes bored therein, on parallel axes. The holes receive rods **133** and **134** which are attached at one end to support pads **136** and **136'**. Mounted on support pads **136** and **136'** are wiper pads **137** and **137'** preferably made of sponge rubber or like material. FIG. **7** shows the plan view configuration of the wiper pads. A helical spring, such as **135**, is mounted on rod **133** and a flange on the end of rod **133** keeps the spring **135** in place. The flattened portions **132** and **132'** of the wiper bars are adapted to engage the ends of rods **133** and **133'** and force them inwardly against the action of compression springs **135** and **135'**. The wipers are adapted to wipe the tip as it is withdrawn upwardly through slot **367** in wiper tray **352**, shown in FIG. **12**.

Wiper tray **352** is shown in FIG. **12** and consists of a flattened planar portion **354** cut away as at **368** and provided with a border strip **353**. As shown in FIG. **8**, the wiper tray is supported within a bracket member **301** having top surfaces **302** and **303**. A plurality of mounting holes such as **302'** provide for mounting the pipette and solid state control logic modules on portions **302** and **303**. Bracket member **301** has a depending portion **304** which allows for operation of the wiper bars **131**. The wiper tray **352** is attached to the brackets by slide blocks **355** and **355'**. The slide blocks are mounted to the bottom sides of portions **302** and **303** by suitable fastening means, such as **356**. Rod anchor blocks, such as **358, 358'**, **359** and **359'** support tray guide rods **357** and **357'** by which are received slide blocks **355** and **355'**. Therefore the wiper tray is mounted for sliding movement out of bracket **301**. A pair of biased snap fasteners (not shown) are used to lock the wiper tray within bracket member **301** against inadvertent displacement. The pull exercised by an operator of the apparatus is sufficient to overcome these snap locks.

The wiper tray, as shown in FIG. **12**, is seen to have a take-up reel **361** mounted for rotation about pin **361'** and a supply reel **360** mounted for rotation about pin **360'**. The wiper tape W is trained around pulley **362** mounted for rotation on **364** and then around wiper spool **366** and around pullyey **363** mounted for rotation on pin **365** and eventually to the take-up reel **361**. As shown in FIG. **12**, the tape travels in opposite directions on either side of slot **367** through which the tip T moves. The slot **367** is elongated to provide for the tip moving up and down in two positions to enter test tubes in both rows of a rack tray. Also shown in FIG. **12** is phantom, are the positions of the wiper pads **137** and **137'**.

Referring now to FIG. **9**, there is shown the bracket **301** having raised portions **302** and **303** and depressed portion **304**. Depending from portion **302** is bracket **305** which rotatably supports on pivot pin **308** a torque arm **309**. Screw **310** maintains the components in a predetermined relationship. Flange portions **306** and **307** support between them a roller (not shown) around which is wound one end of a negator spring **310**. A screw **311** maintains the roller and negator spring in place. The negator spring is attached at its other end by screw **311** to torque arm **309**. Torque arm **309** carries a mounting **316** attached to which is a slip clutch **317**. A machine screw **312** secures an L-shaped bracket **313** to the bottom of torque arm **309**. A clutch spring anchor **314** is mounted on the bottom portion of bracket **313** by machine screw **315**. Connected to slip clutch **317** and resting upon clutch spring anchor **314** is a torquing spring **319**, one end of which is received in an aperture in pin member **318** which depends from slip clutch **317**. A shaft **320** extends upwardly and is mounted in any suitable fashion to a flange **322** of supply spindle **321**. Supply spindle **321** has a groove around the periphery thereof which receives a resilient or elastic band **323**. Supply spindle **321** is adapted to engage the tape which is wound on supply reel **360**, as shown in FIG. **12**. Supply spindle **321** is biased inwardly to ride against the supply of wiper tape W on reel **360** by negator spring **310**.

An anchor block **324** depends from the underside of portion **303** and mounts a torque arm **325** for rotation about a pivot pin **329**. A machine screw **330** maintains the components in assembled relationship. A pair of flange members **326** and **327** support a roller (not shown) therebetween, around which is wound a negator spring **328**. A screw **331** maintains the roller and negator spring between flanges **326** and **327**. The other end of negator spring **328** is fastened to the opposite end of the torque arm by screw **329**. Mounted on the lower portion of torque arm **325** is a motor bracket **332**. Machine screws **333** are used to secure motor bracket 332 to the torque arm. A motor 335 is secured to the lower portion of bracket 332, which is C-shaped in configuration, by machine screws 336. The screws 336 secure the motor to the lower portion 334 of the bracket. A shaft 337 extending from motor 335 is connected to a flexible coupling 338 and a take-up clutch 339.

Shaft 340 is connected to a flange 342 of a take-up spindle 342. The periphery of take-up spindle 342 has a raised scalloped center portion 342'(FIG. 9) such as shown in FIG. 11. It consists of a plurality of arcs which intersect in points such as 345. The arcs are designated as 343. The outline of the remainder of the circumference of spindle 342 is shown in phantom in FIG. 11 and designated as 344. Thus, it is seen that the points 345 project outwardly beyond the peripheray of the remainder of the spindle and are adapted to puncture and grasp the wiper tape W on the take-up reel.

The supply spindle 323 and the take-up spindle 342 are shown in position in FIG. 12. Arm 346 is adapted to engage a microswitch 347 having an actuator arm 350 and contact roller 351. The microswitch 347 is secured to the base of bracket 301 by studs 348. It can be seen from FIG. 12 that the spindles engage the wiper tape W on the reels.

Referring now to FIGS. 2, 13 and 14, there is shown mechanism for controlling the advancement of the wiper tape itself. The mechanism comprises a twist disc 377 having a sloping cam surface 379 which terminates in a peripheral slot 380. The cam surface 379 commences at 381 and is approximately 180° in arcuate length. The twist disc 377 has a hub portion 378 which is adapted to rotate on shaft 375. Plunger 193 of escape cylinder 194 is adapted to ride on cam surface 379 until it drops down into peripheral slot 380. A supporting frame 370 is mounted beneath the twist disc and has a projecting portion 372 having a hollow passageway therein 372' and bearings 374 and 373 mounted at either end of said passageway in countersunk portions. A shaft 375 drives twist disc 377 which rides on bearing 376. Frame 370 has supporting structure (shown in phantom in FIG. 13), such as brackets 371, machine screws 369, etc. On the opposite end of shaft 375 is mounted a gear 383 which is held in place through a lock pin 382 held in aligned passageways in the shaft 375 and the gear itself. Gear 383 turns on bearing surface 384 and engages gear 385 which is on a second shaft 387. This shaft is driven by the wiper 366 rotated by the wiper tape W. Gear 385 is held on shaft 387 through lock pin 386. A projection 388 of frame 370 contains a hollow passageway 389 and journal bearings 390 and 391. Gear 385 rides on bearing surface 393. The upper end of shaft 387 is bored as at 393 and has a passageway receiving a pin 394. Mounted atop this upper end of shaft 387 is member 395 having a passageway 396 therein which receives the upper extremity of shaft 387 and a slotted area 397 which allows pin 394 to move within member 395. A helical compression spring 398 is mounted within passage 393 and is anchored at its upper end in a small passage in member 395. Thus, member 395 rotates with, but is longitudinally biased on, shaft 387 as indicated by the arrow in FIG. 13.

A projection 399 on the top of member 395 engages in an aperture 400 in the bottom of wiper spool 366. Wiper spool 366 is mounted in a journal bearing 401 in tray 354 and has a circular rotating base portion 402. Four projecting tab portions 404 extend upwardly from portion 402. Each tab 404 has a generally vertical surface with upper and lower tab portions, such as 403, and a puncture point 405 which punctures the wiper tape W to meter the tape through the supply reels and take-up reels. As shown in FIG. 14, frame 370 has mounting holes such as 370' and is generally rectangular with one edge rounded. The top of member 395 is shown in FIG. 14 and the projection 399 is shown as equal to the diameter of the upper member of circular member 395. The member is adapted to turn in aperture 406 in the frame member. Thus, it is seen that when plunger pin 193 is engaged in slot 380, it maintains the wiper spool 366 against any further movement. Wiper spool 366 automatically engages and disengages member 395 when the wiper tray 352, FIG. 12 is moved in or out.

Referring again to FIG. 2, it is seen that the cam and cams 141 and 143 clutch mechanism 140 is held in engaging position by washer 167' and a compression spring 171' which acts on washer 168' and surrounds shaft portion 169.

TIP AND TIP WIPER OPERATION

The tip motor (not shown) is bidirectional. The time that it turns in either direction, thus the tip depth stroke, is controlled by a dial setting on knob 38 on panel 36. Before the motor will reverse its direction, however, it must rotate at least 56 ½°. This minumum angular displacement is effected by actuator bar 228 on gear 221 (FIG. 2) striking either lobe, such as 229, on member 230 which in turn actuates switch 232 (FIG. 7). The minimum angle of displacement insures that the snap action of cylinders 261 and 261' will be completed and that one of the cam followers, such as 263, will fall in the back or front cam groove. It is apparent from FIGS. 10*a*, 10*b*, and 10*c*, that the arcuate portion of each groove (as viewed in FIG. 10*a*) on the cylindrical cam 216 surfaces extends through 90° rotation from one side to the center. This represents 56 ½° rotation of the motor when the gear ratio of the drive and driven gear is 2.0:1.25 as is preferable.

Once the cam follower has dropped in a groove, the motor may continue to turn for any angular displacement up to 180° maximum.

An angular displacement greater that 56 ½° is timed. At the end of a set time period, the tip stops and pauses until the pipette operation is completed which usually takes around 3 seconds. At that time, the motor rotational direction is reversed and the tip T is raised in a straight line until it reaches top dead center. Past top dead center position the cam follower riding in the groove in cam 216 is advanced sinusoidally forward, or backward, depending on the groove the follower is in, until a toggling action takes place, which consists of one follower riding out of the surfacing groove and the second follower dropping into the second groove. Naturally, all this action is transmitted to guide bars 99' and 99'' on which the top holder 100 slides. At the same time, the motor turns crank 90 which, via cam follower 118, moves the cross slide subassembly vertically. As can be seen from FIGS. 1 through 4, rods 105 and 105' ride in holes in tip holder 100. In other words, the tip holder 100 is moved horizontally by the rods 105 and 105' and vertically by the rods on the cross slide sybassembly.

While the tip is being moved, the cam shaft **75** is being rotated in either direction via gears **86** and **74**. When the crank **90** is at top dead center, the top lobe **151** on cam **145** (FIG. 5) holds up follower plate **167**, thus disengaging the pin **171** on the plate follower and slot **165'** in the cam plate **143**. Consequently, the cam **145** rotates with gear **74** when the drive shaft **85** and motor rotate. The cam **145** turns until stopped by the top pin **215** in follower **214**. Initially, the pin **215** rests against one of the walls of slots **163** or **165** of the 38° arc cutout. If shaft **75** rotates more than approximately 103°, the radius surface **141** on cam **145** gives way to the smaller radial surface **146**. This allows the follower **214** to move vertically which raises pin **215** into either slot **163** or **164**. As shaft **75** continues to rotate to the angular displacement dictated by the time setting on the motor, the pin **215** remains in the upper portion of either slot. The pin goes into the slot only if more than 103° shaft rotation has occurred. Presuming the motor, hence shaft **75**, reverses at some displacement greater than 103°, then the pin **215** will remain in its slot until the larger cam surface **141** pushes it out. At that time, the friction plates **142** and **144** turn the cam **145** in the direction of shaft rotation. This results in the dropping of follower plate **167** and dropping of pin **171** into notch **165'** of cam plate **143** and locking the cam plate with the ears horizontal. The ears **161** and **162** on cam plate **143** push out the rollers **177** and **177'** which in turn rotate the wiper bars **131** and **131'** which swing the wiper pads **137** against the tip and **137'**. This action wipes the tip T. At near top dead center tip-slide **100**, the top lobe **151** on cam **145** raises follower plate **167** and hence pin **171**. Cam plate **143** is rotated and the ears **161** and **162** move out of the horizontal position causing the wiper pads **137** and **137'** to separate. All the activity just described results in the tip being wiped only as it is raised out of a tube and only for a maximum distance of approximately 1.8 inches. This is the distance from the wipe start to the end of the tip. A shorter distance is wiped if the tip depth setting is less.

The oscillation of cam **145** causes the lever **202** to snap alternately into its positions. Each time an this occurs, one of the plunger pins **193** (in **207** or **184**) is lifted out of slot **380** in twist disc **377**, and the other descends to ride on top of the ungrooved or unslotted portion of the disc. This action frees the disc to rotate 180° before the riding pin **193** drops into the slot and locks the disc. The disc has a constant torque on it due to take-up tension on the wiper tape being transmitted via the wiper spool **366** and the transmission assembly **180**. This snap-action of lever **202** occurs shortly after the tip T passes top dead center. Therefore, the tape moves as the tip is entering the tube. The tape has advanced before the tip is retracted.

Referring now to FIGS. **8, 9** and **12**, a full supply reel is placed on pin **360'** and the wiper tape is routed as shown in FIG. **12**. When the tray is pushed in, the spring loaded clutch assembly shown in FIG. **9** tends to take the slack out of the tape on the supply side of wiper spool **366** and the motor driven clutch **339** (FIG. 9) starts up to take the slack out of the take-up side of the wiper spool. The motor driven clutch **339** runs constantly at approximately 2 revolutions per minute. Both clutches **317** and **339** slip at a constant torque. Therefore, the tension on each side of the wiper spool **366** is always constant. The wiper spool **366** has four needles **405** press-fit with bushings which extend beyond the surface of lands as **404**. During a running operation, there is approximately 3 ounces of tape tension in the supply side and 8 ounces of tension on the take-up side of the spool. Negator springs **310** and **328** are located and sized so that the spindles **321** and **342** exert a constant radial force on reels **360** and **361** at all tape diameters.

The tray **354** cannot be opened except when the tip is at top dead center. In this position, the tip is up and the wiper pads **137** and **137'** are spread to the maximum position. This allows the wiper spool **366** to come out between the wiper pads and the tip assembly housing. Once the tray **354** is in place, the transporter can be started. As previously mentioned, the disc **377** is free to rotate 180° every time the tip T passes top dead center. Since there is a tension differential between the supply and take-up sides of the wiper spool, the tape advances until the disc is locked again. The tape rolling diameter of the wiper spool **366** and the spools' relative distance from the two pad wiper stations provides for the tape to wipe the tip at each retraction but never twice on the same spot on the tape. Also, the wetted part of the tape goes around the wiper spool **366** between lands **404** so that the wiper spool is not contaminated.

ELECTRONIC CONTROLS

The electronic controls are shown in FIGS. 15–29. The overall systems are contained in FIGS. **15, 17, 18, 19, 20, 21, 23, 25** and **26**. Sample circuitry is shown in FIGS. **16, 22, 24, 27, 28** and **29.**

FIG. **15** shows the A.C. motor driver circuit; FIG. **17** is the pipette logic circuitry; FIG. **18** is the tip motor logic circuitry; FIG. **19** is the shift register and logic circuitry; FIG. **20** is the advance and start logic circuitry; FIG. **21** is the lamp driver circuitry; FIG. **23** shows the manual switch buffers and logic circuitry; FIG. **25** shows the automatic switch buffers and logic circuitry; and FIG. **26** shows the malfunction and alarm logic circuitry. The input and output leads of the aforementioned circuits shown on the figures just enumerated do not match up from figure drawing to figure drawing but are described herein. In other words, an output lead on FIG. **25** is described as connected to an input lead on FIG. **15**, for instance. FIG. **18**, the tip motor logic circuitry, consists of two sheets and has been designated FIGS. **18A** and **18B**. The latter two drawings have aligned leads which match up when the drawing sheets are placed together.

The remaining figures show circuitry which is representative of circuits which are shown as boxes on the aforementioned figures. FIG. **16** is the driver and braking circuit; FIG. **22** shows the driver circuitry; FIG. **24** is the power-up reset circuitry; FIG. **29** is the relay timer circuitry; FIG. **27** is the interface circuitry; and FIG. **28** is the timer circuitry.

The control system has six operator-controlled switches which are shown in FIG. **1** and designated as **39–44.** They are the Automatic Mode Switch, the Manual Mode Switch, the Advance Mode Switch, the Pipette Mode switch, the Reset Switch and the Start Switch. To provide power to the electronic system, either the Run or Set switches have to be activated on the pipette console. These switches are shown in FIG. **1** as **26** and **27.** Activation of these switches places the pipettes in a prime sequence and provides power to the electronic control system. Other switches which are activated by the apparatus itself include the Advancement Switch, Paper Reel Supply Switch, the Tray Switch, the Advance Motor Cam Switch, the Ejection Motor Cam Switch, the Rack Limit Switch, the Rack Sensing Switch, the Tube Sensing Front Switch, the Tube Sensing Back Switch, the tip Up Sensor Switch, and the tip "Toggle" Switch. Additional controls are provided by a Rear Stroke Adjustment, a Front Stroke Adjustment, an External Select Switch, and an External Potentiometer, and an Auxiliary Pipette Select Switch.

Referring now to FIG. **15**, the A.C. motor driver circuitry diagram, it is seen that the circuitry consists of a group of small individual circuits for controlling the motors. A signal enters the advance motor circuit through terminal **511** and is an advance motor driver signal from terminal **875** on FIG. **20.** The signal proceeds through the A.C. driver **509** and braking circuit **510** and on to the advance motor **501** which has a capacitance **507** and is connected to the A. C. voltage at **508.** A tip motor driver signal enters at terminal **517** and originates in the tip motor logic circuitry, FIG. **18,** at terminal **730.** The signal continues on through A. C. driver **515** and braking circuit **516.** The signal then proceeds through a tip reversing relay switch **514** to tip motor **502** which has a capacitance **512** and is connected to the A. C. voltage at **513.**

A tip reverse relay signal enters at terminal **521** and originates in the tip motor logic circuitry, FIG. **18,** at terminal **746.** The signal continues on to reversing relay **518,** which is used to reverse the tip motor. Terminal **520** is connected to the logic voltage. The component designated at **519** is a silicon rectifier. A pipette motor driver signal enters at terminal **526** and orginates in the pipette logic circuitry, FIG. **17,** at termainl **638.** The signal proceeds through A. C. driver **524** and braking circuit **525** and then on to pipette motor **503** which has a capacitance at **522** and is connected to the A.C. voltage at **523.**

An ejection motor driver signal enters at terminal **530** and originates in the automatic switch buffer and logic circuitry, FIG. **25,** at terminal **1091.** The signal proceeds through A. C. driver **529** to the ejection motor **504.** Motor **504** has a capacitance **527** and is connected to the A. C. voltage **528.** A tray feed bar motor driver signal enters at terminal **534** and originates in the advance and start logic circuitry, FIG. **20,** at terminal **878.** The signal proceeds through A. C. driver **533** and on to tray feed bar motor **505** which has capacitance **531** and is connected to the A. C. voltage at **532.**

A buzzer driver signal enters at terminal **538** and originates in the malfunction and alarm logic circuitry, FIG. **26,** at terminal **1172.** The signal proceeds through A. C. driver **537** to buzzer **536** which is connected to the A. C. voltage at **535.** A reel motor driver signal enters at terminal **542** and originates in the malfunction and alarm circuitry, FIG. **26,** at terminal **1185.** This signal passes through A. C. driver **541** to reel motor **506.** Motor **506** is connected to the A. C. voltage at **540** and has a capacitance **539.**

FIG. **16** shows a representative A. C. driver and braking circuit. The input signal enters the circuit at terminal **549** and passes through resistor **548.** The signal is then modified by silicon transistors **545** and **547** along with resistors **546, 550, 554** and **555.** The signal then passes through Triac **544** and then proceeds out at terminal **563.** Resistor **556, 558** and **559** and silicon rectifiers **557** and **561** and capacitors **560** and **562** comprise the braking circuit. The entire circuit is shown designated as **566.** Terminals **551** and **565** are ground terminals. Terminal **552** and **553** are logic voltage connections. Terminal **564** is an A. C. voltage connection. The various arrows shown in the lead lines are merely quick-discconnect points so that the various components, such as the motors, can be easily removed from the system. Obviously, the capacitance for each of the motors, **501** thorugh **505,** may vary and have a different value.

Referring now to FIG. **17,** there is shown the pipette logic circuitry. The circuitry contains a plurality of switches which are located in the transporter pipette and are enclosed within the dotted line box **568.** The entire circuit is designated as **567.** Within box **568** are manually operated switches Run and Set, **572** and **573,** respectively. These buttons or switches are depressed to initiate A. C. power into the transporter. When both the Set and Run switches are depressed, the pumps within the pipette unit are in a prime condition. Also located within the transporter are pipette limit switches **570** and **571,** switch **571** being for the left position and switch **570** being for the right position. As shown in FIG. **17,** these contacts are normally closed. Also located within the pipette is a pipette limit set position switch **574,** normally with closed contacts, and a pipette limit right position switch **569** which is located on the double cam within the pipette unit itself. As shown in the circuit, switch **569** is grounded as at **569'**.

Switch **569** has leads connected to a flip-flop acting as a switch buffer and consisting of NAND gates **576, 580,** capacitance **581** and resistors **577, 578** and logic voltage **579.** The output of the gates is passed through terminal **632** to terminal **836** in FIG. **20,** the advance and start logic circuitry.

The signal made by either contact **570, 571,** or **574** or switches **572** and **573** passes through an R-C filter containing resistors **582, 584'** and capacitance **584** which is grounded at **585.** Resistor **582** is grounded as at **583.** The signal then passes through silicon rectifier **586** and through a SCHMITT trigger consisting of NAND gates **587** and **589** and resistors **588** together with capacitance **590** which is grounded at **591.** The signal than passes through gate **592** and onto gates **628** and **629.** The signal is added in AND gate **628** and passes through NAND gate **634** to terminal **633,** which is connected to terminal **763** on FIG. **19,** the shift register and logic circuitry. The output of gate **629** is fed into gate **635** together with a logic voltage signal originating in terminal **575'** and is outputted through gate **638** to terminal **526** on FIG. **15,** the A.C. motor driver circuitry. A capacitance **636** grounded at **637** is connected to the output of gate **635.**

Provision for an auxiliary pipette is made by switch **593** and the auxiliary pipette connector **597** which is connected to the logic voltage as **596** and **595** and has an auxiliary pipette select switch **594.** See FIG. **17.** If a pipette is in use, the output is passed thorugh an R-C filter consisting of resistors **598** and **600'**, capacitance **599** and grounds **598'**, and **599'**. The signal passes through a SCHMITT trigger comprising silicon rectifier **600,** gates **603'** and **603,** resistance **602** and capacitance **604** which is grounded at **605.** The output of the SCHMITT trigger is fed into gate **628** together with the output of gate **592.** If auxiliary devices such as a flame spectrophotometer are used, provision is made through terminals **606** and **607** for external control pulses which pass through gate **608** and are fed also into gate **628**.

A series of four additional signals are provided in the circuitry. A pipette mode signal enters the circuitry at **609** and originates from output terminal **1013** in FIG. **23,** the manjal switch buffer and logic circuitry. A start signal enters the circuitry at terminal **611** and originates from output terminal **1016** in FIG. **23,** the manual switch buffer and logic circuitry. Additionally, signals representing the third and sixth bit from the shift register enter the circuitry at terminals **613** and **614.** respectively, and originate from output terminals **808** and **812,** respectively, in FIG. **19,** the shift register and logic circuitry. The signals from terminals **609** and **611** pass through gate **610** and are mixed with the shift register bit signals from terminals **613** and **614** in OR gate **615.** Also, the sixth bit signal from terminal **614** is carried to a NOR gate **630** and is combined with the outut of gate **629** through capacitance **630'** and resistance **631** to provide an output at terminal **631** which is connected to input terminal **701** in FIG. **18,** the tip motor logic circuitry. Referring back to gate **615,** the output thereof passes through capacitors **616** and through one-shot start pulse system comprising NOR gates **620, 622** and **624** and resistors **618** and **621** grounded at **619** and **621'**, respectively, and capacitance **623.** Capacitor **617** is a filter capacitor. The output from NOR gate **624** is also fed into gates **628** and **629.** Additionally, the output of gate **624** passes through a relay driver **625** and an operator auxiliary pipette start relay **626** which is connected to the logic voltage as at **627.** Also included in the circuit is contact **639** of **626** having terminal connection points **640, 641,** and **642,** which is adapted to operate like a foot switch when an auxiliary pipette is connected into the transporter.

Referring now to FIG. **19,** the shift register components are shown designated as **797, 798, 799, 800, 801, 802, 803** and **804.** The component is an 8-bit Serial In Parallel-Out Shift Register. A series of input terminals are shown on the left-hand side of the drawing. A start signal enters the circuit at terminal **748** and originates from output terminal **877** in FIG. **20,** the advance and start logic circuitry. A tube signal enters the circuitry at terminal **760** and originates in output terminal **1041** in FIG. **25,** the automatic switch buffer and logic circuitry. An advance signal enters the circuitry at terminal **762** and originates in output terminal **876** in FIG. **20,** the advance and start logic circuitry. A pipette signal enters the circuitry at terminal **763** and originates in terminal **633** in FIG. **17,** the pipette logic circuitry. A tip motor signal, for running the tip motor forward or reverse, enters the system at terminal **768** and originates in output terminal **728** in FIG. **18,** the tip motor logic circuitry. An automatic mode signal enters the circuitry at terminal **769** and originates in output terminal **1008** in FIG. **23,** the manual switch buffer and logic circuitry. A manual mode signal enters the circuitry at terminal **770** and originates in output terminal **1009** in FIG. **23,** also the manual switch buffer and logic circuitry. A start signal and automatic and manual signal enter the system at terminals **771** and **778,** respectively, and originate in output terminals **1016** and **1010,** respectively, In FIG. **23,** the manual switch buffer and logic circuitry. A rack sense signal enters the system at terminal **779** and originates in output terminal **1049** in FIG. **25,** the automatic switch buffer and logic circuitry. And, finally, a CLEAR signal enters the system at terminal **780** and originates from output terminal **879** in FIG. **20,** the advance and start logic circuitry.

The start signal entering at terminal **748** is fed through a NOR gate **749** through an A.C. coupling circuit consisting of ground **751,** resistor **752** and capacitor **750,** and through NAND gate **753** and through another A.C. coupling circuit consisting of capacitants **754,** resistor **756** and ground **755.** The signal proceeds through NAND gate **757** and on to a NAND gate, which acts like an OR gate, **781.** A capacitance is attached to the connecting line between gates **757** and **781** and is designated as **759,** which is grounded at **758.**

The tube signal passes through NAND gate **761** and is fed to an AND gate **767.** The advance, pipette, and tip motor signals, originating from terminals **762, 763** and **768,** respectively, are fed to gate **764.** The output of NAND gate **764** is fed through NAND gate **765** to AND gate **767,** together with the signal from gate **761.** The automatic mode signal from terminal **769** is fed through an inverting NAND gate **772,** through an OR gate **774,** where it is coupled with the output of an AND gate **773,** and then on to gate **767.** The manual mode signal and start signal from terminals **770** and **771,** respectively, are fed into AND gate **773.**

The output of gate **767** is fed through an A.C. coupling circuit comprising capacitance **775,** resistor **777** and ground **776,** and fed to OR gate **781.** The output of gate **781** is fed through two NOR gates, **782** and **785,** which have an A.C. circuit comprising ground **783,** resistor **784'** and capacitance **786** connected thereto. The output of gate **785** is fed through an invertor **814** and then on to the components of the shift register.

The automatic and manual signal from terminal **778** and the rack sense signal from terminal **779** are fed into AND gate **821** where they are combined with the start pulse from terminal **748.** The output of gate **821** is fed through inverting NOR gate **822** and then on to OR gate **823.** The output of OR gate **823** is an advance lamp signal going to terminal **820** which is connected to input terminal **890** in FIG. **21,** the lamp driver circuit.

The output of gate **753** is additionally fed to an entry flip-flop circuit consisting of gates **789** and **788** and capacitance **790.** The output of that circuit is fed to OR gate **791** and through NOR gate **792,** NAND gate **795** and invertor **796** to the first component **797** on the shift register. A capacitance **794** grounded at **793** is located between gates **792** and **795.** Additionally, a signal to OR gate **823** is fed up to OR gate **791.**

The connecting line between gates **791** and **823** also is connected to components **803** and **804** of the shift register and provides a seventh bit output from the register at output terminal **813** which is connected to input terminal **658** in FIG. **18,** the tip motor logic circuitry. The clear signal from terminal **780** is fed through invertor **815** into the shift register. The shift register provides several outputs and also circulates a bit back from the shift register from components **803, 804** into gate **791** which is connected to gate **789** of the entry flip-flop. The bit signal from component **797** in the shift register is used to reset the entry flip-flop via gate **787.** A bit signal **1** passes through output terminal **805** and is connected to input terminal **829** in FIG. **20,** the advance and start logic circuitry, and input terminal **886** in FIG. **21,** the lamp driver circuitry. A bit signal **2** passes through output terminal **806** which is connected to input terminal 647 in FIG. 18, the tip motor logic circuitry. A bit signal 3 passes through invertor 807 and through output terminal 808 which is connected to input terminal 613 in FIG. 17, the pipette logic circuitry. A bit signal 4 passes through output terminal 809 which is connected to input terminal 666 in FIG. 18, the tip motor logic circuitry and input terminal 887 in FIG. 21, the lamp driver circuitry. A bit signal 5 passes through output terminal 810, which is connected to input terminal 682 in FIG. 18, the tip motor logic circuitry. A bit signal 6 passes through invertor 811 and output terminal 812 which is connected to input terminal 614 in FIG. 17, the pipette logic circuitry. As stated before, a bit signal 7 passes through terminal 813 which is connected to input terminal 658 in the tip motor logic circuitry.

An output from components 802 and 803 of the shift register is connected through OR gate 818 which also receives an output from components 799 and 800 of the shift register. The output of gate 818 is a tip up lamp signal which passes through output terminal 819 connected to input terminal 889 in FIG. 21, the lamp driver circuitry. An output from components 798 and 799 is coupled with an output from components 801 and 802 of the shift register in OR gate 816. The output of gate 816 is a pipette lamp signal passing through output terminal 817 which is connected to input terminal 888 in FIG. 21, the lamp driver circuitry. Referring now to FIG. 20, there is shown the advance and start logic circuitry. Several inputs are provided on the left-hand side of the figure. A malfunction signal enters the circuit at terminal 826 and originates in output terminal 1183 of FIG. 26, the malfunction and alarm logic circuitry. An advance motor cam signal enters the circuitry at terminal 827 and originates from output terminal 1096 in FIG. 25, the automatic switch buffer and logic circuitry. The 1 bit pulse signal from output terminal 805 in the shift register circuitry enters the advance and start logic circuitry at terminal 829. A tip up signal enters at terminal 830 and originates from output terminal 1058 in FIG. 25, the automatic switch buffer and logic circuitry. An advance mode signal and a start signal enter the circuitry at terminals 831 and 834, respectively, and originate from output terminals 1012 and 1016 in FIG. 23, the manual switch buffer and logic circuit. An ejection signal enters at terminal 835 and originates from output terminal 1090 in FIG. 25, the automatic switch buffer and logic circuitry. A pipette position signal enters the circuit at terminal 836 and originates in output terminal 632 in FIG. 17, the pipette logic circuitry. A rack signal enters at terminal 837 and originates from output terminal 1049 in FIG. 25, the automatic switch buffer and logic circuitry. An automatic and manual signal enters at terminal 838 and 844 and originates from output terminal 1010 in FIG. 23, the manual switch buffer and logic circuitry. A tube signal enters at terminal 843 and originates from output terminal 1041 in FIG. 25, the automatic switch buffer and logic circuitry. A reset signal enters at terminal 847 and originates from output terminal 1015 in FIG. 23, the manual switch buffer and logic circuitry.

The malfunction signal from terminal 826 passes to an AND gate 872. The signal additionally is fed to AND gate 839 and OR gate 851. The advance motor cam signal from terminal 827 is fed to a gate 869, a NAND gate in a flip-flop, and an OR gate 871. The 1 pulse bit signal from terminal 829 is fed through an A.C. coupling circuit comprising capacitance 832', resistor 833' and ground 833 to an AND gate 854. The tip up signal from terminal 830 is fed through an inverting gate 832 and to AND gate 854 and AND gate 855. The advance mode signal from terminal 831 and the start signal from terminal 834 are also fed to AND gate 855. The ejection signal from terminal 835 is also fed to AND gate 855. Additionally, the start signal from terminal 834 is fed to an AND gate 853 and the ejection signal from terminal 835 is fed to a NAND gate 848. The pipette position signal from terminal 836 and the rack signal from terminal 837 are fed to AND gate 839 together with the start signal from terminal 834, the malfunction signal from terminal 826 and the automatic and manual signal from terminal 834. The output of gate 839 is fed through a flip-flop circuit comprising NAND gates 840 and 841 and capacitance 842. Additionally, the pipette position signal from terminal 836 is fed through an inverting gate 828, the output of which is coupled with the start signal pulse in AND gate 853. The output of the flip-flop concluding gates 840 and 841 is fed also to gate 853 and to an AND gate 856, together with the ejection signal from terminal 835. The tube signal from terminal 843 is also fed to AND gate 856. The rack signal from terminal 837 is also fed to AND gate 856 and to an inverting gate 845. The output of inverting gate 845 is passed to a NAND gate 848 which also receives an ejection signal from terminal 835. An A.C. coupling circuit is provided having capacitance 849, ground 850 and resistance 850'. The output of gate 848 is passed to an OR gate 851 which also receives a malfunction signal from terminal 826 and a reset signal from terminal 847. Additionally, the output from inverting gate 845 passes through an A.C. coupling circuit comprising capacitance 845', resistor 846' and ground 846, to a NAND gate 857. The output of OR gate 851 passes through an inverting gate 852 and provides a clear signal at output terminal 879 which is connected to input terminal 780 in FIG. 19, the shift register and logic circuitry. Additionally, the clear signal is fed back to gate 841 of the flip-flop receiving the output of AND gate 839.

The output of gate 857 is fed to a flip-flop including gates 858, 860 and capacitor 859 and the output of that flip-flop controls a three-second timer 861 which is coupled to a resistor 862 and capacitor 863. The output of AND gate 856 is fed through two NOR gates 865 and 866, which together act like an OR gate. Gate 865 also receives an output from the flip-flop including gates 858 and 860.

The tube signal from terminal 843 is also fed to an OR gate 867 and is coupled with the signal output from the 3-second timer 861. The output of AND gate 854 proceeds to a flip-flop including gates 868 and 869 and capacitor 870. The output of the flip-flop is fed to OR gate 871. Gate 869 of the flip flop also receives the reset signal from terminal 847 and the advance motor cam signal from terminal 829. The advance motor cam signal is also fed to OR gate 871 which additionally receives the output of AND gate 855. The output of gates 865 and 866 is also fed into OR gate 871. The output of gate 871 is fed through an inverting gate 873 to provide an advance signal through at output terminal 876 which is connected to input terminal 762 in FIG. 19, the shift register and logic circuitry. A capacitor 874', grounded at 874, is connected to this output line. Additionally, the output of OR gate 871 is fed through AND gate **872** which also receives the malfunction signal from terminal **826.** The output of gate **872** is fed to output terminal **875** which is connected to input terminal **511** in FIG. **15**, the A.C. motor driver circuitry. The output of gate **871** is also fed back to gate **857**, which controls the flip-flop including gates **858** and **860.** The output of AND gate **853** provides a pump sequence signal at terminal **853'** which is connected to input terminal **885** in FIG. **21**, the lamp driver circuitry. The output of gate **841** of the flip-flop is also used to provide a start signal at output terminal **877** which is connected to input terminal **661** in FIG. **18**, the tip motor logic circuitry and input terminal **748** in FIG. **19**, the shift register and logic circuitry. The output of the flip-flop including gates **858** and **860** is also passed out of the system as a tray feed motor signal at output terminal **878** which is connected to input terminal **534** in FIG. **15**, the A.C. motor driver circuitry. An inverting gate **864** is connected to the three-second timer **861** in gate **860** of the flip-flop.

Referring now to FIG. **21**, there is shown the lamp driver circuitry designated generally as **880.** The lamp driver circuitry provides an indication to the operator of what is going to occur next and what is happening at the present time. Additionally, it provides an indication of problems such as jams in the system. An open tray signal enters the system at terminal **881** and originates from output terminal **1173** of FIG. **26**, the malfunction and alarm logic circuitry. The signal passes through lamp driver circuit **895** to the open tray lamp **896** to give the operator warning if he is about to operate the system and the tray is in open conditon. The lamp driver circuits for all of these lamps are substantially identical and are illustrated in FIG. **22** to be described.

An advance jam signal enters at terminal **882** and originates from output terminal **1182** of FIG. **26**, the malfunction and alarm logic circuitry. The signal then proceeds on through lamp driver circuit **897** to advance jam light **898.**

A tip wiper signal enters at terminal **883** and originates from output terminal **1184** in FIG. **26** and passes through lamp driver circuit **899** to the tip wiper lamp **900.**

An ejection signal enters at terminal **884** and originates from output terminal **1090** in FIG. **25**, the automatic switch buffer and logic circuitry, and passes through lamp driver circuit **901** to eject lamp **902.**

A pump sequence signal enters at terminal **885** and originates from output terminal **853'** in FIG. **20**, the advance and start logic circuitry, and passes through lamp driver circuit **903** to pump sequence lamp **904.**

A **1** bit signal enters at terminal **886** and originates from output terminal **805** in FIG. **19**, the shift register and logic circuitry. The signal then proceeds through invertor **907** and lamp driver circuit **905** to the tip down front light **906.**

A **4** bit signal enters at terminal **887** and originates from output terminal **809** in FIG. **17**, the pipette logic circuitry. The signal then proceeds through invertor **908** and lamp driver circuit **909** to the tip down back lamp **910.**

A pipette sequence lamp signal enters at terminal **888** and originates from output terminal **817** in FIG. **19**, the shift register and logic circuitry, and passes through lamp driver circuit **911** to pipette lamp **912.**

A tip up sequence lamp signal enters at terminal **889** and originates from terminal **819** in FIG. **19**, the shift register and logic circuitry. The signal then passes through lamp driver circuit **913** to the tip up lamp **914.**

An advance sequence lamp signal enters the system at terminal **890** and originates from output terminal **820** in FIG. **19**, the shift register and logic circuitry. The signal then passes through lamp driver circuit **915** to light advance lamp **916.**

An automatic mode signal enters at terminal **891** and originates from output terminal **1008** in FIG. **23**, the manual switch buffers and logic circuitry, and then passes through invertor **919** and lamp driver circuit **917** to the automatic mode lamp **918.**

A manual mode signal enters at terminal **892** and originates from output terminal **1009** in FIG. **23**, the manual switch buffer and logic circuitry. The signal then proceeds through invertor **920** and lamp driver circuit **921** to the manual lamp **922.**

An advance mode signal enters at terminal **893** having originated in the manual switch buffer and logic circuitry, FIG. **23**, at output terminal **1012.** The signal then passes through invertor **923** and lamp driver circuit **924** to the advance mode lamp **925.**

A pipette mode signal originates from output terminal **1013** in FIG. **23**, the manual switch buffer and logic circuitry, and enters at terminal **894.** The signal then proceeds on through invertor **926** and lamp driver circuit **927** to pipette mode lamp **928.**

FIG. **22** is representative of the lamp driver circuits used in FIG. **21.** Generally, the circuit is designated by **929** and the signal enters the system at terminal **932.** Terminals **935** and **941** are connected to ground and terminal **930** is connected to the logic voltage. The signal is then processed by resistors **931, 933, 934, 937** and **938** and silicon transistors **936** and **939** to output to the appropriate lamp at output terminal **940.**

Referring now to FIG. **23**, there is shown the manual switch buffers and logic circuitry designated as **942.** There are no inputs to this system, only outputs. The system circuitry is centered around the four major operator switches in the transporter circuitry, namely the automatic mode switch **943**, the manual mode switch **949**, the advance mode switch **955**, the pipette mode switch **961**, the reset switch **967** and the start switch **977.** Each of these switches have ground connections such as **944, 950, 957, 962, 968** and **978.** There are switch buffering circuits associated with each major operator control switch. Switch **943** is buffered through gates **946** and **947** and resistors **945** and **948.** Switch **949** is buffered through gates **952** and **953** and resistors **951** and **954.** Switch **955** is buffered through gates **958** and **959** and resistors **956** and **960.** Switch **961** is buffered through gates **964** and **965** and resistors **963** and **966.** Switch **967** is buffered through gates **969** and **971** and resistors **970** and **972.** Switch **977** is buffered through gates **980** and **981** and resistors **979** and **982.** Each resistor is connected to the logic voltage at **983.** A power up reset **973** has its output connected to invertor gate **976** and is combined in gate **974** with the output from the buffering circuit for switch **967.** The outputs of the buffering circuits for switches **943, 949, 955** and **961** are fed through a series of gates which are designated respectively as **984, 988** and **992** for the automatic mode switch, **985, 989** and **993** for the manual mode switch, **986, 990** and **994** for the advance mode switch, and **987, 991** and **995** for the pipette mode switch. The output of gate **992** is fed into a flip-flop mode circuit consisting of gates **996** and **997** and capacitor **1004.** The output of this flip-flop exits through terminal **1008** in the form of an automatic mode signal and is connected to input terminal **891** in FIG. **21,** the lamp driver circuit, and input terminal **769** in FIG. **19,** the shift register and logic circuit. The output of gate **993** is fed through a flip-flop circuit consisting of gates **998** and **999** and capacitor **1005** and is coupled with a portion of the output of gate **997** in an OR gate **1011** which produces an output signal. The output signal is an automatic or manual signal which exits through output terminal **1010** which, in turn, is connected to input terminal **838** in FIG. **20,** the advance and start logic circuitry, and input terminal **778** in FIG. **19,** the shift register and logic circuit. The output of gate **994** proceeds through a flip-flop circuit consisting of gates **1000** and **1001** and capacitor **1006.** The output of this flip-flop circuit is an advance signal exiting through output terminal **1012** which is connected to input terminal **893** in FIG. **21,** the lamp driver circuit, and input terminal **831** in FIG. **20,** the advance and start logic circuitry.

The output of gate **995** passes through a flip-flop circuit comprising gates **1002** and **1003** and capacitor **1007** and exits as a pipette signal at termianl **1013** which is connected to input terminals **894** in FIG. **21,** the lamp driver circuitry, and input terminal **609** in FIG. **17,** the pipette logic circuitry. The output of gate **974** proceeds through inverting gate **975** to produce a pulse signal at terminal **1015.** The reset signal from gate **975** also connects to gates **984, 985, 986** and **987** to clear the mode flip-flops. Terminal **1015** is connected to input terminal **1119** in FIG. **26,** the malfunction and alarm logic circuitry, input terminal **847** in FIG. **20,** the advance and start logic circuitry, and input terminal **656** in FIG. **18,** the tip motor logic circuitry. A capacitor **1014',** grounded at **1014,** is connected to the output terminal.

The output of the buffering circuit for the start switch **977** produces a start switch signal at terminal **1016.** Terminal **1016** is connected to input terminal **771** in FIG. **19,** the shift register and logic circuitry, input terminal **834** in FIG. **20,** the advance and start logic circuitry, and input terminal **611** in FIG. **17,** the pipette logic circuitry.

Referring now to FIG. **25,** there is shown the circuitry for the automatic switch buffers and ejection logic. The circuitry is designated generally as **1031.** A pair of tube sensing contacts, **1034** and **1035,** have normally open contacts and act in conjunction with a pair of tube sensing contacts **1032** and **1033,** having normally closed contacts for sensing tubes in the front and rear rows of a tube rack. This tube sensing circuit is grounded at **1036** and signals produced thereby are buffered through gates **1038** and **1040,** resistors **1037** and **1039** and capacitor **1041'.** The output of the switch buffer is a tube present signal exiting through output terminal **1041** which is connected to input terminal **760** in FIG. **19,** the shift register and logic circuitry, and input terminal **843** in FIG. **20,** the advance and start logic circuitry.

A rack sensing switch **1042** is grounded as at **1043** and produces a signal when a rack is in position which is buffered through gates **1045** and **1047,** resistors **1044** and **1046** and capacitor **1048.** The output of the buffering produces two signals. The first signal is a rack sense signal exiting at output terminal **1049** which is connected to input terminal **779** in FIG. **19,** the shift register and logic circuitry and input terminal **837** in FIG. **20,** the advance and start logic circuitry. The second signal is a rack sense signal exiting through terminal **1050** which is connected to input terminal **1114** in FIG. **26,** the malfunction and alarm logic circuitry.

A tip up sensing switch **1051** is grounded as at **1052** and is buffered through a buffering circuit comprising gates **1055** and **1056,** resistors **1053** and **1054** and capacitor **1057.** The output of this buffering circuit produces a tip up signal at terminal **1058** which is connected to input terminals **659** in FIG. **18,** the tip motor logic circuitry, and input terminal **830** in FIG. **20,** the advance and start logic circuitry.

A toggle switch **1059,** used to sense the toggle position on the tip motor cam, is grounded as at **1060** and produces a signal which is buffered through gates **1062** and **1064,** resistors **1061** and **1063** and capacitor **1065.** The output of the buffering produces a toggle signal at terminal **1066** which is connected to input terminal **662** in FIG. **18,** the tip motor logic circuitry.

An ejection motor cam switch **1067** is grounded as at **1068** and produces a signal which is buffered through a buffering circuit which includes gates **1070** and **1072,** resistors **1069** and **1071** and capacitor **1073.** A rack limit switch **1074** which is grounded as at **1075** produces a signal which is buffered through a buffering circuit containing gates **1077** and **1085,** resistors **1076** and **1083,** and capacitor **1086.** The combined signals from the latter two buffering circuits are fed into an OR gate **1087.**

An advance motor cam switch **1081** is grounded at **1082** and produces a signal buffered through gates **1092** and **1093,** resistors **1083'** and **1084** and capacitor **1094.** The output from gate **1092** is an advance motor cam signal which exits at terminal **1096** which, in turn, is connected to input terminal **827** in FIG. **20,** the advance and start logic circuitry. A common buss is connected to all the buffering circuits and has its terminal to the logic voltage at **1078.** Another logic voltage terminal **1095** is connected to AND gate **1089** together with the output from OR gate **1087.** The output of gate **1089** produces an ejection motor driver signal at terminal **1091.** Terminal **1091** is connected to input terminal **530** in FIG. **15,** the A.C. motor driver circuitry.

The output from OR gate **1087** is also connected to gate **1088** whose output produces an ejection signal at terminal **1090.** Terminal **1090** is connected to input terminal **1113** in FIG. **26,** the malfunction and alarm logic circuitry, input terminal **884** in FIG. **21,** the lamp driver circuitry, and input terminal **835** in FIG. **20,** the advance and start logic circuitry.

Referring now to FIG. **26,** the malfunction and alarm logic circuitry is shown designated generally as **1112.** An ejection signal enters the circuit through terminal **1113** and originates in output terminal **1090** in FIG. **25,** the automatic switch buffer and logic circuitry. A rack sense signal enters through terminal **1114** an originates from output terminal **1050** in FIG. **25,** the automatic switch buffer and logic circuitry. A reset signal enters through terminal **1119** and originates in output terminal **1015** in FIG. **23,** the manual switch buffer and logic circuitry. The ejection signal from terminal **1113** is passed through a NAND gate **1115,** through an A.C. coupling circuit which includes capacitor **1115',** resistor **1118** and ground **1117** to an AND gate **1116.** The rack sense signal from terminal **1114** is also fed into gate **1116.** The reset signal from **1119** is fed through NAND gate **1120** and NAND gate **1121.** The combined outputs of gates **1116** and **1121** are fed into a flip-flop circuit comprising gates **1122** and **1123** and capacitor **1124.** The output of the flip-flop circuit is fed to gate **1150** which acts like an OR gate and from there to a flip-flop circuit including gates **1155** and **1156** and capacitor **1157.** Another portion of the output from gate **1122** is fed through an A.C. coupling circuit including capacitor **1151,** resistor **1153** and ground **1152** to a NAND gate **1154** and into a gate **1155** in the flip-flop circuit. Additionally, the output from gate **1122** is fed to an AND gate **1162.** The output from NAND gate **1121** is also fed into the gate **1156** of the second flip-flop circuit. The flip-flop circuit controls a seven-second timer **1160** which includes capacitance **1159** and resistor **1158.** The output from the seven-second timer **1160** rpoceeds through gate **1161** to a second flip-flop circuit including gates **1165** and **1166** and capacitance **1167.** Also the output from gate **1121** is bypassed around the seven-second timer to gate **1166** of the third flip-flop circuit. The output of the latter mentioned flip-flop circuit controls a 35-second timer **1170** which includes capacitance **1169** and resistor **1168.** The output from the timer **1170** is fed through a NAND gate **1171** whose output is recycled back to gate **1166.** The output of timer **1170** is also fed back to gate **1150,** an OR gate.

A portion of the output of the flip-flop gate **1155** is fed to gate **1162** together with the output from gate **1122.**

The output from NAND gate **1120** is fed to a series of NOR gates **1129, 1134** and **1140.** These NOR gates are coupled with NOR gates **1128, 1133** and **1139,** respectively, and together with capacitors **1128', 1135** and **1141** comprise switch buffering circuits. A tray open contact switch **1125,** coupled to the logic voltage at **1126** provides an input into gate **1128.** A jam contact switch **1130,** connected to the logic voltage at **1131,** provides an input to gate **1133.** A phototransistor **1136,** grounded at **1137,** provides an input into interface unit **1138.** The interface unit is shown in FIG. **27.** The output from the interface unit is passed into NOR gate **1139.**

A switch **1144,** which is actuated when the tray is shut and if a reel is in place, is connected to the logic voltage at **1145** and provides a signal to either NOR gate **1142** or NOR gate **1143.** The latter two gates together with capacitance **1148** provide a buffering for the signal. The switch buffering resistors **1127, 1132** and **1146** are grounded at **1149.** The output from the buffering circuit which includes gates **1128** and **1129** provides a tray open signal at terminal **1173** which is connected to input terminal **881** in FIG. **21,** the lamp driver circuitry. The output from NOR gate **1133** of the buffering circuit provides an advance jam signal at terminal **1182** which is connected to input terminal **882** in FIG. **21,** the lamp driver circuitry. The output from gate **1139** provides a tip wiper signal at terminal **1184** which is connected to input terminal **883** in FIG. **21,** the lamp driver circuitry. The output from gate **1142** of the buffering circuit provides a reel motor signal at terminal **1185** which is connected to terminal **542** in FIG. **15,** the A.C. motor driver circuitry. The tray signal from gate **1128** and the jam signal from gate **1133** are also connected via OR gate **1174,** whose output goes to inverting gate **1175.** The output of inverting gate **1175** passes through capacitor **1176** and into a flip-flop circuit comprising gates **1177** and **1180** and capacitor **1181.** Capacitor **1176** together with resistor **1178** and ground **1179** comprises an A.C. coupling circuit. The flip-flop gate **1180** additionally receives an input from gate **1121.** The output of the flip-flop provides a malfunction signal at terminal **1183** which is connected to input terminal **826** in FIG. **20,** the advance and start logic circuitry, and input terminal **646** in FIG. **18,** the tip motor logic circuitry. This signal is also passed into OR gate **1163** together with the output from gate **1162.** The output of gate **1163** is inverted by gate **1164** and produces a buzzer signal at terminal **1172** which is connected to input terminal **538** in FIG. **15,** the A.C. motor driver circuitry.

Referring now to FIG. **18***a* is shown one-half of the tip motor logic circuitry. A malfunction signal enters at terminal **646** and originates in output terminal **1183** in FIG. **26,** the malfunction and alarm logic circuitry. The malfunction signal continues on to AND gate **729.** Since the stroke of the tip is dependent upon the time the motor runs, a front stroke adjustment is provided as at **645** and provides an input into a down front timer **724.** Also included in this circuit are maximum stroke adjustment **721** and minimum stroke adjustment **722** which are located within the device and are not operator accessible. These are set before the unit is delivered. Down front timer **724** also includes resistor **722'** and capacitor **723.** The down front timer controls the amount of time the motor is to run and consequently the length of stroke of the tip. The entire unit, together with the minimum and maximum stroke adjustments constitutes a bistable multivibrator.

A 2-bit signal from the shift register in FIG. **19** enters at terminal **647,** passes through A.C. coupling circuit including capacitor **648,** resistor **649** and ground **650** and into inverter **651.** A reset pulse signal enters the system at terminal **656** and originates from output terminal **1015** in FIG. **23,** the manual switch buffer and logic circuitry. The 2-bit signal in terminal **647** originates from output terminal **806** on FIG. **19,** the shift register circuitry. The reset signal passes through two inverters **655** and **677** and, together with the output from inverter **651** into a flip-flop circuit comprising gates **652** and **653** in capacitor **654.**

A 7-bit signal enters the system at terminal **658** and originates in output terminal **813** in FIG. **19,** the shift register and logic circuitry, and enters the gate **660.** A tip up signal enters at terminal **659** and originates from output terminal **1058** in FIG. **25,** the automatic switch buffer circuitry. The tip up signal is combined with the 7 bit signal in gate **660.** A start signal enters at terminal **661** and originates from output terminal **877** in FIG. **20,** the advance and start logic circuitry. A toggle signal enters at terminal **662** and originates from output terminal **1066** in FIG. **25,** the automatic switch buffer and logic circuitry. The start signal and toggle signal are fed into a gate **665.** The signals are additionally combined in gate **664** together with the tip up signal from terminal **659,** but the toggle signal from **662** is inverted by passing through inverter **663.** A 4-bit signal enters at terminal **666** and originates from output terminal **809** in FIG. **19,** the shift register and logic circuitry. The 4-bit pulse signal, together with the tip up signal from terminal **659,** are combined in gate **667.**

The toggle switch signal present at **662** is AND gated with the output of gate **652** by gate **654'.** The output of gate **654'** connects to the input of timer **724.**

The output from gate **653**, **660** and **664** are fed into gate **668**. The output from gate **653** and gate **664** are fed into gate **669**. The output from gate **669** is fed through an A.C. coupling circuit comprising resistor **671**, capacitor **671'** and logic voltage connection **670** to a negative OR gate **678**. The output from gate **665** is fed to a gate **673**. The gate **673** also receives part of its input from AND gate **672** connected to leads **672'** and **673'** which match up with adjoining leads on FIG. **18***b*.

Gate **653** also receives a portion of its input through matching lead **655'**. A matching lead **665'** is coupled with the output from gate **665** before entering gate **673**. A gate **677** receives output from the components on FIG. **18***b* through terminals **674'** and **677'**. The output from terminal **677'** also enters gate **673**. The output from gate **673** passes through an A.C. coupling circuit comprising capacitor **674**, resistor **676** and logic voltage connection **675** to negative OR gate **678**. The output from gate **677** is passed through inverting gate **726'** and onto OR gate **726**. OR gate **726** receives the output also of gate **668** through inverting gate **679**. The output of gate **726** is connected to gate **729** and to gate **727**. Gate **727** inverts the signal and provides a signal at terminal **728**. Terminal **728** is connected to input terminal **768** in FIG. **19**, the shift register and logic circuitry.

The output of gate **678** is passed to the circuitry in FIG. **18***b* through matching lead **678'** and to NOR gate **731**. Gate **731**, together with gate **732**, capacitor **734**, and resistor **736**, grounded at **735**, provides a one-shot pulse to gate **729**. The gate **729** provides a tip motor drive signal at terminal **730** which is connected to input terminal **517** in FIG. **15**, the A. C. motor driver circuit.

Referring now to FIG. **18***b*, the remainder of the tip motor logic circuitry is shown. As FIG. **18***b* shows a front stroke adjustment, FIG. **18***b* shows a rear stroke adjustment **681** which is used to control the stroke of the tip going into the back tube as opposed to the front tube in the rack. Adjustment **681** provides input to a timer circuit **690** containing resistors **688'** and capacitor **689**. As in the front stroke adjustment, a maximum stroke adjustment **687** and a minimum stroke adjustment **688** are provided within the timing circuit. However, these latter adjustments are set and are not operator accessible

A 5 bit signal enters at **682** from output terminal **810** in FIG. **19**, the shift register and logic circuitry. Bit **5** signal passes through an A. C. coupling circuit comprising capacitor **681'**, resistor **683'** and ground **682'** to an inverter **683**. The output of inverter **683** together with the output of inverter **655** in FIG. **18***a*, is passed into a flip-flop circuit containing capacitor **686** and gates **684** and **685**. The inverted toggle switch signal present at the output of inverter **663** in FIG. **18***a* connects to gate **685'** via lead **690'**This signal is AND gated with the output of gate **684** by **685'**. The output of gate **685'** connects to the input of timer **690**. The output of timer circuit **690** passes through inverting gate **691** and is recycled back into the flip-flop gate **685** to reset the flip-flop. The output of timer circuit **690** is passed into AND gate **696**. Terminal **692** is connected to resistor **694** with ground **693** to inverting gate **695**. An external select switch is coupled to terminal **692** when other devices are to be used in conjunction with the operation of the transporter, such as a flame spectrophotometer, etc.

An external potentiometer **700** is used in conjunction with an external select switch when it is connected to terminal **692**.

A delay start signal enters at terminal **701** and originates in output terminal **631** in FIG. **17**, the pipette logic circuitry. The delay start signal goes to gate **705**. Gate **705** also receives an external select signal hooked to terminal **692** and its output enters a flip-flop circuit comprising gates **706** and **707** and capacitor **707'**. This flip-flop circuit is used to control and set a one-second timer **708**. Timer **708** includes capacitor **709** and resistor **710**. The output of timer **708** passes through inverting gate **711** and into a second flip-flop circuit comprising gates **712** and **713** and capacitor **713'**. The output of inverting gate **711** is also fed back into the flip-flop gate **707**. The second flip-flop circuit controls a variable timer **714** which includes resistor **716** and capacitor **715**. The variable timer is connected to the external potentiometer **700** and is set by said potentiometer. The output of timer **714** is fed through inverting gate **717** and onto terminal **718** to provide an external pulse signal which tells an external device, such as a spectrophotometer, to start. Also, the output of gate **717** is fed back into flip-flop gate **713** to reset the flip-flop circuit. The second flip-flop circuit is also connected via matching terminal **677'** to gates **673** and **677** in FIG. **18***a*.

The output of inverting gate **725** in FIG. **18***a* is passed to a gate **697** in FIG. **18***b* via matching terminal **725'**. Gate **697** is one-half of a flip-flop circuit to run the motor in a forward direction, the other half of the flip-flop being gate **698**. The output of gate **696** is fed into gate **698** together with the output of inverting gate **717** in the variable timing circuit. The output of the flip-flop comprising gates **697** and **698** are fed to an OR gate **719** together with the output of gate **665** in FIG. **18***a* via matching terminal **665'**.

The output of OR gate **678** in FIG. **18***a* is fed, via matching terminal **678'** to a NOR gate **737**. The output of NOR gate **737** is fed to an inverting NOR gate **741** and the output of said second NOR gate is fed through an A.C. coupling circuit back into gate **737**. The A.C. coupling circuit includes capacitor **740**, resistor **739** and common ground connection **738**. The output of NOR gate **741** is fed to NAND gate **743** together with the output of an inverting gate **720** which inverts the output of OR gate **719**. The output of gate **737**, together with the output of OR gate **719** are fed to a NAND gate **742**. The outputs of NAND gates **742** and **743** are fed to NAND gate **744**. The output of gate **744** is fed to a relay driver **745** which produces a reverse relay signal at terminal **746**. Terminal **746** is connected to input terminal **521** in FIG. **15**, the A. C. motor driver circuit.

ELECTRONIC SOLID STATE CONTROL SYSTEM OPERATION

The A. C. motor driver circuitry in FIG. **15** is essentially self-explanatory in the sense that when the system receives signals from the other circuit cards or circuitry they energize the appropriate motors.

In FIG. **17**, the pipette logic circuitry, the switches **569**, **570**, **571**, **572**, **573**, and **574** are all located within the transporter pipette. In normal operation the RUN switch **572** is closed which selects the switches **571** and **570**. Whenever the transporter pipette is not running after a dispensing or discharging cycle, either switch

571 or 570 will be operated causing no signal to be present at the filtered Schmitt trigger circuit comprised of gates 587 and 589. Whenever the SET switch 573 is operated for setting the pump stroke for the pipette, switch 574 is selected and will cause the pipette to operate until switch 574 is operated by cam action. Whenever both switches 572 and 573 are selected, a condition is relaized where a signal is always present which will cause the pipette to operate continually, thus enabling pumps to be primed. The circuitry also accommodates the auxiliary pipette which has its contact switch designated as 593. The various arrows accompanying the circuit are merely pin connections as they are throughout the remainder of the circuits. Whenever the auxiliary pipette is not operating, switch contact 593 is closed. This causes a signal to be present at the input of the filtered Schmitt trigger comprised of gates 603' and 603. The auxiliary pipette select switch 594 is used to select contact 593, otherwise, a true signal is always presented to the said Schmitt trigger. The one-shot circuit consisting of gates 620, 622, and 624 produces a pulse whose duration is long enough to run the pipette to operate the cam switches in subcircuit 568 in the pipette. The said one-shot circuit is triggered by the start switch signal when the pipette mode is selected via gates 610 and 615 and by bit signals 3 and 6 from the shift register via terminals 613 and 614 and gate 615, an OR gate. The said one-shot circuit energizes relay coil 626 via relay driver 625. Relay 626 has contacts 639 which operate the auxiliary pipette via terminals 640, 641, and 642.

Gate 608 is used to enable an external device to inhibit transporter operation via gate 628 and 634 and terminal 633. Gates 628 and 634 gives a signal that indicates that the transporter pipette or the auxiliary pipette, if selected, are operating or that the external device, if selected, is functioning. Gates 629 and 635 are used to activate the transporter pipette motor via terminal 638 which connects to the A. C. drivers. Gate 630 is used to produce a delay start signal only after the transporter pipette has completed a discharge cycle. Gates 576 and 580 are used as a switch buffer for the right position limit switch 569 contacts.

Referring now to FIGS. 18*a* and 18*b*, the tip motor logic circuitry, the malfunction signal originating into the system at terminal 646 prevents the tip motor from running. Gates 652 and 653 constitute a timer flip-flop for starting the tip down front timer 724. Gate 725 constitutes a time output gate for timer 724. Each timer in all the circuits in this apparatus has such a timer flip-flop and output gate associated therewith. The purpose of gate 725 is to produce a reset signal for its respective timer flip-flop, gates 652 and 653. Whenever a timer flip-flop is set, its respective timer will start timing. At the end of the predetermined time interval a pulse will appear at its output which in turn resets the timer. This is true for all timers in the apparatus. The timer flip-flop for the tip down front timer is set by the 2-bit signal from the shift register via terminal 647. The timing of the tip motor starts after the toggle switch is operated by the tip motor via gate 654'. The tip down front timer controls the time the motor runs the tip down into the front tube. The timing interval is determined by the setting of control 645.

The operation of the tip down back timer is identical to that of the tip down front timer except that it is triggered by 5 bit signal from the shift register via terminal 682 and that the timing of the tip motor starts after the toggle switch is again operated by the tip motor via gate 685'.

In the normal operation of the tip motor, that is, when the external control is not selected, the motor reversing flip-flop comprised of gates 697 and 698 is always set after a timed forward rotation of the motor and always reset after a timed reverse rotation of the motor. This action predetermines the next direction of rotation. The output of the self-positioning circuitry consisting of gates 664 and 665 also determines the direction of rotation of the tip motor by combining with the output of the motor reversing flip-flop via gate 719. This signal is exclusively OR'ed with the signal from the one-shot circuit comprised of gates 737 and 741 which energizes the tip motor reversing relay via relay driver 745 and terminal 746. The exclusive OR function is accomplished by gates 720, 742, 743, and 744. The said one-shot circuit is normally triggered only after the tip motor runs due to the self-positioning circuitry or due to a timer action. The triggering logic is accomplished with gates 669, 673, and 678. The net result of the exclusive OR logic is to prevent the operation of the reversing relay during dynamic motor braking. Further, the one-shot circuit composed of gates 731 and 732 is also triggered at the same instant as the one-shot circuit previously described. The action of this one-shot inhibits the starting of the tip motor until the aforesaid relay contacts are closed.

The gates 660 and 667 are used to raise the tip up from the back and front tubes respectively upon command from the shift register via terminals 658 and 666 respectively. Logic comprising gates 668, 677, 726, 726', and 727 gives a signal when the tip motor is operating. The inverse of this signal is AND gated with the malfunction signal at 646 and with the output of one-shot composed of gates 731 and 732 by gate 729 to give a tip motor drive signal at 730.

When the external control select switch is operated, the normal operation of the tip is interrupted as described below. After the tip moves down into the back tube, the normal resetting of the motor reversing flip-flop is inhibited by gate 696. Also, the triggering logic for the previously described one-shot circuits is inhibited by gate 672. After a discharge cycle of the pipette, a delay start signal at 701 starts timer 708 via gate 705. Timer 708 has a delay of approximately one second to allow any reagents that the pipette has dispensed to mix with the sample. After the delay of approximately one second, timer 708 starts timer 714. This timer is adjusted through the external potentiometer 700 and makes the tip motor run the tip further down the same tube. In other words, the tip initially discharges above the liquid level in the tube, then waits for a predetermined amount of time as set into the timer 714, usually one-half second, and then goes down into the liquid to aspirate the combined liquid and sample. The external signal going out of the circuit at terminal 718 tells the external device to begin its function.

The reset signal at 656 is buffered by inverters 677 and 655 and is used to reset all timer flip-flops and the motor reversing flip-flop in the tip motor logic system.

Referring now to FIG. 19, the shift register and logic circuitry, the shift register is used to sequentially control the operations of the apparatus by the stepwise circulation of a single bit through it. The appearance of the bit at each bit position initiates the corresponding action required at that step.

The entry of the single bit into the shift register is accomplished by an entry flip-flop comprised of gates **789** and **788**, and pulse delaying gates of **749, 753,** and **757.** When a start signal is presented at terminal **748,** a negative start pulse at gate **753** sets the entry flip-flop. At the output of gate **757,** a negative delayed start pulse triggers a one-shot circuit comprised of gates **782** and **785** which produces a shift signal for the shift register. Since an input signal is presented to the shift register from the entry flip-flop through gates **791, 792,** and **795,** a bit will be entered into the first bit position. The bit appearing at position **1** resets the entry flip-flop.

Subsequent shift pulses are produced by the completion of an advance operation, a tip operation, a pipette operation, or an external operation or by manual means.

The logic consisting of gates **761, 764, 765, 767, 772,** and **774** is used to generate shift pulses when in the automatic mode upon completion of any advance, tip, pipette, or external control operation. The logic is also adapted to give shift pulses when the start switch is depressed while in the manual mode. This is accomplished specifically by gate **773.**

Gates **821** and **822** are used to give an advance lamp signal before starting occurs. Gate **823** OR's this signal with that from the shift register so that the advance lamp will operate after starting at the appropriate time. The lamp driver gates **816** and **818** are connected to act like OR gates.

Referring now to FIG. **20,** the advance and start logic circuitry, the malfunction signal originating at terminal **826** is used to inhibit the advance motor. Gate **853** is used to give a pump sequence signal when starting is attempted when the pipette is to perform a discharge cycle. This signal is inhibited after starting occurs. Gate **839** is used to determine the condition which must be met before the start flip-flop composed of gates **840** and **841** can be set. The conditions which must be met are a false pipette right position signal at terminal **836,** a true rack signal at terminal **837,** a false malfunction signal at termnal at **826,** a true automatic or manual signal at terminal **838,** and a true start switch signal at terminal **834.** Once the start flip-flop is set, a **1** bit signal will appear at terminal **829** setting the advance start flip-flop comprised of gates **868** and **869.** Gate **854** insures that the tip is up before rack advancing occurs. After the advance start flip-flop is set, gate **871** gives an advance motor drive signal at terminal **875** through gate **872.** The signal furnished at terminal **876** through gate **873** is for the shift register logic. Once the advancement motor starts rotating an advance motor cam switch signal will disappear at terminal **827.** This action will reset the advance start flip-flop via gate **869** and furnish another signal to gate **871.** This will cause the advance motor to continue running until the signal at **827** is again true. The advance motor cam switch signal at **827** will only be true after the advance motor causes one complete cycle of rack advancement.

The advance start flip-flop is also set by another means by gate **867** as described below. Whenever a rack advances to its last tube position, the rack signal at terminal **837** disappears causing timer **861** to start by means of gates **845** and **857.** The rack signal must change during an advance cycle in order for timer **861** to be triggered. This is accomplished with gate **857.** If no tubes are present in the last position of the rack, the automatic advance signal produced by gate **856** and described below is inhibited by the timer by neans of gate **865** and **866.** Timer **861** has a time delay which allows time for the next rack to be processed, if any, to move into the processing position. When the delay has expired the pulse from the timer goes to gate **867** and, if no tubes are present, then to the advance start flip-flop which causes an advance cycle.

Two other means are possible for causing a rack advance. Whenever a rack is advanced and no tubes are present at the new tube position and the start flip-flop is set and no rack eject is occurring, gate **856** gives a false signal to gate **871** via gates **865** and **866.** When the rack is moved to the last tube position, this signal is inhibited, as mentioned above, by timer **861.** The rack may also be advanced manually via gate **855.** The output of gate **855** goes false, thus causing an advance signal, when the advance mode signal at terminal **831** is true and when the tip up signal from terminal **830** via gate **832** is true and when the not eject signal at terminal **835** is true and when the start switch signal at terminal **834** is true.

A clear signal is generated by the logic of gate **851** which acts like an OR gate to combine the reset signal at terminal **847,** the malfunction signal at terminal **826,** and the output of gate **848.** The output of gate **848** gives a signal at the completion of the rack processing, that is, after a rack eject occurs with no more racks present to be processed. Therefore, a clear signal occurs at terminal **879** when a reset, a malfunction, or a complete signal is received by gate **851.** This signal is used to reset the start flip-flop and the shift register via terminal **879.**

The operation of the lamp driver circuit shown in FIG. **21** is relatively self-explanatory in the sense that any signal coming in through the lamp driver circuits operates the lamp to inform the operator of the present or impending condition. The manual switch buffer and logic circuitry shown in FIG. **23** is also fairly self-explanatory in that the system allows only one mode flip-flop to be set at a time. The system essentially comprises the six main control switches, the switch buffering flip-flops, the gates which permit only one control flip-flop to be set at a time, and the exclusionary control flip-flops inlcuding gates **996, 997, 998, 999, 1000, 1001, 1002** and **1003.** The power up reset **973** resets the entire logic of the transporter when the run or set switch in the pipette module is operated. Rferring now to FIG. **25,** the automatic switch buffer and ejection logic system, the system contains a tube sensing switch **1034** and **1032** for the front row and a tube sensing switch **1035** and **1033** for the rear row on the rack. The signal goes through a switch buffer comprising gates **1038** and **1040** and provides a "tube-present" signal. The rack sensing switch **1042,** the tip up sensing switch **1051,** the toggle tip switch **1059,** the ejection motor cam switch **1067,** the rack limit switch **1074** and the advance motor cam **1081** are all contacted by moving parts within the apparatus itself and the signals produced by the switch go through switch buffers and provide signals to the other circuits. In the case of the ejection motor cam switch **1067** and the rack limit switch **1074,** the signals, after buffering, are combined in OR gate **1087** and provide an ejection signal at terminal **1090** and an ejection motor driver signal at **1089.** The particular ejection mechanism is not shown as previously stated but is simply a solenoid and motor operated mechanism which operates two thrust push rod rack ejectors **55** and **54**, as shown in FIG. **1**, outwardly to eject the rack along surface **5**.

Referring now to FIG. **26**, the malfunction and alarm logic circuitry, gates **1177** and **1180** comprise a buzzer flip-flop which is set by means of gates **1174** and **1175**. The output of the buzzer flip-flop is fed to gate **1163** which is wired as an OR gate to give a buzzer drive signal at terminal **1172**. Gates **1128** and **1129** comprise a latching switch buffer for the tray open switch **1125**. Similarly, gates **1133** and **1134** comprise a latching switch buffer for the advance jam switch **1130**. When a tray open signal or an advance jam signal occurs, they appear at terminals **1173** and **1182** respectively to connect with the lamp driver circutriy for malfunction indication purposes. These signals are also OR gated together by gates **1174** and **1175** to set the buzzer flip-flop and give a malfunction signal at terminal **1183**. This is the malfunction signal which acts to prohibit other portions of the circuitry in the apparatus from operating. The latching switch buffers are reset by reset signal via gate **1120** after the malfunction condition has been cleared. The reset signal also resets the buzzer flip-flop at gate **1180** to silence the buzzer.

The buzzer also sounds by the means described below to indicate the completion of rack processing. After a rack has been ejected from the processing area and no more racks are to be processed, gate **1116** sets the completion flip-flop containing gates **1122** and **1123**. When the completion flip-flop is set, gates **1150** and **1162** are enabled and a pulse from gate **1154** sets the timer flip-flop for timer **1160**. Timer **1160** is a 7-second timer which sounds the buzzer by means of gates **1162, 1163,** and **1164**. Upon the completion of the 7-second delay, timer **1160** starts timer **1170** and the buzzer is silent. Timer **1170** is a 35-second timer which allows the buzzer to operate intermittently. When the 35-second delay has elapsed, timer **1170** restarts timer **1160** via gate **1150** which, in turn, resounds the buzzer for 7 seconds. This process is repeated until the operator resets the completion flip-flop with a reset signal as at terminal **1119**.

The phototransistor **1136** operates to produce a signal which is buffered by gates **1139, 1140** to produce a tape signal at terminal **1184**. This signal is indicative of a low supply of tape and illuminates a lamp on the panel of the transporter.

The reel switch **1144** is actuated if one shuts the tray and if a take-up reel is in place. If a reel is not in place, the take up spindle will not run. The reel signal exits from the alarm logic circuitry at terminal **1185**.

FUNCTIONS AND APPLICATIONS

The general operating function of the transporter as stated before is determined by the positions of the "auxiliary pipette" and "external control" select switches on the function control panel on the electronic module. There are the four switch combinations, in other words, both "off," either one "on" and both "on."

With the "auxiliary pipette" and "external control" switches off, the following combinations of operation are available: (1) a sample on the front tube row diluted with a single reagent into the back tube row; (2) a reagent dispensed in each tube row; or (3) one or two reagents dispensed in the back tube row only.

With the "auxiliary pipette" switch on and the "external control" switch off, the system is designed to operate in the arrangement shown in FIG. **30**. The tube rack **1300** contains a front tube **1301** and a rear tube **1302** into which the tip **1303** (also shown in phantom lines in the front tube) is designed to enter. A double pipete unit comprising tubes **1304** and **1305** and a holder mechanism **1306** is arranged in fixed position on the transporter. These two tubes constitute the auxiliary dispensing pipette. Basically, the application envisioned here is the preparation of a sample in the tube **1301** diluted with a reagent **1** from the transporter pipette tip **1303** and with reagents **2** and/or **3** from the auxiliary pipette in tubes **1304** and/or **1305**. The transporter pipette will be manifolded in a conventional way through a single tip moved by the tip mechanism. The auxiliary pipette utilizes a fixed tip **1304** or tips **1304** and **1305** mounted over tube **1302** in the rear row. The auxiliary pipette may use one or two pumps as required by the application. As shown, the fixed auxiliary tips **1304** and **1305** do not touch the tube well.

Referring now to FIG. **31**, the device is shown adapted for the "external control" switch on and the "auxiliary pipette" switch off. This application requires the supply of a diluted sample to a readout instrument. It is assumed that either the "external control" unit or the readout unit will have means of aspirating or pumping the sample into the readout instrument. The transporter is provided with a twin tip shown as **1313** and **1314** in FIG. **31**. Line **1316** connects with tip **1314** and is flexible and attached in turn to a valve **1317** which connects said line with the line **1318** going to a readout instrument. FIG. **32** shows a cross-sectional view of the twin tip. A is evidenced from FIG. **32**, the two tubes may be molded as one having two passages. Basically, the rack **1310** contains a front tube **1311** and a rear tube **1312**. The sequence of events is as follows: Valve **1317** is closed to tip **1314**. The double tip enters the front tube **1311** is shown in phantom lines, picks up the sample therein and fills a diluting pump with a reagent. The tips move to position A in the rear tube **1312**, and are wiped in transit. The sample and reagent are dispensed. Position A is preset by the potentiometer **37** on panel **36** of the logic control module. A fixed time delay of approximately 1 second is used to permit mixing and liquid motion damping. The tips **1313** and **1314** then move down tube **1312** into position B, as shown in the drawings, which position is established by an external control potentiometer as shown in the circuitry drawings. Valve **1317** then opens to tip **1314** and the diluted sample is aspirated. The aspiration time is set on a timer in the external control unit. The readout is triggered at a preset time in the aspiration cycle. Then valve **1317** closes. Valve **1317** can be three way to allow air flow through the readout instrument if desired. At this point, controls return to the transporter logic circuitry. The tips **1313** and **1314** are then removed from the rear tube and wiped and the transporter operation proceeds in the usual manner.

With the "auxiliary pipette" switch on and the "external control" switch on, the application is the same as just described except that the auxiliary pipette function allows the introduction of one or two additional reagents through the fixed tips such as **1304** and **1305** in FIG. **30** during the dispensing step of tips **1314** and **1313**. In other words, the fixed pipette having the double tips shown in FIG. 30 can be used with the double-core tip shown in FIG. 31.

With the "auxiliary pipette" switch off and the "external control" switch on, the transporter is adapted for other readout instruments providing minimum sample carryover and rapid sample feed to the instrument. In this configuration, the rear tubes in the rack such as 1320 in FIG. 33 are omitted and a fixed cup such as 1332 is installed in the transporter on a mounting such as 1323. The transporter has a single movable tip 1323 for sample and diluent. The external control package is provided with a diaphragm pump 1335 to pump a solution through valve 1334 and fixed tip 1333 for rinsing cup 1332 and is also provided with a four-way valve 1329. Support 1323 has an aperture 1324 in the base thereof through which a connecting stem 1325 runs to connector 1326. A pipe 1327 runs from connector 1326 through valve 1328 and then on to valve 1329. Conduit 1330 runs to the readout instrument such as a flame spectrophotometer; conduit 1332 is the drain conduit, and conduit 1331 is the vent conduit.

In operation the sequence of events is as follows. Tip 1323 picks up a sample from the front tube 1321 and the dispensing pump (not shown) is filled. Valve 1328 is in the closed position and valve 1329 is in the position which connects the analysis instrument or conduit 1330 to vent and the cup line 1327 to the drain line 1332. Then tip 1323 moves to fixed cup 1332, is wiped in transit, and discharges the sample and diluant. A short time delay is provided for mixing and motion damping and is approximately one second. The external control logic then takes over and initiates the following functions. Valve 1328 opens for a preset time A allowing the diluted sample to flush line 1327 between cup 1332 and valve 1329. Then valve 1329 is shifted to connect the cup 1332 and the analysis instrument connected to conduit 1330. Diluted sample is aspirated into the analysis instrument for a preset time B and the instrument readout is triggered. Valve 1329 shifts then to connect the conduit 1330 to vent conduit 1331, allowing the aspirator to clear the connecting line up to valve 1329. The diaphragm pump 1335 then pulses to rinse the fixed cup 1332 and the line 1327 between the cup and the drain conduit 1332 clears by gravity flow. At this point, valve 1328 is again closed and control is returned to the transporter and normal operation proceeds. Tip 1323 is removed from the fixed cup and is wiped. The rack then advances the next sample tube and the operation is repeated.

While the one embodiment of the tip and wiper mechanism and solid state circuitry has been shown and described, it will become apparent to those skilled in the art that many changes and modifications may be made to the apparatus and circuitry without departing from the scope of the appended claims.

We claim:

1. An apparatus for selectively or automatically processing racks, each having a row of liquid sample-containing tubes and a row of additional tubes either empty or containing suitable re agents, said rows being adjacent so as to form pairs of tubes, said apparatus comprising a base member having a supporting surface divided into a rack-loading area to receive loaded racks for processing, a rack-advancement area, and a rack-ejectment area, rack-advancement means adjacent said rack-advancement area to advance a rack along a linear path from an initial position adjacent the loading area to a final position adjacent the ejectment area, liquid sampling and dispensing means, conduit means in communication with said sampling and dispensing means, an aspirating and dispensing tip means above the path and connected to said conduit means, said rack-advancement means being constructed and arranged to advance said racks incrementally to position successive pairs of tubes under said tip means, tip-moving means comprising means for shifting the tip means to and fro between two positions corresponding to those of a pair of the tubes in a rack, and means for raising and lowering the tip means in a straight line at the two positions, rack-ejection means adjacent said final position for ejecting a processed rack from said path in a direction transverse to said path into said rack-ejectment area, means for feeding the racks in the loading area successively into the initial position of the path by moving said racks transverse to said path in a direction opposite that of ejectment, and control means for coordinating the operation of said liquid sampling means and dispensing means, said rack-advancement means, said tip-shifting means, said tip raising and lowering means, and said ejection means.

2. An apparatus as in claim 1 wherein said tip-shifting means includes a driven grooved cylindrical cam means and a cam groove follower means adapted to ride in a groove of the cam means to control the position of said tip means.

3. An apparatus according to claim 2 in which the cylindrical cam means has two peripheral cam grooves and the follower means comprises a separate follower for each cam groove and a snap-action lever, connected at each of its ends to a separate one of the followers, for alternately bringing a follower into its respective groove, each groove having a portion which raises the follower therein and rocks the lever to its snap-action position, thereby causing the other follower to engage the other groove.

4. An apparatus as in claim 3 including a bidirectional tip motor, said control means adapted to rotate said motor in either direction, one direction of rotation adapted to move said tip downwardly and the other direction of rotation adapted to move said tip upwardly.

5. An apparatus as in claim 4 and further including a switch cam having a pair of lobes located adjacent said cylindrical cam, said cylindrical cam having an actuator bar thereon which is adapted to engage one of said lobes upon rotation in either direction.

6. An apparatus as in claim 1 wherein said tip-moving means includes a pair of guide rods and a cam means to move said guide rods longitudinally to a first and second position, tip holder means mounted on said guide rods, said tip means being located in said tip holder means, and a cross slide assembly means associated with said tip holder to move said tip holder and said tip means down and up along said guide in both said positions.

7. An apparatus as in claim 6 and including a drive means for rotating said cam means, a crank means associated with said drive means and operatively in engagement with said cross slide means to effect downward and upward displacement of said cross slide means and said tip holder when said cam means is rotated.

8. An apparatus as in claim 7 and including a cam follower toggle means, said toggle means having two cam followers and said cam having two cam grooves

therein, said toggle means adapted to toggle when one of said cam followers rides out of one of said cam grooves and thus to force the remaining cam follower into the other cam groove.

9. An apparatus as in claim **7** wherein said crank means has a top dead center cam on one end thereof, a switch means, said top dead center cam means adapted to engage said switch means when said cross slide assembly and said tip holder are in a predetermined position for either aspirating or dispensing.

10. An apparatus as in claim **1**, and including a rack bar means adapted to bias said racks into advancement position on said surface means.

11. An apparatus as in claim **1** wherein said liquid sampling and dispensing means comprises a pair of pump units, each pump unit having a piston and a common driving means for driving the pistons of each said pump unit in a sinusoidal reciprocal manner, each pump unit having at least two port bores thereon and valve means associated with said common driving means and said port bores to alternately place the chamber of each pump unit in communication with one of said port bores respectively.

12. An apparatus as in claim **1** and additionally including means for wiping said tip means as it is moved upwardly by said tip raising and lowering means in each position.

13. An apparatus as in claim **12** wherein said wiper means includes a supply reel of wiper tape and a take-up reel for the wiper tape and a driving spool means for advancing the wiper tape.

14. An apparatus as in claim **13** wherein said tip wiper means also includes a pair of pad means and means to press said wiper tape against the sides of said tip means as it is being raised in either position to effect a wiping thereof.

15. An apparatus as in claim **13** wherein said wiper spool driving means includes a plurality of peripheral projections adapted to penetrate said wiper tape.

16. An apparatus as in claim **12** including a drive means for operatively effecting rotation of said wiper spool drive means upon upward motion of said tip means.

17. An apparatus as in claim **1** wherein said control means includes a malfunction and alarm circuit means, said malfunction alarm circuit means including a buzzer which is adapted to sound for a predetermined period of time upon the completion of processing and then remain silent for a second period of time and again sound for said first predetermined period of time whereby said cycle is repeated until an operator shuts off the apparatus.

18. An apparatus as claimed in claim **1** including wiper means for wiping said tip during its upward movement out of said tubes, said wiper means including a supply reel of wiping tape, and said control means having a circuit means to prevent said apparatus from functioning if there is no supply reel in place.

19. An apparatus as in claim **1** and including wiper means to wipe said tip, said wiper means being mounted on a tray or drawer which may be pulled outwardly from the apparatus into open position for servicing, said control means including a malfunction circuitry means adapted to shut down the operation of the machine if the tray is in open position or if a jam occurs in the rack advancement means.

20. An apparatus as in claim **19** wherein said wiper means includes a reel supply of tape, and said control means has a photoelectric means which gives a signal to the operator if the supply of tape is low.

21. An apparatus as in claim **1** wherein said control means includes automatic switches for sensing the presence of a rack, sensing the condition of the tip being raised, sensing the presence of tubes on both rows on said rack tray, and sensing when said rack is through being porcessed.

22. An apparatus as in claim **21** wherein said control means additionally includes means for providing an ejection pulse, an ejection apparatus, said ejection pulse operating to allow said ejection apparatus to eject a processed rack onto said surface means.

23. An apparatus as in claim **1** wherein said control means has circuitry providing for an automatic mode wherein said tubes are sequentially processed and the rack advanced incrementally.

24. An apparatus as in claim **23** wherein said control means additionally includes a manual mode circuit by which an operator can perform one sampling and dispensing apparatus at a time.

25. An apparatus as in claim **24** wherein said control means also includes an advance mode circuit and means to advance continually the rack without allowing the pipette and tip means to process any of the tubes contained therein.

26. An apparatus as in claim **25** wherein said control means additionally includes a pipette mode circuit means adapted to allow an operator to operate the pipette without operating the tip or liquid sampling and dispensing means.

27. An apparatus as in claim **26** wherein said control means has an exclusionary circuit means allowing only one of said modes to be operated at a single time.

28. An apparatus as in claim **1** wherein said control means includes circuit means adapted to prevent processing or operation of the apparatus before the rack is in a correct position, the pipette is in correct pumping sequence, before and when there is no malfunction signal present.

29. An apparatus as in claim **1** wherein said control mans includes an advance circuit means which will advance the rack until tubes are sensed by said control, means, this allowing for a partially filled rack to be processed.

30. An apparatus as in claim **1** wherein said control means includes a binary shift register and solid state controls, the shift register acting to automatically operate the control means to provide a predetermined sequence of operation with appropriate times and time delays therebetween.

31. An apparatus as in claim **30** wherein said control mans includes a START switch means which is adapted, upon being held in depressed condition, to provide automatic processing and stepping of said shift register.

32. An apparatus as in claim **1** wherein said tip raising and lowering means includes a tip motor means, the length of time of rotation of said motor in either direction controlling the depth of stroke of said tip means, said control means providing that rotation of said motor means in one direction allows said tip to move downwardly in both front and rear positions and rotation of said motor in an opposite direction allows said tip to move upwardly in both front and rear positions.

33. An apparatus as in claim 32 wherein said control means has manually adjustable timer means to control the amount of rotation of said motor means in either direction, thereby determining the depth of stroke of said tip means in both said positions.

34. An apparatus as in claim 32 wherein said control means includes a circuit means adapted to first reverse said motor means, provide a predetermined delay period to allow the dynamic braking of said motor to take effect, switch the contacts on said motor, provide a second time delay of a predetermined amount of time and finally to start said motor rotating in an opposite direction.

35. An apparatus as in claim 1 wherein said control means has an external select switch adapted to allow an operator to control the operation of the transporter externally, said control means also having an external potentiometer means, said control means including two timing means, said first timing means adapted to provide a delay to allow the reagent to mix with a sample after it has been dispensed above the level of the sample in the tube and said second timing means adapted to provide a pulse to said tip raising and lowering means to move the tip down below the level of said mixed reagent and sample in the same tube, said potentiometer providing adjustment ot said timer whereby an operator may select the depth of additional stroke which the tip moves down into said tube.

36. An apparatus as in claim 1 wherein said liquid sampling and dispensing means includes a control circuit, said control circuit, when activated, providing power to said control means for the entire apparatus.

37. An apparatus as in claim 1 wherein said control means includes circuit means to operate an auxiliary pipette or liquid sampling and dispensing means which can be used in conjunction with said liquid sampling and dispensing means.

38. An apparatus as in claim 37 wherein an auxiliary pipette is provided on said liquid sampling and dispensing means and is attached thereto in fixed position so as to be in a position to dispense into the tubes in one row on said rack.

39. In an apparatus for transferring liquids with respect to containers, especially test tubes, comprising a base, means for incrementally moving a holder or rack having a plurality of receptacles for the containers longitudinally along a path over the base from an initial station to a final station, a movable nozzle or "tip" above an intermediate station along the path, positive-displacement pump means comprising a piston reciprocable in a cylinder having a port for passage of liquid, a flexible conduit connecting the port with the tip for communication therewith, means for moving the tip relative to the base, and control means for coordinating the operation of the several means,

the improvement wherein:

the rack has two rows of receptacles for the containers extending longitudinally of the rack,

the means for moving the tip comprises (1) means for moving it back and forth transversely of the rows from a position over a receptacle in one row of the rack to a position over a receptacle in another row of the rack and (2) means for lowering and raising the tip in each of its positions, and

the control means is constructed and arranged to perform one or more cycles, each cycle including the following steps in the order recited:

the rack is advanced in its path to bring a receptacle in one of the rows under the tip, at which time the rack-advancement-ceases,

the tip is moved down into the container under the tip,

the piston is moved through one of its alternate strokes while the tip is in the container,

the tip is raised out of the container,

the tip is moved transversely of the rack to a position over a receptacle in the other row,

the tip is lowered into the container under the tip,

the piston is moved through the other of its alternate strokes,

the tip is raised out of the container, and

the tip is moved transversely back to a position over the first row.

40. In an apparatus for transferring liquids with respect to containers, especially test tubes, comprising a base, means for intermittently moving a test tube holder or rack longitudinally along a path over the base from an initial station to a final station, a movable aspirating and dispensing tip above an intermediate station along the path, positive displacement pump means comprising a piston reciprocable in a cylinder having a port for inlet and outlet of liquid, a flexible conduit conecting the port with the tip, means for lowering and raising the tip relative to the base, and control means for coordinating the operation of the several means, the improvement wherein: the apparatus also comprises means for wiping the tip comprising a rotatable reel carrying a wound supply of an absorbent wiping material in the form of a tape of indefinite length, a driven take-up reel for the tape, means for guiding the tape from the supply reel to the take-up reel along a path adjacent the path of the tip, and means for pressing the tape into wiping engagement with the tip whenever the latter rises.

41. In an apparatus for transferring liquid with respect to containers, especially test tubes, comprising a nozzle, a plurality of receptacles, pump means, a flexible conduit connecting the pump means to the nozzle for communication therebetween, means for moving, relative to one another, the nozzle and the receptacles including means for raising and lowering the nozzle in a path relative to the receptacles, the improvement wherein there is provided nozzle-wiping means comprising a rotatable reel carrying a wound supply of absorbent wiping material in the form of a tape of indefinite length, a driven take-up reel for the tape, means for guiding the tape from the supply reel to the take-up reel along a path adjacent the path of the nozzle, and means for pressing the tape into wiping engagment with the nozzle.

42. Apparatus according to claim 41 comprising means for actuating the pressing means in response to upward movement of the nozzle.

43. In an apparatus for transferring liquids with respect to containers, especially test tubes, comprising a rack having a plurality of receptacles for supporting containers therein, a nozzle, means for intermittently moving the rack to position the receptacles successively under the nozzle, pump means, and a flexible conduit connected to the pump means and the nozzle to provide fluid intercommunication therebetween, an improved nozzle module unit comprising a support, stationary, vertically extending guide rods secured to the support, a cross-head slidably mounted for motion up

and down on the guide rods, a rotatable crank arm having a roller secured thereto and projecting into a guideway in the cross-head, means for rotating the crank arm, and means secured to the cross-head for supporting the nozzle to move it up and down with the cross-head.

44. Apparatus according to claim **42** in which the nozzle module unit also comprises a pair of guide bars inclined to both vertical and horizontal and the nozzle-supporting means is a holder slidable up and down the guide bars.

45. Apparatus according to claim **52** in which the nozzle module unit also comprises a pair of normally spaced-apart sponge rubber pads and means for moving the pads towards each other and gainst the nozzle as it moves upwardly.

46. Apparatus according to claim **42** in which the nozzle module unit also comprises a pair of guide bars inclined to both vertical and horizontal and the nozzle-supporting means is a holder slidable up and down the guide bars, and the module unit also comprises a pair of sponge rubber pads, mounted on rods slidable transversely with respect to the lower ends of the inclined guide bars, spring means for normally holding the pads in an opposed but spaced relationship with each other, and means for urging the pads together against the nozzle when the nozzle moves upwardly.

47. Apparatus according to claim **46** which also comprises means for shifting the inclined guide bars back and forth between two positions so that lowering of the nozzle holder lowers the nozzle into different containers supported in the receptacles of the rack under the two positions and the means for urging the pads together is effective to press them against the nozzle in both positions.

48. Apparatus according to claim **47** in which the means for urging the pads against the nozzle comprises a pair of arms pivotally mounted on parallel horizontal axes and rotatable cam means for swinging the arms on their pivotal axes.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,753,657 Dated August 21, 1973

Inventor(s) Harvey T. Downing, Charles V. Lawson & Byron E. Sturgis

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 14, line 25, "rack tray" should read --rack--.

Column 16, line 40, "surfaces" should read --surface--.

Column 39, line 2, "core" should read --bore--.

Column 42, line 10 (last line of claim 21), "porcessed" should read --processed--.

Column 42, lines 44 and 55 (lines 2 of claims 29 and 31) "mans" should read --means--.

Column 42, line 23 (last line of claim 24), "apparatus" should read --operation--.

Column 42, line 41, (line 5 of claim 28) "before and when" should read --and--.

Column 42, lines 66 and 68 (lines 7 and 9 of claim 32), "front and rear" should read --of the aforesaid two-- in both lines.

Signed and sealed this 1st day of January 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents

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