United States Patent [19]

Gallant

[11] **3,776,700**

[45] **Dec. 4, 1973**

[54] **SERIAL DILUTION APPARATUS**

[75] Inventor: **Reginald R. Gallant**, Bristol, Conn.

[73] Assignee: **Linbro Chemical Co. Inc.**, New Haven, Conn.

[22] Filed: **Dec. 8, 1971**

[21] Appl. No.: **205,828**

[52] **U.S. Cl.**..... **23/259**, 23/253 R, 23/292, 73/423 A

[51] **Int. Cl.. G01n 31/00**, G01n 31/16, G01n 33/16

[58] **Field of Search**..... 23/259, 253 R, 292, 23/230 B, 230 R; 73/423 A

[56] **References Cited**

UNITED STATES PATENTS

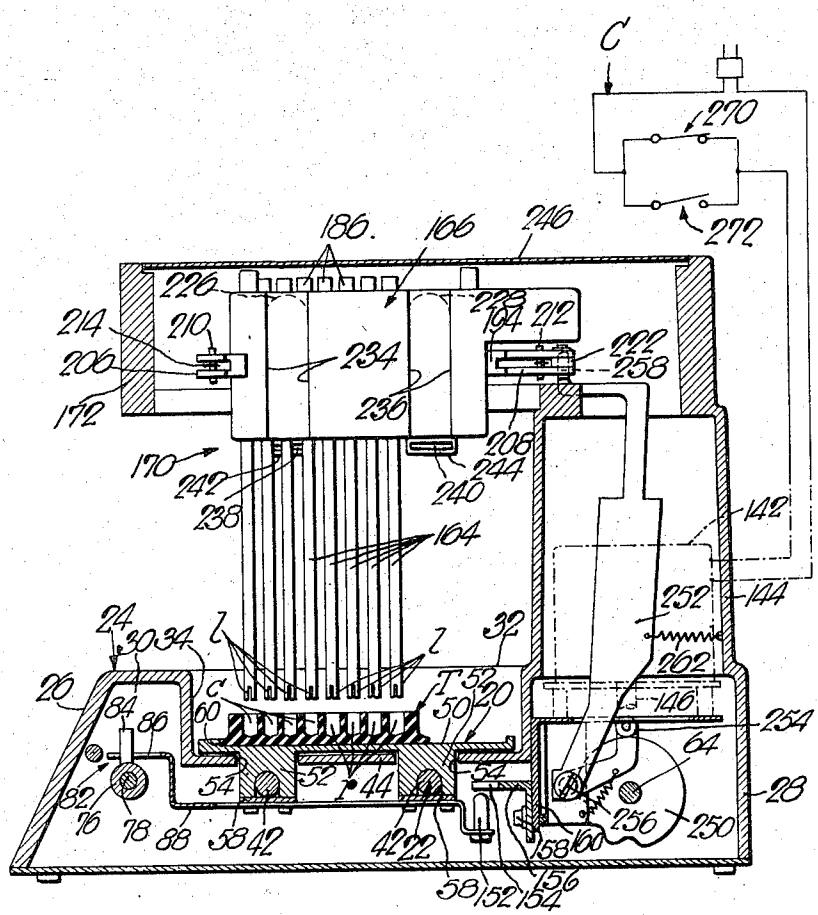
3,578,412	5/1971	Martin	23/259
3,645,690	2/1972	Rochte et al.	23/259 X
3,536,449	10/1970	Astle	23/253 R X
3,484,206	12/1969	Loebl	23/253 R

Primary Examiner—Joseph Scovronek
Attorney—Walter Spruegel

[57] **ABSTRACT**

Apparatus for making serial dilutions in longitudinal titration trays having equally spaced transverse rows of cups, providing an elevator vertically movable into upper and lower positions, a carriage for removably supporting and locating a tray thereon and being supported and guided on the elevator for horizontal movement lengthwise of a located tray, fixed oscillatory loops above the carriage and arranged for their alignment with the cups in any row in a located tray on movement of the carriage on the elevator in its lower position, and for their reach into the aligned cups on movement of the elevator into its upper position, and operating mechanism, including controls, performing in a presettable number of cycles in each of which the elevator is raised to its upper position, the loops are oscillated, the elevator is moved to its lower position, and the carriage is indexed to bring a next cup row in a tray thereon into alignment with the loops.

20 Claims, 11 Drawing Figures



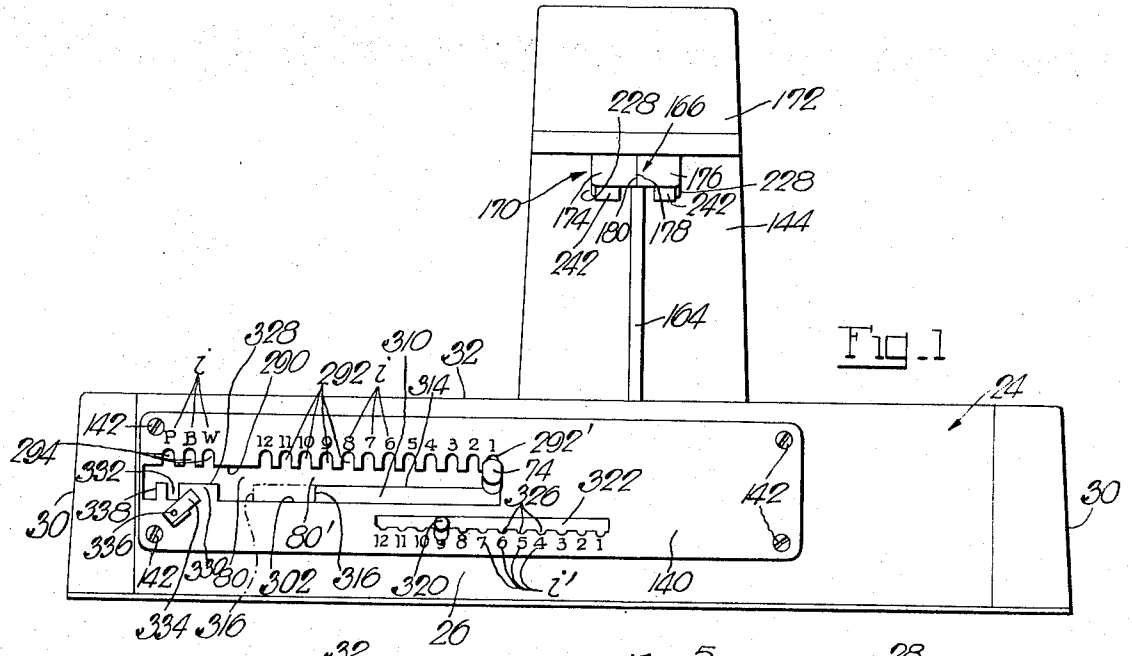


Fig. 1

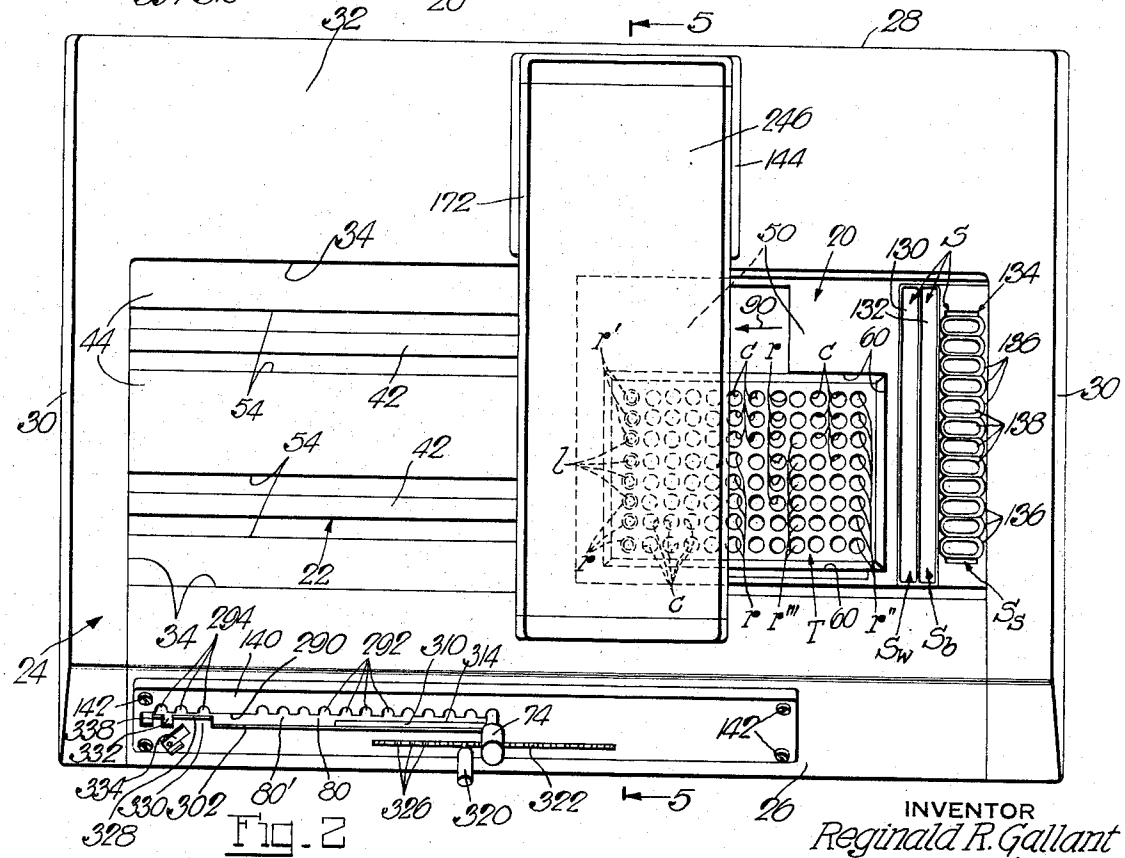


Fig. 2

INVENTOR
Reginald R. Gallant
by Walter Sprung
ATTORNEY

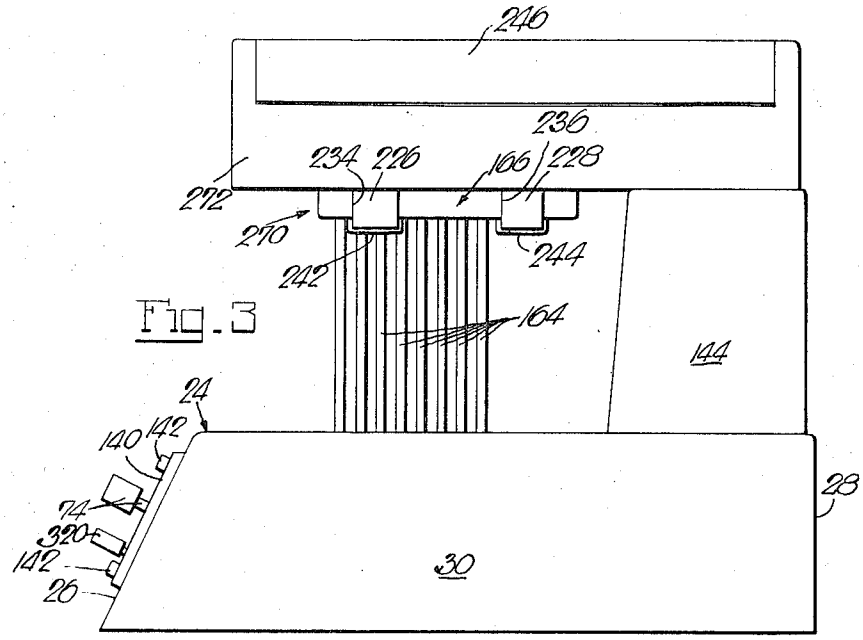


Fig. 3

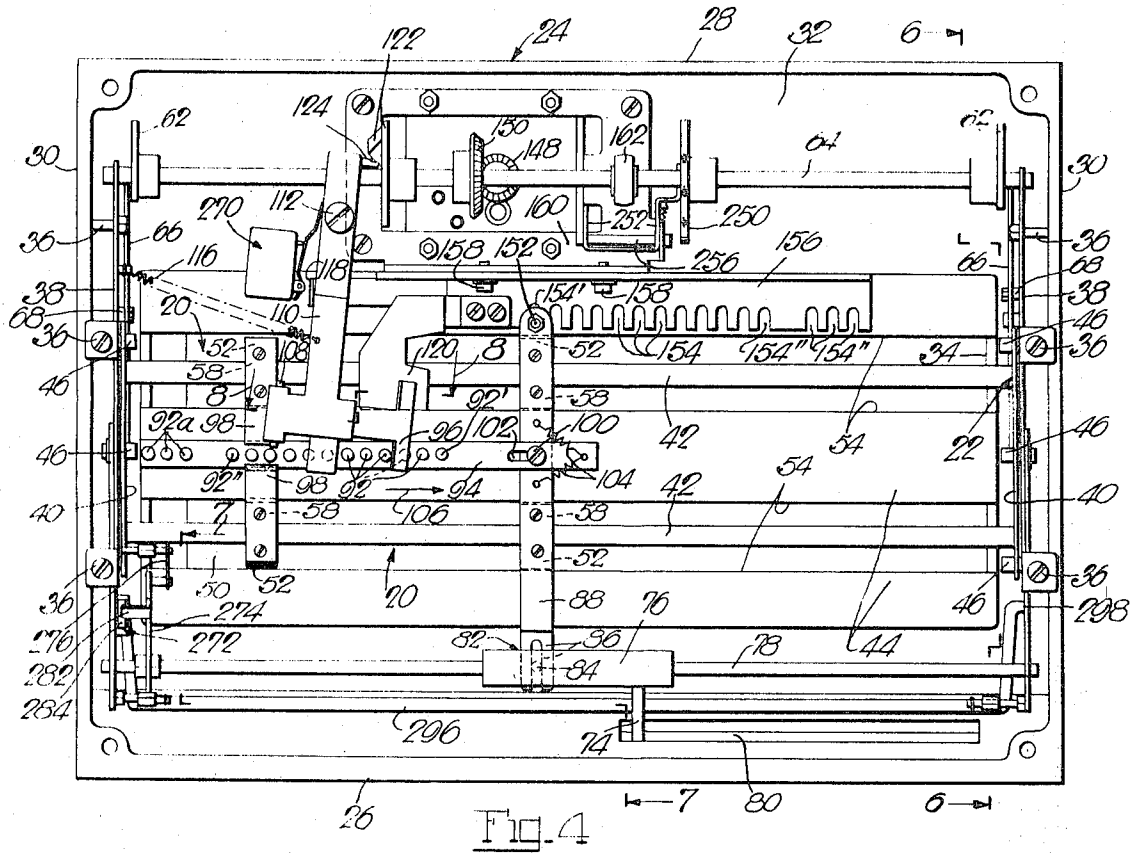


Fig. 4

INVENTOR
Reginald R. Gallant
by Watts Hoffmann
ATTORNEY

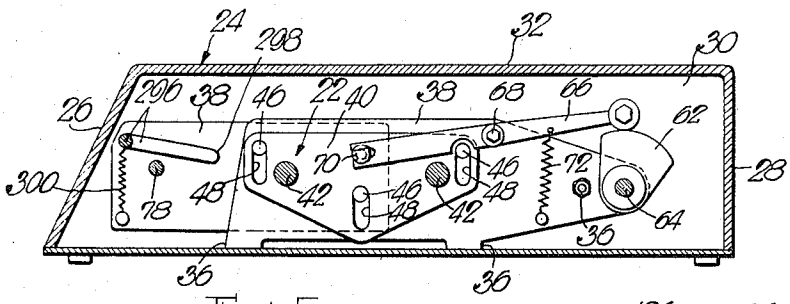


Fig. 6

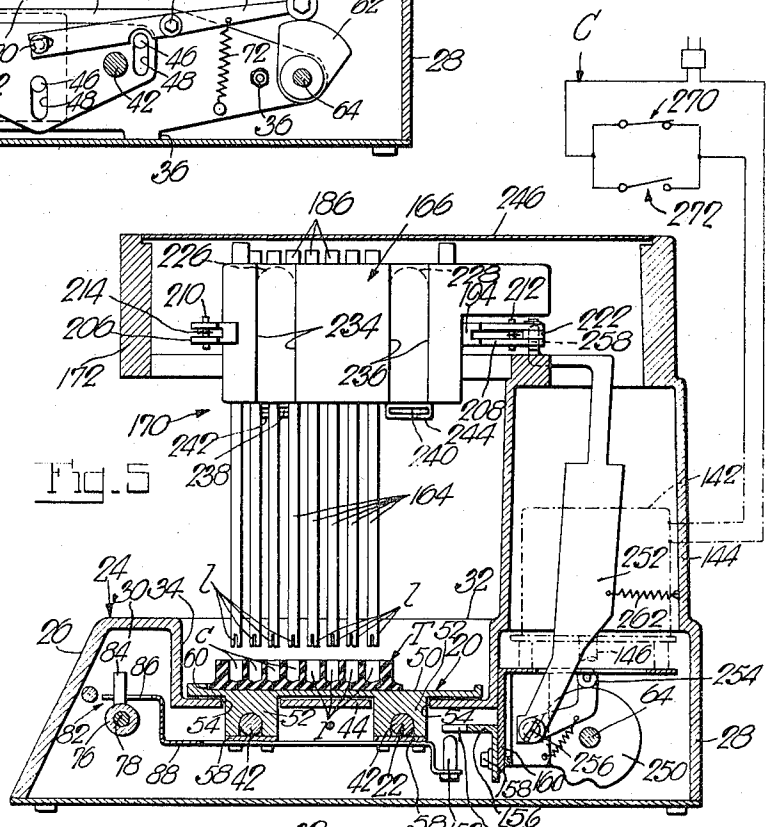


Fig. 5

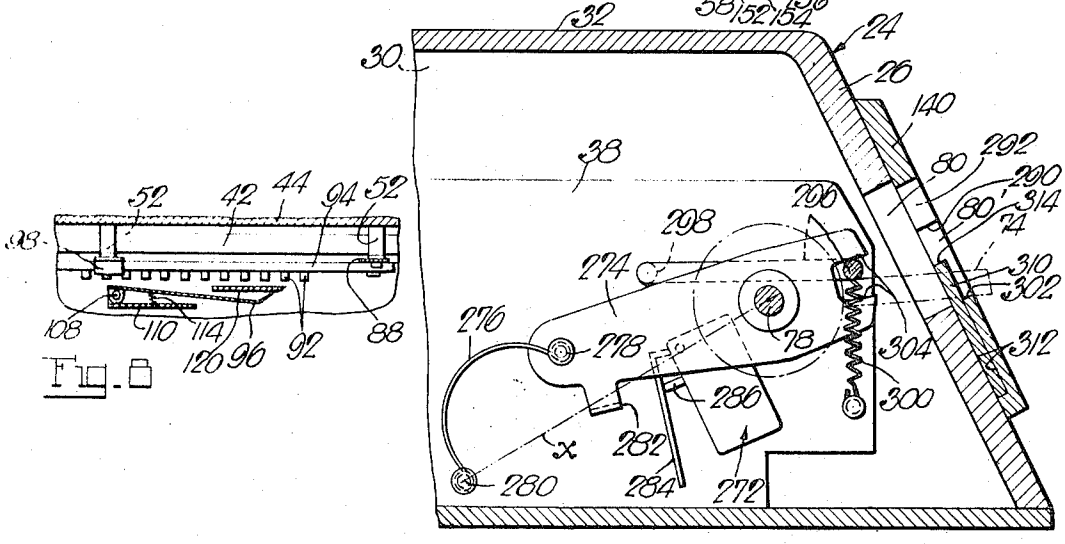


Fig. 7

Fig. 8

INVENTOR
Reginald R. Gallant
By Watts, Hoffmann & Fisher
ATTORNEY

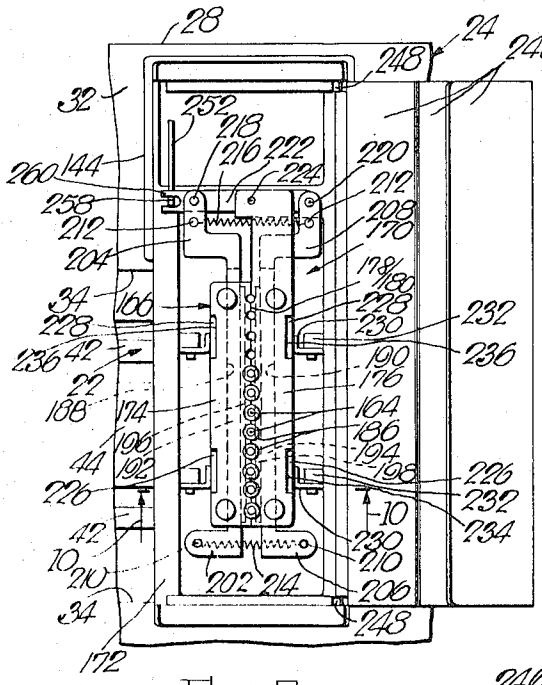


Fig. 9

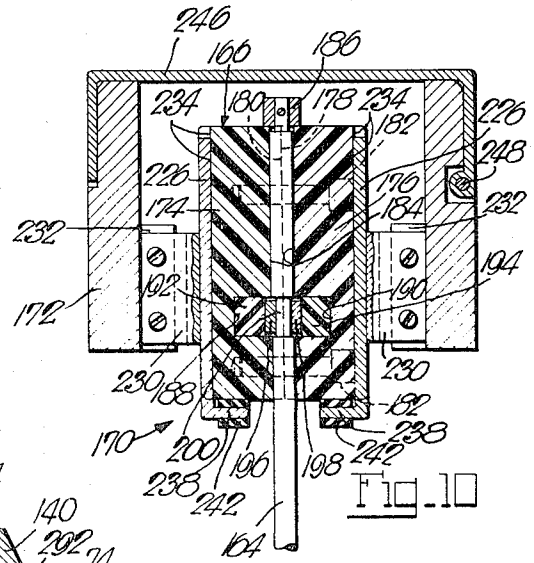


Fig. 10

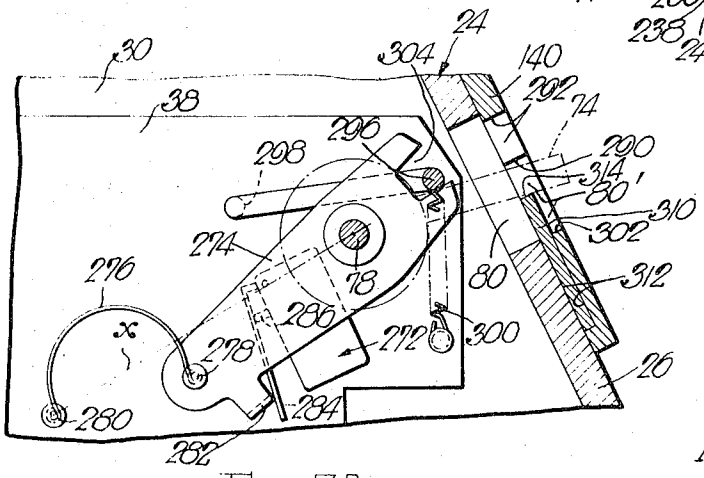


Fig. 7A

INVENTOR
Reginald R. Gallant
By
ATTORNEY

SERIAL DILUTION APPARATUS

This invention relates to laboratory testing equipment in general, and to serial dilution apparatus in particular.

Apparatus of this type perform serial dilutions for various medical tests, involving depositing measured amounts of a particular diluent in rows of cups in a titration tray, adding to the diluent in the cups of one row a measured amount of a sample liquid to be essayed for a virus, for example, mixing the diluent and test liquid in the respective cups, transferring a measured amount of these mixed liquids into the cups of the next succeeding row, and repeating the mixing of liquids in, and the transfer of measured amounts thereof to, succeeding rows of cups, thereby to provide progressively decreasing concentrations of the test liquid in the cups of succeeding rows. So-called loops are customarily used in mixing and transferring the liquids, with these loops being introduced into the cups and turned for mixing the liquids therein, and carrying measured amounts of the mixed liquids on their removal from the cups of one row and introduction into the cups of the next row.

Prior apparatus of this type customarily provide a carriage on which to locate a titration tray, a row of loops, means for indexing the carriage to align the cups of successive rows in the tray with the loops, and lowering the loops into and raising them from the aligned cups in each row and also oscillating the loops while lowered in the cups. Some of these prior apparatus have manually initiated cyclic performance in intermittently indexing the carriage and operating the loops in a built-in pattern. While these prior apparatus are satisfactory in most respects, they are lacking in at least one important respect which has to do with the accuracy of the test result of any particular dilution series. The accuracy of the test result of any dilution series depends very much on the transfer of equal volumes of liquid from the cups of one row to the cups of the next succeeding rows, which is a most exacting requirement considering that the volume of diluent in each cup is exceedingly mixing the diluent and test liquid in the respective cups, transferring a measured amount of these mixed liquids into the cups of the next succeeding row, and repeating the mixing of liquids in, and the transfer of measured amounts thereof to, succeeding rows of cups, thereby to provide progressivly decreasing concentrations of the test liquid in the cups of succeeding rows. So-called loops are customarily used in mixing and transferring the liquids, with those loops being introduced into the cups and turned for mixing the liquids therein, and carrying measured amounts of the mixed 0liquids on their removal from the cups of one row and introduction into the cups of the next row.

Prior apparatus of this type customarily provide a carriage on which to locate a titration tray, a row of loops, means for indexing the carriage to align th cups of successive rows in the tray with the loops, and lowering the loops into and raising them from the aligned cups in each row and also oscillating the loops while lowered in the cups. Some of these prior apparatus have manually initiated cyclic performance in intermittently indexing the carriage and operating the loops in a built-in pattern. While these prior apparatus are satisfacotry in most respects, they are lacking in at least one important respect which has to do with the accuracy of the test result of any particular dilution series. The accuracy of the rest result of any dilution series depends very much on the transfer of equal volumes of liquid from the cups of one row to the cups of the next succeeding rows, which is a most exacting requirement considering that the volume of diluent in each cup is exceedingly small, usually one or two drops, and the volume of liquid picked up and transferred by each loop is equally small or even smaller. Thus, with serial dilution involving such very small liquid volumes, evaporation of liquid may adversely affect the transfer of equal liquid volumes, yet there is no possible way to check the volumes of transferred liquids in the course of a dilution series performance of an apparatus. In this connection, it has been found from experience that liquid evaporation may become a disturbing factor in the transfer of equal liquid volumes by virtue of mechanical lowering and raising of the loops and ensuing impingement of the surrounding air on the liquid being transferred by the loops. Further, the small volumes of liquid transferred by the loops are held therein by surface tension, wherefore some liquid is occasionally jarred loose in the course of lowering and raising the loops.

It is among the important objects of the present invention to provide apparatus of this type in which in the operational transfer of liquid from cup to cup, the liquid undergoes no motion in space, thereby to avoid undetectible inaccuracies of possibly serious consequences in the test results of dilution series stemming from loss of liquid in transfer either by evaporation or by gravitation, or both.

It is another object of the present invention to provide apparatus of this type in which loops, that are generally used, and particularly well suited, for picking up and holding accurate assigned liquid volumes and also mixing their liquid content with liquids in the cups, are also used with more accurate results than heretofore in transferring equal liquid volumes from cup to cup, by imparting no motion to the liquid in transfer as beforementioned. To this end, the loops are held bodily immovable in the apparatus, and the carriage on which a titration tray is supported and located, undergoes all the motions required for the transfer of liquid from cup to cup, with these motions being indexing steps of the carriage for aligning the cups in successive rows with the loops, and raising and lowering the carriage for bringing the liquid in the cups of each row in the tray into and from dip relation with the loops, and the loops being merely oscillated about their longitudinal axes when in dip relation with liquid in the cups for mixing their liquid content with that of the cups.

It is a further object of the present invention to provide apparatus of this type in which the aforementioned tray carriage is for its indexing motions movable on a track on an elevator which between indexing steps of the carriage is raised and lowered for bringing the liquid in each row of cups in a tray into and from dip relation with the overhead loops. Further, for intermittently indexing the carriage through successive steps in a given operating direction, the carriage is provided with depending rack teeth in the preferred form of spaced pins which in the lower position only of the elevator are in operative relation with an indexing pawl, and there is further provided on the carriage an upright pilot pin which, on each operational rise of the carriage and, hence, retraction of the same from operating relation with the indexing pawl, moves into register with

one of a series of fixed locating holes, with these holes being coordinated with the cup rows in a located tray on the carriage such that on register of the dowel pin with any one of these holes the carriage is locked in position on the elevator track in which the cups in the coordinated row in the located tray are in accurate alignment with the loops. With this arrangement, the tray carriage is in all of its multi-directional operational motions alternately locked in accurate coordination with the indexing pawl and with the loops, with the dowel pin and locating holes cooperating to lock the carriage on each rise in accurate coordination with the loops, and to guide the carriage on each return to its lower position into accurate operating relation with the indexing pawl.

Another object of the present invention is to provide apparatus of this type which has a casing with opposite front and rear walls, opposite end walls, and a top wall, and the elevator and indexing pawl and their operating components are arranged inside the casing and, hence, hidden from view, while the tray carriage is arranged above the top wall for ready access of a tray into located support on the carriage and its operational rise to and descent from the overhead loops. To this end, the tray carriage has depending lugs which project through space longitudinal slots in the top wall of the casing and are slidably supported on the elevator track inside the casing as well as support the depending rack pins, with the elevator being conveniently formed by spaced end plates and spaced parallel connecting and bracing bars between the end plates, of which the connecting bars from the elevator track, and the end plates are guided for vertical movement on the adjacent end walls of the casing, and are in follower relation with identical cams for operational raising and lowering of the elevator.

A further object of the present invention is to provide apparatus of this type in which the aforementioned cams for operation of the elevator are arranged for positive lowering of the elevator and for spring-urged rise of the same under the control of the cams, thereby to avoid any possible jamming of and likely damage to the elevator or tray carriage thereon if either should perchance encounter any obstacle in the course of their programmed rise.

It is another object of the present invention to provide apparatus of this type in which the aforementioned indexing pawl is also cam-operated, and is spring-urged against a fixed run-off track which holds the pawl out of reach of any rack pin on the tray carriage throughout each operational pawl reciprocation, except during a latter part of its forward or indexing stroke when the pawl clears this track and snaps into the path of the nearest rack pin for indexing the carriage one step, with the pawl being, after passage through the same initial part of its return stroke, dragged back onto the run-off track. In thus providing the run-off track, the operating stroke of the indexing pawl may be of a length best suited for effective and most convenient cam operation of the pawl, and may even surpass the necessarily narrow spacing of the rack pins in keeping with the existing narrow spacing of successive cup rows in titration trays, yet the pawl will on successive operating strokes reliably cooperate with successive rack pins in indexing the carriage through successive steps of the required short length. Even more important, repose on the run-off track of the indexing pawl in idle condition of the apparatus with the tray carriage then in its lower position, permits manual movement of the tray carriage on the elevator track into any desired position thereon, with the ensuing advantages of enabling an attendant to position the carriage for starting a dilution series with any cup row in a located tray, or position the carriage for alignment with the loops of contemplated loop washing, blotting and sample pick-up provisions at designated loop service stations on the carriage, as well as quickly to move the carriage to a position in which readily to remove a tray from the carriage and replace it with another tray without interference from the overhead loops.

It is a further object of the present invention to provide apparatus of this type in which the rack pins on the tray carriage depend from a separate member which is suspended from the carriage and has with the latter a lost-motion connection in indexing direction, and spring means urge the member to one end of the lost-motion connection at which the force of the spring means is normally effective to transmit the pawl-induced index motion of the member to the carriage, but any pawl-induced index motion of this member is toward the oposite end of its lost-motion connection with the carriage and, hence, relative to the latter, if the carriage should encounter any obstruction to its follower response to the member, whereby operational jamming of the carriage and likely damage to the same and also to the indexing parts are avoided in case of such obstruction.

Another object of the present invention is to provide apparatus of this type in which for the aforementioned manual movement of the tray carriage in idle condition of the apparatus, there is provided a handle which is coupled with the carriage for movement with the latter on the elevator, and which projects through a longitudinal slot in the front wall of the casing to the outside thereof where it is within ready manipulative reach of an attendant.

A further object of the present invention is to provide apparatus of this type in which the aforementioned slot in the front wall of the casing through which the handle on the tray carriage extends, is provided with appropriate stop marks which in readily perceptible manner are coordinated with corresponding cup rows in a located tray on the carriage and with corresponding ones of the aforementioned loop service stations on the carriage, and to either one of these stop marks the handle may be moved to thereby bring the coordinated cup row in a located tray, or the coordinated loop service station, on the carriage into alignment with the overhead loops in a manner which is quicker and far more accurate than if the attendant would gauge such alignment from observation of a located tray or of the loop service stations on the carriage in relation to the overhead loops.

It is another object of the present invention to provide apparatus of this type in which, besides cam operation of the elevator and of the indexing pawl for the tray carriage, the loops are operationally oscillated also by cam action, with all cams involved being operatively connected with a constant-speed prime mover, preferably a synchronous motor, for accurate timing of each cyclic performance of the various operating components, and the cams being phased for each cyclic performance of their operating components in the sequence of raising the elevator, oscillating the loops, lowering the elevator, and indexing the tray carriage one step in the given direction. With this arrangement,

and by virtue of the aforementioned manual alignment, in idle condition of the apparatus, of any cup row in a located tray, or any of the loop service stations, on the carriage with the loops and, hence, preset of the apparatus for different cycles of operation from various starting positions of the tray carriage, complete control over the start and conclusion of any of these different cycles of operation of the apparatus is achieved advantageously by a switch in the circuit of the synchronous motor, with this switch being preferably closed manually for the start of any cycle of operation at the election of an attendant.

It is a further object of the present invention to provide apparatus of this type in which the aforementioned stop marks at the slot in the front wall of the casing are notches, preferably with identification marks, in the upper side wall of this slot, and the aforementioned coupling between the handle and carriage is of flexible type to permit manual lift of the handle into fitting register with any of these notches on prior alignment therewith, with the aforementioned switch in the circuit of the synchronous motor being associated with this handle so as to be closed thereby on manual lift of the handle into register with any of these notches, and a control then taking over to keep this switch closed not only on release of the lifted handle and its preferably spring-urged drop back into the slot, but until conclusion of the preset cycle of operation of the apparatus. With this arrangement, manual alignment of any selected cup row in a located tray, or of any of the loop service stations, on the carriage with the loops prior to starting a cycle of operation of the apparatus, is particularly accurate and foolproof due to the requirement of manually lifting the handle on the carriage into fitting register with one of the notches in the slot which are easily coordinated with the cup rows in a located tray, and with the loop service stations, on the carriage for such accurate alignment. Moreover, an attendant may release the handle immediately after it is lifted into register with a notch.

Another object of the present invention is to provide apparatus of this type in which, for most efficient and simplest cyclic performance of the apparatus, the tray carriage will, in one end position, align an end row, i.e., the "first" row, of cups in a located tray thereon with the overhead loops, and will, on successive indexing steps from this end position in the given index direction, align all successive cup rows with the loops, and the carriage will only on subsequent successive indexing steps align the successive loop service stations thereon with the loops. Therefore, in order to achieve any desired start of a cycle of operation of the apparatus in positioning the tray carriage in the proper cycle-start position by aligning its handle with the corresponding notch in the front slot in the casing and then lifting it into momentary register therewith, it is imperative that these notches, in their succession from one end of this slot in index direction of the tray carriage, are by their marks idenfified with the first and all succeeding cup rows in a located tray on the carriage and then with the successive loop service stations on the carriage.

A further object of the present invention is to provide apparatus of this type which affords many more variations in dilution series over and beyond those afforded by selective positioning of the tray carriage in any of the numerous cycle-start positions. To this end, the aforementioned control for concluding any cycle of operation of the apparatus, is presettable to open the circuit switch at the conclusion of any preselected indexing step of the tray carriage with which the dilution series is to conclude. This presettable control is in the form of a control bar which is guided in the front wall of the casing for manual movement parallel to the slot therein to and from coextension with the latter over any desired part of a given length thereof, starting at the aforementioned one end thereof, and ending in the vicinity of that notch in the slot which is associated with alignment of the last cup row in a located tray with the loops, with this bar extending, over any coextension with the slot, widthwise part-way into the latter and being with its top edge equally spaced from the notched upper side wall of this slot, and the circuit switch being arranged to be closed only on lifting the carriage handle into register with any of the notches in the slot as aforementioned, to remain closed while the carriage handle rests on the top edge of the bar and slides thereon with each indexing step of the carriage, and is opened when in the course of an indexing step of the carriage the handle drops from th end of the bar onto the lower side wall of the slot. With this arrangement, the control bar may manually be set for drop-off of the carriage handle onto the lower slot wall in the course of any dilution series, and more particularly during any selected one among all the indexing steps of the carriage available for serial dilution procedures, including a last indexing step following alignment of the last cup row in a located tray with the loops.

It is a further object of the present invention to provide apparatus of this type in which the three remaining notches in the front slot in the casing for alignment of the loop-service stations on the tray carriage with the overhead loops, are arranged, in their succession from first to third in index direction of the carriage, for alignment with the loops of the washing, blotting and pick-up stations in that preferred order, and the slot has built-in provisions for holding the carriage handle, after its release from register with the first or third notch, respectively, in position in which the circuit switch remains closed, and for shifting the carriage handle to cause opening of this switch during the indexing step of the carriage following alignment with the loops of the blotting station of pick-up station, respectively.

Another object of the present invention is to provide apparatus of this type in which any cycle of operation thereof is sufficiently prolonged beyond the opening of the circuit switch during the last indexing step of the tray carriage in the preset cycle, to prevent the apparatus from coming to rest while the indexing pawl is still off its run-off track and, hence, would block manual movement of the carriage at least counter to its index direction in idle condition of the apparatus. This is achieved by providing in the motor circuit a second, normally-closed switch which is in parallel with the switch associated with the carriage handle, and is opened by the indexing pawl when in its retracted position.

Further objects and advantages will appear to those skilled in the art from the following, considered in conjunction with the accompanying drawings.

In the accompanying drawings, in which certain modes of carrying out the present invention are shown for illustrative purposes:

FIG. 1 is a front elevation of apparatus embodying the invention;

FIGS. 2 and 3 are top and side views, respectively, of the apparatus;

FIG. 4 is a bottom view of the apparatus;

FIG. 5 is a section through the apparatus taken substantially on the line 5—5 of FIG. 2;

FIG. 6 is a section through the apparatus taken on the line 6—6 of FIG. 4;

FIG. 7 is an enlarged fragmentary section through the apparatus taken substantially on the line 7—7 of FIG. 4;

FIG. 7A is a fragmentary section similar to FIG. 7, but with certain operating parts in a different position;

FIG. 8 is a fragmentary section through the apparatus taken substantially on the line 8—8 of FIG. 4;

FIG. 9 is a top view of a part of the apparatus, with a cover being shown in open position to bring a normally covered assembly unit into view;

FIG. 10 is an enlarged section taken substantially on the line 10—10 of FIG. 9.

Referring to the drawings, there is shown apparatus which lends itself to serial dilutions for various medical tests such as hemagglutionation tests for various antibodies, diagnostic complement fixation tests, hemagglutination inhibition tests, tests for essaying viruses, and virus neutralization tests. Serial dilutions involve the use of titration trays in the apparatus. FIGS. 2 and 5 show a typical titration tray T which has been placed in the apparatus for a serial dilution procedure. The tray T, which is customarily molded of transparent plastic, is of rectangular outline and has in its top a multiplicity of depressions in the form of cups *c* which are arranged in equally spaced transverse rows *r*, with the cups in each row being also equally spaced. A typical serial dilution procedure may involve, for example, charging a tray T while removed from the apparatus, by depositing a measured amount of diluent in the cups of all rows *r*, except those of an end row in which a measured amount of a liquid sample or test substance is deposited. The tray thus charged is then placed in the apparatus, whereupon the latter takes over in raising the tray to bring the sample charge in the end row of cups into dip relation with overhead loops l (FIG. 5) which by surface tension and/or capillary action retain a given amount of the sample charge. The tray is next lowered, then shifted horizontally to bring the cups in the next row into alignment with the loops, and is again raised to bring the aligned cups into dip relation with the loops, whereupon the latter are oscillated to thereby mix their sample content with the diluent in the cups and leave in the latter a mixture of both in which the sample specimen is in a first diluted state. Oscillation of the loops is then stopped just prior to lowering the tray in order that the loops may pick up a given amount of the mixture in the cups while still in dip relation with the loops. Once lowered, the tray is again shifted horizontally to bring the cups in the next row into alignment with the loops, the tray is then raised to bring the diluent in the aligned cups into dip relation with the loops, whereupon the latter are again oscillated for mixing their charges with those in the cups, followed by renewed lowering of the tray after pick-up by the loops of a given amount of the mixture in those cups in which the sample specimen is then in a second, more advanced diluted state. This procedure is repeated over and over until the cups in a particular row hold a mixture in which the sample specimen is in a prescribed final diluted state.

In order that the apparatus will perform in this fashion, the same has for its major operating components a Tray Supporting And Operating Mechanism, A Loop Assembly And Loop Operating Mechanism, and Operating Controls.

TRAY SUPPORTING AND OPERATING MECHANISM

For the support of a tray and for its multi-directional operational movements, the same is placed on a carriage **20** which is supported and guided for horizontal movement on an elevator **22** that is, in turn, mounted in a casing **24** for vertical movement into upper and lower positions. The casing **24** has in this instance front and rear walls **26** and **28**, opposite side walls **30**, and a top wall **32** with a recess **34**. Suitably secured to the side walls **30** of the casing, as at **36**, are mounting brackets **38** for the elevator **22** (FIGS. 4 and 6). The elevator **22** comprises in this instance opposite end plates **40** and horizontal connecting bars **42** which extend longitudinally of the casing below the bottom wall **44** of the recess **34** therein (see also FIG. 5), with the elevator being guided for vertical movement by studs **46** which extend from the end brackets **38** into vertical slots **48** in the conveyor end plates **40** (FIGS. 4 and 6).

The tray carriage **20** provides a longitudinal plateform **50** which is located in the casing depression **34** (FIGS. 2 and 5), and has two longitudinally spaced pairs of depending lug formations **52** of which those of each pair extend into the interior of the casing through longitudinal slots **54** in the bottom wall **44** of the casing recess **34** (FIGS. 4 and 5). These depending lug formations **52** have spaced prongs which reset on and having a sliding fit with the respective elevator bars **42**, and they are held thereon by retainer pieces **58** (FIG. 5). The carriage **20** is thus supported on the elevator **22** and guided thereon for horizontal movement longitudinally of the casing **24**. The carriage has in its exposed platform **50** suitable raised shoulders **60** for placement thereagainst of a tray in properly located position on the platform in which the tray extends lengthwise parallel to the guided motion path of the carriage on the elevator and the cups *c* in each row *r* in the tray may be brought into alignment with the overhead loops *l* on moving the carriage on the elevator **22** in its lower position (FIGS. 2 and 5).

As already mentioned, the elevator **22** is movable into a lower position in which the cups in a located tray on the carriage **20** are below the overhead loops (FIG. 5) and the elevator is also movable into an upper position (not shown) in which the loops *l* reach into aligned cups in any row in a located tray. To the end of moving the elevator **22** into its upper and lower positions, there are provided a pair of identical cams **62** on a drive shaft **64** which is suitably journalled with its ends in the mounting brackets **38** (FIGS. 4 and 6). Cooperating with these cams **62** are follower arms **66** which at **68** are pivoted on the respective mounting brackets **38** and have floating pivot connections **70** with the respective end plates **40** of the elevator. The arms **66** are by springs **72** urged into follower engagement with the respective cams **62** (FIG. 6), so that the cams positively move the elevator to its lower position, and the springs **72** urge and move the elevator into its upper position under the control of the cams **62**.

To move the carriage 20 on the elevator for alignment of the cups in any row in a located tray with the overhead loops *l*, there is provided a handle 74 on a sleeve 76 which is slidable on a fixed rod 78 that is suitably anchored with its ends in the mounting brackets 38 (FIG. 4). This handle projects through a longitudinal slot 80 in the front casing wall 26 to the outside of the casing so as to be readily accessible to an operator for manipulation (FIGS. 1, 2, 4 and 7), and the sleeve 76 is at 82 coupled with the carriage, whereby on movement of the handle 74 along the slot 80, the carriage 20 is moved on the elevator 22. Since the handle-carrying sleeve 76 on the fixed rod 78 cannot participate in the operational rising and lowering motions of the carriage 20 with the elevator 22, the coupling 82 is of flexible type, providing in this instance an upright pin 84 on the sleeve 76 and a fork projection 86 on the carriage above the sleeve 76 (FIGS. 4 and 5), with the pin 84 projecting into the fork projection 86 in either the lower or upper elevator position and thus retaining the sleeve 76 in operative coupled relation with the carriage at all times. The fork projection 86 is in this instance formed by a strap 88 which is secured to one of the pairs of depending lug formations 52 on the carriage platform 50 (FIGS. 4 and 5).

There is also provided indexing mechanism for moving the tray carriage 20 on the elevator 22 through intermittent steps equal to the spacing of successive cup rows in a tray. Thus, on aligning the cups in any row in a located tray on the carriage with the overhead loops *l* by manipulation of the handle 74 along the slot 80 (FIG. 2), the mechanism, when operating, will index the carriage in successive steps in one direction, i.e., the indexing direction indicated by arrow 90 in FIG. 2, to thereby bring the cups in the next successive rows in the tray into alignment with the overhead loops. To this end, the mechanism provides a row of rack teeth in the preferred form of pins 92 which depend in this instance from a flat bar 94 on the carriage, and a reciprocatory pawl 96 which is to cooperate with successive pins 92 in indexing the carriage through successive steps (FIGS. 4 and 8). More particularly, the flat pin bar 94 is mounted for longitudinal movement in indexing direction between gibs 98 on the rearmost pair of depending lug formations 52 on the carriage platform 50, and by a screw 100 which projects through a longitudinal slot 102 in the bar 94 and is threadedly received by the strap 88 on the foremost pair of depending lug formations 52 on the carriage platform (FIG. 4). The screw 100 and slot 102 form a lost-motion connection between the carriage 20 and the pin bar 94, and the latter is by springs 104 normally urged to one end of this lost-motion connection as shown in FIG. 4. The pawl 96 operates on an indexing stroke to engage the nearest pin 92 and move the pin bar 94 one step in indexing direction which in FIG. 4 is indicated by the arrow 106, and the force of the springs 104 will normally drag along the strap 88 and, hence, the carriage 20. However, if in the course of a pawl-induced indexing step of the pin bar 94 the carriage 20 should encounter any obstacle to its follower motion with the pin bar, the carriage will simply stop and the pin bar will harmlessly move to the other end of its lost-motion connection with the carriage strap 88, as will be readily understood.

The pawl 96 is at 108 pivotally mounted on one end of an arm 110 which, in turn, is at 112 pivotally mounted in the casing 24 (FIGS. 4 and 8) and a spring 114 between the arm 110 and pawl 96 urges the latter against the pin bar 94. The pawl 96 and its arm 110 are by a spring 116 urged into retracted or home position (FIG. 4) in which the arm rests against a fixed stop lug 118 and the pawl rests on a fixed track 120 and is thereby held out of reach of the pin bar 94. The drive shaft 64 carries an indexing cam 122 with which the pawl arm 110 is in follower relation as at 124. During each turn of this cam 122, the pawl 96 will have an indexing stroke from home position, followed by a return stroke to home position, with the pawl on its indexing stroke riding off the track 120 and engaging the nearest pin 92 to index the carriage one step, with this pin being the foremost pin 92′ in the exemplary carriage position in FIG. 4 which corresponds to the carriage position in FIG. 2, and the pawl on its return stroke overriding the pin to be indexed next and riding onto the track 120. Accordingly, the carriage 20 may at the handle 74 be moved on the elevator 22 in either direction without interference from the pawl 96 whenever the latter is in its home position. Of course, with a tray on the carriage, the latter may manually be moved in this fashion only when the elevator is in its lower position (FIG. 5), for such carriage movement would be interfered with by the tray and the loops *l* if the elevator were in its upper position. Also, the indexing pawl 96 is only operative when the elevator is in its lower position, for on movement of the elevator to its upper position the pin bar 94 on the carriage rises with the elevator, i.e., out of operative reach of the pawl 96.

As already mentioned, the indexing mechanism is so arranged that on successive indexing steps of the carriage the cups in successive rows in a located tray are brought into alignment with the loops *l*. Thus, with the carriage 20 being in the exemplary end position in FIGS. 2 and 4 in which the cups in a first row *r′* in the located tray are in alignment with the loops *l*, the pawl 96 will on its first indexing stroke cooperate with the foremost pin 92′ in indexing the carriage one step to bring the cups in the next row in the tray into alignment with the loops, and the pawl will on further successive indexing strokes cooperate with the next successive pins 92 in indexing the carriage through successive steps to bring the cups in the next successive rows in the tray into alignment with the loops, with the pawl, when cooperating with the rearmost pin 92″ (FIG. 4) indexing the carriage to bring the cups in the last row *r″* in the tray out of alignment with the loops (FIG. 2).

The tray carriage 20 is in this instance also provided with a plurality of loop service stations S which are spaced rearwardly from a located tray and are spaced from each other as the cup rows in a tray, with these stations being a loop-washing station S_w, a loop-blotting station S_b and a sample-supply or pick-up station S_s, in that order, and the loop-washing station S_w being among these stations the one leading in the indexing direction of the carriage (FIG. 2). The loop-washing station S_w provides an elongated tray 130 holding any suitable loop-washing substance, such as distilled water, for example, which, on alignment of this station with the loops *l* and subsequent operational rise of the elevator 22 to its upper position, is in dip relation with the loops so that on their operational oscillation they are being washed. The loop-blotting station S_b provides a similar elongated tray 132 that holds any suitable spongy material, for example, which will dry wet loops

l, especially after washing, when brought into engagement therewith on first aligning this station with the loops and on the subsequent operational rise of the elevator to its upper position, followed by operational oscillation of the loops. The samply-supply or pick-up station S_s provides in this instance a shelf **134** with a row of receptacles **136** for vials **138** that may hold any particular liquid sample or test substance or substances which, on prior alignment of this station with the loops and subsequent operational rise of the elevator to its upper position, will be in dip relation with teh loops, so that on conclusion of the following operational oscillation of the loops the same will retain given amounts of sample substance. Either one of the loop-service stations S may manually be brought into alignment with the overhead loops *l* by shifting the handle **74** along the slot **80** in the casing wall **26,** with the carriage **20** following on the elevator **22** in its lower position.

For accurate manual alignment of any cup row in a located tray on the carriage **20,** or of any of the loop service stations S on the latter, with the overhead loops *l*, on manually moving the handle **74** along the slot **80** in the casing wall **26,** there are provided along this slot suitable stop marks with which to align the handle to thereby achieve corresponding alignment of any cup row or loop service station with the loops. These stop marks are indicia *i* along the slot **80** in the casing wall **26,** and they are in this instance provided along a slot **80'** which is lengthwise coextensive with the slot **80** and provided in a longitudinal control plate **140** which at **142** is secured to the front casing wall **26** at the outside thereof (FIGS **1, 2** and **7**), with the indicia *i* being in this instance numerals from "**1**" to "**12**" identified with successive cup rows in a located tray, starting with the first cup row *r'* and ending with the last cup row *r''*, and being exemplary letters "W," "B" and "P" identified with the loop-washing station S_w, the loop-blotting station S_b, and the sample-supply or pick-up station S_s, respectively. Thus, on shifting the handle **74** along the slot **80, 80'** into alignment with the "**1**" indicium, as in FIG. **1,** the first or leading cup row *r'* in a located tray on the carriage **20** will be in accurate alignment with the overhead loops *l*. Should it be desired to align the ninth cup row *r'''*, for example, in a located tray with the overhead loops *l*, it is merely necessary to shift the handle **74** along the slot **80, 80'** into alignment with the "**9**" indicium. Should it be desired to shift any of the loop service stations into alignment with the overhead loops *l*, it is merely necessary to shift the handle **74** along the slot **80, 80'** into alignment with the corresponding "W," "B" or "P" indicium.

The pin bar **94** is provided with **3** additional pins **92***a* (FIG. **4**) which are associated with the loop service stations S, respectively, on the carriage, and may cooperate with a pawl **96** in indexing the carriage through successive steps, for example, to bring the successive stations S_w, S_b and S_s out of alignment with the overhead loops l on first aligning the first station S_w with the loops on moving the carriage at the handle **74.**

As described, the elevator **22** is moved to its upper and lower positions by the cams **62** on the drive shaft **64,** and the carriage indexing mechanism is operated by the cam **122** on the same drive shaft **64,** with this drive shaft **64** being operated by a prime mover which is perferably a synchronous motor **142** suitably mounted in an upright hollow column **144** which is preferably cast integrally with the casing **24** (FIG. **5**). The motor **142** carries on its output shaft **146** a bevel gear **148** which is in mesh with a bevel gear **150** on the drive shaft **64** for the drive of the latter.

Any operational rise of the elevator **22** to its upper position is for the designated purpose of bringing within operative reach of the overhead loops the aligned cups in a row in a located tray on the carriage or an aligned loop service station S on the latter. To make certain that on such elevator rise a cup row in a located tray or a loop service station S will remain in alignment with the loops l, or if need be, even brought into more accurate alignment with the loops, and be held locked in such alignment with the loops while the elevator is in its upper position, there is provided on the carriage strap **88** an upright pilot pin **152** which is to cooperate with slots **154** in a locating bar **156** which at **158** is mounted on a bracket **160** that is, in turn, suitably mounted in the casing **24** and provides an additional bearing **162** for the drive shaft **64** (FIGS. **4** and **5**). The slots **154** are coordinated with the overhead loops l so that on operational rise of the elevator to its upper position, the pilot pin **152** will rise into register with an aligned slot **154** and thereby lock the carriage in the particular alignment position on the elevator in which a corresponding cup row in a located tray or a corresponding loop service station S on the carriage is in accurate alignment with the loops. Thus, with the pilot pin **152** being in FIG. **4** shown in exemplary alignment with the endmost slot **154'** that is associated with the first cup row *r'* in a located tray (FIG. **2**), this first cup row *r'* will become locked in accurate alignment with the loops when on the rise of the elevator to its upper position the pilot pin **152** rises into register with the slot **154'**. By way of another example, when the carriage is moved on the elevator, either manually at the handle **74** or by the indexing mechanism, to bring the pilot pin **152** opposite the exemplary slot **154''**, the last cup row *r''* in a located tray (FIG. **2**) will be locked in accurate alignment with the loops l on the rise of the elevator to its upper position and ensuing rise of the pilot pin **152** into register with the slot **154''**. The slots **154'''** to the right of slot **154''** (FIG. **4**) are for alignment lock of the loop service stations S with the loops.

LOOP ASSEMBLY AND LOOP OPERATING MECHANISM

The loops l have axial stems or shanks **164** by which they are supported in an overhead holder **166** at a spacing from each other equal to that of the cups in a row in a tray (FIG. **5**). The loops l with their shanks **164** and the holder **166** together form a complete loop assembly or unit **170** which is removably supported in an overhanding frame **172** on top of the upright column **144** on the casing **24** (FIGS. **1** to **3, 5, 9** and **10**).

The loop holder **166** is formed of companion sections **174** and **176** which have abutting faces **178** and **180** and are secured to each other by screws **182** (FIG. **10**). The sections **174** and **176** are at their abutting faces provided with bores **184** which serve as bearings for the loop shanks **164,** and each loop shank is at its top end provided with a thrust collar **186** that rests on the top surface of the holder **166.** Provided in the abutting faces **178** and **180** of the sections **174** and **176** are guide grooves **188** and **190** for reciprocatory bars **192** and **194** which at their confronting faces carry strips **196** and **198** of any suitable friction material, with these friction strips engaging diametrically reduced

portions 200 of the loop shanks 164 so as to oscillate the latter with their loops l on reciprocating the bars 192 and 194 (FIGS. 9 and 10). The bars 192 and 194 have at their ends slotted arms 202, 204 and 206, 208 (FIGS. 5 and 9), with the arms 202, 206 and 204, 208 carrying pins 210 and 212 on which are anchored the ends of tension springs 214 and 216, respectively, which urge the bars 192 and 194 with their respective friction strips 196 and 198 into driving engagement with the loop shanks 164. Also extending across the arms 204 and 208, and being pivotally connected therewith at 218 and 220, is a lever 222 which at 224 is also pivotally connected with the loop holder 166 (FIG. 9). Accordingly, on rocking the lever 222 back and forth about its pivot mount 224, the bars 192 and 194 will reciprocate in opposite directions and, through their friction strips 196 and 198, oscillate the shanks 164 and their loops l.

For removable support of the loop assembly 170 in the overhanging frame 172 on the casing 24, there are provided two pairs of spaced vertical tracks 226 and 228 (FIGS. 5, 9 and 10), of which the tracks of each pair are suitably mounted on angles 230 that, in turn, are mounted on lug formations 232 in the overhanging frame 172. The loop holder 166 is in its opposite side faces provided with two pairs of opposite grooves 234 and 236 which have a sliding fit with the tracks 226 and 228. The tracks 226 and 228 are at their lower ends provided with inwardly turned stop lugs 238 and 240 to which cushioning sleeves 242 and 244 are preferably applied. Thus, the loop assembly 170 is introduced through the open top of the overhanging frame 172 and is slid with its holder 166 onto the tracks 226 and 228 until coming to rest against the cushioned stop lugs 238 and 240, with the loop assembly being then properly supported and positioned in the apparatus. Conversely, the loop assembly 170 may be removed from the apparatus by simply sliding its holder 166 upwardly from the tracks 226 and 228 and removing the assembly through the open top of the overhanging frame 172. The overhanging frame 172 is normally closed at its top by a cover 246 which at 248 is hingedly mounted on the frame 172.

For rocking the lever 222 on the loop assembly 170 for operational oscillation of the loops 1, the drive shaft 64 carries another cam 250 (FIGS. 4 and 5) which has an operating connection with the lever 222. This operating connection is another lever 252 which at one end is in follower relation with the cam 250 as at 254, and is pivotally mounted on a fixed pin 256, with this lever projecting upwardly through the hollow column 144 on th casing 24 and having at its upper end an upwardly projecting finger 258 which extends inlo a forked end 260 in the lever 222 on the loop assembly 170 (FIGS. 5 and 9). The lever 252 is urged into follower engagement with the cam 250 by a spring 262 (FIG. 5). With the operating connection between the levers 252 and 222 being the finger 258 and forked end 260, the forked end 260 will move from and into operative reigster with the finger 258 on removal of the loop assembly from, and its return to, the overhanging frame 172, as will be readily understood.

OPERATING CONTROLS

The operating controls include switches 270 and 272 in the circuit C of the synchronous motor 142 (FIG. 5), with the circuit having a conventional plug-in connection with a commercial power line, and the switches being in parallel so that the circuit will be closed when either of these switches is closed. Switch 270 is normally closed, and is mounted in the casing 24 in association with the pawl-carrying arm 110 (FIG. 4) so as to be opened by this arm 110 when in its illustrated retracted or home position. The other switch 272 is suitably mounted on one of the end brackets 38 in the casing 24 (FIGS. 4, 7 and 7A). Switch 272 as such is in this instance normally open (FIG. 7), and associated with this switch is an arm 274 for closing the switch and controlling its opening. Switch arm 274, which is rockable on the fixed rod 78 (FIGS. 4 and 7), is a snap-over arm, and to that end is operatively connected with a spring 276 which in this instance is a flexed leaf spring anchored with its ends on the arm 274 and on the nearby end bracket 38 as at 278 and 280, respectively. The switch arm 274 is provided with a bent lug 282 for cooperation with a pivoted lever 284 of the switch 272 which by depressing a switch plunger 286 closes the switch 272. Thus, with th spring anchor 278 on the arm 274 being to one side of the neutral axis x, the arm 274 is held in a switch-opening position (FIG. 7) in which its lug 282 is retracted from the switch lever 284 and switch 272 is in its normally open position. On then turning the switch arm 274 counterclockwise (FIG. 7) until the spring anchor 278 thereon moves beyond the neutral axis x, the spring 276 will snap the arm 274 into a switch-closing position (FIG. 7A) in the course of which its lug 282 turns the switch lever 284 to depress the plunger 286 and thereby close switch 272.

With switch 270 being held open by the pawl-carrying arm 110 in its retracted position (FIG. 4) and, hence, in idle condition of the apparatus, any operating cycle of the apparatus is started by closing the other or main switch 272, with this main switch being closed manually by certain manipulation of the carriage handle 74 involving a rocking motion of the same with its sleeve 76 on the fixed rod 78. To this end, the top edge of the slot 80 in the front casing wall 26, and in this instance the top edge 290 of the lengthwise coextensive slot 80′ in the control plate 140 is provided with notches 292 and 294 (FIGS. 1 and 7) which are in alignment and associated with the indicia i from "1" to "12" and with the other indicia from "W" to "P." To the same end, there is provided in the casing 24 a bale 296 which at 298 is pivotally mounted in the end brackets 38 and extends parallel to the fixed rod 78 (FIGS. 4, 6 and 7), with this bale having a lost-motion connection with the switch arm 274, and being by a spring 300 forced against the carriage handle 74 to urge the same toward the lower edge 302 of the slot 80′ in the control plate 140 on the front casing wall 26 (FIGS. 1 and 7). The lost-motion connection between the bale 296 and the switch arm 274 is provided by a notch 304 in the latter through which the bale extends (FIG. 7). Thus, to start an operating cycle of the apparatus with any selected cup row r in a located tray, say the exemplary first cup row r' (FIG. 2), the carriage handle 74 is first moved along the slots 80 and 80′ in the casing wall 26 and control plate 140 into alignment with the "1" indicia and therewith associated notch 292′ in order to bring this first cup row r' into alignment with the overhead loops l. Thereupon, the operating cycle of the apparatus is started by simply rocking the handle 74 upwardly into register with the aligned notch 292′, with the specific flexible coupling 82 between the handle-carrying sleeve 76 and the carriage strap 88 permitting

such rocking motion of the sleeve relative to the carriage (FIG. 5). The handle **74**, on being manually rocked into register with the aligned notch **292'**, takes along the bale **296** against the force of its spring **300**, and with the bale then being at the one end of its lost-motion connection shown in FIG. 7, the bale turns the switch arm **274** counterclockwise until the spring anchor **278** thereon passes across the neutral axis *x* when the spring **276** snaps the switch arm **274** to switch-closing position (FIG. 7A) to close the main switch **272** and with it the circuit of the motor **142**.

To start an operating cycle of the apparatus, it is merely necessary to rock the handle **74** momentarily into register with the aligned notch **292** for closure of the main switch **272**, and then to release the handle for retraction from this notch by the spring-urged bale **296**. However, in order to prevent the bale **296** from returning the handle **74** all the way against the lower edge **302** of the slot **80'** in the control plate **140**, which would cause snap-over of the switch arm **274** to switch-opening position and, hence, opening of the main switch **272** (FIG. 7), there is provided a control bar **310**. This control bar is guided on the front casing wall **26**, and more particularly in a guideway **312** between the latter and the control plate **140** (FIG. 7), the movement lengthwise of the slots **80, 80'** into coextension with the latter from their right end to any extent up to and including the dot-and-dash line end position (FIG. 1), with this bar **310** having a top edge **314** which over any coextension of the bar **310** with the slots **80, 80'** extends within the widthwise confines of the latter and parallel to their top and bottom edges. Thus, with the control bar **310** being positioned so that its top edge **314** is in the path of the released handle **74** on its return from register with a notch **292** by the spring-urged bale **296**, the handle **74** will come to rest on the top edge **314** of the control bar **310** and the bale **296** will move to the opposite end of its lost-motion connection with the switch arm **274** without shifting the latter from switch-closing position (FIG. 7A), so that the main switch **272** remains closed. Thus, assuming that the control bar **310** has been preset to its dot-and-dash line end position (FIG. 1), and that an operating cycle of the apparatus is started by rocking handle **74** into momentary register with the exemplary notch **292'** which is associated with the "1" indicium and, hence, with alignment of the first cup row *r'* in a located tray with the overhead loops **1** (FIGS. 1 and 2), the released handle **74** will ride on the top edge **314** of the control bar **310** for **11** full indexing steps of the carriage **20**, and will in the course of the twelfth indexing step of the carriage ride off the end **316** of the control bar and drop against the bottom edge **302** of the slot **80'** (FIG. 7) and thereby cause snap-over of the switch arm **274** to its switch-opening position and, hence, opening of the main switch **272**. The twelfth indexing step of the carriage, during which the handle **74** drops off the control bar **310** and onto the bottom edge **302** of the slot **80'**, brings the last, i.e., the twelfth, cup row *r''* in the located tray out of alignment with the loops *l*, with this twelfth indexing step of the carriage being completed despite prior opening of the main switch **272**, because the other normally closed switch **270** in the motor circuit will keep the latter closed until after conclusion of the twelfth indexing step and return of the indexing pawl **96** and its arm **110** to home position (FIG. 4) in which the arm **110** opens switch **270** and therewith the motor circuit. Accordingly, this exemplary operating cycle of the apparatus was concluded after **12** indexing steps of the carriage and on return of the indexing pawl **96** to home position following the twelfth indexing step of the carriage. Assuming now that the same exemplary operating cycle of the apparatus is to be repeated for a serial dilution procedure involving all cup rows in a tray, a new charged tray is placed in located position on the carriage preferably while the latter remains in the position in which the preceding last, i.e., the exemplary twelfth indexing step has brought it, whereupon the handle **74** is raised from the bottom edge **302** of the slot **80'** and moved to the right on and along the top edge **314** of the control bar (FIG. 1) into alignment with the "1" indicium and therewith associated notch **292'**. Raising of the handle **74** in this fashion to the level of the top edge **314** of the control bar **310** and its movement therealong will not bring about closing of the main switch **272**, for such rise of the handle, while rocking the switch arm **274** counterclockwise through intermediation of the bale **296** (FIG. 7), will limit such rocking motion of the switch arm to where the spring anchor **278** thereon remains on the same side of the neutral axis *x* (FIG. 7) and the switch arm will not snap over to switch-closing position so that the main switch **272** remains open. However, on the following rise of the handle **74** into register with the notch **292'**, the bale **296** will further rock the switch arm **274** counterclockwise (FIG. 7) in the course of which the spring anchor **278** thereon passes the neutral axis *x* and the spring **276** snaps the switch arm to switch-closing position to close the main switch **272** and, hence, the motor circuit for starting the next operating cycle of the apparatus.

Let is now be assumed that the apparatus is to perform a dilution series involving the first nine cup rows in a located tray, i.e., the cup rows from *r'* to *r'''* in FIG. 2, the control bar **310** is shifted to the full-line position in FIG. 1 in which its end **316** is between the notches **292** associated with the "9" and "10" indicia. Then, on momentarily raising the handle **74** into register with the aligned notch **292'** (FIG. 1), the operating cycle will be started, and the same will be concluded with the return of the indexing pawl **96** to home position following drop-off of the handle **74** from the control bar **310** during the ninth indexing step of the carriage, as will be readily understood. Accordingly, any operating cycle of the apparatus involving serial dilution may be concluded with any cup row in a located tray, depending on selected presetting of the control bar **310** in the slots **80, 80'**. Likewise, any operating cycle of the apparatus involving serial dilution may be started with any cup row in a located tray on simply aligning the handle **74** with the corresponding notch **292** and then momentarily raising this handle into register with the aligned notch. The operating controls thus afford a wide variety of operating cycles of the apparatus for serial dilution.

For presetting the control bar **310** in any of its cycle stop positions, the same is provided with a handle **320** which projects through a slot **322** in the control plate **140** to the outside of the casing where it is readily accessible for manipulation (FIGS. 1 and 2). Thus, the control bar **310** will be moved to varying coextension with the slots **80, 80'** on moving the handle **320** along the slot **322**. Preferably, the control plate **140** bears indicia *i'*, in this instance numerals from "1" to "12" which are spaced as the notch-identifying indicia *a*

from "1" to "12" and are coordinated with the latter so that on alignment of the handle 320 with any of the indicia *i'*, the control bar 310 is preset for drop-off of the handle 74 therefrom and onto the bottom edge of the slot 80' during the indexing step of the carriage which brings the handle 74 out of alignment with the corresponding one of the indicia *i*. Thus, with the handle 320 being in exemplary alignment with the " 9" indicium in FIG. 1, the control bar 310 will be preset for drop-off of the handle 74 therefrom during the indexing step of the carriage which brings handle 74 out of alignment with the notch 292 that is identified by the "9" indicium. The lower edge of the slot 322 in the control plate 140 is preferably provided with depressions 326 which are aligned with the indicia *i'* and in which the handle 320 becomes seated for accurate presetting of the control bar 310 in relation to the notches 292.

A selectable operating cycle of the apparatus may also involve washing the loops *l* and then drying them, for example. To that end, the carriage 20 is moved at the handle 74 to bring the loop-washing station S_w into alignment with the overhead loops *l*, i.e., the handle 74 is brought into alignment with the notch 294 associated with the indicium "W" (FIG. 1). In so moving the handle 74, the same must clear, i.e., be above, the top edge 328 of an inward lug formation 330 on the bottom edge 302 of the slot 80', with this top edge 328 being at the level of the edge 314 of the control bar 310, so that movement of handle 74 on and along the top edge 328 into alignment with the notch 294 with the associated "W" indicium will not result in closure of the main switch 272 and, hence, of the motor circuit. However, once the handle 74 is aligned with this particular notch, the handle is momentarily raised into register therewith to start the operating cycle, with the main switch 272 remaining closed on the following return of the handle onto the top edge 328 of the lug formation 330 and on its ride thereon for the next two indexing steps of the carriage, in the course of the last or second one of which the handle 74 drops into a notch 332 in the lug formation 330 to cause opening of the main switch 272, with the operating cycle being concluded on the following return of the indexing pawl 96 to home position and ensuing opening of the switch 270 and, hence, of the motor circuit.

Another selectable operating cycle may involve pick-up by the loops *l* of a liquid sample or test substance at the sample supply and pick-up station S_s on the carriage. This procedure is preferred to charging the cups of the first row *r'* of a tray with such sample substance and have the loops *l* pick-up this substance from these cups as the first step in a serial dilution procedure. To the end of having the loops pick-up the sample substance at the station S_s, the handle 74 is brought into alignment with the notch 294 associated with the indicium "P" (FIG. 1) to thereby bring this station on the carriage into alignment with the loops, whereupon the handle is momentarily raised into register with this notch to start the operating cycle. The released handle will drop onto the top edge 328 of the lug formation 330, and will on the first indexing step of the carriage drop off this top edge 328 and onto the bottom edge 302 of slot 80' to cause opening of the main switch 272, followed by return of the indexing pawl 96 to home position and ensuing opening of the other switch 270 and, hence, of the motor circuit, which concludes this particular operating cycle.

For many serial dilutions it is preferred that the loops *l* be washed, then dried, and then be charged with a particular sample substance, all in a single operating cycle of the apparatus preparatory to a following operating cycle for serial dilution in a tray in the apparatus. To that end, there is provided a gate 334 which in this instance is pivotally mounted on the control plate 140 as at 336 (FIG. 1), with this gate being manually shiftable into and from cover relation with the notch 332 in the lug formation 330 and being shown out of cover relation with this notch. However, on shifting gate 334 into cover relation with the notch 332, this gate will bridge the notch 332 so that an operating cycle started with the loop-washing station S_w in alignment with the loops *l*, will be concluded after three successive indexing steps of the carriage, in the course of the last or third step of which the handle 74 drops off the end 338 of the lug formation 330 onto the bottom edge 302 of the slot 80' to cause opening of the main switch 272, whereupon on the following return of the indexing pawl 96 to home position the other switch 270 is opened and, hence, also the motor circuit, which concludes the operating cycle.

Any operating cycle of the apparatus is concluded with the return of the indexing pawl to home position and ensuing opening of the motor circuit, with the cams 62, 122 and 250 on the common drive shaft 64 always assuming the same angular home or idle position on opening of the motor circuit (FIGS. 4 and 5). The cams 62, 122 and 250 are in this instance designed to perform their respective functions once during each revolution of the drive shaft 64, with the function of the cams 62 being to raise the elevator 22 from its lower position to its upper position and then return it to its lower position, the function of the cam 122 being to operate the indexing pawl 96 for one indexing step of the carriage, and the function of the cam 250 being to oscillate the loops *l* a given number of times. More particularly, these cams are so phased that during their first revolution from home position they perform a cam cycle which involves raising of the elevator to its upper position, oscillation of the loops while the elevator is in its upper position, lowering the elevator from its upper to its lower position shortly after oscillation of the loops is stopped, and then indexing of the carriage through one step, in that order. This cam cycle, which is repeated during each following revolution of the cams, is distinct from any operating cycle of the apparatus for which the latter may be preset, and which is usually formed of a selected number of successive cam cycles, except where an operating cycle of the apparatus is concluded with one cam cycle as, for example, where the entire operating cycle involves pick-up of sample substance by the loops from the pick-up station S_s on the carriage.

What is claimed is:

1. Serial dilution apparatus for use with longitudinal titration trays having lengthwise thereof equally spaced transverse rows of cups, comprising an elevator mounted for vertical movement into upper and lower positions; a carriage for removable support of a tray in located position thereon, said carriage being supported and guided on said elevator for horizontal movement in forward and rearward directions lengthwise of a located tray thereon; fixed oscillatory loops on a level

above said carriage, and coordinated with said carriage for their alignment with the cups, respectively, in any row in a located tray on movement of said carriage on said elevator in its lower position, and for their reach into the aligned cups on movement of said elevator into its upper position; a device operable to reciprocate said elevator into its upper and lower positions; a device operable to oscillate said loops; a device operable in cycles in each of which successively to index said carriage in its lower position one step in said forward direction and release said carriage for independent movement in either direction in said lower position, with successive indexing steps of said carriage bringing successive cup rows in a located tray into alignment with said loops; a marker operatively connected with said carriage for horizontal movement therewith; and stop marks along the horizontal motion path of said marker and spaced as the cup rows in a tray, with said stop marks being so coordinated with said carriage that on alignment of said marker with the stop marks in their succession in either horizontal direction corresponding cup rows in a located tray in their succession in the opposite horizontal direction will be in alignment with the loops.

2. Serial dilution apparatus as in claim 1, which further provides power-operating mechanism for said devices, including a synchronous motor and a circuit therefor with switch means for opening and closing said circuit, said mechanism performing, on circuit closure, to operate said devices in timed repeat cycles in each of which said elevator is moved to its upper position, said loops are oscillated, said elevator is moved to its lower position, and said carriage is indexed one step, in that order, with said switch means being manually operable to close said circuit; and control means selectively presettable for operating said switch means to open said circuit in timed relation with the conclusion of an operating cycle of said indexing device in which said carriage is indexed to bring any selected cup row in a located tray out of alignment with said loops.

3. Serial dilution apparatus as in claim 1, in which said marker is a handle with which to move said carriage on said elevator.

4. Serial dilution apparatus as in claim 1, which further provides an upright pilot pin on said carriage, and a member having successive apertures in said forward direction spaced as the cup rows in a tray, said apertures being coordinated with said carriage for alignment of said pin with successive apertures on alignment of successive cup rows in a located tray with said loops, and said pin moving into and from carriage-locking register with an aligned aperture on operational movement of said elevator into said upper and lower positions, respectively.

5. Serial dilution apparatus as in claim 3, which further provides a plurality of loop service stations on said carriage spaced in said forward direction as successive cup rows, and spaced from a located tray in said rearward direction so that on movement of said carriage for alignment with said loops of the station leading in said forward direction, succeeding ones of said stations align with said loops on successive indexing steps of said carriage, and each station in alignment with said loops is raised and lowered into and from servicing relation with said loops on movement of said elevator into its upper and lower positions, respectively; and other control means selectively presettable for operating said switch means to open said circuit in timed relation with the conclusion of an operating cycle of said indexing means in which said carriage is indexed to bring a selected station out of alignment with said loops.

6. Serial dilution apparatus as in claim 5, in which said loop service stations are loop-washing, loop-blotting and sample-supply stations, of which said loop-washing station is said leading station and said sample-supply station is the trailing station, and said other control means is presettable for operating said switch means to open said circuit in timed relation with the conclusion of that operating cycle of said indexing device in which said carriage is indexed to bring either said loop-blotting station or said sample-supply station out of alignment with said loops.

7. Serial dilution apparatus as in claim 5, which further provides other stop marks along the horizontal motion path of said marker spaced as the cup rows in a tray and so coordinated with said carriage that on alignment of said marker with said other stop marks in their succession in said forward direction corresponding stations on said carriage in their succession in said rearward direction will be in alignment with the loops.

8. Serial dilution apparatus as in claim 7, which further provides an upright pilot pin on said carriage, and a member having two series of successive apertures in said forward direction, of which the apertures of each series are spaced as the cup rows in a tray, with said apertures being coordinated with said carriage, for alignment of said pin with successive apertures of one series on alignment of successive cup rows in a located tray with said loops, and for alignment of said pin with successive apertures of the other series on alignment of successive stations on said carriage with said loops, and said pin moving into and from carriage-locking register with an aligned aperture on operational movement of said elevator into said upper and lower positions, respectively.

9. Serial dilution apparatus for use with longitudinal titration trays having equally spaced transverse rows of cups, comprising an elevator mounted for vertical movement into upper and lower positions; a carriage for removable support of a tray in located position thereon, said carriage being supported and guided on said elevator for horizontal movement in forward and rearward directions lengthwise of a located tray thereon; fixed oscillatory loops on a level above said carriage, and coordinated with said carriage for their alignment with the cups, respectively, in any row in a located tray on movement of said carriage on said elevator in its lower position, and for their reach into the aligned cups on movement of said elevator into its upper position; a carriage indexing device providing dependent rack teeth on said carriage arranged in a row lengthwise of a located tray thereon and being spaced as the cup rows in a tray, a reciprocatory pawl having indexing and return strokes from and into a home position, respectively, and being located to be within operating reach of said rack teeth in said lower elevator position only, with said rack teeth being so coordinated with said pawl that the latter will, on successive indexing strokes in said lower elevator position, engage successive rack teeth and index said carriage through successive steps in said forward direction to bring successive cup rows in a located tray into alignment with said loops, and means operative on each return stroke of said pawl to its home position to retract

the same from reach of said rack teeth to permit manual movement of said carriage on said elevator in its lower position when said pawl is in said home position; a device operable to reciprocate said elevator into its upper and lower positions; another device operable to oscillate said loops; power-operating mechanism for said devices, including a synchronous motor and a circuit therefor with switch means for opening and closing said circuit, said mechanism performing, on circuit closure, to operate said devices in timed repeat cycles, in each of which said elevator is moved to its upper position, said loops are oscillated, said elevator is moved to its lower position, and said pawl is reciprocated once from its home position back into its home position, in that order, with said switch means being manually operable to close said circuit; and control means operating said switch means to open said circuit in timed relation with the conclusion of an operating cycle in which said carriage is indexed to bring a predetermined cup row in a located tray out of alignment with said loops.

10. Serial dilution apparatus as in claim **9,** in which said pawl strokes are longer than the spacing of said rack teeth, said pawl is spring-urged into operative reach of said rack teeth in said lower elevator position, and said pawl retracting means is a fixed track in the path of the returning pawl onto which the latter rides after overriding only the next rack tooth to be engaged by the pawl on its next indexing stroke.

11. Serial dilution apparatus as in claim **9,** in which said indexing device further provides a bar from which said rack teeth depend and which is suspended from said carriage and has with the latter a lost-motion connection lengthwise of a located tray, and spring means urging said bar to one end of said connection at which the force of said spring means is normally effective to transmit pawl-induced indexing motions of said bar to said carriage, but in any pawl-induced motion of said bar the same will move relative to said carriage toward the other end of said lost-motion connection if said carriage should encounter any obstruction to its indexing motion.

12. Serial dilution apparatus for use with longitudinal titration trays having equally spaced transverse rows of cups, comprising a casing with a front wall; an elevator mounted in said casing for vertical movement into upper and lower positions; a carriage for removable support of a tray in located position thereon, said carriage being supported and guided on said elevator for horizontal movement in forward and rearward directions lengthwise of a located tray thereon and parallel to said casing wall; fixed rotary loops on a level above said carriage, and coordinated with said carriage for their alignment with the cups, respectively, in any row in a located tray on movement of said carriage on said elevator in its lower position, and for their reach into the aligned cups on movement of said elevator into its upper position; a carriage indexing device providing depending rack teeth on said carriage arranged in a row lengthwise of a located tray thereon, and being spaced as the cup rows in a tray, a reciprocatory pawl having indexing and return strokes from and into a home position, and being located at a level to be within operating reach of said track teeth only when said elevator is in said lower position, with said rack teeth being so coordinated with said pawl that the latter will, on successive indexing strokes in said lower elevator position, engage successive rack teeth and index said carriage through successive steps in said forward direction to bring successive cup rows in a located tray into alignment with said loops, and means operative on each return stroke of said pawl to its home position to retract the same from each of said rack teeth to permit manual movement of said carriage on said elevator in its lower position when said pawl is in its home position; a device operable to reciprocate said elevator into its upper and lower positions; another device operable to oscillate said loops; power-operating mechanism for said devices, including a synchronous motor and a circuit therefor having therein first and second switches in parallel, of which said first switch is manually shiftable into closed position, and said second switch is normally closed and is opened by said pawl on each return stroke to its home position, with said circuit being closed on closure of either switch, said mechanism performing, on closure of said first switch, to operate said devices in timed repeat cycles, in each cycle of which said elevator is moved to its upper position, said loops are oscillated, said elevator is moved to its lower position, and said pawl is reciprocated once from and back to its home position for indexing said carriage through one step, in that order; and control means operating, in timed relation with the indexing stroke of said pawl which brings a predetermined cup row in a located tray out of alignment with said loops, to shift said first switch into open position, whereupon on the following return stroke of said pawl to its home position said second switch is opened to open said circuit.

13. Serial dilution apparatus as in claim **12,** which further provides a fixed rod in said casing extending parallel to the guided motion path of said carriage on said elevator, with said casing wall having therein a first slot with opposite side edges extending parallel to said rod; a first handle slidable on said rod and projecting through said slot; a coupling between said handle and carriage, with said coupling being flexible to permit movement of said carriage with said elevator into its upper and lower positions, and being operative for moving said carriage on said elevator on manually moving said handle along said slot and rod; and stop marks on said casing wall along said slot and spaced as the cup rows in a tray, with said stop marks being so coordinated with said carriage that on alignment of said handle with the stop marks in their succession in said forward direction corresponding cup rows in a located tray in their succession in said rearward direction will be in alignment with said loops.

14. Serial dilution apparatus as in claim **13,** in which said first switch is mounted in said casing and has a spring-loaded arm for snap-over into switch opening and closing positions, said power operating mechanism further includes a rockable bale in said casing spaced from and parallel to said rod and having a lost-motion connection with said switch arm, with said bale being spring-forced against said handle to urge the latter against one of said slot edges, and said stop marks are notches of a first set provided in the other slot edge and arranged from first to last in their succession in said forward direction, with said flexible coupling also permitting rocking movement of said handle on said rod relative to said carriage, and said handle being, on alignment with any of said notches, manually rockable into register with the aligned notch to thereby rock said bale counter to its spring force, and said control means provide a bar guided on said casing wall for manual move-

ment lengthwise of said slot into any coextension with the latter from a home position in which the end of said bar leading in said forward direction is spaced forwardly from said first notch less than the spacing of said notches, to an end position in which said bar end is spaced forwardly from said last notch less than the spacing of said notches, and said bar having a side edge which over any coextension of said bar with said slot extends between and parallel to said slot edges, said bale is at one end of said lost-motion connection with said switch arm at which the latter is snapped-over into switch closing position on rocking said handle into register with any of said notches, said bale will, on release of said handle while in register with a notch opposite said bar edge, urge said handle against said bar edge and move to the other end of its lost-motion connection with said switch arm at which the latter remains in switch-closing position, and when during an indexing step of said carriage said handle clears said bar end, said bale will rock said handle against said one slot edge and snap said switch arm to switch-opening position.

15. Serial dilution apparatus as in claim **14,** in which said casing wall has a second slot parallel to said first slot, and there is further provided a second handle secured to said bar and extending through said second slot for moving said bar.

16. Serial dilution apparatus as in claim **15,** in which said casing wall bears adjacent said notches first indicia which in their succession in said forward direction denote corresponding cup rows in a located tray in their succession in said rearward direction, and said longitudinal casing wall further bears along said second slot second indicia which are identical with said first indicia, are spaced as the cup rows in a tray, and denote in their succession in said forward direction corresponding cup rows in a located tray in their succession in said rearward direction, with said second indicia being so coordinated with said bar that on alignment of said second handle with any second indicium denoting a certain cup row said bar end is spaced, less than the spacing of said notches, forwardly from that notch which denotes the same cup row, whereby on alignment of said second handle with any one of said second indicia said bar is preset to cause opening of said first switch in the course of the indexing step of said carriage which brings out of alignment with said loops that cup row in a located tray which is denoted by that second indicium with which second handle is aligned.

17. Serial dilution apparatus as in claim **14,** which further provides a plurality of loop service stations on said carriage spaced from each other lengthwise of a located tray thereon as successive cup rows, and spaced from a located tray in said rearward direction so that on movement of said carriage for alignment with said loops of the station leading in said forward direction, succeeding ones of said stations align with said loops on successive indexing steps of said carriage, and each station in alignment with said loops is raised and lowered into and from servicing relation with said loops on movement of said elevator into its upper and lower positions, respectively, said other slot edge is provided with second notches which are spaced from each other as successive cup rows in a tray, and are so coordinated with said carriage that on alignment of said handle with successive ones of said second notches from last to first in said forward direction successive ones of said stations from first to last in said forward direction will be in alignment with said loops, with said handle, on being rocked into register with any aligned one of said second notches, causing closure of said first switch through intermediation of said bale and switch arm, and said slot being shaped to provide a lug formation extending inwardly from said one slot edge and having an inner edge in alignment with said bar edge and extending from adjacent said last one of said second notches along the latter and beyond said first one of said second notches for a distance less than the spacing of said second notches, whereby said bale will, on release of said handle while in register with any of said second notches, urge said handle against said inner edge and move to said other end of its lost-motion connection with said switch arm at which the latter remains in switch-closing position, and when during an indexing step of said carriage said handle clears said inner edge, said bale will rock said handle against said one slot edge and snap said switch arm to switch-opening position.

18. Serial dilution apparatus as in claim **17,** in which said loop service stations are loop-washing, loop-blotting, and sample-supply stations, of which said loop-washing and sample-supply stations are said first and last stations, respectively, and said loop-blotting station is the second station.

19. Serial dilution apparatus as in claim **18,** in which said lug formation has in its inner edge a third notch so coordinated with the intermediate one of said second notches that during the indexing step of said carriage which brings said loop-blotting station out of alignment with said loops, said bale will rock said handle into said third notch and snap said switch arm to switch-opening position.

20. Serial dilution apparatus as in claim **19,** which further provides a gate on said casing wall manually shiftable into first and second positions in which it continues said inner edge of said lug formation across said third notch and exposes the latter for reception of said handle, respectively, whereby in said first gate position there will be a repeat operating cycle following the conclusion of an operating cycle which brings said sample-supply station into alignment with said loops, and in said second gate position said first switch will be opened with the indexing step of said carriage which brings said loop-blotting station out of alignment with said loops.

* * * * *