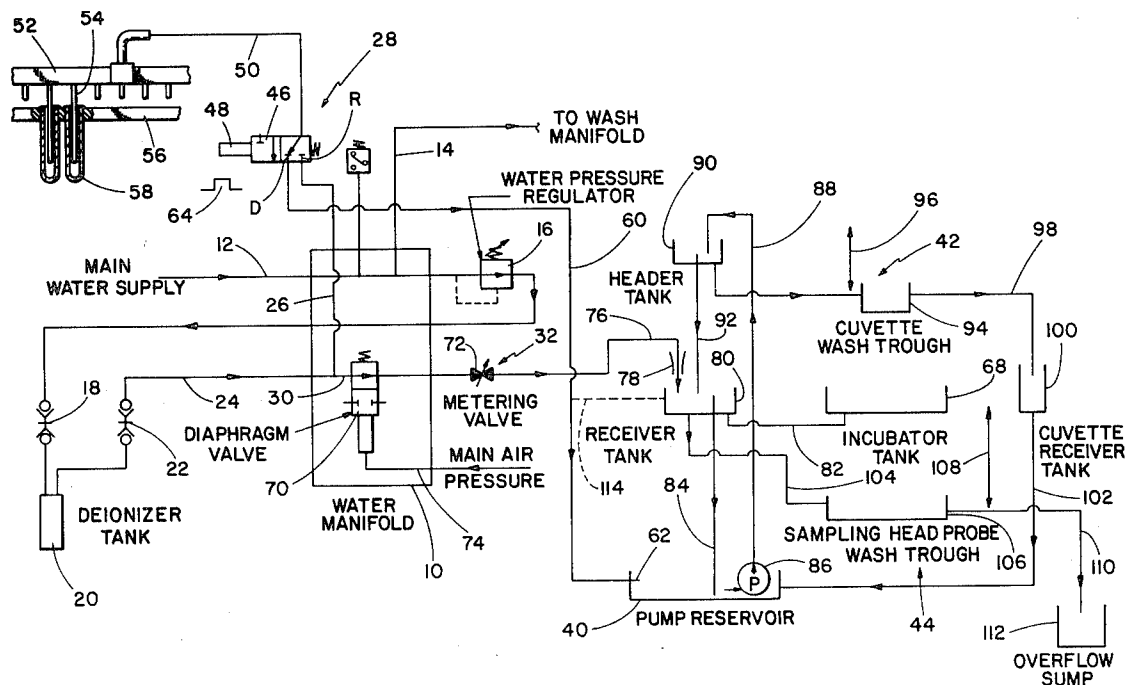
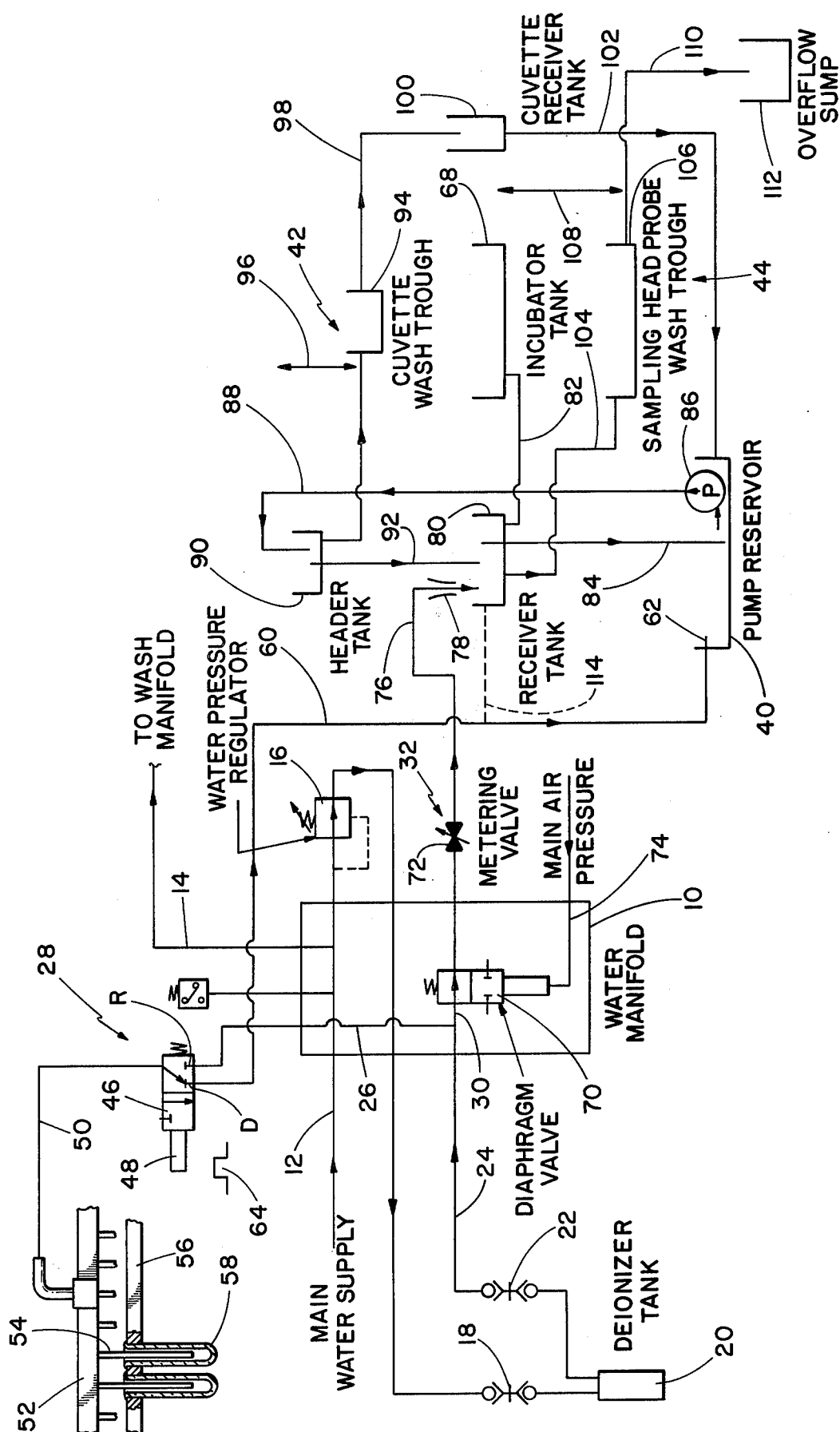


[54] **FLUID CIRCUIT INCLUDING TUBE RINSING SYSTEM AND BATH LEVEL MAINTAINING SYSTEM**[75] Inventor: **Alan Richardson Jones**, Miami, Fla.[73] Assignee: **Coulter Electronics Inc.**, Hialeah, Fla.[22] Filed: **Oct. 23, 1973**[21] Appl. No.: **408,850**[52] U.S. Cl. **23/253 R; 23/259; 134/15; 134/32; 134/34**[51] Int. Cl. **G01n 1/14; B08b 1/02; B08b 9/08**[58] Field of Search **23/253 R, 259; 134/34, 134/32, 15**[56] **References Cited****UNITED STATES PATENTS**3,432,271 3/1969 Wasilewski 23/253
3,728,079 4/1973 Moran 23/259 XPrimary Examiner—**R. E. Serwin**Attorney, Agent, or Firm—**Silverman & Cass, Ltd.**[57] **ABSTRACT**

The fluid circuit is useful in an automatic chemical analysis apparatus for supplying fluid to a tube rinsing system, to an incubator tank for maintaining the level of heated bath fluid in the tank to a system for washing the tubes, to a system for washing cuvettes in colorimeters of the apparatus and to a system for provid-

ing fluid for sampling head probes of the apparatus. The tube rinsing system includes a valve for connecting a manifold, from which depends a plurality of cannulas, to either a source of rinsing fluid or a drain conduit leading to a pump reservoir or to a receiver tank so that the used rinsing fluid can be utilized for maintaining the bath level in the incubator tank. The fluid connections and the valve passageways between the cannulas and the pump reservoir or receiver tank are sized to control the flow of fluid that is siphoned out of the tubes so that the meniscus of the rinsing fluid in each tube recedes at a rate which is slow enough to inhibit, if not altogether prevent, droplets of fluid from breaking away from the meniscus and clinging to the inner side walls of the tubes whereby, most, if not all, of the rinsing fluid is withdrawn from the tubes by siphoning. The receiver tank is connected to the incubator tank and rinsing fluid, supplied to the receiver tank either directly from the cannulas or via a pump in the pump reservoir, is maintained at a desired level by a standpipe extending into the receiver tank and emptying into the pump reservoir. Additionally, the fluid circuit includes a diaphragm valve and a needle metering valve connected between the source of rinsing fluid and a conduit emptying into the receiver tank. The diaphragm valve and metering valve being operable to supply a trickle of fluid to the receiver tank only when the tube rinsing system is in a non-operative stand-by state, the trickle of fluid serving to maintain the bath level in the incubator tank when the apparatus is in a stand-by condition.

16 Claims, 1 Drawing Figure



FLUID CIRCUIT INCLUDING TUBE RINSING SYSTEM AND BATH LEVEL MAINTAINING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

The subject matter of this application is related to subject matter disclosed in: U.S. application Ser. No. 189,092 filed Oct. 14, 1971 and now issued to U.S. Pat. No. 3,799,794; U.S. application Ser. No. 342,161 filed on Mar. 16, 1973; and U.S. application Ser. No. 351,793 filed on Apr. 16, 1973 and now abandoned. The disclosures of the above identified applications are incorporated herein by reference.

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to a fluid circuit utilized in an automatic chemical analysis apparatus and including a tube rinsing system and a bath level maintaining system. The fluid circuit is particularly useful in an automatic chemical analysis apparatus of the type disclosed in U.S. application Ser. No. 189,092.

In the automatic chemical analysis apparatus disclosed in U.S. application Ser. No. 189,092 a plurality of reaction tubes are mounted in racks and each rack is caused to travel a closed circuit path which can be described as follows starting from a standby position for the racks beneath an incubator tank of the apparatus. From this point each rack is moved: to a position adjacent and below one end of the incubator tank; upwardly to a tube rinsing system where the tubes in the rack are brought into communication with a plurality of cannulas depending from a manifold of the rinsing system; downwardly into the incubator bath; incrementally horizontally in the bath where at certain positions of the rack fluid samples, reagents and/or diluents are inserted into the tubes; further horizontally for predetermined incubation times to the other end of the tank; upwardly to a colorimeter system where depending probes of cuvettes of the colorimeter system are brought into communication with the reaction tubes for withdrawing aliquots from the tubes for making colorimetric analyses of the aliquots; downwardly to a dumping station where the contents of the tubes are dumped; further downwardly and horizontally in the other direction beneath the tank to a tube washing system where water is sprayed into the tubes for washing the same; and horizontally underneath the tank to the stand-by position.

While the reaction tubes are in the incubator tank a sample metering and mixing system comprising a plurality of sample heads with depending probes for dipping into sample cups containing a quantity of sample therein are operated at predetermined times when a rack of reaction tubes is located opposite a particular sample head for withdrawing a quantity of sample from a sample cup, for mixing it with a diluent or reagent, and for thereafter transferring the mixture to one of the reaction tubes. This sample metering and mixing system is disclosed in U.S. applications Ser. Nos. 189,092 and 342,161. Reference may also be had to the sample metering and mixing apparatus disclosed in U.S. Pat. No. 3,747,412.

The apparatus disclosed in U.S. application Ser. No. 189,092 includes a tube rinsing system comprising a manifold having connections to a source of rinsing fluid

and to a source of vacuum, a plurality of cannulas depending from the manifold, and mechanisms for causing relative movement between the manifold and a rack for bringing the cannulas into communication with the interiors of the tubes carried by the rack. The fluid circuit and tube rinsing system of the present invention provide an improvement over the tube rinsing system disclosed in U.S. application Ser. No. 189,092 by eliminating the need for vacuum connections and the need for the application of vacuum to the interiors of the reaction tubes. The fluid circuit also provides an improvement over the previously disclosed tube rinsing system by utilizing the used rinsing fluid for maintaining the bath level in the incubator tank. The fluid circuit also includes a system for trickling fluid into the incubator tank to maintain a desired fluid level in the incubator tank while the apparatus and rinsing system are in a stand-by condition.

The fluid circuit further includes fluid circuitry for supplying fluid to a cuvette washing system such as disclosed in U.S. application Ser. No. 351,793 which enables the cuvettes of the colorimeters to be washed and for supplying fluid to a sampling head probe rinsing system such as disclosed in U.S. application Ser. No. 342,161 which enables rinsing fluid to be drawn through the sampling head probes in between samplings.

According to the invention there is provided in a system for rinsing tubes which are closed at one end and which are supported in a rack, and in which system there is provided at least one cannula and mechanisms for causing relative movement between the cannula and the rack to bring the at least one cannula into one of the tubes, structure connected to the cannula for causing rinsing fluid to flow through the cannula into the tube for a predetermined time sufficient to fill the tube with a desired amount of rinsing fluid and thereafter draining the fluid by siphon and gravity from the tube.

Preferably, the tube rinsing system is incorporated into a fluid circuit for supplying fluid to various systems and an automatic chemical analysis apparatus. In this respect the rinsing fluid drained from the tubes is preferably utilized in maintaining the bath level in an incubator tank and forms part of a system for maintaining the bath level in the incubator tank. The fluid circuit also includes structure for supplying fluid to systems for rinsing or washing cuvettes in colorimeters and probes in sampling heads.

BRIEF DESCRIPTION OF THE DRAWING

In the FIGURE there is illustrated schematically the fluid circuit of the invention and the various systems incorporated therein including the tube rinsing system and the bath level maintaining system of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the FIGURE in greater detail, the fluid circuit of the invention illustrated therein includes a water manifold **10** which is connected to a main water supply via a conduit **12**. A tap line **14** off of the conduit **12** supplies water to the wash manifold of the tube washing system utilized in the apparatus disclosed in U.S. application Ser. No. 189,092. The conduit **12** supplies water serving as a rinsing fluid through a pressure regulator **16** to an input connector **18** for a deion-

izer tank 20. An output connector 22 from the deionizer tank 20 is connected to a fluid conduit 24 which communicates with a conduit 26 forming part of the tube rinsing system of the invention generally identified by the reference numeral 28, and to a conduit 30 forming part of a bath level maintaining system generally identified by the reference numeral 32.

The fluid circuit also includes a pump reservoir 40 which is coupled to a system for supplying washing fluid to the cuvettes, this system being generally identified by the reference numeral 42, and to a system for supplying fluid to sampling head probes, this latter system being generally identified by the reference numeral 44.

The tube rinsing system 28 includes a valve 46 which is operated by a solenoid 48, and a conduit 50 forming a fluid connection between the valve 46 and a water manifold 52 which has a plurality of cannulas 54 depending therefrom. Part of a rack 56 and two reaction tubes 68 supported therein is also illustrated. It is to be understood that further details of the manifold 52 and the rack 56 can be found in U.S. application Ser. No. 189,092.

Although not shown, the tube rinsing system 28 includes mechanisms for causing relative movement between the manifold 52 and the rack 56 to bring the cannulas 54 into the test tubes 58 as shown. The tube rinsing system 28 also includes a fluid drain conduit 60 connected at its upper end to the valve 46 and having an outlet end 62 emptying into the pump reservoir 40.

In the FIGURE the fluid rinsing system 28 is shown in a quiescent or stand-by state where the fluid conduit 50 is connected through the valve 46 to the drain port D of the valve 46 to which is connected the drain conduit 60. In this quiescent state of the system 28 any residual fluid in the various fluid passageways between the end of the cannulas 54 and the outlet of the drain conduit 60 is allowed to drain by gravity therefrom. Then when the mechanisms (not shown) bring the cannulas 54 into the tubes 58, a control mechanism, which may be cam operated and which is associated with the mechanisms for bringing the cannulas 54 into the tubes 58, sends an electrical signal, schematically indicated at 64 in the FIGURE, to the solenoid 48 for actuating same to connect the fluid conduit 50 to the rinse port R of the valve 46 to which is connected the fluid supply conduit 26. The duration of the signal 64 is such that a sufficient amount of water is supplied to the manifold 52 to fill the tubes 58 with deionized rinse water to a predetermined level. At the end of the signal 64 the valve 46 is returned to the position shown in the FIGURE and the rinse fluid is allowed to drain by siphon and gravity action from the tubes 58. The operation of the automatic chemical analysis apparatus and the control mechanisms therefor are slow enough such that the repetition rate of the signal 64 is sufficiently long to maintain the valve connection shown in the FIGURE for a length of time sufficient to allow most, if not all, of the rinsing fluid to be drained from the tubes 58. Also, the various conduits and valve passageways are sized to control the rate of fluid flow therethrough when the valve 46 connects the cannulas 54 with the fluid drain conduit 60 so that the meniscus of the rinsing fluid in each tube recedes at a rate which is slow enough to inhibit, if not altogether prevent, droplets of fluid from breaking away from the meniscus and clinging to the inner side wall of the tube whereby most, if

not all, of the rinsing fluid is withdrawn from the tubes 58.

The system 32 for maintaining a predetermined bath level in an incubator tank identified schematically by the reference numeral 68, when the automatic chemical analysis apparatus is in a stand-by condition, includes the fluid supply conduit 30, a fluid pressure operated diaphragm valve 70 and a needle metering valve 72. The fluid pressure is preferably air pressure and is applied via a fluid line 74 to the valve 70 to close the valve 70 when the chemical analysis apparatus is operative and the tube rinsing system 28 is being operated. When the chemical analysis apparatus is in a non-operative stand-by state there is no air pressure on the line 74 and the valve 70 is open to allow deionized water to flow to the metering valve 72 which is set to allow only a trickle of water to flow therethrough to a conduit 76 emptying through a restricted orifice 78 into a receiver tank 80. The receiver tank 80 is connected via conduit 82 to the incubator tank 68. As shown, a standpipe 84 extends upwardly into the receiver tank 80 to a predetermined height therein and serves to maintain a predetermined level of fluid in the receiver tank 80 and also, by reason of the conduit 82, in the incubator tank 68.

In the operation of the system 32 water is trickled into the receiver tank 80 when the automatic chemical analysis apparatus is in a stand-by state to maintain a predetermined bath level in the incubator tank 68.

As shown, a pump 86 is connected to the pump reservoir and pumps fluid upwardly via a conduit 88 to a header tank 90. The header tank 90 has a standpipe 92 extending upwardly therein for establishing a predetermined level of fluid in the header tank 90. The standpipe 92 is arranged to empty into the receiver tank 80. With this arrangement, when the automatic chemical analysis apparatus is operative, the pump 86 is operative to pump fluid draining into the pump reservoir 40 from the drain conduit 60 up to the header tank 90 and the fluid above the height of the standpipe 92 overflows into the standpipe 92 and then into the receiver tank 80 for maintaining the fluid in the tank 80 at the level of the upper end of the standpipe 84 and in this way maintain the level of the bath in the incubator tank 68. When the pump 86 is operating, air pressure is supplied via the air line 74 to the diaphragm valve 70 to close the same.

As shown, the header tank 90 forms part of the system 42 for supplying rinse or washing fluid to a cuvette trough 94. As explained in greater detail in U.S. application Ser. No. 351,793 the automatic chemical analysis apparatus includes cuvettes (not shown in the FIGURE) which dip down into the cuvette wash trough 94 for receiving washing fluid therefrom. It will be understood that the cuvette wash trough is movable from a lower position shown in the FIGURE where the cuvettes can be dipped into the trough 94 to an upper position above the level of fluid in the header tank 90 as established by the upper end of the standpipe 92. This movement is indicated schematically by the arrow 96. A drain conduit 98 drains fluid from the cuvette wash trough 94 to a cuvette receiver tank 100, and the fluid received in the receiver tank 100 is drained via a conduit 102 to the pump reservoir 40. The cuvette receiver tank 100 is inserted in the fluid circuitry connecting the cuvette wash trough 94 with the pump reservoir 40 to prevent bubbles from being entrapped in the line 102,

which bubbles could cause a stoppage of flow through the conduit 102. As such, the cuvette receiver tank 100 can be considered a bubble eliminator tank.

It will be apparent that when the cuvette wash trough 94 is in its upper retracted position it is above the level of the fluid in the header tank 90 so that fluid does not flow into the cuvette wash trough 94. Then when the cuvette wash trough 94 is lowered to a position where the cuvette can be inserted therein, washing fluid, namely deionized water flows by gravity from the header tank 90 into the wash trough 94.

Preferably, the receiver tank 80 has a conduit 104 connected thereto and forming part of a system for supplying rinsing fluid to sampling head probes. Such a system is disclosed in U.S. application Ser. No. 342,161 and as shown in the FIGURE includes a sampling head probe wash trough 106. As indicated by the arrow 108 the wash trough 106 is movable between a lower position shown in the FIGURE where sampling head probes can be dipped therein for aspirating washing fluid from the trough 106 to an upper retracted position where the wash trough 106 is above the level of the fluid in the receiver tank 80. Thus, when the trough 106 is in the upper position, rinsing fluid does not flow into the trough 106. Then when the trough is lowered to the position shown in the FIGURE rinsing fluid flows by gravity via the conduit 104 into the wash trough 106. A conduit 110 is connected to the wash trough 106 to carry any overflow fluid from the wash trough 106 to an overflow sump 112.

In one modified embodiment of the fluid circuit shown in the FIGURE, the system for supplying washing fluid to the depending probes of the cuvettes, namely the system 42, is excluded from the fluid circuit. With this modification the pump reservoir 40, the pump 86 and the connections between the pump 86, the header tank 90 and the receiver tank 80 can be eliminated. The drain conduit 60 is then coupled via a conduit 114 shown in dashed lines directly to the receiver tank 80. In this modification the tube rinsing system 28 forms part of a bath level maintaining system which is operative when the automatic chemical analysis apparatus is operative. With this modification the standpipe 84 will flow directly into the overflow sump 112 instead of the eliminated pump reservoir 40.

The fluid circuit of the invention and the systems incorporated therein provide a number of advantages some of which have been described above and others of which are inherent in the invention. In particular, it is to be noted that the tube rinsing system 28 provides a simple means for rinsing and drying the reaction tubes 58 and eliminates the need for a vacuum source and vacuum connections to the cannulas 54. Also, the fluid circuit and the modification thereof described above provide for the utilization of the rinsing fluid drained from the tubes 58 for maintaining the level of the bath in the incubator tank 68 and for reuse of the rinsing fluid from the cannulas 54 for washing cuvette probes and sampling head probes. Accordingly, the scope of the invention is only to be limited as necessitated by the accompanying claims.

What it is desired to be secured by Letters Patent of the United States is:

1. In a system for rinsing tubes which are closed at one end and which are supported in a rack, and in which system there is provided at least one cannula and means for causing relative movement between the can-

nula and the rack to bring the at least one cannula into one of the tubes, the improvement comprising means connected to said cannula for causing rinsing fluid to flow through the cannula into the tube for a predetermined time sufficient to fill the tube with a desired amount of rinsing fluid said means thereafter draining said fluid by siphon and gravity from the tube through said at least one cannula and a fluid drain conduit.

2. The system according to claim 1 wherein said fluid flow causing means includes valve means for controlling the flow of rinsing fluid to and from said cannula, a fluid connection between said valve means and said cannula, a fluid connection between said valve means and a source of rinsing fluid, and said fluid drain conduit which is connected between said valve means and a sump situated at a level below the cannula and said valve means.

3. The system according to claim 2 wherein said valve means includes a solenoid for actuating same, said solenoid being connected to control means for applying a signal of predetermined duration to said solenoid for operating said valve means for a predetermined period of time during which rinsing fluid is supplied to the cannula, and the repetition rate of said signal being long enough so that said solenoid is inoperative for a sufficient amount of time to allow fluid to be siphoned out of the tube.

4. The system according to claim 2 wherein said fluid drain conduit and the passageways in said valve means are sized to control the rate of fluid flow therethrough when said valve means connects said cannula to said fluid drain conduit so that the meniscus of the rinsing fluid in the tube recedes at a rate which is slow enough to inhibit, if not altogether prevent, droplets of fluid from breaking away from the meniscus and clinging to the inner side wall of the tube whereby most, if not all, of the rinsing fluid is withdrawn from the tube.

5. The system according to claim 1 in combination with a fluid circuit for supplying fluid to an incubator tank in which the tubes are inserted for controlling chemical reactions to take place within the tubes, said fluid drain conduit being coupled to the incubator tank whereby the rinsing fluid can be utilized for maintaining the level of an incubating bath within the incubator tank.

6. The combination according to claim 5 including a receiver tank into which said drain conduit empties, a fluid connection between said receiver tank and said incubator tank, a standpipe extending upwardly into said receiver tank for maintaining a predetermined level of fluid in said receiver tank and a reservoir situated beneath the lower end of said standpipe for receiving fluid which flows into said standpipe.

7. The combination according to claim 5 wherein the source of rinsing fluid is also connected to a fluid flow controlling and throttling means which trickles fluid to said incubator tank when said rinsing system is in an inoperative standby state and which blocks the flow of fluid to said incubator tank when said rinsing system is in an operative state.

8. The combination according to claim 7 wherein said fluid flow controlling and throttling means includes a fluid operated diaphragm valve which is normally open when said rinsing system is in a non-operative state and which is normally closed when said system is in an operative state.

9. The combination according to claim 7 wherein said fluid flow controlling and throttling means includes a needle valve for throttling the flow of fluid into said incubator tank whereby said rinsing fluid trickles to said incubator tank when said rinsing system is in a standby non-operative state.

10. A fluid circuit for an automatic chemistry analysis apparatus including the rinsing system according to claim 1, a reservoir, and a pump for pumping fluid out of said reservoir, said fluid drain conduit being coupled to said reservoir.

11. The fluid rinsing assembly according to claim 10 including a header tank located at a level above said reservoir, said header tank being positioned to supply rinsing fluid to a cuvette washing system for washing cuvettes in a colorimeter apparatus and the output of said pump being connected to said header tank for supplying rinsing fluid thereto.

12. The fluid circuit according to claim 11 including a first standpipe which extends upwardly into said header tank for maintaining a predetermined level of fluid in said header tank, a receiver tank connected to an incubator tank of the automatic chemical analysis apparatus for supplying fluid to, and for maintaining the level of fluid in, said incubator tank, and the outlet of said first standpipe being arranged to drain into said

receiver tank.

13. The fluid circuit according to claim 12 including a system for supplying rinsing fluid to the probes of sampling heads in the automatic chemical analysis apparatus and a fluid connection between said receiver tank and said system for supplying rinsing fluid to the sampling head probes.

14. The fluid circuit according to claim 13 wherein said system for supplying rinsing fluid to the sampling head probes includes a trough movable between a lower fluid receiving position where the probes can move into and out of said trough and where fluid flows by gravity from said receiver tank through said fluid connection to said trough, and an upper retracted position where said trough is at a level above said receiver tank.

15. The fluid circuit according to claim 12 including means connected to the source of rinsing fluid for trickling fluid into said receiver tank only when said rinsing system is in a non-operative standby state.

16. The system according to claim 1 including a plurality of the cannulas depending from a manifold which is connected to said means for causing rinsing fluid to flow into and out of said cannulas.

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