United States Patent

[11] 3,565,286

[72] Inventor Allen Latham, Jr.
Jamaica Plain, Mass.
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[45] Patented Feb. 23, 1971
[73] Assignee Cryogenic Technology, Inc.
Waltham, Mass.

[54] **LIQUID PROGRAMMING AND PUMPING APPARATUS**
16 Claims, 13 Drawing Figs.

[52] U.S. Cl. 222/4, 417/319, 417/426, 417/477, 23/258.5
[51] Int. Cl. B67d 5/14, F04b 23/06, F04b 45/06
[50] Field of Search 222/144.5; 103/11, 149, 6; 250/202, 219; 23/258.5

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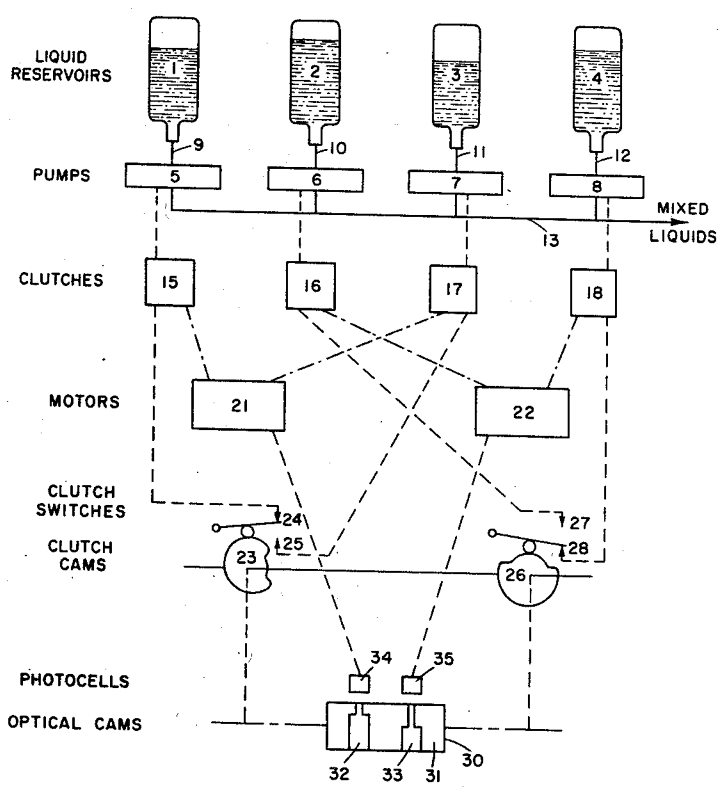
Primary Examiner—William L. Freeh
Attorney—Bessie A. Lepper

ABSTRACT: A liquid programming and pumping apparatus for delivering a liquid mixture, the flow rate and composition of which may be continuously varied in accordance with a predetermined protocol. Liquid reservoirs deliver liquid to a mixing manifold through flexible tubings which pass through roller pumps, the speeds of which are automatically adjusted by programmed optical cams which control the amount of radiant energy reaching detectors, the output of which are electrical signals controlling variable speed pump drive motors. The apparatus is particularly well-suited for integration with a centrifuge used in glycerolization and deglycerolization of red blood cells.



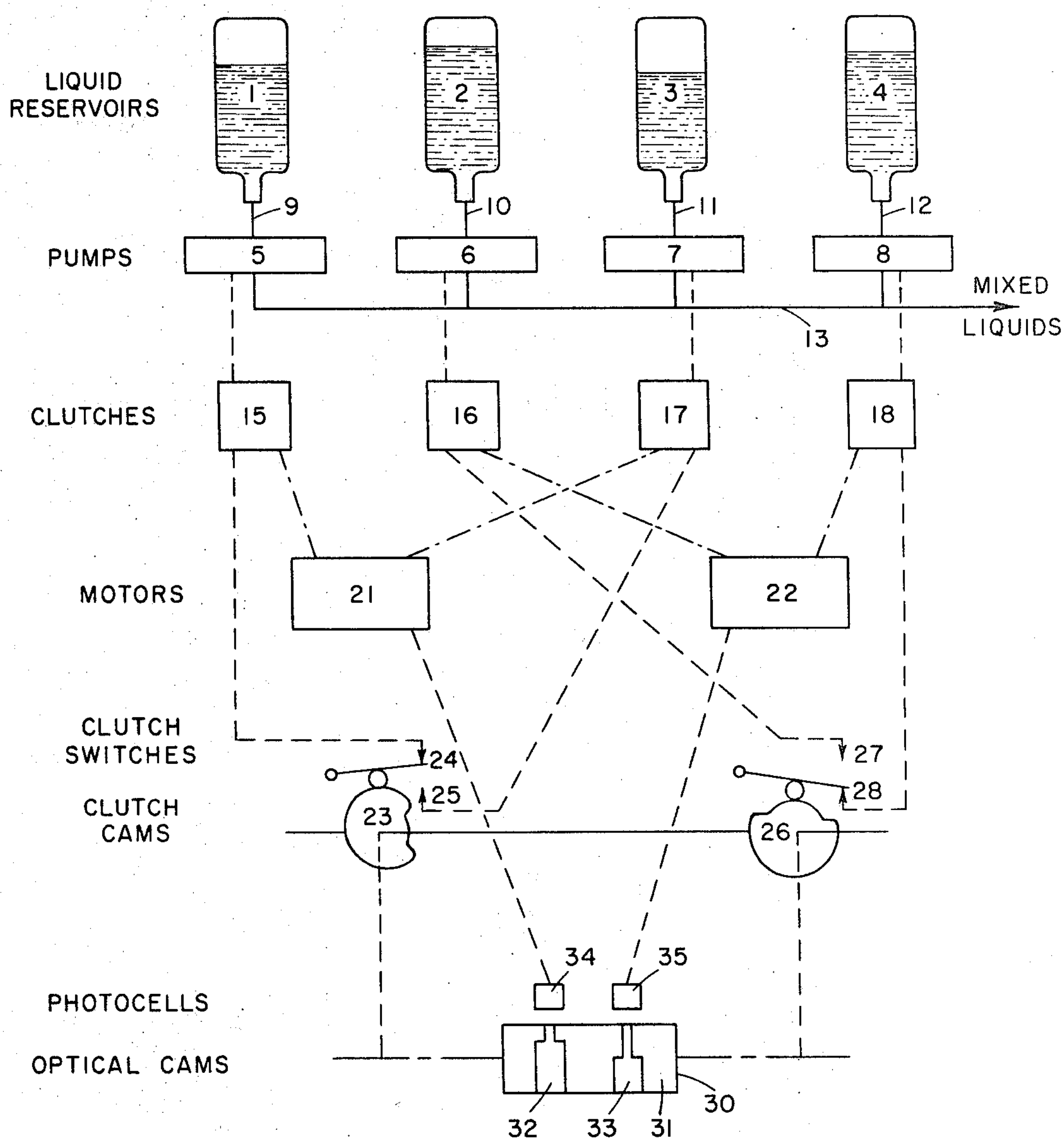


Fig. 1

INVENTOR.
Allen Latham, Jr.
BY
Bernie A. Lyons
Attorney

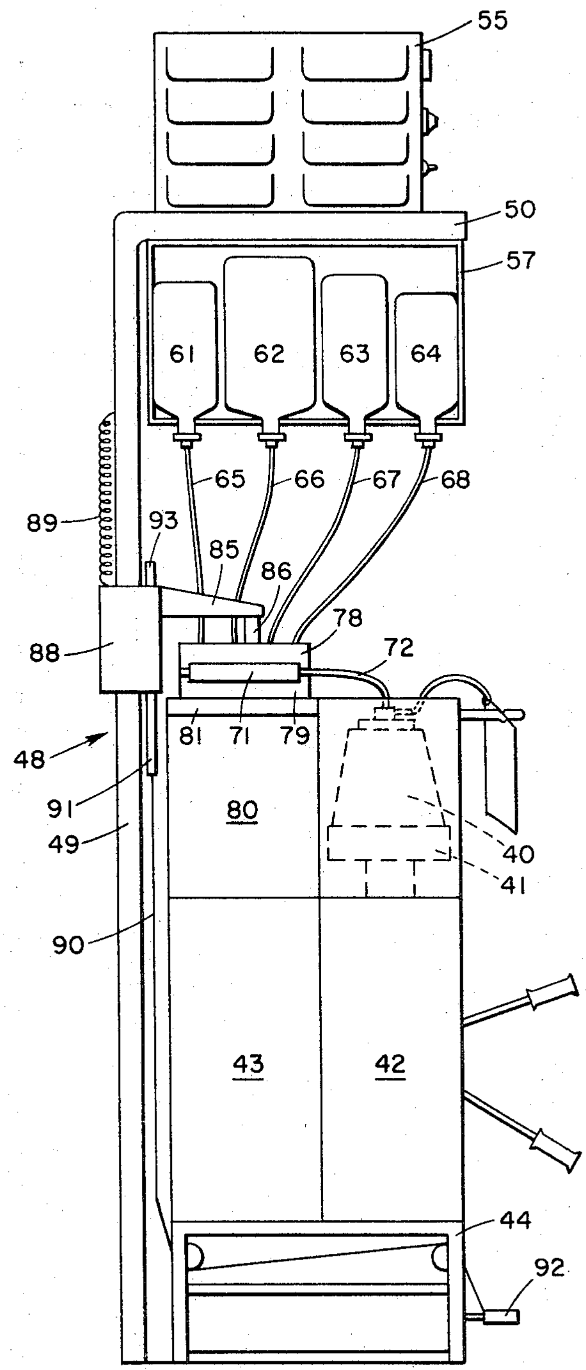


Fig. 2

INVENTOR.
Allen Latham, Jr.
BY Bruce A. Lepper
Attorney

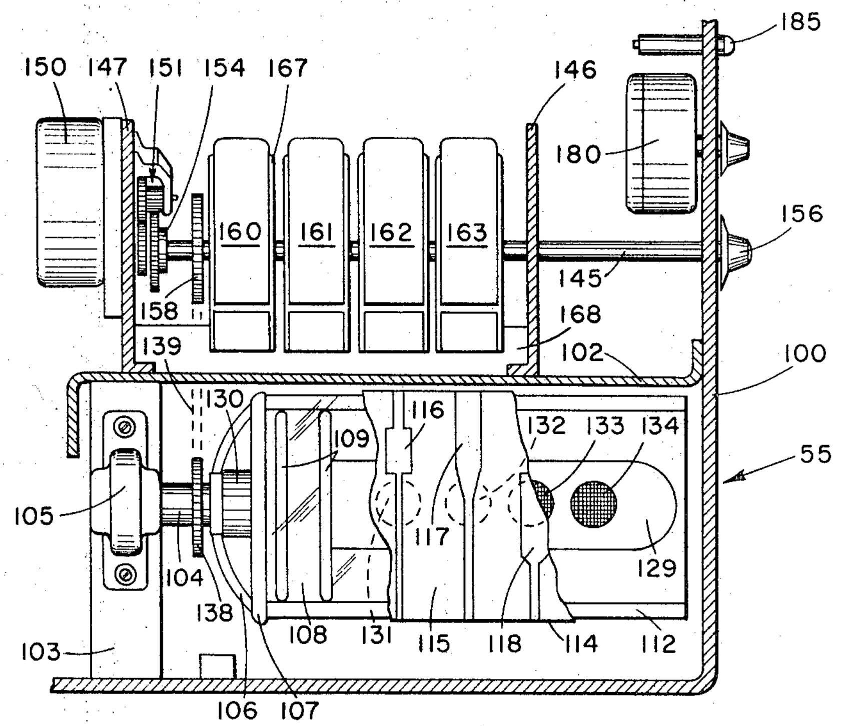


Fig. 3

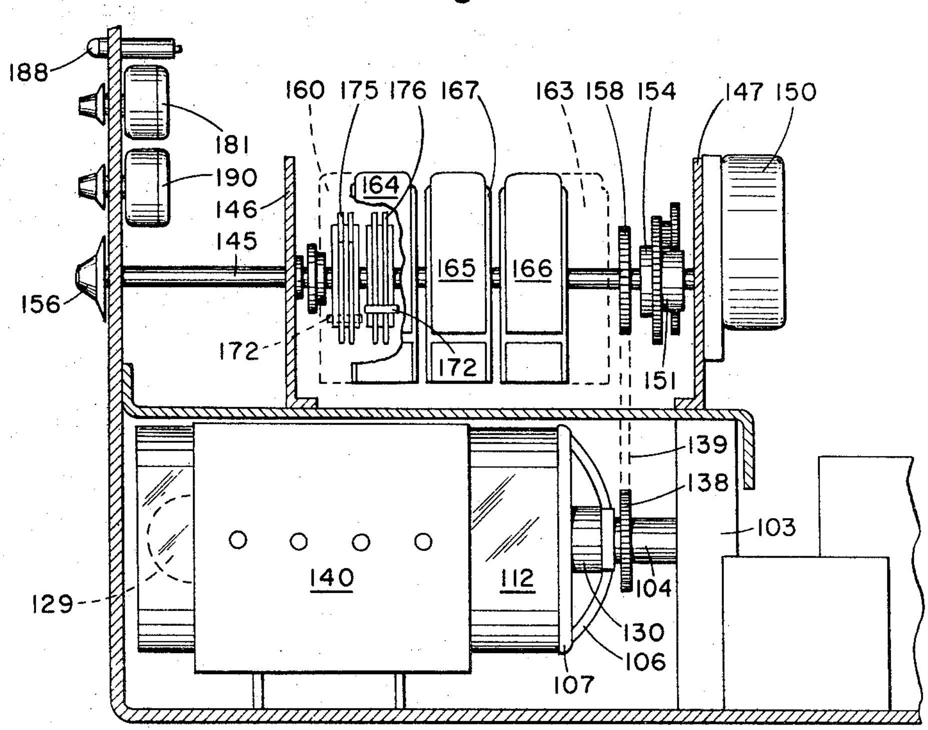


Fig. 4

INVENTOR.
Allen Latham, Jr.
BY Bernie A. Lynne
Attorney

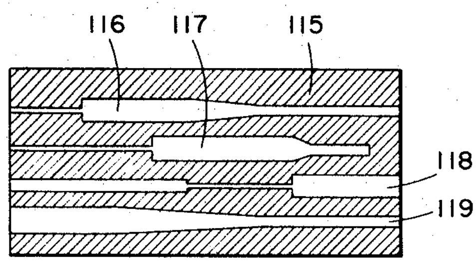


Fig. 5

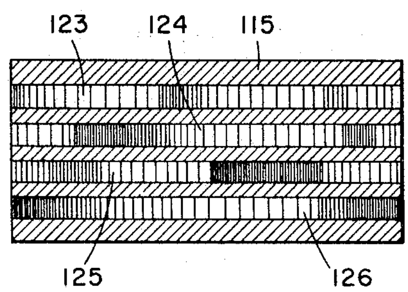


Fig. 6

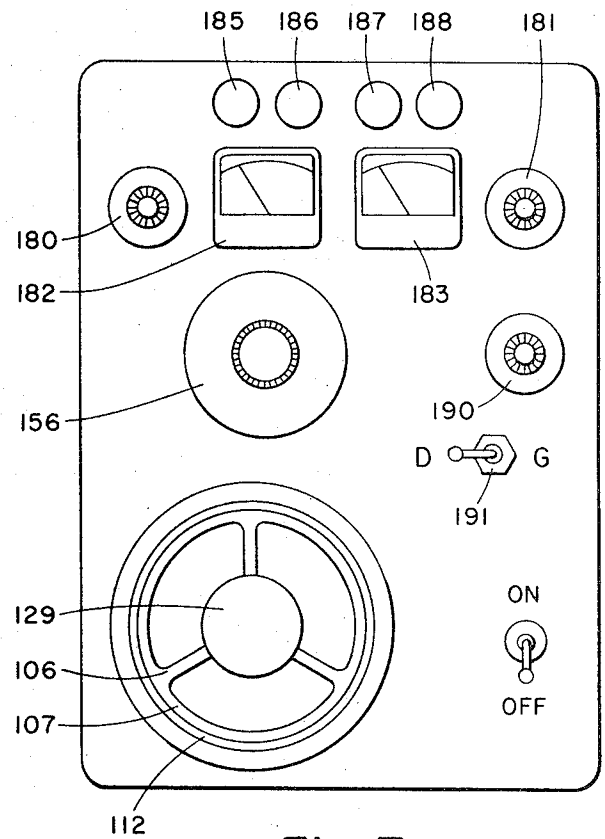


Fig. 7

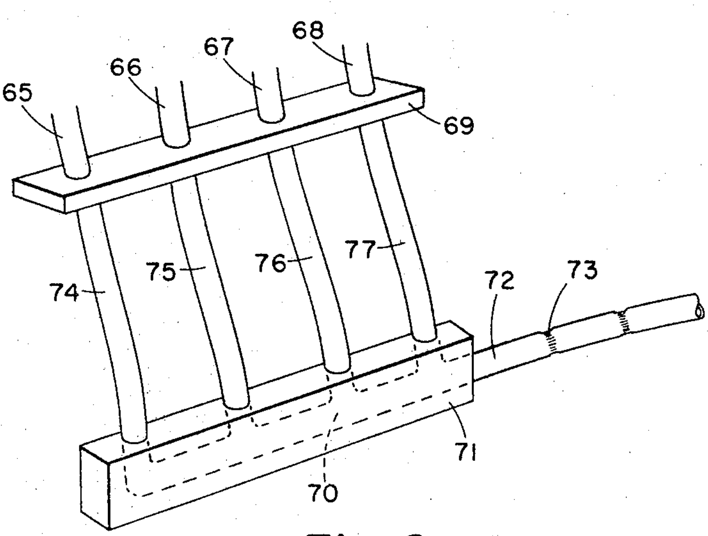


Fig. 8

INVENTOR.
Allen Latham, Jr.

BY Bernie A. Lynne

Attorney

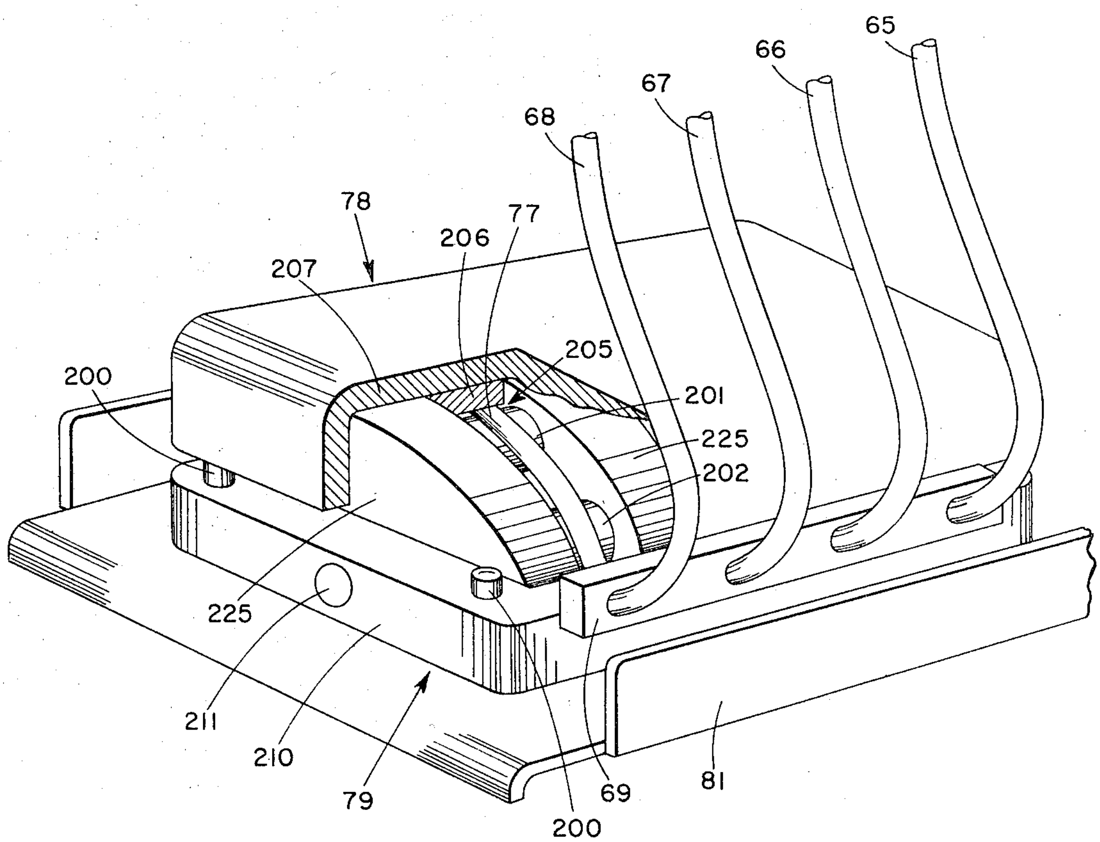


Fig. 9

INVENTOR.
Allen Latham, Jr.
BY
Attorney

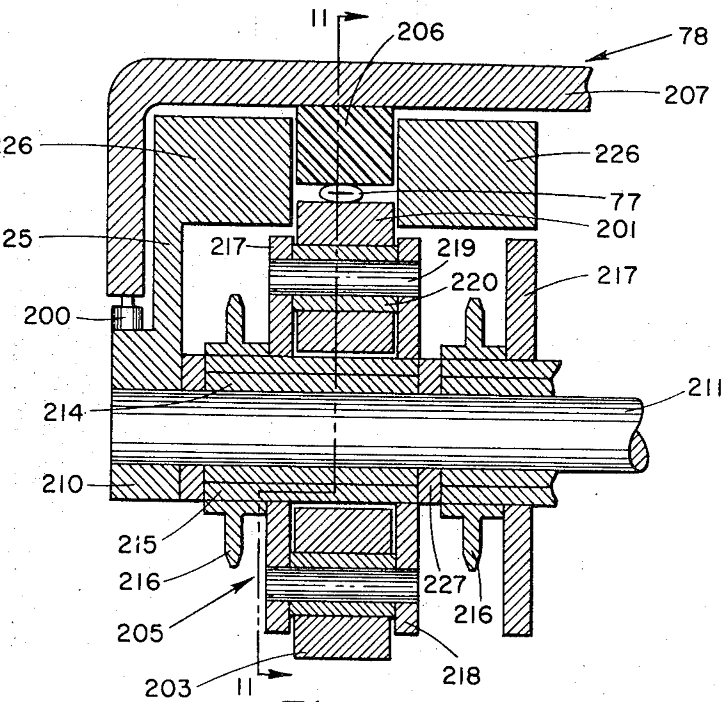


Fig. 10

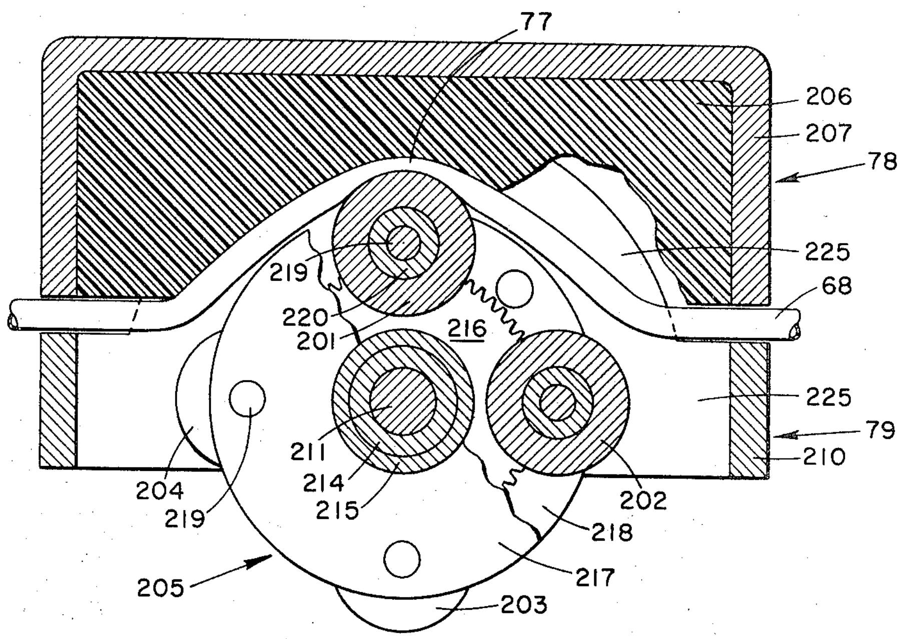


Fig. 11

INVENTOR.
Allen Latham, Jr.
BY
Attorney

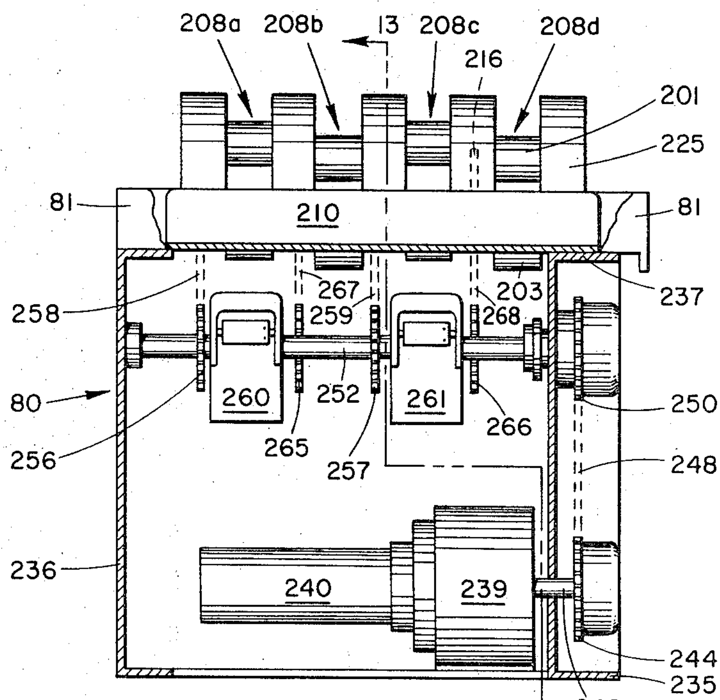


Fig. 12

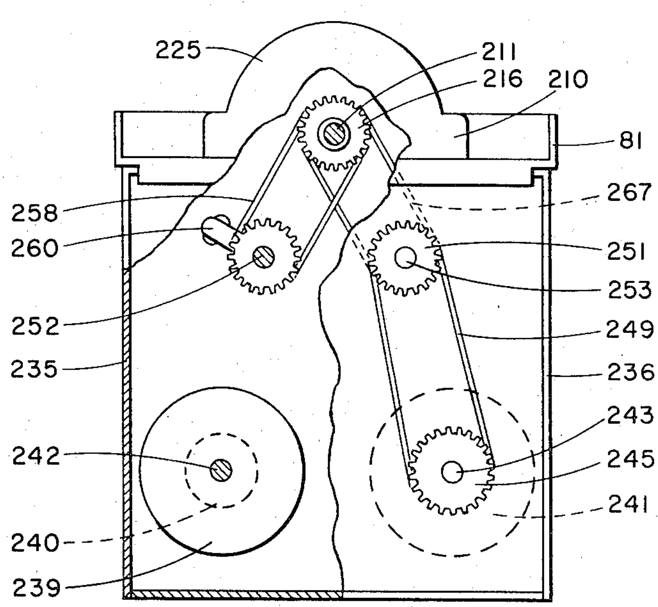


Fig. 13

INVENTOR.
Allen Latham, Jr.
BY Bernie A. Leyyner
Attorney

LIQUID PROGRAMMING AND PUMPING APPARATUS

This invention relates to a multiple pump for liquids and a programmer for use with the pump. More particularly, it relates to means for pumping a plurality of different liquids at predetermined rates to give a varying predetermined liquid composition for glycerolization of red blood cells prior to their low-temperature storage and for deglycerolization of the red blood cells retrieved from longterm, low-temperature storage.

Longterm storage of human blood requires that it be frozen in a liquid medium to protect it during storage. U.S. Pat. No. 3,145,913 describes and claims a preferred method and apparatus for handling blood which is to be stored. The blood is collected directly into a one-use sterile plastic liner placed in a centrifuge rotor wherein the red cells are stored after replacement of the intracellular and intercellular water by glycerol. When the blood is to be used, it is brought up to temperature, the liner is placed again in the centrifuge rotor and the glycerol is replaced by a suitable saline liquid while the red cells remain in the centrifuge liner.

Subsequent to the collection of the blood from the donor, the red cells must be concentrated by centrifuging and the replacement of the natural intercellular and intracellular water with glycerol must be gradual with the composition of this replacement liquid being varied from low to high glycerol. Likewise, when the blood is to be used it is brought up to ambient temperature and then the glycerol is gradually replaced during centrifugation with water by a wash solution, the composition of which is gradually varied by blending in order a low glycerol solution, then sodium lactate and then a buffered isotonic saline liquid.

In copending applications I have disclosed apparatus particularly suitable for processing blood for longterm storage. In Ser. No. 761,663 filed Sept. 23, 1968, I have disclosed a centrifuge spindle designed to be maintained at essentially ambient temperature; and in Ser. No. 761,558 filed Sept. 23, 1968, I have disclosed an improved centrifuge chunk which is largely automatic in operation and does not require a technician with special training to operate. The pump and programming apparatus of this invention are designed to be used in conjunction with such apparatus along with the method and apparatus of U.S. Pat. No. 3,145,913 and the rotary centrifuge seal of U.S. Pat. No. 3,409,213.

In U.S. Pat. No. 3,359,910 I have disclosed a mechanical pump for achieving somewhat the same type of liquid pumping and mixing. The pump assembly disclosed in this prior art is programmed through the use of mechanical cams which must be replaced one by one to change a program. Although such a pump assembly is capable of functioning in the desired manner it now becomes desirable to have an improved pumping and programming apparatus which is more flexible in operation, less complicated to operate and more easily integrated with centrifuge apparatus. The apparatus of this invention provides such a device.

It is therefore a primary object of this invention to provide a unique system of pumps and controls for automatically programming the flow of a liquid, the composition of which may be periodically or continuously varied in accordance with a predetermined program. It is another object of this invention to provide a pump and programming apparatus of the character described which is particularly suitable for controlling the flow and composition of liquids in a sterile regime thus making it particularly suitable for use in glycerolization and deglycerolization of red blood cells. It is yet another object to provide apparatus of the character described which is flexible in its use and operation, making it possible to change programs, connect in other equipment and to operate manually if desired. Other objects of the invention will in part be obvious and will in part be apparent hereinafter.

The invention accordingly comprises the features of construction, combination of elements and arrangement of parts which will be exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings in which:

FIG. 1 is a schematic diagram of the liquid programmer and pump system;

FIG. 2 is a side elevational view of the fluid programmer and pump incorporated into a complete processing apparatus;

FIGS. 3 and 4 are side elevational views partly in cross section of the programming mechanism and its control means;

FIGS. 5 and 6 are top plan views of two embodiments of optical cams in extended form;

FIG. 7 is a front elevational view of the programming mechanism and its control means;

FIG. 8 is a perspective view of the tubing harness which fits into the pump;

FIG. 9 is a perspective view of the pump assembly;

FIG. 10 is a cross section through a portion of the pump;

FIG. 11 is a cross section of the pump taken along line 11–11 of FIG. 10;

FIG. 12 is a side elevational view of the pump and its associated driving means; and

FIG. 13 is an end view of the pump and its associated driving means.

In the case of glycerolization and deglycerolization of red blood cells, it is customary to use several different solutions in making up the final liquid solution which is used to wash and then suspend the blood cells. As the centrifuging continues the amounts of the various liquids are changed. There are several "protocols" for programming the composition of the liquids introduced into the centrifuge. One such protocol under evaluation employs four different reservoirs constituting the source of different feed solution components. An automatic programmer suitable for following this protocol must be able to mix the output from the four reservoirs as follows: 1 and 2, 2 and 3, 3 and 4. Although the apparatus of this invention is capable of being constituted to handle any number of different feed solutions and hence of following any predetermined protocol, it will be described in terms of achieving this protocol in glycerolization and deglycerolization of red blood cells.

It will be apparent to those skilled in the art that the pump and programmer may also be used for various other purposes, for example in supplying a liquid having a continuously changing composition for analytical work or for supplying liquid reactant compositions in industrial processes wherein reactant ratios must be periodically or continuously changed.

In the blood-processing protocol chosen to illustrate the apparatus of this invention it is possible, if desired, to use only two variable-speed drive motors with four pumps by providing means for clutching between the motors and two pair of pumps. Another feature of the apparatus of this invention is the use of a wide-range type of speed control capable of running over a ratio change of from one to one thousand, thus making it possible to achieve very fine control over the final composition of the liquid mixture. Associated with this wide-range speed control is the use of varying light intensity cams and photocell sensors in conjunction with an amplifier circuit to attain the fine control. These optical cams may be arranged for two or more processing protocols, e.g., glycerolization and deglycerolization.

FIG. 1, which is a schematic diagram of the fluid programmer and pump system, may be used to present a general description of the apparatus components and their interrelationships which go to make up the system. As noted previously, a protocol requiring four separate solutions will be used. However, the apparatus is applicable to any number of liquids.

As diagrammed in FIG 1, the liquid components are supplied from four liquid reservoirs, 1,2,3 and 4, by gravity into four pumps 5,6, 7 and 8, respectively, through liquid conduits 9,10,11 and 12. The output from each pump is directed into a manifold 13 for transfer directly to a point of use. As will be described subsequently, this manifold may be provided with liquid mixing means. The pumps in turn are driven through associated clutches 15, 16, 17 and 18 by two motors 21 and 22, clutches 15 and 17 being associated with motor 21 and clutches 16 and 18 with motor 22. The actuation of clutches 15 or 17 is controlled by a cam 23 which may act to close switch 24 connected to clutch 15 or switch 25 connected to clutch 17. In like manner the actuation of clutches 16 or 18 is controlled by cam 26 and switch 27 and 28, respectively. The motor which rotates cams 23 and 26 also rotates a drum having an optical cam system 30 mounted thereon. The optical cam system 30 takes the form of a cylindrical drum member having a background 31 opaque to radiant energy and two transparent cams 32 and 33 which control the amount of radiant energy falling upon two detectors, e.g., photocells 34 and 35, at any given time. Thus by coordinating the movement of the cams 23 and 26 with the rotation of the optical cam system and with the design of the optical cams 32 and 33, it is possible to control the operation of motors 21 and 22, clutches 15, 16, 17 and 18, and hence pumps 5, 6, 7 and 8.

From the general description of the programmer and pump system it is possible to turn to a description of specific embodiments of the apparatus as represented in FIGS. 2—13. The various components illustrated and described are to be assumed to be illustrative of the various types of components and therefore it is not meant to limit the apparatus of this invention to the precise components shown.

To avoid any confusion in describing these components in detail, the number system of FIG. 1 will be replaced by a new set of numerals in FIGS. 2—13 in which FIGS. like reference numerals refer to like elements. Where necessary, the components of FIGS. 2—13 will be identified with their corresponding schematics of FIG. 1.

In FIG. 2 the programmer and pump system of this invention is shown incorporated in a complete blood-processing system. The centrifuge rotor 40 is mounted in a chuck 41, the mechanism for the operation of which is contained in housing sections 42 and 43, all supported on frame 44. The chuck 41, and spindle (not shown) for the centrifuge are subjects of the above-identified Ser. Nos. 761,558 and 761,663. The pump and programmer are mounted on a frame 48 comprised of a vertical support 49 and an upper horizontal support arm 50. The programming mechanism and control 55 are affixed to the upper surface of the support arm 50 while a slidably mounted fluid receptacle holder 57 is hung on the bottom of the support arm. A number of fluid receptacles 61, 62, 63 and 64 are mounted neck-down in the holder 57 and are joined through suitable connecting pieces to flexible tubings 65, 66, 67 and 68, respectively. As will be seen in perspective view of the tubing harness in FIG. 8, these tubings pass through a positioning and holding bar 69 and then join a single manifold tubing, a first section 70 of which is positioned within a second holding bar 71. A second section 72 of the manifold tubing extends beyond the holding bar 71 and is integral with or adapted to be connected to the inlet line of the centrifuge rotor 40. In the second section 72 and immediately beyond the first section there is at least one constriction 73 to achieve better mixing of the liquid components leaving the manifold and before introduction into the centrifuge rotor. Typically the constriction or constrictions should have a flow area between about 15 percent and 40 percent of the second section 72.

Between the two holding bars 69 and 71 of the harness are lengths 74, 75, 76 and 77 of the four tubings which fit into the pump assembly between the upper pump assembly section 78 and lower pump assembly section 79 (FIG. 2).

The pump assembly is supported on a housing 80 and set in a tray 81. The upper section 78 of the pump assembly is suspended from a pump assembly arm 85 through a connecting piece 86. Arm 85 is in turn mounted on a collar 88 which may be moved up and down on vertical support 49 and which is affixed thereto by a spring 89. A wire 90 joins the collar, through pin 91, to a foot pedal 92 to make it possible to raise and lower the upper section 78 of the pump by foot action. An adjustment nut 93 makes it possible properly to position the upper pump assembly section firmly against stop screws 200 (FIG. 9).

FIGS. 3 and 4 are side elevational views from opposite sides of the programming mechanism and control section 55. This section contains the clutch cams and switches, the optical cam system, the motor for driving these components and the photocell detectors and thus represents detailed embodiments of clutch switches 24, 25, 27 and 28, of cams 23 and 26, of photocells 34 and 35 and of optical cams 32 and 33 of FIG. 1.

The internal volume of housing 100 is divided by a horizontal frame 102 into lower and upper sections. Frame 102 is supported by a vertical support bar 103 on which is mounted an optical cam system stationary shaft 104 through its support block 105. On the shaft 104 there is rotatably mounted a frame 106 which holds an annular end plate 107 to which is affixed a mounting ring 108 having two elastomeric gripping rings 109. A transparent plastic cylindrical optical cam drum mount 112 slips onto the mounting ring 108 and serves to hold and support the optical cam system sheet 114 in the form of a cylindrical drum. This cam system sheet 114 may take one of several forms as illustrated in the extended views of FIGS. 5 and 6. In either form the the sheet is a flexible member suitable for bending into cylindrical drum form to be mounted on the plastic cylinder drum mount 112. The background 115 (shown cross-hatched) is opaque to radiation while the optical cam sections, which are of striplike configuration, are arranged to pass a predetermined amount of radiation. In the embodiment of the cam system of FIG. 5 (as well as FIG. 2) these cam sections are transparent strips 116, 117, 118 and 119 having varying widths, which in turn determine the amount of radiation striking the detector and hence the speed of the pump motor and the amount of liquid pumped from the reservoir attached to the particular pump.

In the embodiment of the cam system of FIG. 6 the strips of varying widths are replaced by constant-width strips 123, 124, 125 and 126 having varying optical densities throughout their length in somewhat the same fashion in which step tablets are constructed. The embodiment of FIG. 6 possesses the advantage of not requiring precise strip widths or precise alignments of the strips with respect to the detectors.

Returning to FIG. 3, it will be seen that the frame also supports a source of radiant energy, e.g., light bulb 129 mounted in socket 130, within the plastic cylinder drum mount 112. Positioned on one side is a series of four photocells 131, 132, 133 and 134 in a position to receive radiant energy through the optical cams 116, 117, 118 and 119 (the last not being shown). As pointed out previously, it is only necessary to provide two motors, each with two clutches, to program the flow of liquid from four reservoirs. However since, as will be described below, the apparatus is capable of operating on two protocols (glycerolization and deglycerolization) by merely actuating a switch, two separate photocells and their cams are conveniently provided for each of the two protocols. The apparatus thus has in effect two distinct modes of operation and could have additional modes by the incorporation of additional sets of cams and detectors. It is also, of course, within the scope of this invention to have a motor associated with each pump used.

A sprocket 138 is affixed to frame 106 for engaging chain 139. As will be seen in FIG. 4, the photocells are contained within a suitable housing 140 having connecting wire outlets for making suitable electrical connections in any well-known manner.

In the upper section of the housing 100 are located the clutch switches along with the cams which actuate them. A shaft 145 supported by uprights 146 and 147 is connected to a small clock motor 150 through appropriate gearing 151. Adjacent to gearing 151 is a slip clutch 154 and at the other end of the shaft is a manual control knob 156. The purpose of the slip clutch 154 is to prevent overloading of the motor and to make it possible manually to turn to any point in the cycle even when the motor is not running. Sprocket 158, affixed to shaft 145, engages chain 139 and thus the optical cam system, as well as the clutch cams, is driven by motor 150.

In the embodiment shown in FIGS. 3 and 4 a series of seven cams and associated switches are provided, the four cam-switch combinations shown in FIG. 3 being used for the two protocols of pump operation, two for the glycerolization protocol and two for deglycerolization. Two of the three cam-switch combinations facing them and shown in FIG. 4 are used to program the operation of the centrifuge and to stop the clock motor at the end of the cycle; while the remaining cam and switch are reserved as a spare actuating device for the automatic operation of desirable additional apparatus components.

The switches 160—166 may be of any standard construction which are suitable for actuation between two operational modes by the face of a cam. Those shown in FIGS. 3 and 4 are mounted in plastic mounts 167 and are attached to a switch mounting plate 168. As sketched in FIG. 4, each switch has a small spring-mounted cam-contacting roll 172 which engages the face of the cams, e.g., cams 175 and 176 associated with switches 160 and 164, respectively. There is, of course, a cam associated with each of the switches, all being mounted on shaft 145.

By use of the DC motor-generator, e.g., 240 (FIG. 12) in which the voltage produced by the generator is the feedback signal and is directly related to the speed of the motors (i.e., motors 21 and 22 of FIG. 1), it is possible to use voltmeters to read pump speeds and throughputs. Thus, there are provided potentiometers 180 and 181 and their associated voltmeters 182 and 183 for this purpose. One voltmeter for a motor can be used to read out the flow rate for two pumps (e.g., pumps 5 and 7 operated by motor 21 of FIG. 1). The four pilot lights 185—188 indicate which pump of each pair is being driven. Finally, as shown in FIG. 7, there is provided a switch 191 for choosing between the glycerolization cycle, G, and deglycerolization cycle, D. Other switches and related equipment are also provided in keeping with standard electrical circuitry practice.

The pumps (i.e., those schematically represented as pumps 5—8 in FIG. 1) are roller pumps of the complete occlusion type, i.e., there is no flow through them when they are not running and during operation they produce a flow approximately proportional to their rotational speed. A plurality of such pumps are contained within one pump assembly which in FIGS. 2 and 9 is shown to comprise an upper section 78 which is movable in a vertical direction and the lower section 79 which sits in and partly extends through tray 81 for connection with the pump motors as described below. The pump assembly is shown in perspective view in FIG. 9 and in two partial cross-sectional views in FIGS. 10 and 11. Reference will also be made to FIG. 8 which shows the tubing harness which fits into the pump.

Pumping of the liquid is achieved by delivering the liquid by gravity into a flexible plastic tubing (e.g., tubing 68 of FIG. 2) and then alternately compressing and decompressing its associated tubing section (e.g., 77 of FIG. 8) within the pump between a roller and a pressure surface. The rate of compressing and decompressing is controlled (as will be explained) by the rate of rotation of the motor which in turn is controlled by the output of an associated photocell (see FIG. 1 for schematic relation). For certain protocols for which a constant ratio between two or more liquid flows is desired, regardless of pump rotational speed, two or more tubes may be used in parallel and operated by one set of rollers.

In the embodiment shown in FIGS. 8 and 9, four tubings are shown while in FIGS. 10 and 11 cross sections are shown of one of the pumps, all of them being of identical construction.

In FIG. 9 the pump assembly is shown in operational condition with the tube harness of FIG. 8 in place. Adjustable spacer screws 200 maintain the upper and lower sections in spaced relationship to provide the desired degree of occlusion of the tubes. The holding bar 69 serves properly to space the tubings and to anchor them against the drag of the pump rollers.

Tubing section 77 of tubing 68 is shown in the pump in a compressed condition in FIGS. 9—11. It is compressed between roller 201 (which is one of four rollers 201, 202, 203 and 204 rotatably mounted on a rotating assembly 205) and a contoured pressure platen 206 which is bonded to the inside of the cover 207 of the upper pump section. One of these pressure platens is provided for each pump, and they are preferably formed of a synthetic resin which exhibits some degree of resiliency. The platens should be sufficiently hard to assure occlusion of the tubing section in the pumps; while at the same time being sufficiently resilient to accommodate variations in dimensional tolerances within the roller pumps and within the tubings. An example of a suitable resin for the pressure platens is a polyurethane having a 60-Durometer hardness.

Mounted in the bottom section housing 210 is a stationary shaft 211 on which the rotating assembly 205 carrying the rollers is rotated. Each of the rotating assemblies is constructed as shown in FIGS. 10 and 11 and comprises a bushing 214, a hub 215 affixed to or integral with the bushing and a sprocket 216 affixed to the hub. Also attached to the hub are two end plates 217 and 218 in which a roller pin 219 is firmly mounted. The roller pin 219 has the rollers, e.g., roller 201 rotatably mounted on it through a roller bushing 220. Each of the sprockets 216 is enclosed in the upper section of the pump in a sprocket housing comprising a vertical semicircular member 225 cast integral with bottom section housing 210. As seen in FIG. 10 the upper portion 226 of this housing is relatively heavy walled giving weight and stability to the pump assembly. Each pump of the pump assembly is isolated from its adjacent pump or pumps by a spacer 227.

It will be seen that a pump assembly may comprise any number of pumps (e.g., roller assembly, associated sprocket and pressure surface) and since each is driven separately at its own speed, each pump is capable of delivering liquid to the manifold at a predetermined rate pattern separate and distinct from all of the other pumps. Thus, the amount of liquid pumped over any given period by each pump may be accurately controlled.

Returning to FIG. 1 it will be seen that the four pumps shown are driven by two motors each having a pair of clutches associated therewith. The mechanism for achieving the pump drive is illustrated in FIGS. 12 and 13 in which like reference numerals are used to refer to like elements in FIGS. 2—11. The pump-driving means and control 80 are mounted in a housing comprising front end plate 235, rear end plate 236 and a top frame 237 which sits in tray 81 and permits the lower portion of the pump assembly to extend into the housing defined by this framework.

Within this framework are two variable speed DC motor-generators 240 and 241, the shafts 242 and 243 of which are connected to sprockets 244 and 245. Associated with each motor-generator is a speed-reducing means, e.g., 239 of FIG. 12. Through chains 248 and 249 these lower sprockets are mechanically linked to upper sprockets 250 and 251 which are affixed to two parallel shafts 252 and 253, respectively. On shaft 252 are mounted two clutches 260 and 261 which through sprockets 256 and 257 and chains 258 and 259 are mechanically linked to the sprockets 216 associated with pumps 208*a* and 208*c*. Clutches 260 and 261 which are electrically connected to the appropriate clutch switches (FIGS. 3 and 4) determine which of the two sprockets 256 or 257 and hence which of the two pumps 208*a* or 208*c* the motor 240 drives at any one time.

In like fashion two sprockets 265 and 266 and associated chains 267 and 268 are connected to the sprockets 216 of pumps 208*b* and 208*d*. A clutch (not shown) is associated with each of these sprockets and each clutch is electrically connected to an appropriate clutch switch which in turn determines whether motor 241 drives pump 208*b* or 208*d*.

The operation of the pump and programmer of this invention begins with a determination of a protocol under which the apparatus is to operate. Assume as an example that for deglycerolization it is desired to deliver liquids from a first and second reservoir in equal volumes during a first period, then liquids from a second and third reservoir in a volume ratio of 2 to 1 during a second period and finally liquids from a third and fourth reservoir in a volume ratio of 1 to 2 during a third period. It will, of course, be appreciated that these ratios may be varied by discrete steps or continuously during a period, this being accomplished by the design of the optical cams. However, for purposes of simplification of this illustration, such varying of the ratios within a period is not assumed.

Assume further that, in accordance with the general scheme of FIG. **1**, the liquid reservoirs in order of their use are reservoirs **61—64** (FIG. **2**), and that the pumps for these reservoirs are **208*a*—208*d***, respectively (FIG. **12**). Clutches **260** and **261** and sprockets **256** and **257** control the operation of the first and third pumps, namely pumps **208*a*** and **208*c***; and optical cam **116**, photocell **131**, switch **160**, its clutch cam **175** (FIGS. **3** and **4**) and motor **240** are connected to clutches **260** and **261**. In similar fashion the two clutches on shaft **253** and sprockets **265** and **266** control the operation of the second and fourth pumps **208*b*** and **208*d***; the optical cam **119**, photocell **134**, switch **163** and its clutch cam, and motor **241** are connected to the clutches (not shown) which are mounted on shaft **253**. These relationships may be summarized in the following tabulation, the numbers referring to the apparatus components in the drawings.

Apparatus Component	Periods: First				Second				Third			
Liquid	1	2	3	4	1	2	3	4	1	2	3	4
Reservoirs	61	62	63	64	61	62	63	64	61	62	63	64
Volume ratio	1	1	--------			2	1	-----------			1	2
Pumps	208a	208b	--------			208b	208c	-----------			208c	208d
Pump Drive Sprockets	256	265	--------			265	257	-----------			257	266
Clutches	260	ns*	--------			ns	261	-----------			261	ns
Motor	240	241	--------			241	240	-----------			240	241
Clutch Cam and Switch	160	163	--------			163	160	-----------			160	163
Photocells	131	134	--------			134	131	-----------			131	134
Optical Cams	116	119	--------			119	116	-----------			116	119

*Not shown in drawings but described in text.

As motor **150** (FIGS. **3** and **4**) slowly rotates the optical cam system, the amount of light striking photocells **131** and **134** through optical cams **116** and **119** is adjusted to adjust the speed of motors **240** and **241** to pump the desired volume of liquid by pumps **208*a*** and **208*b***. This requires that the clutch cams be designed in this part of the protocol to engage through their switches the proper clutches associated with pump drive sprockets **256** and **265**.

During the second period the clutch cam associated with switch **160** is designed to engage the clutch associated with sprocket **257** to drive pump **208*c*** associated with reservoir **63**. The rate of rotation of motor **240** remains the same since the volume desired from this pump is the same as from pump **208*a*** in the first period. With this change of motor **240** from pump **208*a*** to **208*c***, the liquid flow from the first reservoir is cut off. During this second period, however, the flow rate from pump **208*b*** is to be doubled so that cam **119** is cut to permit a sufficient quantity of radiation to strike photocell **134** to provide a signal to motor **241** to double its speed.

Finally, during the third period the clutch cam associated with switch **163** effects the disengagement of the clutch associated with pump drive sprocket **265** and the engagement of clutch associated with pump drive sprocket **266**, thus stopping pump **208*b*** to stop the flow from reservoir **62** and starting pump **208*d*** and the flow of liquid from reservoir **64**. Optical cam **119** is so designed to rotate the motor **241** at the same speed required during the previous period since the volume ratios required from reservoir **64** remains the same as from reservoir **62**.

In a similar manner optical cams **117** and **118**, photocells **132** and **133**, and switches **161** and **162** with their clutch cams may be used to perform a glycerolization protocol. Switching from one protocol to another is accomplished through shifting a selector switch.

Great versatility of control is made possible in the use of this apparatus through the provision of the slip clutch in the clock motor gear train which permits manual override of the clock motor; and the electronic gain controls **180**, **181** and **190** may be used to override the optical cams at any time during the cycle. Modes of operation, other than those outlined above in the description of operation, are possible with the apparatus of this invention. For example, the device is amenable to the incorporation of other sensing means such as a photocell which picks up the point when first red cells appear at a predetermined point to indicate that the centrifuge rotor is filled. A signal transmitted by this photocell could be used to change pump speed. Thus liquid level, color or some other physical change in the centrifuge can be used to effect changes in the pump and programmer operation.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the scope of the inventions, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. A liquid programming and pumping apparatus, comprising in combination:
   a. a plurality of reservoirs arranged for discharge of liquids therefrom;
   b. a plurality of roller pumps, each of said roller pumps comprising;
      1. a rotatable assembly having mounted thereon a plurality of rollers; and
      2. a contoured pressure platen arranged with said rollers in rotating sequence to engage and compress flexible tubing, said pressure platen being formed of a resin of sufficient hardness to assure occlusion of said tubing and of sufficient resiliency to accommodate variations in dimensional tolerances within said roller pumps and said tubings;
   c. flexible tubing conduit means providing fluid communication between said reservoirs through said pumps to manifold means and mixing means;
   d. variable pump drive means associated with each of said pumps and comprising a motor and motor speed control means capable of responding to signals of varying magnitude; and
   e. means for controlling each of said variable pump drive means comprising programmed cam means and means

responsive to said programmed cam means and being adapted to generate said signals, whereby the volume flow rate of liquid from each of said reservoirs and the total volume flow rate and composition of liquid in said manifold and mixing means are controlled.

2. An apparatus in accordance with claim 1 wherein those portions of said flexible tubing conduit means passing through said pumps are held in a removable harness comprising first and second tubing holding bars, said manifold means being in part located in said second tubing holding bar and said mixing means being characterized as being constrictions in the fluid passage immediately beyond said manifold means.

3. An apparatus in accordance with claim 1 wherein said programmed cam means are optical cams and said means responsive to said programmed cam means comprise radiant energy-detecting means adapted to generate said signals.

4. An apparatus in accordance with claim 1 wherein said programmed cam means are rotatable optical cams and means for rotating said optical cams, said optical cams being adapted to transmit radiant energy in amounts following a predetermined pattern and said means responsive to said programmed cam means comprise, in combination:

1. a photocell associated with each of said optical cams and adapted to receive said radiant energy and to convert it to an electrical signal; and
2. means adapted to amplify said signal and to transmit an amount of electrical energy to said motor to exactly sustain said motor speed called for by said signal.

5. A liquid-programming and -pumping apparatus, comprising in combination:

a. a plurality of reservoirs arranged for gravity discharge of liquids therefrom;
b. a plurality of roller pumps;
c. flexible tubing conduit means providing fluid communication between said reservoirs through said pumps to manifold and mixing means;
d. variable pump drive means associated with each of said pumps and comprising a motor and motor speed control means capable of responding to signals of variable magnitude;
e. optical cam means, comprising in combination:
   1. a rotatable cylindrical drum having a plurality of circumferential striplike optical cam members adapted to control the amount of radiant energy transmitted therethrough;
   2. means for rotating said drum; and
   3. a source of radiant energy positioned within said drum;
f. detecting means adapted to receive radiant energy from said source through said cam members and to convert said energy to signals, the magnitude of which are functions of the amount of radiant energy transmitted to said detecting means through said cam members; and
g. means to transmit said signals to said motor speed control means whereby the speeds of said pumps and hence the flow rates of said liquids are determined by said optical cam members.

6. An apparatus in accordance with claim 5 wherein said striplike optical cam members vary in width thereby to control the transmission of said radiant energy.

7. An apparatus in accordance with claim 5 wherein said striplike optical cam members vary in optical density thereby to control the transmission of said radiant energy.

8. An apparatus in accordance with claim 5 further characterized by having clutch means associated with said variable pump drive means and adapted to effect engagement and disengagement of said pump drive means and selected ones of said roller pumps with which said pump drive means are associated.

9. An apparatus in accordance with claim 8 further characterized by having clutch control means synchronized with said optical cams means.

10. A liquid programming and pumping apparatus, comprising in combination:

a. a plurality of reservoirs arranged for discharge of liquids therefrom;
b. a plurality of roller pumps;
c. a liquid mixing manifold;
d. flexible tubing conduit means providing fluid communications between said reservoirs through said pumps to said manifold, those portions of said flexible tubing means passing through said pumps being held in a harness comprising first and second tubing holding bars;
e. variable pump drive means associated with said pumps;
f. optical cam means, comprising in combination:
   1. a rotatable cylindrical drum having a plurality of circumferential striplike optical cam members adapted to control the amount of radiant energy transmitted therethrough;
   2. means for rotating said drum; and
   3. a source of radiant energy positioned within said drum;
g. detecting means adapted to receive radiant energy from said source through said cam members and to convert said energy to signals, the magnitudes of which are functions of the amount of radiant energy transmitted to said detecting means through said cam members;
h. clutch means associated with said variable pump drive means and adapted to effect engagement and disengagement of said pump drive means and selected ones of said roller pumps with which said pump drive means are associated; and
i. clutch control means synchronized with said optical cam means.

11. An apparatus in accordance with claim 10 wherein each of said roller pumps comprises;

1. a rotatable assembly having mounted thereon a plurality of rollers; and
2. a contoured pressure platen arranged with said rollers in rotating sequence to engage and compress said flexible tubing, said pressure platen being formed of resin of sufficient hardness to assure occlusion of said tubing and of sufficient resiliency to accommodate variations in dimension tolerances within said roller pumps and said tubing.

12. An apparatus in accordance with claim 10 wherein said striplike optical cam members vary in width thereby to control the transmission of said radiant energy.

13. An apparatus in accordance with claim 10 wherein said striplike optical cam members vary in optical density thereby to control the transmission of said radiant energy.

14. An apparatus in accordance with claim 10 wherein said mixing manifold is a flexible tubing, a first section of which is positioned within said second tubing holding bar and a second section of which is adapted for connection to a centrifuge rotor, said second section having at least one constriction to serve as a liquid mixing means.

15. An apparatus in accordance with claim 14 wherein said constriction has a flow area between 15 percent and 40 percent of said second section.

16. An apparatus adapted to provide liquid at a predetermined rate and composition to a centrifuge, comprising in combination:

a. a plurality of reservoirs arranged for discharge of liquids therefrom;
b. a plurality of roller pumps;
c. flexible tubing conduit means in fluid communication with said reservoirs passing through said roller pumps and being held in a harness comprising first and second tubing holding bars;
d. a liquid-mixing manifold to which said flexible tubing conduit means are joined, said mixing manifold being a flexible tubing, a first section of which is positioned within said second tubing holding bar and a second section of which has at least one constriction to serve as a liquid-mixing means;
e. a centrifuge rotor adapted for connection with said second section of said mixing manifold;
f. variable pump drive means associated with said pumps;
g. optical cam means, comprising in combination

1. a rotatable cylindrical drum having a plurality of circumferential striplike optical cam members adapted to control the amount of radiant energy transmitted therethrough;
2. means for rotating said drum; and
3. a source of radiant energy positioned within said drum;

h. detecting means adapted to receive radiant energy from said source through said cam members and to convert said energy to signals, the magnitudes of which are functions of the amount of radiant energy transmitted to said detecting means through said cam members;

i. clutch means associated with said variable pump drive means and adapted to effect engagement and disengagement of said pump drive means and selected ones of said roller pumps with which said pump drive means are associated; and

j. clutch control means synchronized with said optical cam means.