Sept. 2, 1969 C. L. KING ETAL 3,464,359

APPARATUS FOR MOVING FLUID FROM ONE SYSTEM TO A SECOND SYSTEM

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Fig.1

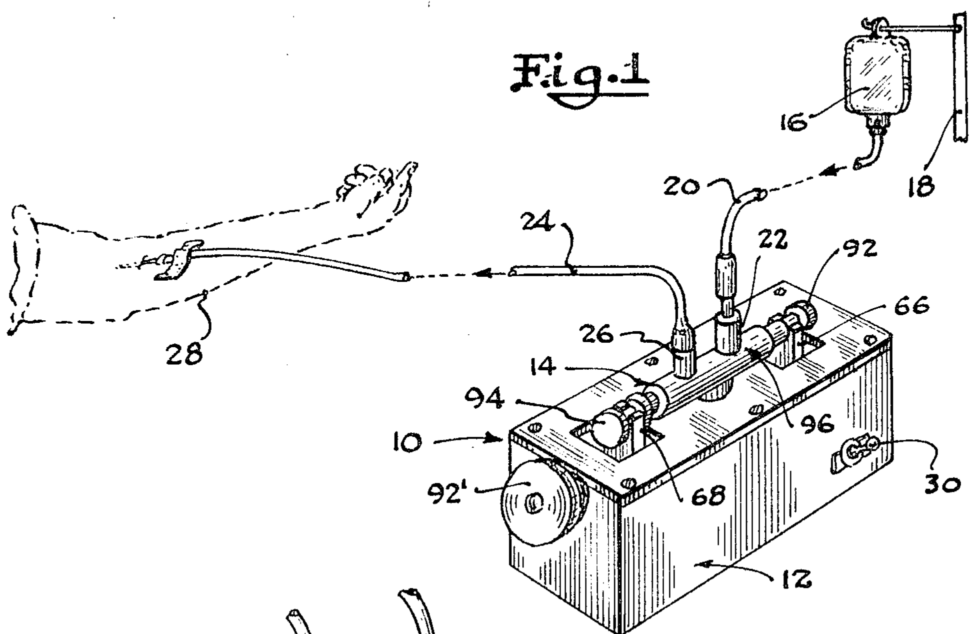

Fig.2

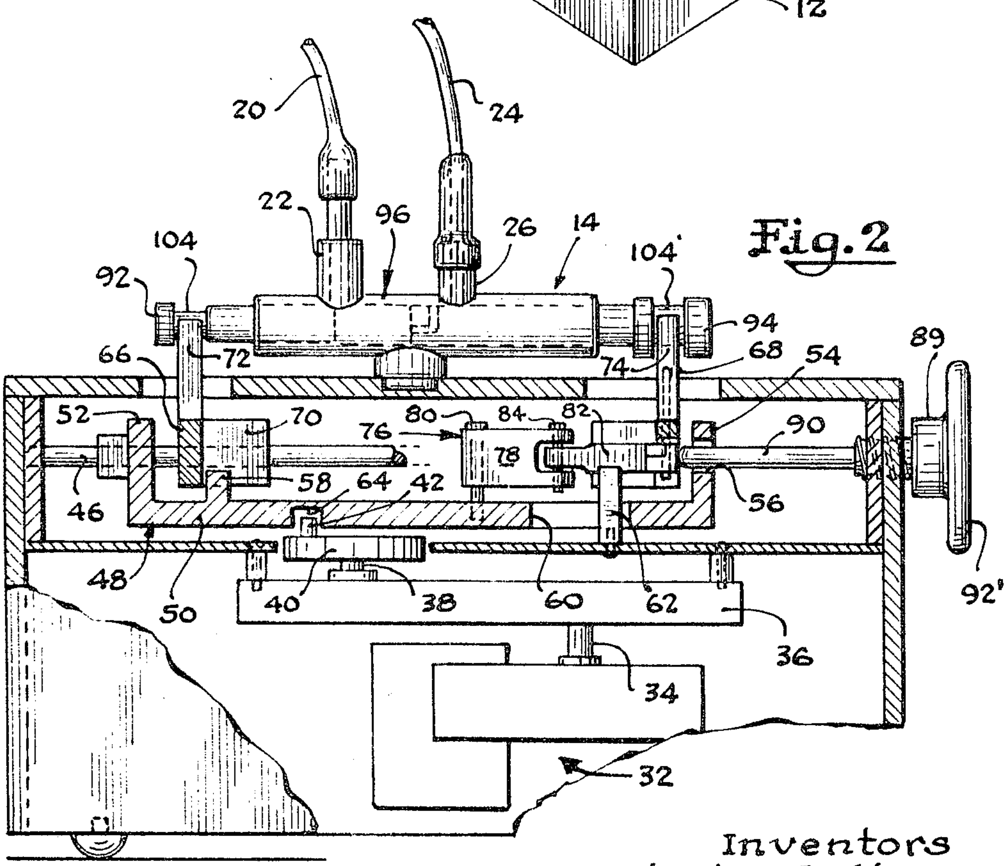

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Fig. 3

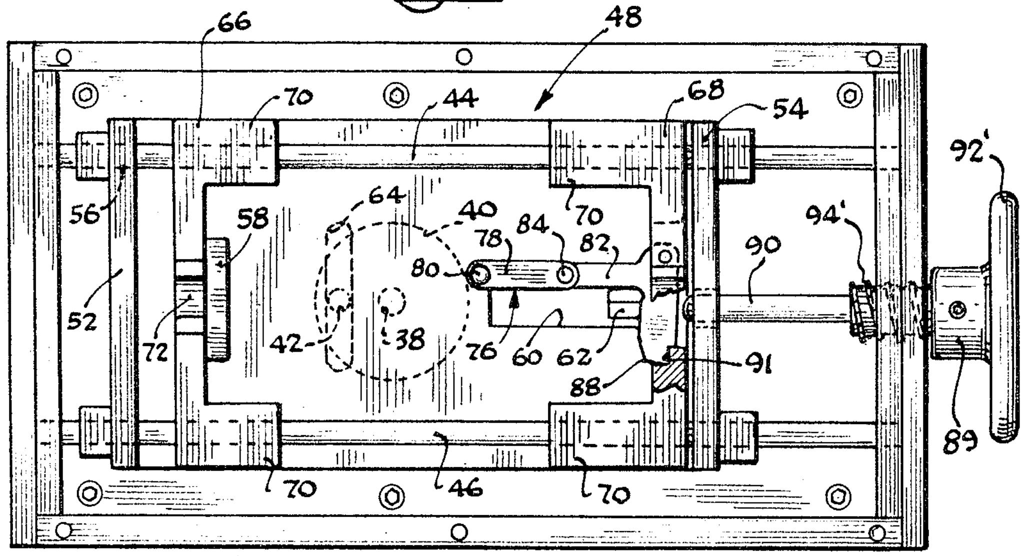


Fig. 4

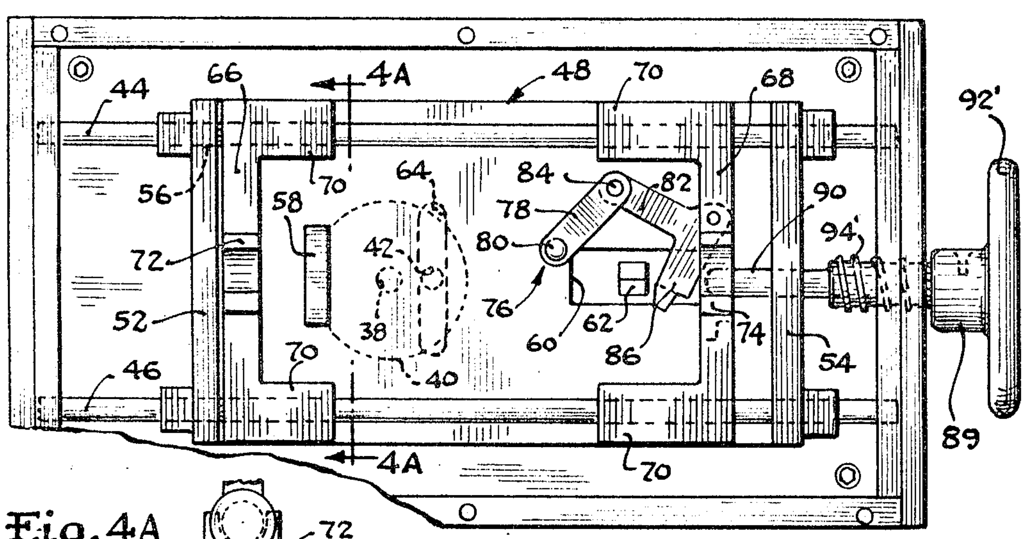
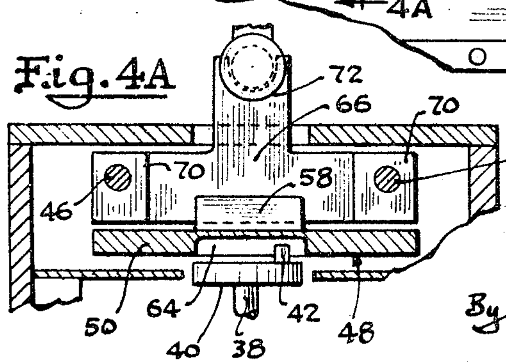


Fig. 4A



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APPARATUS FOR MOVING FLUID FROM ONE SYSTEM TO A SECOND SYSTEM

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Fig. 5

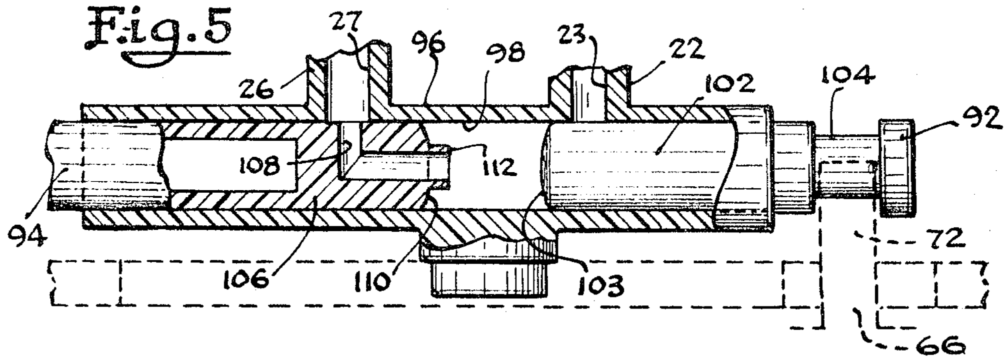


Fig. 6

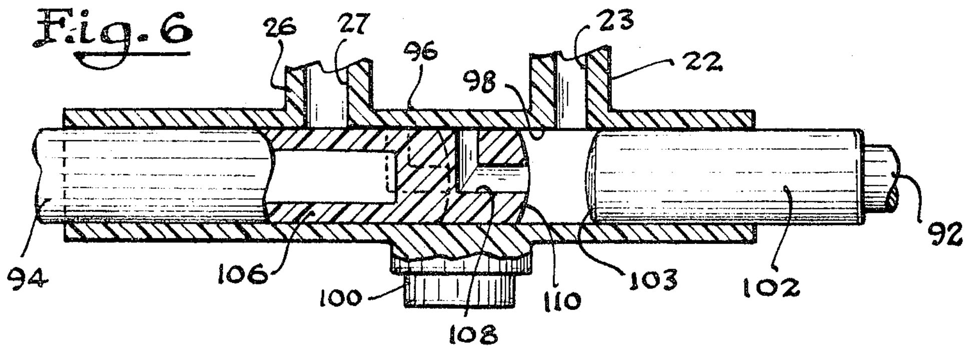
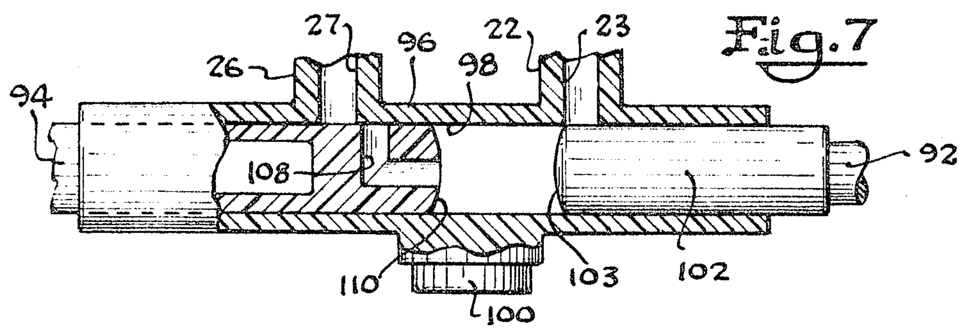


Fig. 7



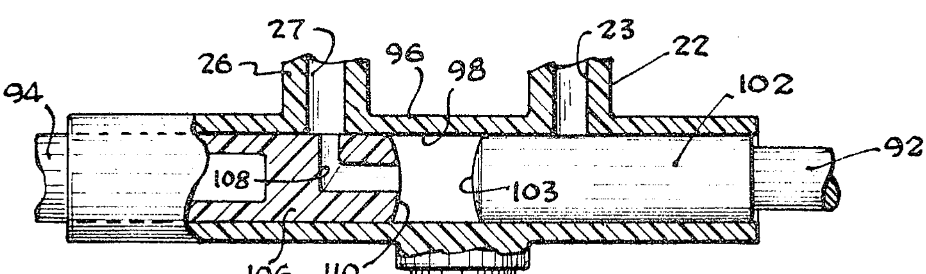


Fig. 8

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United States Patent Office

3,464,359

Patented Sept. 2, 1969

3,464,359

APPARATUS FOR MOVING FLUID FROM ONE SYSTEM TO A SECOND SYSTEM

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Filed Nov. 13, 1967, Ser. No. 682,474
Int. Cl. F04b *49/00, 3/00*
U.S. Cl. 103—38 16 Claims

ABSTRACT OF THE DISCLOSURE

A fluid pump for moving fluid from one system to another under pressure having means to assert positive, precise control over the flow rate and to isolate the outlet of the pump from small quantities of air occurring therein, the pump including control means to shuttle the inlet and outlet pistons in regulated manner.

Disclosure

The present invention is directed to the provision of an improved fluid pump and, more particularly, is directed to a pump adapted for transferring fluid from one system to another at a positively controlled flow rate while isolating the outlet from small quantities of air that may occur in the system.

Background of invention

Fluid transfer devices, of course, are generally well known and exist in many different forms. It should be observed, however, that a satisfactory fluid pump has not been developed for control of the pumping and flow rate when transferring intravenous solutions, including blood from a reservoir, or bag, to the body. The system commonly used for this purpose is the gravity feed system where a bag is supported above the level of the body to which it is being introduced and where the flow rate is controlled by the gross pressure of a clamp upon the flexible tube extending between the bag and the body. It can readily be seen that the flow rate of fluid through the tube will be a function of the amount of constriction of the tube.

Control of flow rates in the manner defined above is difficult at best and not amenable to precise regulation or quick, controlled change in flow rates.

It should be noted that a simple pump action would not be generally suitable for transferring blood, for example, since close control of flow rate may be desired and because of the critical requirement to avoid the transfer or introduction of air during the fluid transfer action. It can readily be seen that the introduction of air could result in an embolism.

The present invention is directed to the provision of a fluid pump suitable for the transfer of intravenous solutions, including blood, which will provide positive, controlled pumping and flow rate and which isolates the outlet from air which may occur in the system.

It is, accordingly, a general object of the present invention to provide an apparatus for the transfer under pressure of fluid from one system to another.

Another object of the present invention resides in the provision of an improved fluid transfer apparatus having positive, controlled pumping action.

A further object of the present invention resides in the provision of an improved fluid transfer apparatus having means to vary the flow rate in a controlled manner.

An additional object of the present invention resides in the provision of an improved fluid pump for transferring intravenous fluids from one system to another.

Another object of the present invention resides in the

provision of an improved fluid pump for transferring intravenous fluids from one system to another with means to isolate the outlet from any quantity of air that may occur in the system.

A further object of the present invention resides in the provision of an improved fluid transfer apparatus that is comprised of relatively few elements, that is economical to manufacture, easy and economical to use, provides positive control of fluid transfer and has means to vary flow rates.

The invention itself is set forth with particularity in the appended claims. Further objects and advantages of the invention, however, will be understood from reading the following description of the invention in conjunction with the drawings, in which:

FIGURE 1 is a perspective view of the apparatus of the present invention illustrating the control means and pump, in combination, and schematically showing transfer of fluid from a bag to a body;

FIGURE 2 is a side elevation, partly in section, of the apparatus of the present invention showing the details of the control means, its functional elements and its relation to the pump of the apparatus;

FIGURE 3 is a top plan view of the control means of FIGURE 1 illustrating the control means in one extreme operative position;

FIGURE 4 is a top plan view of the control means, like FIGURE 3, with the control means shown in the other extreme operative position;

FIGURE 4A is a fragmentary sectional view of the apparatus of FIGURE 1 particularly illustrating the cam means utilized to control movement of the shuttle;

FIGURE 5 is a side view, partly in section, of the pump of the present invention illustrating the inlet piston in sealing relating to the inlet port and the outlet piston in fluid discharge relation to the outlet port;

FIGURE 6 is a side view of the pump, like FIGURE 5, showing the pump with the pistons in position to permit entry of fluid to the central chamber of the pump;

FIGURE 7 is a view of the pump, like FIGURE 5, showing the pump in the stage of operation sequentially following that illustrated in FIGURE 6 and showing the inlet and outlet ports both in sealed relation; and

FIGURE 8 is a view of the pump, like FIGURE 5, illustrating the fluid discharge position and the stage of operation sequentially following that illustrated in FIGURE 7.

Referring more particularly now to the drawings, the apparatus is indicated generally at **10** and includes the control means **12** and pump **14**. The apparatus of the present invention will specifically be described as an apparatus for transferring intravenous solutions, including blood (whole or plasma), from a reservoir to the body. It should be noted, however, that the fluid transfer apparatus of the present invention may be employed to transfer fluid from one system to another system generally without restriction to the character of the fluid. It has its more useful aspects in the transfer of intravenous solutions and blood, however, and is particularly suited for this purpose.

A blood reservoir, or bag, **16** is shown in FIGURE 1 and is supported by a conventional hanger stand **18**. A suitable fluid conduit **20** extends from the reservoir **16** to the inlet **22**. A second conduit **24** extends from the pump outlet **26** to the body **28** where it may intravenously be introduced by means well known in the art.

The control means **12** of the apparatus of the present invention is encased in a suitable housing. A power supply control switch **30** may be provided on the housing to control the on-off condition of the apparatus. The switch **30** is disposed within the line (not shown) leading to the power supply or motor **32** and is adapted for interruption of the continuous circuit otherwise defined between the motor **32** and a 60 cycle 115–120 volt supply line (not shown).

The output shaft **34** of the motor **32** moves at a relatively high angular velocity which may be about 1700 r.p.m.'s. This is much to high to be within the useful range for the present apparatus. Accordingly, the output shaft **34** defines the input to a suitable speed reduction means **36**. The output of the speed reduction means **36** is defined at the shaft **38** and will be a fraction of the input velocity.

A cam plate **40** is non-rotatably secured to the shaft **38**. A cam follower **42** is secured to the plate **40** in a radially outboard position thereon to define a circular path of motion when driven in operation of the apparatus disclosed herein.

Support bars **44** and **46** are mounted in the housing of the control means **12**. As shown in FIGURES 3 and 4, the ends of said bars are supported by the end walls of the housing for the control means **12**. These bars define guide and support members for the reciprocating elements of the control means, as defined hereinbelow.

A shuttle member **48** is mounted on the bars **44** and **46** for sliding movement in either direction along said bars. The shuttle **48** is defined by a base section **50** terminating at either end in upstanding leg sections **52** and **54**, respectively. Suitable openings **56** are provided in the legs **52** and **54**, in axially aligned relation, to receive the bars **44** and **46**.

The base section **50** of the shuttle **48** is provided with a block or projection **58** on the upper surface thereof and near the leg **52** of the shuttle. An opening **60** is defined in the base **50** near the leg **54** of said shuttle. A projection **62**, carried by the housing of the control means **12**, extends through the opening **60**, the function of said projection being set forth in detail hereinbelow.

The bottom surface of the shuttle **48** is provided with a cam track **64** which extends in a generally straight path, normal to the longitudinal axis of the shuttle and in which the cam follower **42** is guided. It should be observed that the cam assembly may assume any suitable configuration, other than disclosed, to satisfy the motion requirement of the apparatus. It can readily be seen that as the cam plate **40** rotates the cam follower **42** will move in a generally circular path with the plate. The path defined by the cam follower **42** will be translated into a linear reciprocatory motion of the shuttle **48** by reason of the follower **42** riding in the cam track **64** during its movement. The path length of the cam track **64**, of course, is necessary to accommodate the lateral vector movement of the follower **42** as it moves in its circular path. The vector quantity of the follower movement which lies in direction parallel to the longitudinal axis of the shuttle **48** will cause the shuttle **48** to move in a reciprocatory motion along the bars **44** and **46**.

A first piston engaging means **66** is mounted on the bars **44** and **46** for sliding action therealong in response to movement of the shuttle, as indicated hereinbelow. A second piston engaging means **68** is mounted on the bars **44** and **46** adjacent the other end of the shuttle **48** and is disposed on said bars for sliding motion therealong in response to movement to the shuttle **48**.

Each of the piston engaging means (**66** and **68**) of the present apparatus is defined by spaced apart arms **70** having openings extending therethrough to receive the bars **44** and **46**, respectively. The arms **70** of the means **66** are joined to an upstanding trunnion-like element **72** on the first piston engaging means **66**. The arms **70** of the means **68** are joined to an upstanding trunnion-like element **74** of the second piston engaging means **68**. The trunnion-like elements **72** and **74** of the apparatus each are open at the top and include spaced apart arms that may be sprung apart slightly to receive a mating portion of the piston associated therewith to grasp the pistons and move them in conjunction with movement of the means **66** and **68**, respectively.

A control element, indicated generally at **76**, is provided to define means for varying the flow rate of the apparatus and for control thereof during operation of the apparatus. The control element **76** includes a first link **78** pivotally mounted at one end thereof to the base **50** of the shuttle **48** by the pin **80**. The link **78** is pivotally joined at the other end to a second link **82** by the pin **84** to define a toggle-like linkage for the control member **76**.

The link **82** is in the general shape of a crank-arm having the first leg pivotally joined to the link **78**, as noted hereinabove, and having a second leg extending substantially at right angles to the first leg to define a control bar stop **86**. The second link **82** is pivotally mounted to the second piston engaging element **68** at the point where the first and second legs of the link are joined. Accordingly, the link **76** then is pivoted at three positions:

(1) At the outboard end of the link **78**;
(2) At the common ends of the link **78** and link **82**; and
(3) At the joint of the first and second legs of the link **82**.

A rate adjustment member **89** threadably extends through a wall of the housing for the control means **12**. The member **89** is defined by a probe **90** and an adjustment knob **92'** secured thereto. A threaded section **94'** is interposed between the knob **92'** and the probe **90** and threadably engages a mating threaded portion in the wall of the housing (FIGURES 3 and 4). The flow rate may be adjusted by moving the knob **92'** clockwise or counterclockwise to move the probe **90** into or out of the housing of the control means **12**. The specific control function will be set forth in detail hereinbelow.

The control element **76** is shown in one position in FIGURE 3 with the links **78** and **82** in aligned relation and in a second position (FIGURE 4) with an included angle between said links. It can readily be seen that the control element positions of FIGURES 3 and 4 represent the extreme operative positions of the apparatus. The shuttle **48** is in the extreme left position in FIGURE 3 and in the extreme right position in FIGURE 4.

The link **76** is urged into the straightened position of FIGURE 3 by the projection **62** which moves into contact with the bar stop **86** when the shuttle **48** moves to the left (FIGURE 3) bringing the stop **86** against the projection **62**. The bar stop **86** includes a slight shoulder **88** at the free end thereof which moves against a mating shoulder **91** on the piston engaging means **68** to prevent movement of the link **76** to an "over-center" position and to assure pivoting in the direction shown in FIGURE 4. It is possible that without this stop the link **76** might lock or freeze and inhibit movement of the shuttle **48** and related mechanism thereby giving rise to a condition which could result in damage to the apparatus.

As shown in FIGURE 2, the pump means **14** is provided with two pistons **92** and **94**. The first piston **92** is disposed in operative relation to the inlet **22** of the pump and is retained in the piston engaging means **66** of the apparatus. The second piston **94** is disposed in operative relation to the outlet **26** of the pump and is operatively associated with the piston engaging means **68** of the apparatus.

The pump **14** of the present invention is shown in greater detail in FIGURES 5 to 8, inclusive, of the drawings. The pump **14** includes a pump body **96** having an inlet **22** and an outlet **26** interconnected by a pump chamber **98**. The pump chamber **98** is the central bore of the body **96** and extends continuously along the body to define the fluid conveying chamber and means for insertion and operation of the pistons **92** and **94** of the apparatus.

A positioning lug **100** is provided on the body **96** to orient the body with respect to its associated apparatus. It should be noted that any suitable means of orientation may be employed. This particular use of the lug is only one means of many that would satisfy this requirement. The lug **100** may be received in a mating opening in the housing of the apparatus **12** to position the pump **14** properly with respect to the apparatus for engagement of the pistons of the pump and for operation of the pump by the control means set forth herein. The positioning lug also may be adapted to assure proper orientation of the pump with respect to the control. It also should be noted that the pump of the present invention may be operated by other suitable control means, if desired. It may be desirable in some conditions of use to operate the pistons in simultaneous shuttle movement within the body rather than in sequential movement as disclosed herein. Such operation would require the use of a modified pump operating and control means different from that specifically disclosed herein which would provide the required action. Still other desired programmed operation may be achieved with other devices in combination with this pump which would not detract in any way from the use of the pump but which suggest the flexibility of operation of the pump disclosed herein apart from the control means specifically set forth by way of illustration of the apparatus.

The piston **92** is disposed in the central chamber **98** of the pump body **96** adjacent to the inlet end **22** thereof, as indicated in FIGURE 5 of the drawings. The bore of the chamber **98** is such as to receive the head **102** of the piston **92** in fluid sealing relation therein without additional sealing means being employed. It should be observed, however, separate sealing means may be used. For example, one may elect to use O-rings along the head of the piston. Another, and perhaps more suitable sealing means in pumping fluids would reside in the use of formed disposable jacket elements (not shown) which would be telescopically received over the piston heads and would seal between the piston head and the inner wall of the chamber **98**. This would provide the required sealing action between the piston head and the central chamber **98** of the pump body **96**. Additionally, it would provide the attractive advantage of being able to form the pistons from a different material than the sealing element. This may result in sustantial economy in the forming operation and, of course, in the expense of the apparatus. The sleeve may be molded of an inert, elastomeric material which would not react in any way to the fluid being pumped and which would, at the same time, provide the necessary sealing action for the apparatus.

The outboard ends of the pistons **92** and **94** are provided with a recessed portion as illustrated at **104** of the piston **92**. The recessed portion **104** of the piston **92** is received in the trunnion **72** of the piston engaging means **66** of the apparatus. The recessed portion **104'** of the piston **94** is received in the trunnion **74** of the piston engaging means **68** (see FIGURE 2). In this manner the pistons **92** and **94** are engaged by the means **66** and **68**, respectively, and are caused to move in accordance with the movement of the means **66** and **68**, as noted below.

The piston **94** is received in the chamber **98** of the pump body **96** adjacent to the outlet **26** of the pump **14**. The piston **94** includes a piston head **106** having an opening **108** therein extending from the inboard end **110** of the piston **94** continuously through the piston head and to the wall of the piston to define a continuous fluid passage from the chamber **98** between the ends of the pistons **92** and **94** to the outlet opening **27** of the outlet **26** when the opening **108** is in registration with the opening **27**. A flange **112** may be provided at the chamber terminal of the opening **108** as illustrated in FIGURE 5 for a reason to be noted below.

The outside diameter of the piston **94** may be substantially the same as the inside diameter of the chamber **98** so that a sealing relation between the piston head and the chamber will be defined in use. It should be observed, however, that an auxiliary seal for piston **94** may be provided when the differential pressure across the piston head is significant which seal will be the same as noted above for piston **92**. The molded sleeve or piston head, however, would carry the opening or provide access for the opening **108** to permit fluid flow through the piston head **106**.

The operation of the pump may be understood by reference to FIGURES 6, 7 and 8 in conjunction with the description set forth below. The intake cycle of the pumping operation is illustrated in FIGURE 6. At this stage of operation the second, or outlet piston **94**, is fully inserted into the chamber **98** and is at its maximum path of travel inwardly of the chamber. At this point it remains stationary for a brief interval while the first, or inlet piston **92**, is withdrawn past the inlet opening **23**. As the piston head **102** uncovers the opening **23** fluid begins to enter the chamber and continues to enter the chamber during opening movement of the piston **92**. The fluid reservoir is disposed above the level of the pump in most instances in our specific example and in this position a fluid pressure head will be established which will cause the fluid to flow from the reservoir to the pump chamber any time that a chamber volume is presented to it and the inlet opening **23** is opened to permit the passage of fluid into the chamber **98**. The fluid is fed to the chamber **98** by a combination of gravity feed and pressure differential between the reservoir and expanding chamber volume.

When the desired amount of fluid has been introduced into the chamber **98** the piston head **102** will, in sequence, move to the left (FIGURE 6) to cover the inlet opening **23** to seal it and thereby isolate the chamber **98** from the reservoir **16**. This position is shown in FIGURE 7 where the desired amount of fluid has entered the chamber **98** and is trapped therein between the piston head **102** of the first piston **92** and the head **106** of the second piston **94**. It can readily be seen that fluid cannot flow through the opening **108** to the outlet opening **27** during the intake (FIGURE 6) or transport (FIGURE 7) stages since the wall terminal of the opening **108** is still isolated from the opening **27**. Accordingly, the fluid is trapped between the end **103** of the piston head **102** and the end **110** of the head **106** with, of course, a small amount of fluid also being trapped within the full extent of the opening **108**.

The discharge portion of the cycle is illustrated in FIGURE 8 where the opening **108** is brought into registration with the outlet **27** to permit flow of fluid from the chamber **98** into the outlet **27**. The fluid is discharged from the chamber **98** into the outlet by bringing the end **103** of the piston **92** into close spaced relation to the end **110** of the piston head **106**. If the flange **112** is present then, of course, the end **103** is stopped prior to engagement of said end with the flange.

The cycle then is repeated with the pistons **92** and **94** being moved to the right (FIGURES 6, 7 and 8) to the position substantially as shown in FIGURE 6 of the drawings.

It can be seen that if any air is in the system it will naturally rise to the top of the chamber **98** and will not pass into the outlet **27** since the top of the chamber **98** is isolated at all times from connection with the outlet **27**. In this way air in the system is prevented from entering the outlet system for possible discharge to the body where it could cause an embolism or air blockage. The pump of the present invention is adapted for use in any position while still maintaining the characteristic of preventing air flow to the outlet. This feature is readily seen with the pump in the position shown in FIGURES 6, 7 and 8, for example. If the pump were oriented such that the piston **92** is at the top, then the air would rise against the head **102** of the piston **92** and would not enter the outlet **27** during pumping operation. It should be noted that not all of the fluid is pumped from the chamber during each cycle. A small amount is left each time to prevent discharge of air to the outlet and to provide a simpler mode of operation. If the chamber **98** is completely filled with air, the outlet piston will not be forced to a position where the opening **108** will register with the outlet opening. Air is compressible, of course, and the inlet piston will only compress the air in chamber **98** without forcing the piston **94** to expose the outlet opening.

If the pump **14** is oriented such that the piston **94** is at the top, the flange **112** will be necessary. It can readily be seen that any air in the system will rise to the top and move against the end **110** of the piston head **106**. However, the flange extension **112** on the conduit **108** will define a fluid path to the chamber **98** which will be slightly immersed and which will be below the air entrapped within the chamber. In this manner air again will be prevented from entering the outlet **27**, as in each of the other cases noted above.

The operation of the control means of the present invention may best be understood by reference to FIGURES 2–4A, inclusive, in conjunction with the following description of its operation.

The fluid intake position of the control means **12** when used in conjunction with the pump disclosed herein is shown in FIGURES 2 and 3 of the drawings. As indicated, the first piston engaging means is moved fully to the left by the pushblock **58** on shuttle **48** (the shuttle movement having been described above). Movement of the means **66** to the left will, of course, carry the associated piston **92** along with it. As the piston **92** moves to the left (FIGURES 2 and 3) it will eventually expose the intake opening **23** of the intake opening **22** and permit fluid to enter the chamber **98** from the reservoir **16** which is connected thereto by the conduit **20**.

It can be seen that the upstanding leg **52** moves to the left beyond the back face of the means **66** for a slight distance. The leg **52**, of course, does not carry the means **66** to the left (FIGURE 2)—the means **66** is moved to the left by the push block or projection **58**. As the shuttle **48** moves to the left it eventually will engage the front face of the means **66** and will cause the piston engaging means **66** to slide along the bars **44** and **46** in unison with the continued leftward movement of the projection **58** (the projection, of course, being rigidly secured to the base **50** of the shuttle). However, a lost motion is provided between the projection **58** and the upstanding leg **52** to permit filling of the chamber **98** during the intake operation of pump cycle. This lost motion is achieved by permitting the shuttle to begin its leftward movement and to continue it for a short distance before the projection **58** engages the means **66** to start movement of the piston **92** leftward (FIGURE 2). At this time the upstanding leg **52** has moved a short distance toward the left and is in spaced relation to the back face of the first piston engaging means **66**. The leg **52** and means **66** remain in the spaced relation during continued movement of the shuttle **48** toward the left. Accordingly, when the leftward movement of the shuttle has been completed the space between the front face of the leg **52** and the back face of the means **66** defines the time interval during which the piston **92** will remain stationary during continued movement of the shuttle **48** in a reverse, or rightward, direction.

As the cam assembly continues in its operation to move the shuttle **48** the direction of movement will change from left to right, as noted above. At the extreme left position of the shuttle, the link **76** will be in its straight position, as shown in FIGURES 2 and 3. The stop **62** will be resting fully against the face of the control bar stop **86**.

Continued movement of the shuttle **48** to the right will bring the leg **52** into engagement (after a predetermined interval) with the piston engaging means **66** and start the piston **92** moving toward the right. The piston **92** then will move over the opening **23** to seal it and isolate it from the reservoir **16**. As the shuttle **48** continues to move to the right pumping action eventually will occur moving the fluid from the chamber **98** to the outlet **26** of the pump **14**.

When the pump **14** is in the fluid intake position, the outlet piston **94** will be positioned such that the outlet opening **27** will be sealed and the opening **108** will be out of registration therewith, as illustrated in FIGURES 2 and 6. During the fluid intake sequence of operation, the piston **92** will temporarily be stationary. However, the piston **94** will move toward the right (as shown in FIGURE 2) with the shuttle **48** to define a pump chamber opening **98** which is continually enlarging to permit introduction of a predetermined, measured quantity of fluid to the chamber **98**. The amount of fluid drawn into the chamber on each stroke is regulated by the position of the member **89**. When the probe **90** engages the bar **86** continued shuttle directed movement of the piston **94** is terminated. Piston **94** may only be moved now by the force of the fluid trapped between the pistons **92** and **94**. Since the fluid is not compressible the piston **94** will move in direct response to movement of the piston **92** until the opening **108** registers with the outlet of the pump. The piston **94** stops at this position since further movement of piston **92** will only push the fluid from the chamber **98** through the opening **108** to the pump outlet.

Prior to the time that the opening **108** begins to fall into registration with the outlet opening **27**, the piston head **102** will pass over the inlet opening **23** to seal it and to prevent an open fluid circuit between the reservoir and the outlet system. This position is illustrated at FIGURE 7 of the drawings and will be between the positions of FIGURE 3 and FIGURE 4 of the control means.

The shuttle **48** continues movement toward the right (FIGURE 2) under action of the cam assembly, as noted above. The link **76** will remain in the straight condition shown in FIGURE 3 until the bar stop **86** engages the probe **90** of the rate adjustment member **89**. One end of the link **76** is pivotally secured to the base **50** of the shuttle **48** while the other end of the link **76** is pivotally secured to the second piston engaging means **68**. Accordingly, movement of the shuttle **48** will result in a corresponding movement of the means **68** as long as the link **76** remains in the straight position of FIGURE 3. The link assumes the function of a pusher arm in this position.

When the bar stop **86** strikes the positionally adjustable probe **90** of the rate control member **89**, the second link **82** and the first link **78** pivot about the pin **84** in accordion fashion. This action of the link arm **76** permits continued movement of the shuttle **48** rightward (FIGURE 2) while stopping continued movement of the piston engaging means **70** and the related piston **94**. As noted above, when this occurs the chamber **98** is full.

The piston **94** is stopped when in registration with the outlet opening **27** but while the piston **92** is still moving to the right with the shuttle **48**. Accordingly, the continued movement of the piston **92** will serve to move substantially all of the fluid within the pump chamber **98** through the opening **108** of the piston head **106** and into the outlet opening of the pump.

The shuttle **48** completes its rightward movement as shown in FIGURE 4. The leg **54** of the shuttle **48** is slightly to the right of the back face of the means **68** and is about the same distance from means **68** as the projection **58** is to the means **66**. As the shuttle **48** begins to move toward the left again under the action of the cam assembly (noted above) the front face of the leg **54** will engage the means **68** to move the piston **94** to a position where the opening **108** is out of registration with the outlet opening **27** and a fluid seal is defined at the outlet. The projection **58** engages the means **66** at the same time to cause it and piston **92** to move left to later expose the inlet **23** and permit introduction of another supply of fluid to the chamber **98**. The cycle noted above is repeated during the pumping operation.

The link **76** is straightened during continued movement of the shuttle to the right. It will be noted that as the assembly moves toward the right the shuttle **48** will pull the link **76** to a partially straight condition with a large included angle (but less than 180°) between the first and second links of the assembly **76**. The link is finally brought to a straight condition by movement of the bar stop **86** against the projection **62**. The projection **62** forces the bar stop **86** against the shoulder **91** to force the elements **78** and **82** into mutually aligned relation ready for the next pumping cycle.

It should be noted that the rate adjustment member **89** may be moved toward or away from the center of the control means to vary pump chamber volume during the pumping operation. If the adjustment member **89** is moved inwardly the chamber volume will be smaller and the rate of transfer of fluid will be less per unit of time, or per stroke of the pump apparatus.

It also should be observed that when the pump apparatus of the present invention is used for introducing intravenous solutions a safety feature may be employed which will automatically interrupt flow of solution continuously through the outlet when the needle (or other device) is displaced from the vein. This is accomplished in the present apparataus by providing a slip fit between the outlet tubing **24** and the outlet projection **26** of the apparatus. If the needle of the outlet should become displaced from the vein, for example, and enter the muscular tissue, or other tissue surrounding the vein, it is important to stop the flow of solution to that area to avoid pumping of solution into the tissue thereby giving rise to a condition which may result in damage. The slip fit between the tubing **24** and the outlet projection **26** is designed such that it will blow off upon a predetermined resistance to flow through the tubing **24**. Accordingly, if the needle becomes displaced, the soltuion will very likely not flow freely and a pressure build up will occur in the tubing **24**. When this pressure reaches a predetermined level (set at whatever safety level is necessary for the use) the tubing **24** will slip off of the projection **26** and the solution thereafter will merely continue to flow over the projection **26** onto the apparatus rather than into the tissue.

While we have shown and described a specific embodiment of the present invention it will, of course, be understood that other modifications and alternative constructions may be used without departing from the true spirit and scope of this invention.

What we claim as new and desire to secure by Letters Patent of the United States, is:

1. An apparatus for moving fluid from one system to a second system at a controlled regulatable flow rate, said apparatus comprising, in combination:

- control means having a power supply associated therewith and regulating means thereon to define means to vary the output action of the control means; and
- a pump operatively associated with said control means and responsive to the output action of said control means to provide for varying fluid flow rates, the pump including a central chamber having an inlet and outlet port and pistons associated with each said port, means associated with the outlet port piston to provide for independent interruption of outlet port piston movement while the outlet port is closed to said central chamber, said pistons each being moveable within the central chamber between its respective part open and part closed position to move fluid from one system through the inlet port and central pump chamber to the outlet port and the second system.

2. The apparatus of claim **1** wherein the control means includes first and second piston engaging members each of which reciprocates independently of the other, the first piston being operatively engaged to said first piston engaging member and the second piston being operatively engaged to said second piston engaging member.

3. The apparatus of claim **2** wherein said piston engaging members are moved by a common shuttle member connected to the power supply.

4. The apparatus of claim **3** wherein the shuttle is moved in shuttle-reciprocating action by a cam connected to the output of the power supply, said cam having a cam follower thereon operatively engaging a cam track in said shuttle.

5. The apparatus of claim **4** wherein means operatively associated with the second piston engaging member is provided to allow for varying the amount of fluid moved from inlet port to outlet port per piston cycle.

6. The apparatus of claim **1** wherein the regulating means is defined by stop means to define maximum piston movement of the piston associated with the inlet port of the pump.

7. The apparatus of claim **1** wherein the piston associated with the outlet port of the pump is provided with a continuous opening extending from the central axis of the piston on the end thereof internally of the piston to the outer wall thereof to define a fluid flow path from the central pump chamber through said continuous opening to the outlet port of the pump when the opening in the outer wall of the piston is in registration with the outlet port.

8. An apparatus for use in defining a shuttle action for moving a member in reciprocatory fashion, comprising:

- a housing;
- power supply means in said housing and having an outlet;
- a shuttle member operatively associated with said power supply means and adapted to move in a predetermined reciprocatory motion in response to operation of the power supply means;
- first member engaging means associated with said shuttle member and moveable in reciprocatory motion in response to movement of the shuttle;
- second member engaging means associated with said shuttle member and moveable in reciprocatory motion in response to movement of the shuttle; and
- a link joint secured at one end to the shuttle and at the other end to the second member engaging means, said link joint being collapsable to prevent movement of the second member engaging means in response to movement of the shuttle when it is desired to prevent such movement.

9. The apparatus of claim **8** wherein the power supply means is provided with a speed reducing means to provide the proper outlet motion for use by the shuttle of the apparatus.

10. The apparatus of claim **8** wherein the power supply means and shuttle, in combination, define cam means for reciprocatory movement of the shuttle in the path of movement thereof in the apparatus.

11. The apparatus of claim **8** wherein the shuttle is provided with spaced apart projections, one of said projections engaging the first member engaging means for movement thereof in one direction of shuttle movement and the other of said projections engaging the first member engaging means for movement thereof in the other shuttle direction.

12. A pump apparatus for use in transferring fluid from one system to another, comprising:

- a pump body having a central chamber and inlet and outlet openings communicating therewith;
- a first member disposed in said pump body for movement axially of the chamber and adapted in one position to seal the inlet of the pump to isolate the pump chamber from the inlet fluid system and in a second position to open the inlet of the pump to permit fluid to move from the inlet system to the pump chamber;
- a second member disposed in said pump body for movement axially of the chamber and being in axially spaced relation to said first member in said chamber, said second member having an opening in the body thereof extending continuously from the chamber end to the wall thereof, said second member

adapted in a first position to seal the outlet of the pump to isolate the pump chamber from the outlet fluid stream and in a second position to open the inlet of the pump to permit fluid to flow from the chamber to the outlet fluid system;

means to move the first and second members between their first and second positions, respectively; and

means to prevent movement of said second member from first to second position when a compressible fluid is contained in said central chamber.

13. The pump of claim **12** wherein said means to prevent movement of said second member includes a collapsible hinged member associated with said second member which may be collapsed to allow compression of fluid in the central chamber without movement of the second member to its said second position.

14. The pump of claim **12** wherein the means is directly associated with the first member to engage it for movement to and between said first and second positions.

15. The pump of claim **12** wherein the second member is moved to said first position in direct response to movement of said means but is disengaged from said means prior to movement to said second position.

16. The pump of claim **15** wherein said second member is moved to said second position as a function of movement of the first member of the pump until the second member is moved to a position where the outlet opening is exposed to the chamber whereby continued movement of the first member will not result in further movement of the second member.

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U.S. Cl. X.R.

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