

[54] FLUID PUMP CONTROL SYSTEM

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[51] Int. Cl. **F04b 49/06**

[58] Field of Search **417/43, 20, 25, 26, 300, 417/38, 45; 200/83 B, 81.4**

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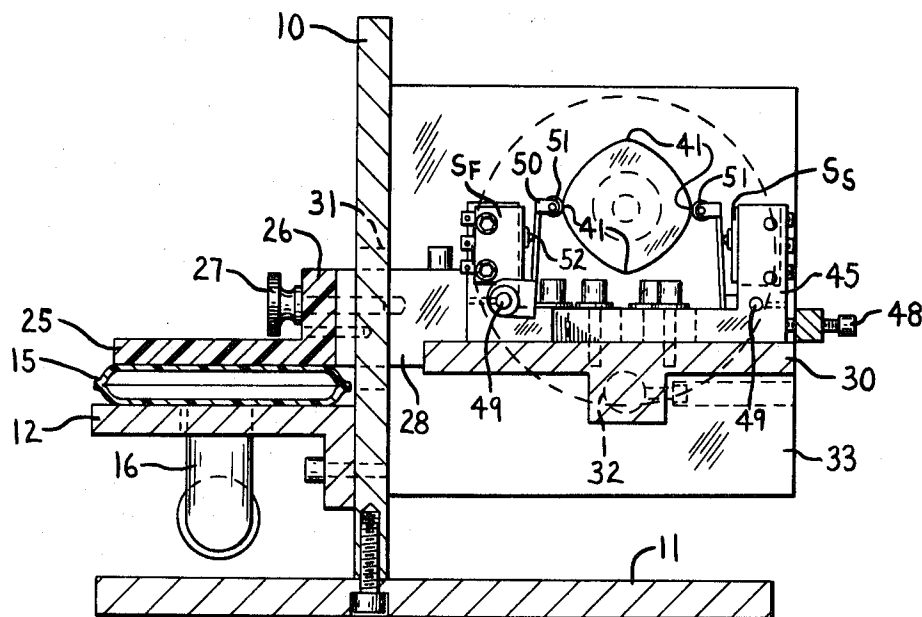
[57] ABSTRACT

This device controls the amount of blood flow in an extracorporeal blood circuit of a patient requiring long term profusion to prevent the excessive blood

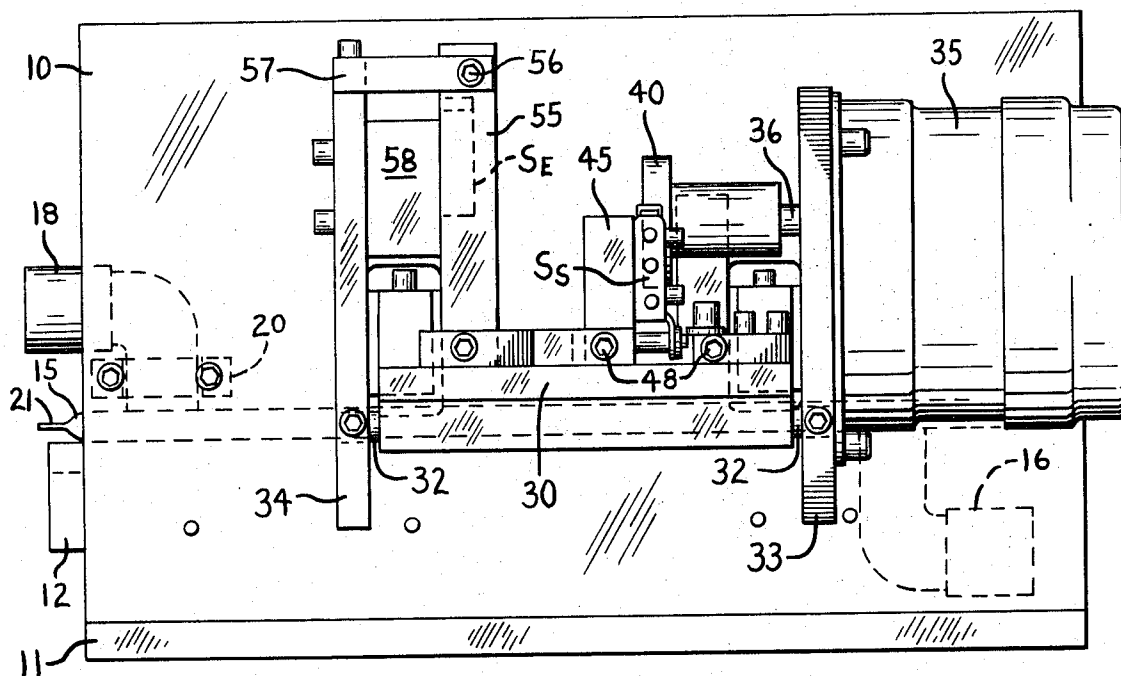
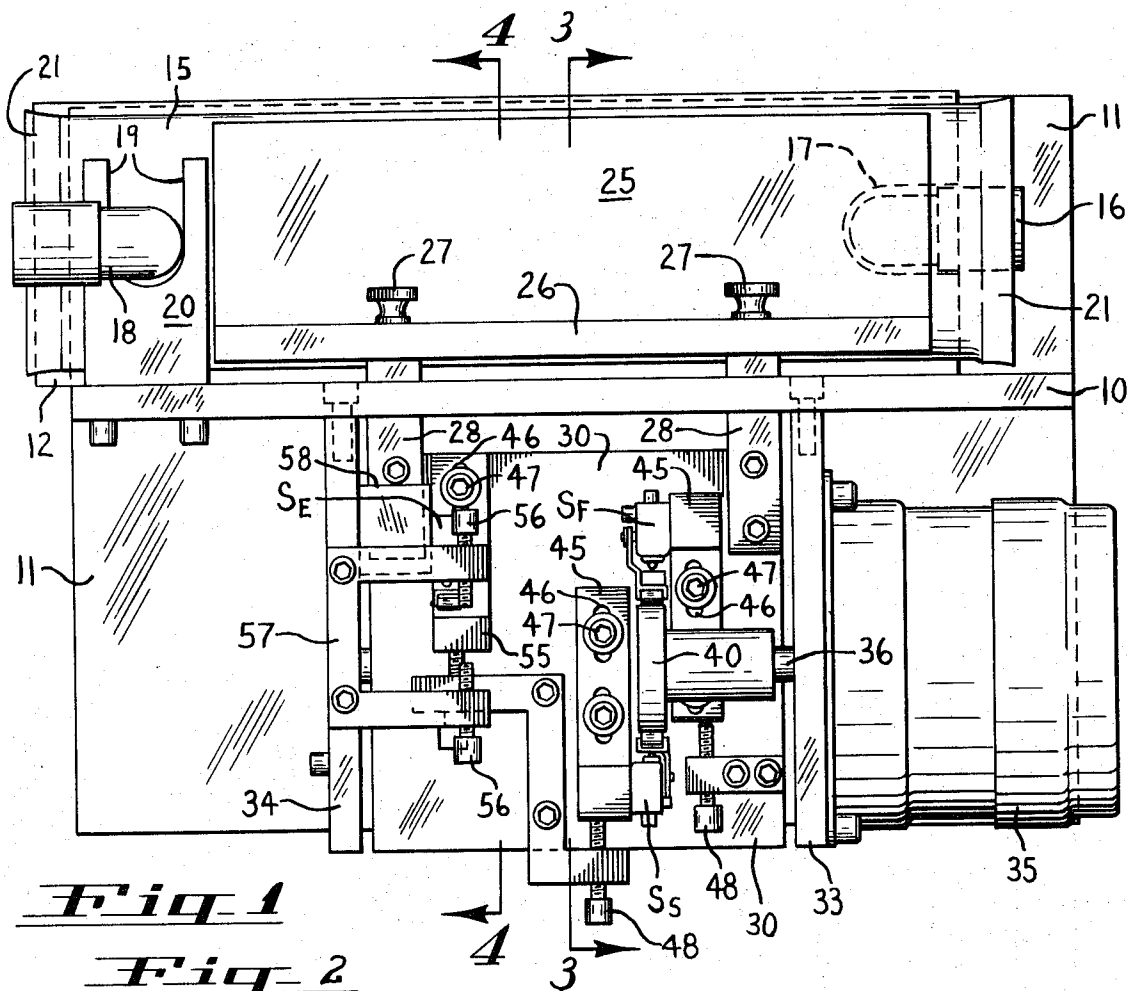
damage as is likely to occur in the usual heart-lung machines employed during surgery if it were to be used for an extended time. The device regulates the speed of the blood pump in accordance with rate of flow of blood from the body so that the pump does not impose a back pressure on the blood supply by running too slowly and does not create suction pressure on the body by running too fast. The speed of the blood pump is controlled by a potentiometer having a slider contract driven in opposite directions by a reversible motor. A constant speed rotating cam intermittently actuates one or the other, or both, of a pair of switches on opposite sides of the cam. One switch energizes the potentiometer motor for rotation in one direction and the other switch energizes the potentiometer motor for rotation in the opposite direction. The switches are shifted relative to the cam by a platen bearing against a tubular bladder in the blood inlet to the pump. As the bladder expands, the pump is speeded up and as the bladder contracts, the pump is slowed down.

In addition to normal adjustment of pump speed to comply with normal small variations in blood flow, an emergency safeguard is provided which causes the pump to stop immediately in case the blood supply is abruptly interrupted such as would occur if the blood supply tubing were suddenly closed by a kink or by an attendant stepping on it. If the blood pump were to continue to operate when the bladder is empty, the pump could draw fatal air bubbles into the blood stream.

4 Claims, 6 Drawing Figures



SHEET 1 OF 3



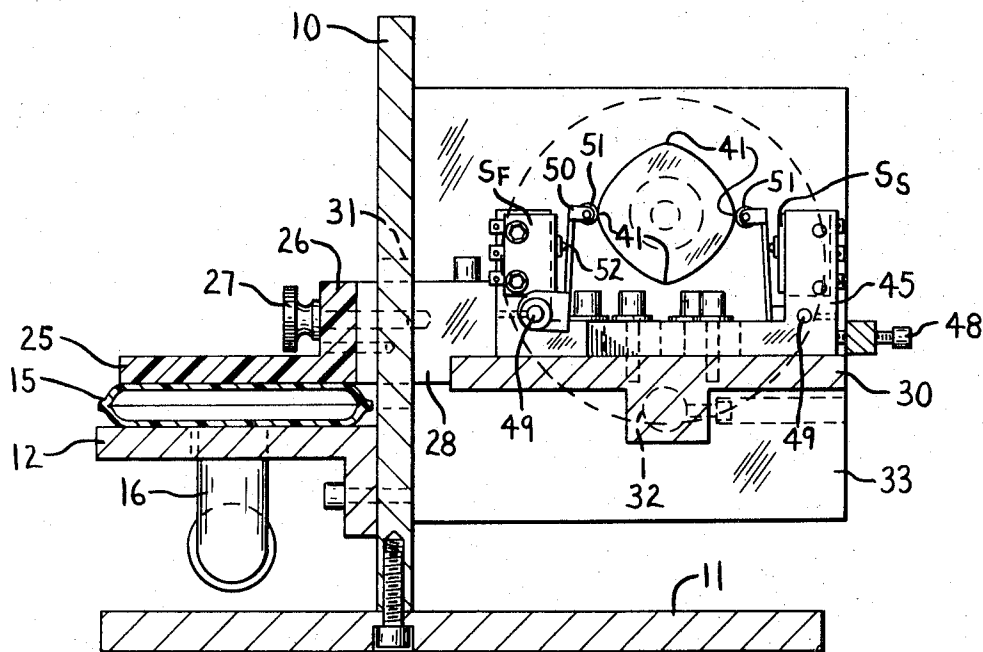


Fig 3

Fig 4

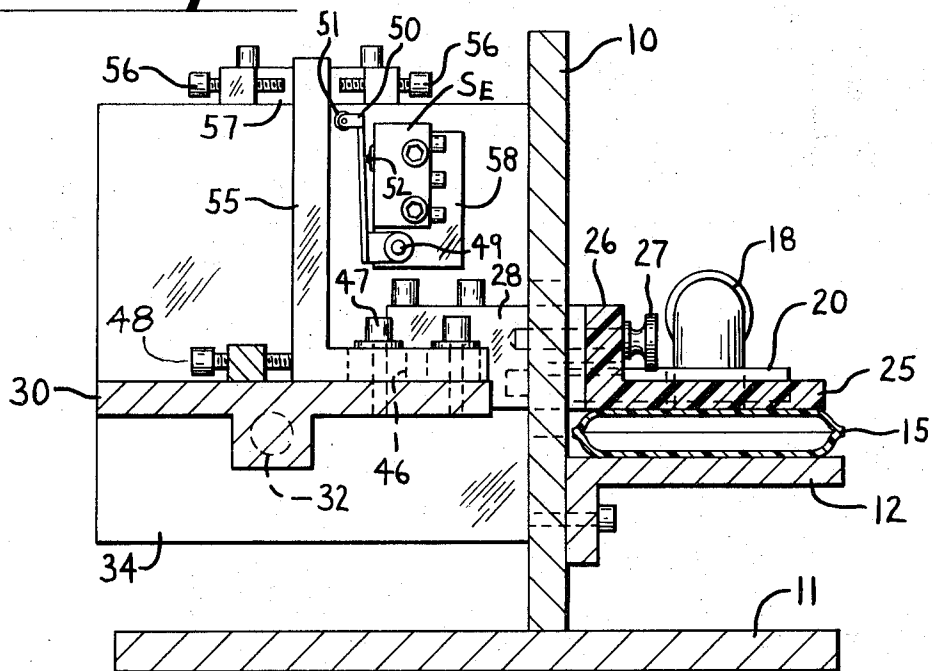


Fig. 6

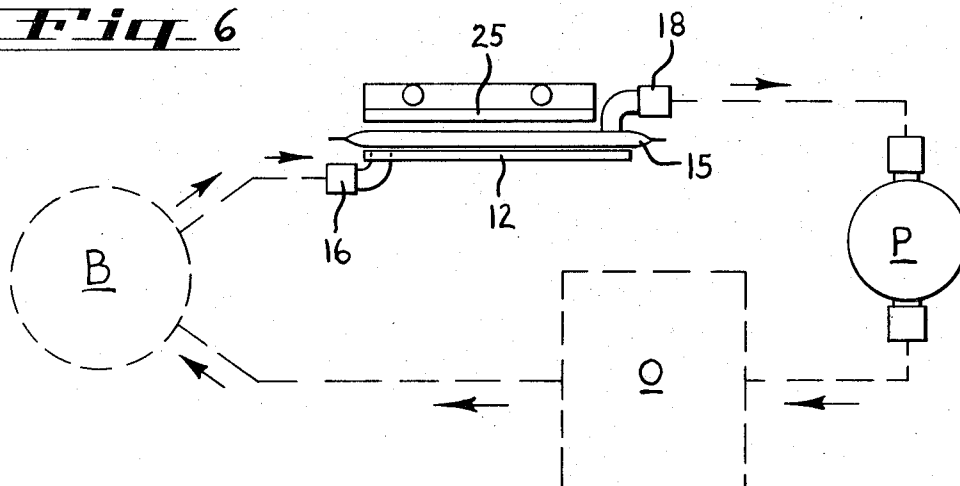
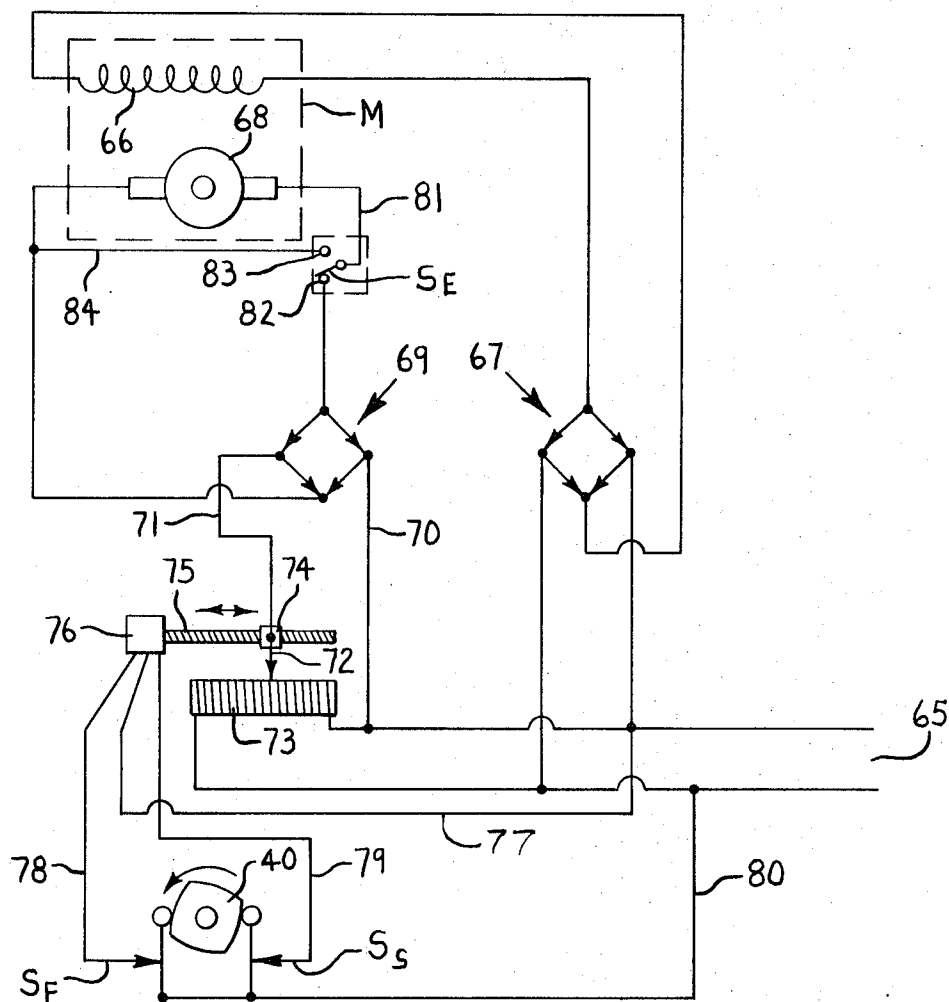


Fig. 5



FLUID PUMP CONTROL SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to a fluid pump control system for regulating the speed of a pump in accordance with the fluid supply so that the pump does not impose a back pressure on the source of supply by running too slowly and does not create suction pressure on the source of supply by running too fast. The invention is of general application for the specified purpose but it is disclosed herein with particular reference to an extracorporeal blood circuit for a patient.

Open heart practices are today very well established as applied to surgical procedures where the normal blood supply to the muscles of the heart and to the brain must not be interrupted during repair of critical organs.

With the advancement of the art of fabricating membrane oxygenators, which are notably low in damage to the blood, there has been a need for developing new procedures to permit long time profusion of a patient during periods of crisis. Patients suffering from heart attack, emphysema, asthma, or the like, may over a period of days with supplementary profusion with well oxygenated blood develop sufficient recovery of natural organ functions to carry on without the need of the extracorporeal blood supply.

To do this it is desirable to make connection through catheterized connections to more peripheral blood vessels of the body. This avoids the necessity of opening the patient's chest for access to the larger vessels near the heart.

It is also important to provide the equipment which will permit carrying on the longer period of a procedure in an intensive care area of the hospital without usurping a surgical area for the extended period.

The present system makes it possible to operate an extracorporeal blood circuit without the close attention of a skilled pump attendant as is usually employed in cases where a short term profusion is indicated as is usual during heart surgery.

During heart surgery, a pump and oxygenator take over the normal functions of the heart and lungs to circulate and oxygenate the blood in order to keep those organs of the patient alive which require a continuous supply of fresh blood. An array of mechanical equipment attended by a team of specialists is necessary to do this in addition to the team of surgeons who perform the operation. One of the functions which demands constant attention is to maintain a proper speed of the blood pump so as not to let the extracorporeal circuit become too out of phase with blood supply and demands of the profused organs. The purpose of the present device is to regulate the pump automatically so that manual supervision is not required.

Objects of the invention are, therefore, to provide an improved fluid pump control system, to provide a pump control system which regulates the speed of the pump according to the rate of flow of its source of supply, to control a pump so that it does not impose a back pressure on its source of supply by running too slowly and does not create suction pressure in its source of supply by running too fast, to provide an electric control system for the purpose described which is operable on standard 120 volt alternating current house wiring, and to provide a control system of the type described

which is suitable for use in connection with the flow of blood in an extracorporeal blood circuit.

SUMMARY OF THE INVENTION

In the present pump system the speed of the pump is controlled by a potentiometer having a slider contact driven in opposite directions by a reversible motor. A constant speed rotating cam intermittently actuates one or the other, or both, of a pair of switches on opposite sides of the cam. One switch energizes the potentiometer motor for rotation in one direction and the other switch energizes the potentiometer motor for rotation in the opposite direction. The switches are shifted relative to the cam by a platen bearing against a tubular bladder which conveys the fluid input to the pump.

As the bladder expands, the pump is speeded up and as the bladder contracts, the pump is slowed down. Thus, the speed of the pump is regulated to correspond to its input flow so that the pump does not impose a back pressure on the input flow by running too slowly and does not create suction pressure in the source of supply by running too fast.

In addition to normal adjustment of pump speed to comply with normal small variations in blood flow, an emergency safeguard is provided which causes the pump to stop immediately in case the blood supply is abruptly interrupted such as would occur if the blood supply tubing were suddenly closed by a kink or by an attendant stepping on it. If the blood pump were to continue to operate when the bladder is empty, the pump could draw fatal air bubbles into the blood stream.

The invention will be better understood and the foregoing and other objects and advantages will become apparent from the following description of the preferred embodiment illustrated in the accompanying drawings. Various changes may be made, however, in the details of construction and arrangement of parts and certain features may be used without others. All such modifications within the scope of the appended claims are included in the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top plan view of a fluid pump control system embodying the invention;

FIG. 2 is a side elevation view;

FIG. 3 is a view on the line 3—3 in FIG. 1;

FIG. 4 is a view on the line 4—4 in FIG. 1;

FIG. 5 is a schematic wiring diagram of the control circuit; and

FIG. 6 is a schematic diagram of the fluid circuit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As best shown in FIGS. 3 and 4, a vertical front plate 10 is mounted on a horizontal base plate 11. A stationary horizontal table 12 is mounted on the front side of vertical plate 10 to support a flexible tubular bladder 15. Bladder 15 conveys the fluid input to the pump P in FIG. 6 which is to be controlled.

One end of bladder 15 is provided on its underside with an inlet ell connection 16 which is received in a slot 17 in one end of table 12. The opposite end of the bladder is provided on its upper side with an outlet ell connection 18 which is inserted in a slot 19 in a bracket

20 on vertical plate 10 a short distance above the table 12. The ends of tubular bladder 15 are sealed at 21.

A horizontal platen 25 rests on the upper side of bladder 15 and is vertically movable in response to volumetric expansion and contraction of the bladder. Platen 25 has a vertical flange 26 connected by thumb-screws 27 to a pair of arms 28 on a rocker plate 30 on the back side of vertical plate 10. Arms 28 project through openings 31 in plate 10. Rocker plate 30 is mounted for oscillation on a pair of horizontal stub shafts 32 mounted in a pair of transverse vertical plates 33 and 34 which are attached to the back side of vertical plate 10. The vertical movements of platen 25 in response to expansion and contraction of bladder 15 oscillate rocker plate 30 on its stub shafts 32.

As best shown in FIG. 1, a constant speed motor 35 is mounted on plate 33 with its horizontal shaft 36 extending through the plate. Shaft 36 supports a cam 40 having four lobes 41 as shown in FIG. 3. Cam 40 rotates continuously about a fixed horizontal axis. The direction of rotation is immaterial.

Mounted on opposite sides of cam 40 is a pair of micro switches, one being a fast switch S_F and the other being a slow switch S_S . Each of these switches is mounted on the upright arm of an L-shaped mounting bracket 45. The horizontal arm of each bracket 45 contains a pair of slots 46 which receive screws 47 in rocker plate 30. Slots 46 permit adjustment of the switches toward and away from cam 40. Since the adjustments of the switch brackets 45 involve very minute movements, the positioning of the brackets is accurately adjusted by means of adjusting screws 48 before the screws 47 are tightened. Screws 48 form stops which bear against brackets 45 to hold the adjustment.

Each bracket 45 also carries a pin 49 for pivotally mounting a cam follower arm 50 having a roller 51 bearing against the cam 40. The roller is pressed against the cam by a switch actuating button 52 which bears against arm 50. Button 42 is biased outward from the switch body to switch open position by an internal spring within the switch body.

The oscillation of rocker plate 30 is limited by an L-shaped arm 55 having a lower horizontal leg provided with slots 46 receiving screws 47 in the plate 30 for adjustment purposes. Adjustment is facilitated and maintained by a stop screw 48. The movements of the upper end of arm 55, and hence the movements of rocker plate 30, are limited by a pair of stop screws 56 in a U-shaped bracket 57 mounted on vertical plate 34, as shown in FIG. 4. An emergency low level control single pole double throw micro switch S_E is mounted on a block 58 on vertical plate 34 adjacent the arm 55. A pivotal switch arm 50 has a roller 51 normally spaced away from arm 55. An internal spring in switch S_E presses the switch actuating button 52 outward, holding the switch in one closed position in normal operation.

It will be observed in FIGS. 3 and 4 that the weight of platen 25 and its supporting arms 28 unbalances the rocker plate 30 whereby platen 25 tends to rotate downward by gravity so as to bear lightly against the top of bladder 15. The switch spring forces applied by switches S_F and S_S are relatively insignificant in comparison with the weight of platen 25 and its supporting arms 28 acting on a relatively long lever arm with respect to the supporting stub shafts 32.

FIG. 5 illustrates the electrical system for energizing the present control device from a 120 volt alternating current supply source 65. The pump motor M is a direct current motor having a constant potential field winding 66 energized directly from alternating current supply wires 65 through rectifier 67. The motor armature 68 is energized through a rectifier 69. One input terminal of rectifier 69 is connected by a wire 70 to one wire of the supply source 65. The other input terminal of rectifier 69 is connected by a wire 71 with a sliding contact 72 on a potentiometer 73 which is connected across the supply wires 65.

Slider contact 72 is mounted on a non-rotatable nut 74 on a screw 75 which may be rotated in opposite directions by a reversible capacitor-type, single phase, alternating current motor 76. One terminal of motor 76 is connected directly to a line wire of supply source 65 by means of a wire 77. A second wire 78 from motor 76 is connected to fast switch S_F and a third wire 79 is connected to slow switch S_S . Both of these switches are connected through a common wire 80 to the opposite line of supply source 65.

With reference to FIG. 3, as the bladder 15 expands it raises platen 25 moving fast switch S_F toward cam 40 and moving slow switch S_S away from the cam. When switch S_F is thus closed repeatedly by the cam and switch S_S remains open, motor 76 rotates screw 75 repeatedly in one direction to shift slider contact 72 to the left in FIG. 5, increasing the voltage applied to motor armature 68 to cause the pump P in FIG. 6 to run faster.

When bladder 15 contracts, platen 25 drops to a lower position, causing slow switch S_S to move toward cam 40 while fast switch S_F moves away from the cam. In this position of rocker plate 30, slow switch S_S is closed repeatedly and fast switch S_F remains open. This causes potentiometer motor 76 to rotate screw 75 to reverse direction, moving slider contact 72 to the right in FIG. 5. This decreases the potential applied to motor armature 68, causing the pump to slow down.

When bladder 15 is expanding or contracting, switch S_F or S_S is actuated about 128 times per minute by cam 40, which is about two actuations per second. Thus, the bladder 15 is monitored about twice per second and the pump speed adjusted, if necessary, every one-half second. This affords much closer control of the pump speed than can be accomplished manually over a long period of time in conventional practice.

When fluid flows through bladder 15 at a uniform rate, platen 25 and rocker plate 30 become stabilized in a neutral position which does not actuate either one of switches S_F or S_S . In such condition both wires 78 and 79 remain deenergized, preventing rotation of potentiometer motor 76, and slider contact 72 remains stationary in equilibrium position maintaining a constant speed of pump motor armature 68.

If the fluid supply should stop, bladder 15 would collapse completely allowing platen 25 to drop until arm 55 engages the right stop screw 56 in FIG. 4. This condition would actuate emergency low level control switch S_E , opening the circuit to armature 68 at wire 81 and stopping the pump motor. In this actuation the switch arm at S_E leaves contact 82 and engages contact 83, short circuiting the armature 68 through wires 81 and 84 for rapid dynamic braking to stop the pump quickly.

Resumption of fluid flow through bladder 15 moves arm 55, shifting switch arm S_E back to contact 82 to energize motor armature 68 and re-start the pump. In the meantime, the collapsed bladder has caused potentiometer slider 72 to move to the extreme right for slow pump speed. Thus, the pump re-starts at slow speed and accelerates as bladder 15 fills and expands.

Arm 55 is adjusted on rocker plate 30 so that the normal up and down movements of platen 25 while fluid is flowing through bladder 15 do not actuate switch S_E .

The extracorporeal blood circuit is shown in FIG. 6. Blood from the patient's body B passes through bladder tube 15 to the inlet of blood pump P. Pump P returns the blood to the body through oxygenator O. In order to purge air from the system when it is initially primed with blood, the inlet 16 to the bladder 15 is on the underside and outlet 18 is on the upper side.

Having now described my invention and in what manner the same may be used, what I claim as new and desire to protect by Letters Patent is:

1. A fluid pump control system comprising a flexible tubular bladder connected in the fluid supply line to

said pump, a platen bearing on said bladder and movable in response to the expansion and contraction of the bladder with variations in the rate of inlet flow to the pump, a continuously rotating cam, a pair of switches on opposite sides of said cam movable in unison by said platen in a diametral direction relative to the axis of the cam, a reversible motor energized for rotation in opposite directions by said switches, a potentiometer having a sliding contact movable in opposite directions by said reversible motor, and a variable speed motor driving said pump under the control of said potentiometer, whereby the speed of said pump varies in accordance with said inlet flow.

2. A system as defined in claim 1 including a switch operable by said platen to stop said pump motor in response to cessation of said inlet flow.

3. A control unit as defined in claim 1, said switches and platen being mounted on a pivotal rocker plate.

4. A control unit as defined in claim 3 including an arm on said rocker plate, and a switch mounted for actuation by said arm when said bladder is substantially fully contracted.

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