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Apstein

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[54] **PROGRAMMED VENOUS ASSIST PUMP**

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[52] **U.S. Cl.** **128/64,** 128/DIG. 10

[51] **Int. Cl.** **A61h 7/00**

[58] **Field of Search** ..... 128/24 R, 64, 60, DIG. 10

[56] **References Cited**

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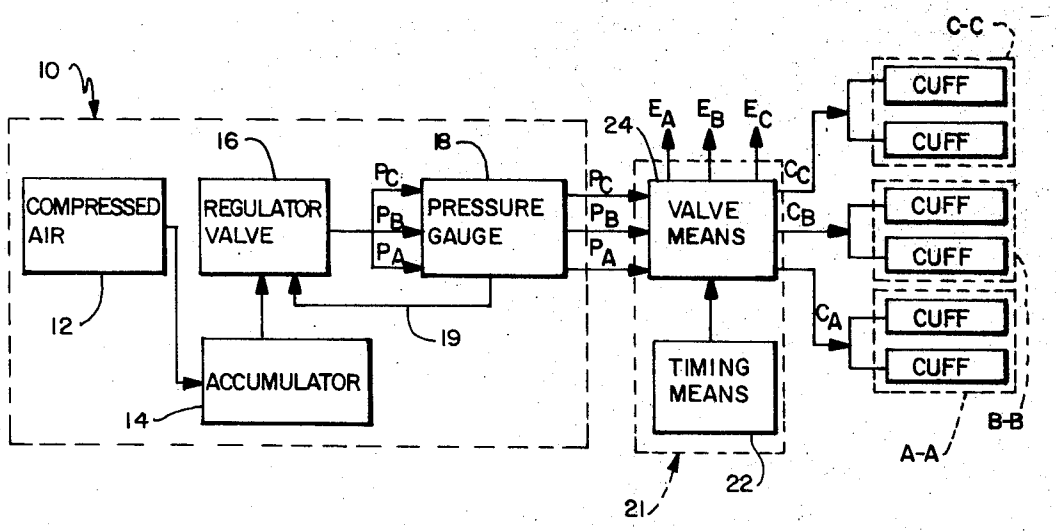
[57] **ABSTRACT**

An apparatus for providing circulatory assistance to a bed patient to preclude the pooling or clotting of venous blood in the legs or other extremities. A plurality of pairs of pressure cuffs are disposed along the legs of a patient needing circulatory assistance. Programming means are provided to facilitate the sequential inflation of said pressure cuffs, in such a manner that a progressive pressure wave travels up the patient's legs pushing the venous blood ahead of it.

5 Claims, 9 Drawing Figures



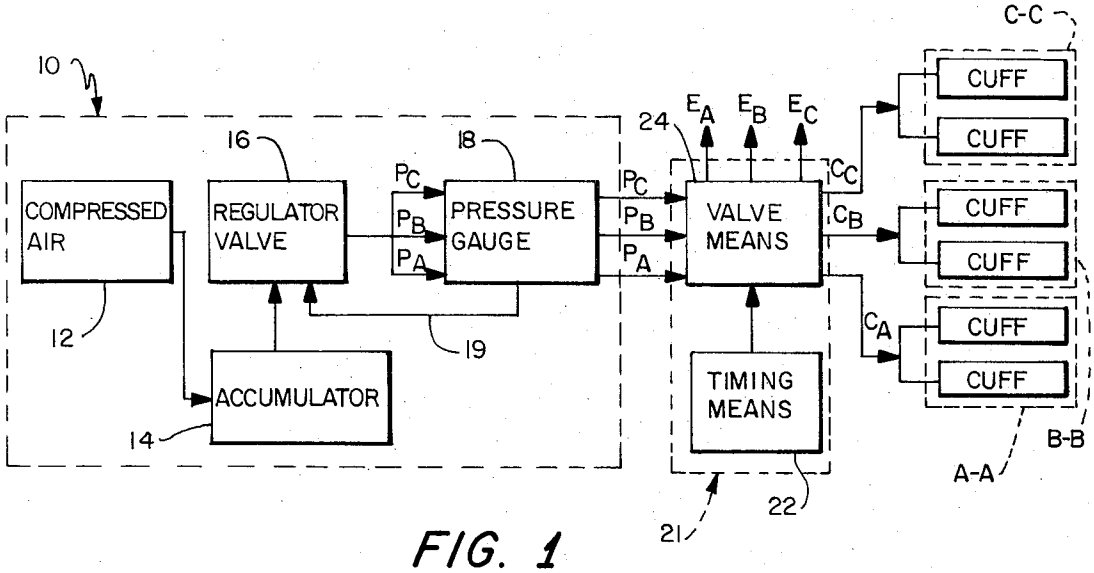


FIG. 1

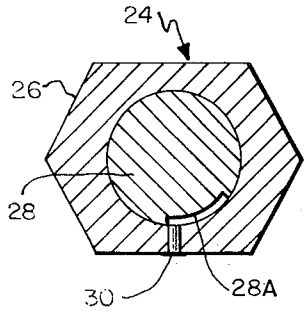


FIG. 2

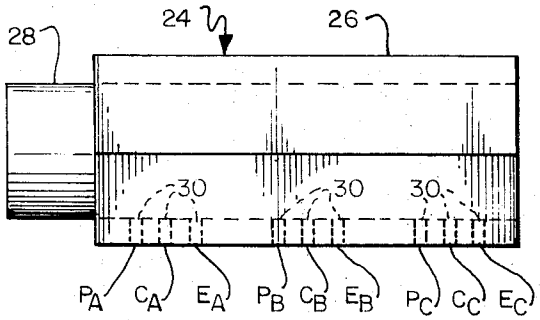


FIG. 3

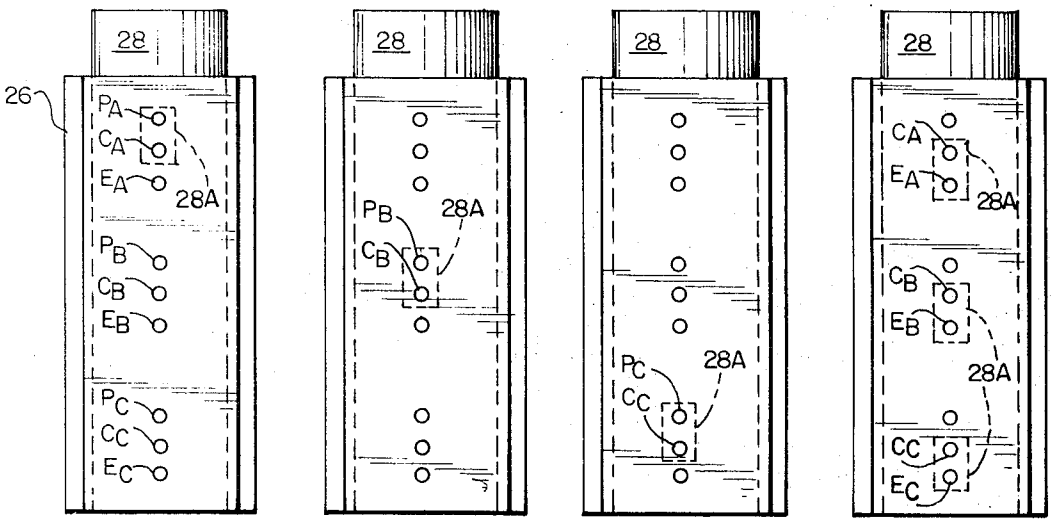


FIG. 4A FIG. 4B FIG. 4C FIG. 4D

CUFFS	0 – 60°	60°–120°	120°–180°	180°– 360°
A-A	INFLATE	CLOSE	CLOSE	EXHAUST
B-B	CLOSE	INFLATE	CLOSE	EXHAUST
C-C	CLOSE	CLOSE	INFLATE	EXHAUST

FIG. 5

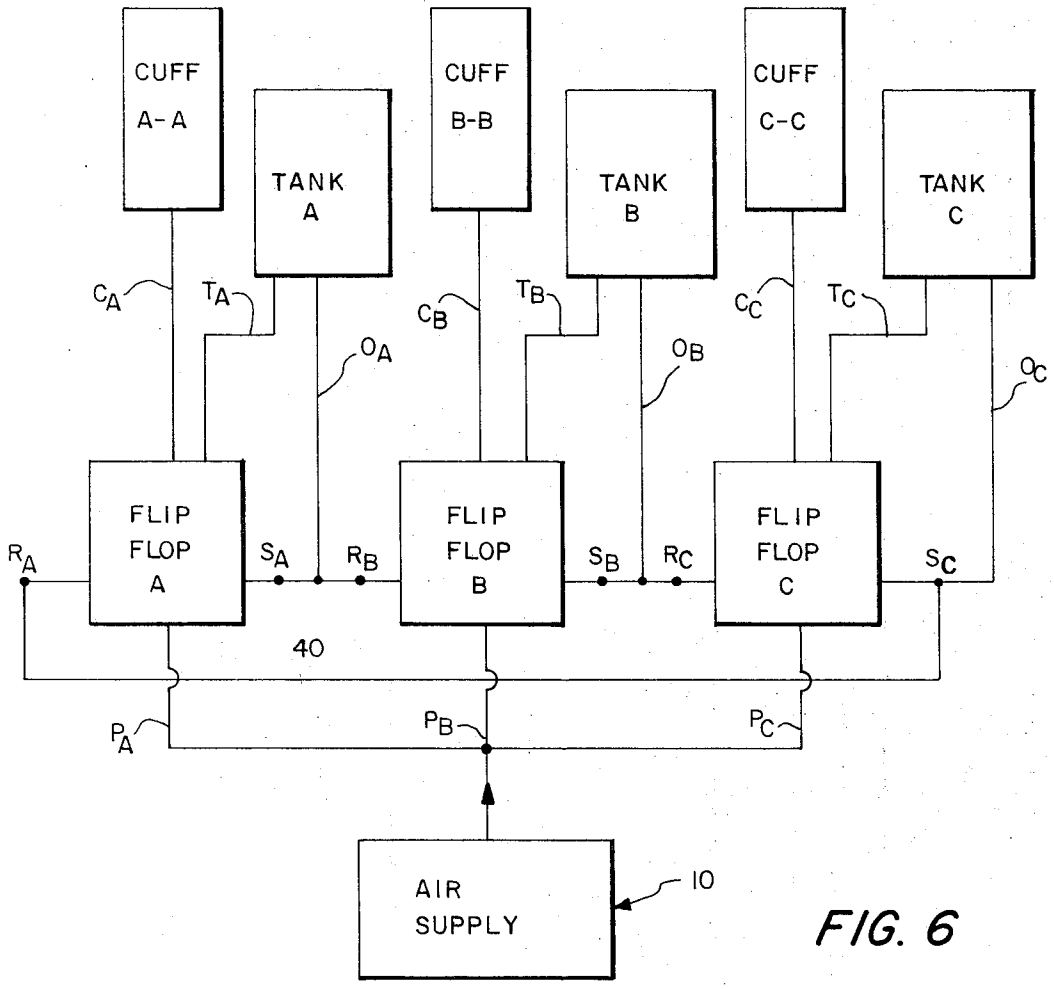


FIG. 6

PROGRAMMED VENOUS ASSIST PUMP

ORIGIN OF INVENTION

BACKGROUND OF INVENTION

1. Statement of Invention

The present invention relates to a system and apparatus for preventing the pooling of venous blood in the extremities of patients. More specifically, the present invention relates to a programmed venous assist pumping means is safe to use in the explosive environment of operating rooms.

2. Description of Prior Art

The pooling of blood in the extremities of bedpatients is quite common due to the inactivity of the patients. This is particularly true of post-coronary patients, since the impaired heart does not have the capacity to return the blood through the venous system to the heart. It is known that the pooling of blood can be kept to a minimum by massaging the extremities of the patient either by hand or with the aid of a plurality of sequentially inflatable pressure devices wrapped around the extremities of a patient. Devices of this type are generally known in the art.

It was recently discovered that similar devices would be useful for preventing clot formation during surgery by intermittently compressing the extremities of a patient while on the operating table. However, the potentially explosive environment of operating rooms limits the design possibilities of the apparatus which can be used therein. For example, the use of electrical components should be avoided, since sparking or arcing could lead to a severe explosion. Also the devices employed should be compact and portable. Known prior art devices do not meet these requirements and are, therefore, not suitable for use in preventing blood clots or venuous pooling during surgery.

SUMMARY OF INVENTION

Accordingly, it is an object of the present invention to provide a venous assist pump suitable for use in operating rooms.

It is another object of the present invention to provide a venous assist pump which is compact and quiet in operation.

It is still another object of the present invention to provide a venous assist pump which does not require the use of electrical components in the explosive environments of operating rooms.

It is a further object of the present invention to provide a programming means for the venous assist pump comprised of purely fluidic or flueric components.

It is a still further object of the present invention to provide a novel mechanical programming means including a valve means driven by an adjustable timing means.

These and other objects of the present invention are accomplished by securing a plurality of pairs of pressure cuffs, similar to those used in blood pressure measuring devices, around the extremities of a patient. For example, in a preferred embodiment a first pair of pressure cuffs is wrapped around the patient's ankles a second pair around the mid calves and a third pair pair around the upper calves or lower thighs. These pressure cuffs are sequentially inflated beginning with said first pair at the ankle until all three pairs of cuffs become inflated. All of the cuffs are then simultaneously deflated. The cycle is then repeated to create a progressive compressional wave which travels up the patient's leg pushing the venous blood ahead of it. The timing cycle of inflation may be varied depending on the needs or comfort of the particular patient being treated.

The sequential inflation of the pressure cuffs is controlled by a programming means which regulates the supply of compressed air to the respective pairs of pressure cuffs. In one embodiment of the present invention the programming means consists of the combination of a rotating valve driven by a timing motor. For example, the timing mechanism of a wind-up clock may be employed to rotate the programming valve means. In a second embodiment of the present invention a purely flueric or fluidic programming means may be used including a plurality of flueric or fluidic bistable flip-flops. Both embodiments or programming means of the present invention are devoid of any electrical components and, therefore, may be safely used in the explosive environment of an operating room. In a third embodiment, an electric motor-driven compressor and programmer is remotely located from the operating room and a triple air hose connects the programmer to the pressure cuffs within the operating room. All embodiments of programming means of the present invention are also compact and quiet in operation.

The objects of the present invention and the attendant advantages thereof will become more fully apparent with reference to the drawings and the following description thereof, wherein:

FIG. 1 is a schematic diagram illustrating a first embodiment of the programmed venous assist pump of the present invention;

FIG. 2 is an end view in section of a programming valve means of the present invention;

FIG. 3 is a side view of the programming valve means illustrated in FIG. 2;

FIGS. 4A to 4D are bottom plan views illustrating the operation of the programming valve means of FIGS. 2 and 3;

FIG. 5 is a chart illustrating a preferred program for inflating the pressure cuffs of the present invention; and

FIG. 6 is a schematic diagram of a second embodiment of the venous assist pump of the present invention having a flueric or fluidic programming means.

Referring to FIG. 1 in more detail, there is generally shown an air supply means **10** including a source of compressed air **12** including a pump for pumping compressed air into an accumulator tank **14.** In the alternative a tank of compressed air may be used in place of the pump. Accumulator tank **14** is connected to a regulator valve **16.** A pressure gauge **18** is in turn connected to regulator valve **16** to control the pressure of compressed air passing through regulator valve **16.** In addition accumulator **14** may have a pressure regulator therein to keep the internal pressure at a desired level. Pressure gauge **18** may be an automatic device with a feed back path **19** to regulator valve **16** or in the alternative pressure gauge **18** may be a meter which an operator observes and manually adjusts regulator valve **16** in accordance with the meter reading. Pressure gauge **18** is disposed in any or all of lines P_A, P_B, and P_C

connected to a valve means **24** which is driven by suitable timing means **22.** Valve means **24** and timing means **22** constitute a programming means **21** which may either be a mechanical means as illustrated in FIGS. **2** and **3,** or a purely flueric or fluidic programming means as illustrated in FIG. **6** to be described more fully hereinafter. Programming means **21** has outputs connected to a plurality of pairs of pressure cuffs A—A, B—B and C—C respectively. In a preferred embodiment the cuffs of pair A—A are disposed around the ankle of the patient to be treated; the cuff pair B—B is placed around the mid-calf of the patient to be treated; and the cuff pair C—C may be placed either around the upper calf of the patient to be treated or the lower thigh as desired.

Referring to the operation of the system of FIG. **1,** the cuffs are wrapped around the legs of the patient in pairs in the manner indicated above. When pump **12** is energized it fills accumulator **14** to some convenient pressure for example 10 to 20 P.S.I. This air bleeds through regulator valve **16** at a lower pressure determined by its setting and the indication or monitoring function of pressure gauge **18.** From there the air begins to inflate the various pairs of cuffs in a sequence determined by programming means **21.**

As the air passes to the respective pairs of cuffs in accordance with the control by programming means **21,** the respective cuffs begin to inflate starting with cuff pair A—A around the ankles. After cuffs A—A are inflated the intake valve for that pair closes and the pressure is maintained in the cuffs. Next the programmer opens the intake valve of cuff pair B—B and inflates them. Then this valve closes and the pressure in cuff pair B—B is maintained. Next the programmer inflates cuff pair C—C and holds it inflated for a specified period of time. Finally the programmer opens all three exhaust valves and the pressure in all cuffs is released and all cuffs deflate. The net result of the above program is that a pressure valve travels upwards toward the knees in a slow progression gently forcing venous blood to return to the heart.

In a preferred embodiment of the present invention cuff pairs A—A, B—B and C—C are rubber bags similar to the pressure cuffs used in measuring blood pressure. However, any other form of pressure cuff means may be employed without departing from the spirit and scope of this invention.

Referring to FIGS. **2** to **4,** there is shown a rotary valve means generally designated **24.** Rotary valve **24** includes a housing **26** formed of a hexagonal plastic or square rod having a central substantially cylindrical longitudinal bore therein. A plurality of holes **30** are provided in the surface of housing **24** in communication with the longitudinal bore therein. Holes **30** are provided at substantially right angles to the direction of said longitudinal bore and consist of three sets of three holes. These nine holes act as input and exhaust ports. A cylindrical rotor **28** is disposed for rotation in the longitudinal bore of valve housing **25.** In a preferred embodiment rotor **28** is simply a plastic rod with flats or channels **28A** milled into its surface, so that as it rotates it connects the various ports to each other as desired. The operation of rotary valve means **24** will become more fully apparent hereinafter with reference to FIGS. **4A** to **4D** and FIG. **5.**

For example, a flat or channel portion **28A** shown in FIG. **4A** places holes P_A and C_A in communication with each other. The letter P_A designates the source of pressure for cuff pair A—A which is supplied through pressure gauge **18,** as shown in FIG. **1.** The letter C_A represents the connection between programming means **21** and pressure cuff pair A—A. The letter E_A designates the exhaust port for cuff pair A—A. In a like manner the letters P_B, C_B, and E_B refer to the respective pressure sources, inlet means, and exhaust means of cuff pair B—B. In the same manner the letters P_C, C_C, and E_C represent the pressure source, inlet means, and exhaust means for cuff pair C—C. The flats or channels **28A** in rotor **28** of valve means **24** may be milled in any desired way to provide any desired sequence of energization of the respective cuff pairs A—A, B—B and C—C respectively. In a preferred embodiment rotor **28** is divided into three 60° sectors and one 180° which are sequentially rotated past holes **30.** For example, the first 60° sector is provided with a flat or channel **28A** as shown in FIG. **4A** which connects hole P_A to hole C_A as it is rotated into alignment therewith. This causes compressed air to be supplied to cuff pair A—A which is thereby inflated. As the next 60° sector of rotor **28,** as shown in FIG. **4B,** is rotated into alignment with holes **30,** holes P_A, C_A, and E_A and P_C, C_C, and E_C are all closed while a flat or channel portion **28A** is moved into alignment with hole P_B and C_B to provide communication therebetween. This, of course, facilitates the inflation of cuff pair B—B. As the next 60° sector of rotor **28** is rotated into alignment with hole **30,** as shown in FIG. **4C,** holes P_A, C_A, E_A, P_B, C_B, and E_B are closed and a flat or channel **28A** moves into alignment with holes P_C and C_C. This causes cuff pair C—C to be inflated. Rotor **28** continues to rotate until the 180° sector thereof is aligned with holes **30** in housing **26,** as shown in FIG. **4D.** In this position all cuff pairs are connected to their respective exhaust ports. That is hole C_A is connected to E_A through programming means **20** by way of channel or flat **28A** in rotor **28.** In a like manner holes C_B, E_B and C_C, E_C, respectively are connected together by flats or channels **28A.** This facilitates the deflation of all cuff pairs simultaneously in preparation for the next successive cycle of operation.

Referring to FIG. **5** there is shown a chart which further explains the operation of the valve means **24** of FIGS. **2** to **4.** The left hand column designates the cuff pairs and the corresponding rows in the successive columns to the right illustrate the condition of said cuff pairs as rotor **28** makes one complete revolution.

It should be understood that the program illustrated in FIGS. **4** and **5** is merely a preferred embodiment of the present invention. Other programs can be chosen by varying the position of flats **28A,** as desired, without departing from the spirit and scope of this invention.

Rotor **28** of valve means **24** may be rotated by any suitable timing motor **22.** However, in a preferred embodiment motor **22** is purely mechanical i.e., there are no electrical components therein. For example, motor **22** may be similar to a wind-up clock mechanism. In other words it may be a wind-up spring type motor. It may be provided with means for adjusting the speed of rotation to thereby facilitate the control of the rate at which the compressional wave is directed up the extremity of a patient. This is very important because different rates may be desirable for different patients and different conditions for which they are being treated. The use of purely mechanical components in motor **22**

facilitates the safe use thereof in the explosive environments of operating rooms.

The entire valve means **24** may be fabricated of light weight plastic or other synthetic materials which decreases the costs of manufacture and enhances the portability of the device.

Timing means **22** may, alternatively, consist of an electrically driven motor in which case the programming means **21** would be located outside the operating room and only a triple air hose would lead into the operating room.

Referring to FIG. **6** there is shown a purely fluidic or flueric programmer comprising a plurality of fluidic or flueric bistable flip-flops A, B, and C, respectively. Any suitable type of flueric or fluidic flop-flop may be used as would occur to one of ordinary skill in the art. Flip-flops A, B and C are connected to pressure input lines P_A, P_B, and P_C which are in communication with air supply **10.** Air supply **10** may be of the same type described in the embodiment of the present invention illustrated in FIG. **1.** Each flip-flop A, B, and C has a set terminal S, and a reset terminal, R, designated S_A, R_A; S_B, R_B; and S_C, R_C, respectively. Each flip-flop A, B and C is connected to a set of pressure cuffs and an associated accumulator tank. As illustrated in FIG. **6** flip-flop A is connected to pressure cuffs A—A through line C_A and to tank A through line T_A; flip-flop B is connected to pressure cuffs B—B through line C_B and to tank B through line T_B; and flip-flop C is connected to cuffs C—C through line C_C and to tank C through line T_C. There are no "pressure switches." The switching pressure is determined by the flip-flop design and the size of the tank determines the delay. As will become more fully apparent hereinafter the tanks A, B, C comprise a timing means which controls the switching pressure and the sequence of the flip-flops A, B, C and hence the sequential rate of inflation of cuffs A—A, B—B and C—C.

In operation flip-flops A and C are biased so that at the beginning of a cycle they are in the set position and flip-flop B is in the reset position. In the set position each respective flip-flop connects its pressure input line to the respective output line leading to the associated cuffs. In the reset position each flip-flop connects its associated input line to its associated tank.

Thus, when air is supplied through lines P_A, P_B, and P_C with flip-flops A and C in the set position and flip-flop B in the reset position, line P_A is connected to line C_A which inflates cuffs A—A; line P_C is connected to line C_C which inflates cuffs C—C; and line P_B is connected to line T_B which fills tank B. When the pressure in tank B reaches some predetermined level, determined by the switching threshold of the flip-flop, a pressure signal is generated through line O_B which switches flip-flop B to the set position and flip-flop C to the reset position. This relieves the pressure in cuffs C—C and allows compressed air to be supplied to tank C through lines P_C and T_C. When the pressure in tank C reaches a predetermined level, a signal is transmitted through lines O_C and **40** to reset flip-flop A. This permits cuffs A—A to drain and tank A to fill up to some predetermined level of pressure. Thus the process continues so that a pressure wave progresses from cuffs A—A to B—B to C—C. Of course other programs may be used without departing from the spirit and scope of this invention.

It should be understood that the present invention is not limited to the exact details of construction shown and described, for obvious modifications can be made by a person skilled in the art.

I claim:

1. In a programmed venous assist pump for providing circulatory assistance to a patient including a source of compressed fluid, a plurality of pressure cuff means adapted to be disposed around selected portions of said patient, programming means for selectively connecting said source of compressed fluid to selected pressure cuff means in a predetermined sequence to generate a compressional wave along the selected portion of said patient which pushes the venous blood ahead of it toward the patient's heart, said programming means including a valve means, and a timing motor for operating said valve means, the improvement comprising a valve means including:

a. a housing having a substantially cylindrical longitudinal bore therein, a plurality of sets of holes in a face of said housing communicating with said longitudinal bore, each of said sets of holes including a fluid inlet hole, a fluid outlet hole, and an exhaust hole;

b. means for connecting the fluid inlet hole of each set to said source of compressed fluid;

c. means for connecting said fluid outlet hole of each set to a selected pressure cuff means;

d. means for connecting said exhaust hole of each set to the atmosphere; and

e. a substantially cylindrical rotor means, journaled in said longitudinal bore, the cylindrical periphery of said rotor being in sealing engagement with said sets of holes, said rotor means being divided into a plurality sectors, each of said sectors having depressions milled therein at selected locations for alignment with selected combinations of said fluid inlet holes, said fluid outlet holes, and said exhaust holes in each respective set of holes as said sectors of said rotor means are rotated past said face of said housing means in response to the operation of said timing motor, whereby said milled depressions permit the flow of fluid between the selected combinations of holes with which said milled depressions are aligned in each respective set.

2. The invention of claim **1** wherein there is provided three of said sets of holes, each of said sets being associated with a selected pressure cuff means.

3. The invention of claim **1** wherein said timing motor may be adjusted to vary the speed of rotation of said motor.

4. In a programmed venous assist pump for providing circulatory assistance to a patient including a source of compressed fluid, a plurality of pressure cuff means adapted to be disposed around selected portions of said patient, programming means for selectively connecting said source of compressed fluid to selected pressure cuff means in a predetermined sequence to generate a compressional wave along the selected portion of said patient which pushes the venous blood ahead of it toward the patient's heart, the improvement comprising a fluidic programming means including:

a. a plurality of bistable fluidic switching means connected between said source of compressed fluid and a corresponding number of said pressure cuff means; and

b. tank means association with each of said pressure cuff means having input means connected to each of said bistable fluidic switching means, means for generating an output signal in response to the pressure built up in each of said tank means, said output signals being applied to selected switching terminals of said bistable fluidic switching means to thereby control the timing cycle of said bistable switching means and the supply of fluid to said pressure cuff means.

5. In a programmed venous assist pump for providing circulatory assistance to a patient including a source of compressed fluid, a plurality of pressure cuff means adapted to be disposed around selected portions of said patient, programming means for selectively connecting said source of compressed fluid to selected pressure cuff means in a predetermined sequence to generate a compressional wave along the selected portion of said patient which pushes the venous blood ahead of it toward the patient's heart, the improvement comprising a flueric programming means including:

a. a plurality of bistable flueric switching means connected between said source of compressed fluid and a corresponding number of said pressure cuff means; and

b. tank means associated with each of said pressure cuff means having input means connected to each of said bistable flueric switching means, means for generating an output signal in response to the pressure built up in each of said tank means, said output signals being applied to selected switching terminals of said bistable flueric switching means to thereby control the timing cycle of said bistable switching means and the supply of fluid to said pressure cuff means.

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