Feb. 15, 1966 K. E. WOODWARD 3,234,934

FLUID AMPLIFIER CONTROLLED PISTON

Filed April 6, 1965 3 Sheets-Sheet 1

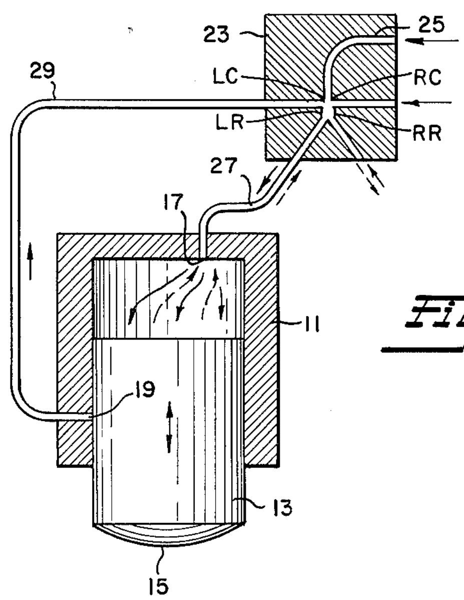

Fig. 1

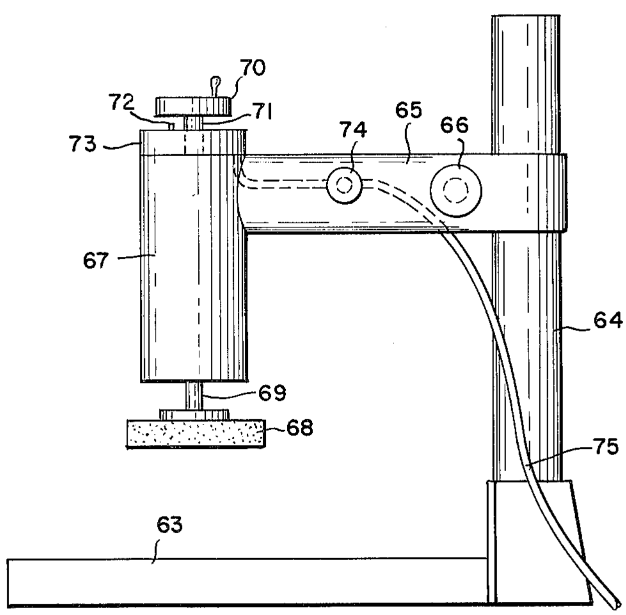

Fig. 3

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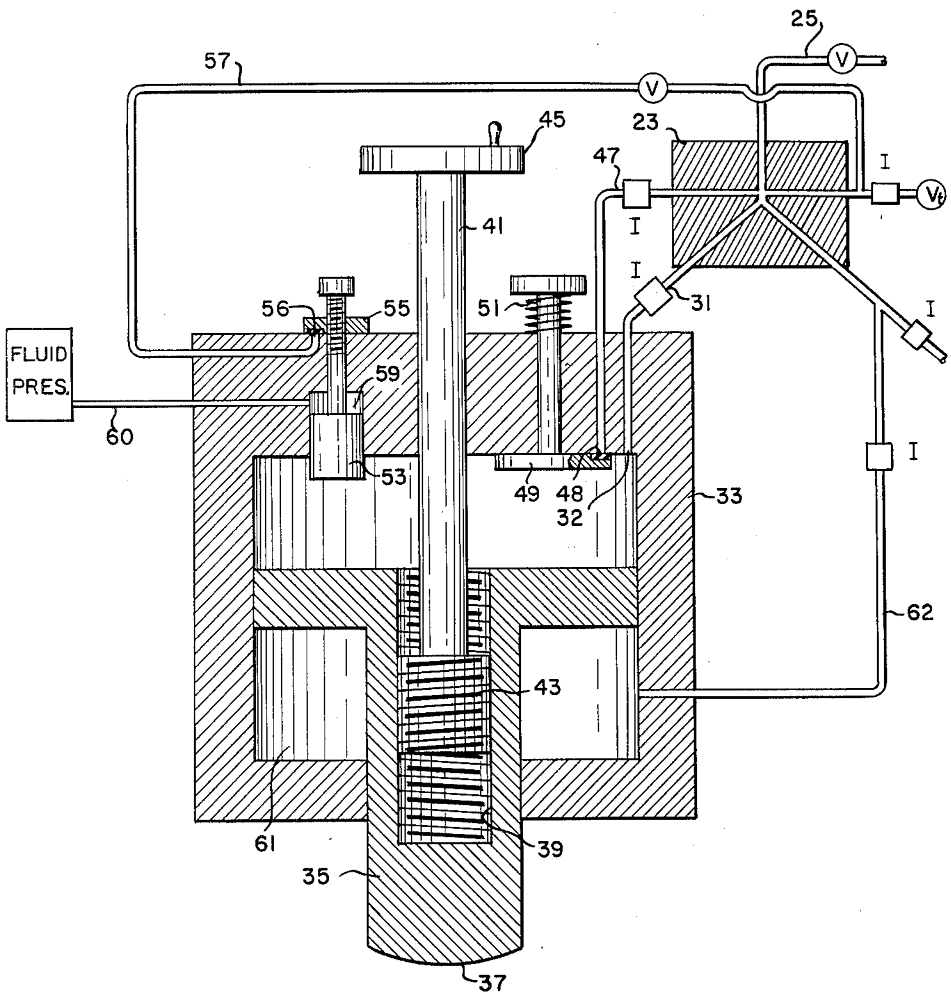

Fig. 2

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FLUID AMPLIFIER CONTROLLED PISTON

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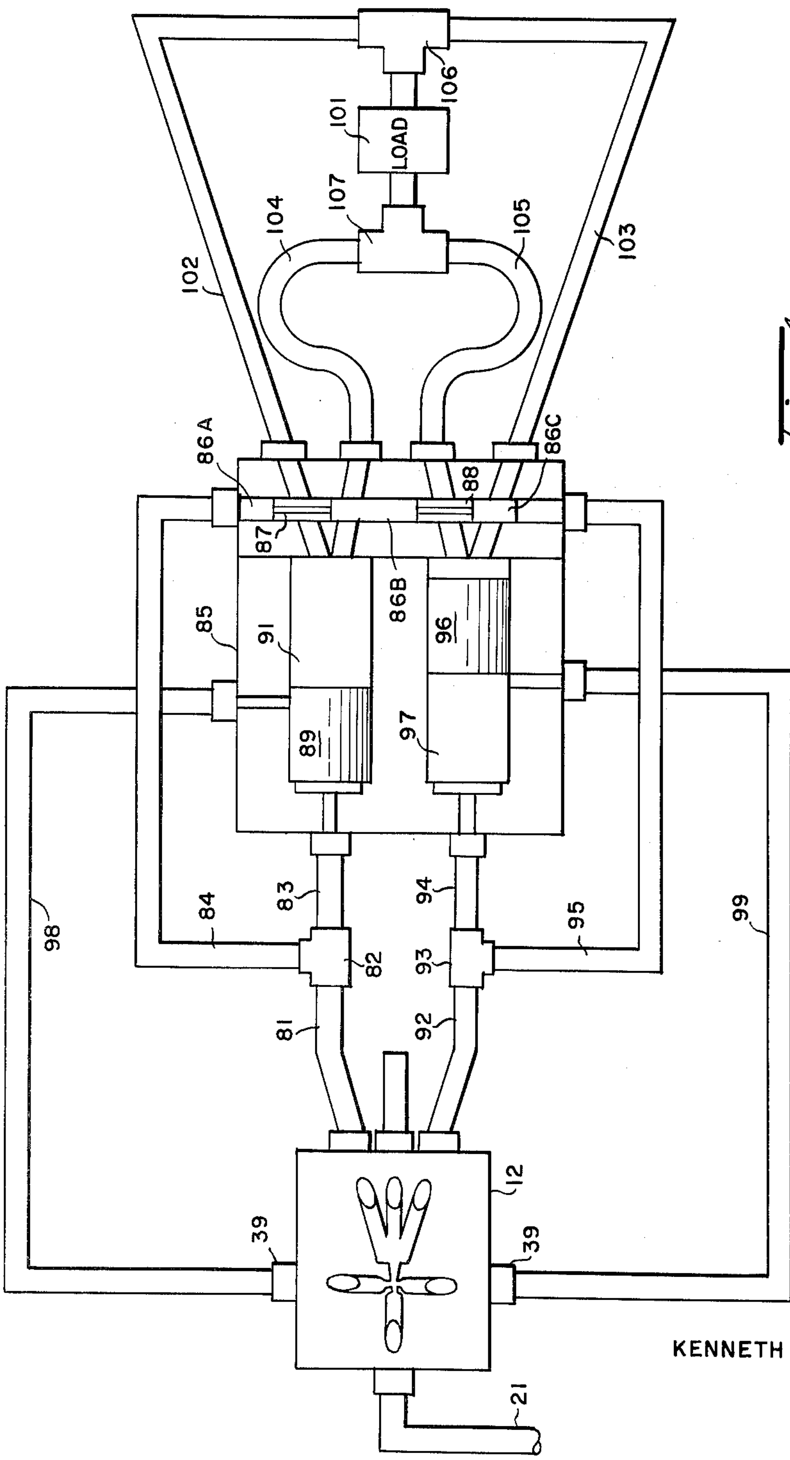

Fig. 4

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FLUID AMPLIFIER CONTROLLED PISTON

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9 Claims. (Cl. 128—53)

The present application is a continuation-in-part of U.S. application Serial No. 170,851 filed February 2, 1962, and entitled, "Artificial Heart."

There are many well-known devices in use today wherein fluid or hydraulics are used as a means for driving a piston. These devices normally use the fluid pressure to drive the piston on its work stroke and some mechanical means for returning the piston back to the starting point of the cycle. The mechanical means, such as a spring, place a certain limitation upon the use of such a piston-driven device. When a device such as a spring is used, the spring force of the spring is normally not variable, because of a fixed spring constant, and even if it were variable, it is difficult to adjust for critical types of operations. Additionally, such a spring over a period of time will fatigue by its nature and lose some of its resiliency and it will also be affected by variations in temperatures. Such variations are also undesirable for any critical type of operation.

It has further been proposed to use what is now commonly known as a fluid amplifier for supplying the driving pressure to a piston. However, to my knowledge, these devices still have required the use of some type of mechanical component for returning the piston to its original position in preparation for another power stroke.

Accordingly, it is an object of this invention to provide a fluid amplifier controlled piston.

A further object of this invention is to provide a fluid amplifier controlled piston wherein the reciprocating motion of the piston occurs without any mechanical forces being necessary for movement of the piston.

Another object of this invention is to provide a fluid amplifier controlled piston wherein the amplifier provides the driving force for the power stroke of the piston and also provides a negative pressure through an entrainment means for return of said piston to its starting position.

Yet another object of this invention is to provide a fluid amplifier controlled piston device for use as an external cardiac compressor.

These and other objects of the invention will be obvious from the following description when taken in conjunction with the drawings wherein:

FIG. 1 is a diagrammatic showing of a basic cylinder-piston combination as driven and controlled by a bistable fluid amplifier;

FIG. 2 is a schematic of a modification of the device of FIG. 1;

FIG. 3 is an illustration of a device using the present invention for external cardiac compression; and

FIG. 4 is an illustration of the use of the device of the present invention in a dual piston fluid pump.

Turning now more specifically to the drawings as illustrated in FIG. 1, there is shown an open ended cylinder 11 having a piston 13 movable therein in a reciprocating fashion. The piston has a face 15 extending outwardly from the cylinder.

A bistable fluid amplifier, indicated schematically at 23, has the normal channel 25 for the fluid power stream input and the two output receivers designated LR for the left receiver and RR for the right receiver. Additionally, the amplifier also has the normal two control channels designated LC for left control and RC for right control.

The inner chamber of the cylinder 11 is connected to

the left receiver of the fluid amplifier 23 by means of a conduit 27 which terminates at a port 17.

The fluid amplifier may be any of the well-known bistable fluid amplifiers and preferably would be the fluid amplifier disclosed and claimed in copending application Serial No. 389,049, filed August 12, 1964. In a bistable fluid amplifier, the power stream will lock into either the left or right receiver dependent upon the pressure differential across the power stream, such pressure differential being created by the outflow from left control and right control. With the piston in the position illustrated, the right control is open to atmosphere and is able to entrain freely therefrom while the left control is blocked off and is not able to entrain freely. Consequently, the power stream will be caused to lock onto the left receiver with the power stream directed through conduit 27 and into the interior of the cylinder 11. The movement of the power stream through the left receiver will also entrain a certain amount of fluid through the right receiver, which may also open to atmosphere or any suitable pressure datum.

When the piston has moved to an extended position such that the feed-back port 19 is uncovered, a pulse of fluid will pass through conduit 29 to left control LC and will switch the power stream from the left receiver to the right receiver.

As the fluid, which in this case is preferably a gas, is exhausted through the right receiver, a negative pressure caused by the entraining character of the amplifier is created above the piston 13 and thus pulls it toward the head of the cylinder 11.

As the piston moves upward, fluid is entrained through the left receiver, the right control and the left control as illustrated by the broken arrows. After exit port 19 is again covered by the piston 13, fluid is less freely entrained from the left control than from the right.

As discussed more thoroughly below, by choosing appropriate impedance values for the control and receiver channels, a pressure difference across the controls can be achieved in conjunction with the entrainment process which will switch the power fluid flowing in the amplifier from the right receiver back to the left receiver when a specified volume remains above the piston. Alternately, the piston can be allowed to strike the top of the cylinder at which time switching will occur due to a very rapid buildup of a pressure differential across the controls in a direction to switch the power flows in the amplifier from the right receiver to the left receiver. In either case, when the switching effect returns the fluid power stream to the left receiver, the cycle is complete.

Turning now to FIG. 2, there is shown a schematic of a modified type of cylinder and piston using the principle of the present invention.

Again, the fluid amplifier 23 is schematically illustrated as having a similar type of power stream supplied through conduit 25. In the device shown in FIG. 2, the power stream passes through the left receiver and into a conduit 31 and out of the port 32 into the interior of the cylinder 33. This drives the piston 35 downwardly so that the face 37 may be used as the desired work surface. Piston 35 may have a flat cylindrical head which is internally threaded at 39 axially into the major body of the piston. A shaft 41 passes through the cylinder 33 and terminates in an externally threaded member 43 which mates with the internal threading 39 of the piston. Therefore, as the piston passes downwardly, it carries the shaft 41 with it.

A valve 49, having a shaft extending upwardly and outwardly of the cylinder 33, is biased by a spring 51 so as to maintain port 48 normally closed. Port 48 communicates with conduit 47 which in turn is coupled to the left control of the fluid amplifier. The head 45 of the shaft 41 is of a dimension sufficient that when the piston has reached its desired stroke, the head 45 will strike the top of the valve 49 and force it downwardly against the spring bias so as to open port 48. This allows a flow of fluid to travel through conduit 47 to the left control of the fluid amplifier for switching the power stream from the left receiver to the right receiver, thereby reversing the direction of the ram travel due to the now present suction forces as described in connection with FIG. 1. The threaded member 43 allows the stroke of the piston to be varied, since rotation of the head 45 will control the point at which the head strikes the top of valve 49.

As the piston travels upwardly and reaches a point near the top of cylinder 33, it will strike valve 53. Valve 53 is designed so that its shaft extends upwardly and out of the cylinder 33 and has an enclosed volume 59 which is connected by means of conduit 60 to a source of fluid pressure. This fluid pressure maintains valve 53 in a maximum extended position into the interior of the cylinder 33 so that a plate 55 on the upper portion of the cylinder 33 will maintain a port 56 closed.

Valve 53 may be threaded up or down in the plate 55 so as to permit adjustment of the upper limit of piston travel. Alternately, it can be threaded upwardly high enough to prevent the piston from striking it. In the latter case this position is used when it it desired to synchronize the piston by means of external signals as discussed below.

When the valve is in the position shown and the piston strikes it so as to open port 56, a pulse of fluid, which in the illustrated case results from atmospheric pressure, is allowed to travel to the right control by means of conduit 57 and thus switches the amplifier power stream from the right receiver to the left receiver. This switching completes the cycle of operation of the cylinder.

Additionally, if desired, a portion of the exhaust flowing through the right receiver can be directed within the cylinder below the working surface of the piston by means of conduit 62 in order to assist further the piston in the return stroke toward the top of the cylinder.

Various impedances designated I may be placed in the conduits leading to the right control, the left control, the left receiver, the right receiver and in the conduit 62. These impedances may take any number of shapes, a number of which are illustrated in the above-identified parent application. Basically, they are designed to control the various flows so as to have the desired switching pressure differentials available from the left and right controls across the power stream. Additionally, there are shown valves in the two conduits leading to the right control to the fluid amplifier. If these valves were completely closed, the power stream would stay locked into the right receiver and the operation of the piston would stop. By momentarily opening valve V_t, the entraining requirements of the power stream can be satisfied such that the power stream will be caused to switch to the left receiver and the piston will move through one complete cycle. At the end of the cycle, the power stream will be in the right receiver and remain there until V_t is again actuated.

A specific device using the present invention is illustrated in FIG. 3. This is a device which is designed for external cardiac compression.

A base plate 63 is provided upon which the patient may be placed. The plate has an upwardly extending support member 64 which may be integral with the base and is of a height sufficient so that a cantiliever arm 65 may be adjusted in a vertical position along the support member 64. A standard type of tightening device such as a screw with a manual knob 66 is provided in order to retain the cantilever arm at the desired position.

A cylinder and piston such as previously described are enclosed in housing 67 with a flexible pad 68 secured to shaft 69 which, in turn, is secured to the moving piston. In the particular device shown, the fluid amplifier 73 is shown attached directly above the cylinder for convenience and compactness.

Conduit 75 supplies the fluid power stream through a valve controlled by a manual control knob 74 which is the equivalent of the valve shown in conduit 25 of FIG. 2.

A rotatable member 70 which is similar to that shown in FIG. 2, is illustrated together with the valve 72 which is similar to valve 49 of FIG. 2.

In the operation of the cardiac compressor, the massage pad 68 is pushed to its maximum operative upper position by lowering the entire cantilever arm toward the chest of the subject. The air from the power stream supply is then allowed to flow into the fluid amplifier. Presuming conditions are such that the air is caused to flow into the left receiver, such air would subsequently flow into the cylinder housing above the piston. The piston is forced downwardly until the feedback port is uncovered by striking valve 72, whereby entraining air flowing in the left control orifice switches the power stream to the right receiver. As air flows in the right receiver, it entrains the air from the left receiver, thus creating a vacuum and pulling the piston upwardly. The stored elastic forces in the chest of the subject allow the chest to reexpand. Air continues to flow in the right receiver until the air pressure variations across the power stream resulting from flows through the control orifices are sufficient to cause the power stream to switch from the right to the left receiver and the cycle is then complete. The continuous cycling of the device provides proper external cardiac compression.

The operation of the embodiment shown in FIG. 4 is controlled by the fluid amplifier 12. The fluid power source enters through tube 21 and is selectively channeled into tube 81 or 92 depending upon the lock-on characteristics of the fluid amplifier 12. When the pistons are in the positions illustrated, the power stream has passed through tubes 92, 94 and 95 to force piston 96 to its extreme limit away from the power source to the position shown.

The power stream has also passed through tube 92, junction 93, tube 95 to force piston 86 to its extreme upward position. The opening in cylinder 97 which allows the power stream to be fed back through tube 99 has just been uncovered and the fluid amplifier 12 has just received the pulse from tube 99 to cause the power stream to shift so as to begin to go through tubes 81, 83 and 84. With the power stream now in tube 81, piston 89 will be driven away from the power source toward the other end of cylinder 91 and piston 96 will immediately move downward when the pressure is applied through tube 81, junction 82 and tube 84 thereto. Piston 89 will force the fluid from cylinder 91 through channel 87, tube 104, junction 107, load 101, junction 106, tube 103, cavity 88, into cylinder 97 on the right side of piston 96 to aid in movement of said piston toward the left. When the fluid amplifier 12 directs the pressure from the fluid pressure source through tube 92 into cylinder 97, piston 96 forces the residual fluid from the right side of cylinder 97 into the cavity 88 through tubes 105, junction 107, load 101, junction 106, tube 102, cavity 87 and into cylinder 91 to aid in the movement of piston 89 to the left as illustrated. It is seen that the passage of fluid pressure through load 101 is always in the same direction.

It will be noted that the particular device of FIG. 4 is a closed system using the present invention and, therefore, aiding pressures may be used on the work side of the piston in the same manner as illustrated in FIG. 2. However, the basic entrainment operation still prevails.

The above description and associated drawings are illustrative only and are not to be considered as a limitation of the broad scope of the invention. It will now be obvious that the work produced by the piston may be used in any mechanical device by merely securing proper coupling devices thereto so as to produce the desired mechanical motion. Accordingly, the scope of the invention is to be limited only by the following claims.

I claim:

1. A reciprocating pressure-applying device comprising
a cylinder,
a piston within said cylinder,
rigid means coupled to said piston and extending axially through one end of said cylinder,
a fluid amplifier having a fluid power inlet port, first and second fluid power output ports, and first and second control ports, means interconnecting said ports for providing communication therebetween,
means connecting said first fluid power output port through the other end of said cylinder,
a closed orifice in said cylinder coupled to said first control port,
and means for opening said orifice to the interior of said other end of said cylinder when said piston reaches a predetermined position within said one end of said cylinder whereby said fluid amplifier removes fluid from said cylinder by entrainment means.

2. Apparatus for converting fluid pressure energy into mechanical reciprocating energy comprising
a cylinder,
a piston in said cylinder,
mechanical coupling means extending from said piston through one end of said cylinder,
a bistable fluid amplifier of the type including a power input channel, two output channels, and control port means for diverting the power jet stream to one of said output channels, and wherein the fluid power jet stream locks onto a wall of one of said two of said output channels to which it is diverted,
means for connecting one of said output channels through the other end of said cylinder whereby the fluid pressure from said output channel drives said piston in the direction of said one end of said cylinder,
activating means for temporarily connecting said control port means to the inner volume of said other end of said cylinder when said piston has travelled a predetermined distance so as to divert said power jet stream to the other of said output channels and evacuate said cylinder by means of entrainment through said amplifier.

3. The apparatus of claim 2 wherein said activating means comprises a normally closed port in said cylinder wall which is opened by the movement of said piston.

4. Apparatus for converting fluid pressure energy into mechanical reciprocating energy comprising,
a bistable fluid amplifier of the type including a fluid power input channel, two output channels, and associated control jets for diverting the power jet stream to a selected one of said output channels and wherein the fluid power jet stream locks onto a wall of one of said two output channels and remains locked onto said wall until diverted to the opposite channel by a pulse from one of said associated control jets of a pressure sufficient to cause said diversion,
a cylinder,
a piston in said cylinder,
means coupled to said piston and extending through one end thereof for transmitting mechanical energy from said piston,
means for coupling one of said two output channels through the other end of said cylinder,
means for coupling the control jet associated with said one of said output channels through said cylinder wall, and

means for maintaining said coupling means closed until said piston has travelled a predetermined distance toward said one end of said cylinder,
said control jet being in communication with said one of said output channels when said coupling means is open so as to divert said power jet stream to the other of said output channels and evacuate said cylinder by entrainment of the fluid in the cylinder through said amplifier.

5. In combination:
a bistable fluid amplifier including a power input channel, two output channels, and control jet means for diverting the power jet stream to one of said output channels,
a cylinder having an input at one end thereof connected to one of said output channels,
a piston in said cylinder,
a port through said cylinder, said port being alternately covered and uncovered by said piston,
a feedback conduit means connected between said port and said control jet means for providing a switching signal to said amplifier when said port is uncovered, and
entrainment means for removing said fluid from said cylinder when said amplifier is switched upon said port being uncovered.

6. In combination:
a bistable fluid amplifier including a power input channel, first and second receiver means and associated control jet means for diverting the power stream to one of said receiver means,
a cylinder having an input at one end thereof connected to one of said receivers,
a piston in said cylinder,
a port through said cylinder, said port being alternately covered and uncovered during the reciprocating travel of said piston, and
a feedback conduit connected between said port and said control jet means for switching said amplifier to said second receiver when said port is uncovered, whereby the flow of fluid into said second receiver creates a negative pressure in said cylinder and causes the piston to move to said one end of said cylinder.

7. The device of claim 6 further comprising,
means for mounting said cylinder containing said piston in a fixed position,
a rod connected to said piston and extending outwardly from said cylinder, and
means connected to the free end of said rod for providing a surface for external cardiac compression.

8. The device of claim 6 further comprising means for controlling the power fluid output of the bistable amplifier by an external synchronizing signal.

9. The device of claim 7 further comprising means for adjusting the maximum distance which the free end of said rod extends beyond said cylinder.

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