# United States Patent

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Continuation-in-part of application Ser. No. 22,425, Mar. 25, 1970.

[54] **FLUID-OPERATED VALVE**
**20 Claims, 4 Drawing Figs.**

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[51] Int. Cl. .................... F16k 31/143
[50] Field of Search .................... 251/61, 61.4, 62, 63.4; 92/52, 65

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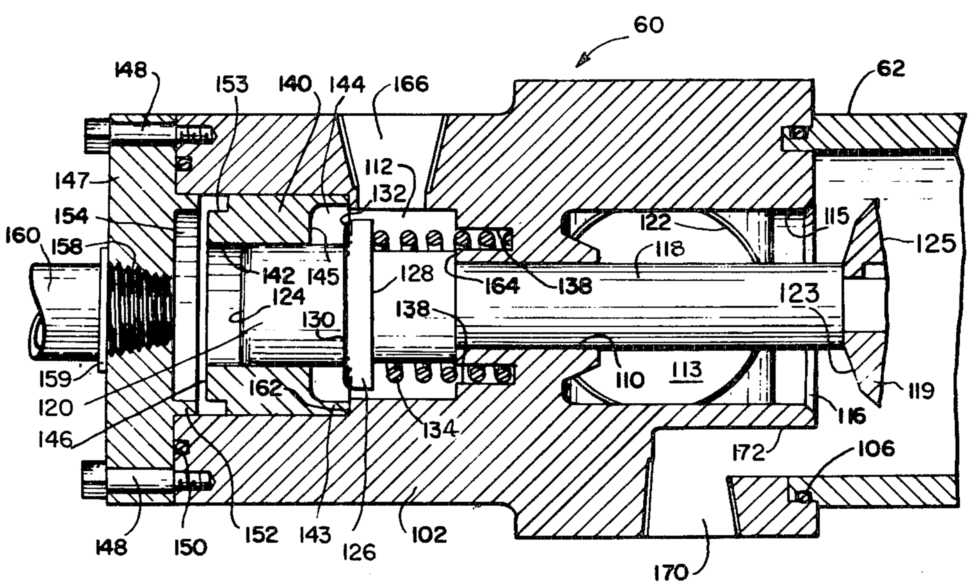
**ABSTRACT:** A fluid-operated valve for controlling the flow of pressurized fluid to and from a fluid-operated device, such as a hydraulic cylinder, is provided. The valve design provides an initially large operating force to open the valve and a subsequent lesser operating force to move the valve to its fully open position. In addition, the valve is designed for automatic closing when a predetermined back pressure occurs in the fluid-operated device. The valve includes a fluid control chamber for receiving pressurized fluid to control the pressure required to operate the valve.



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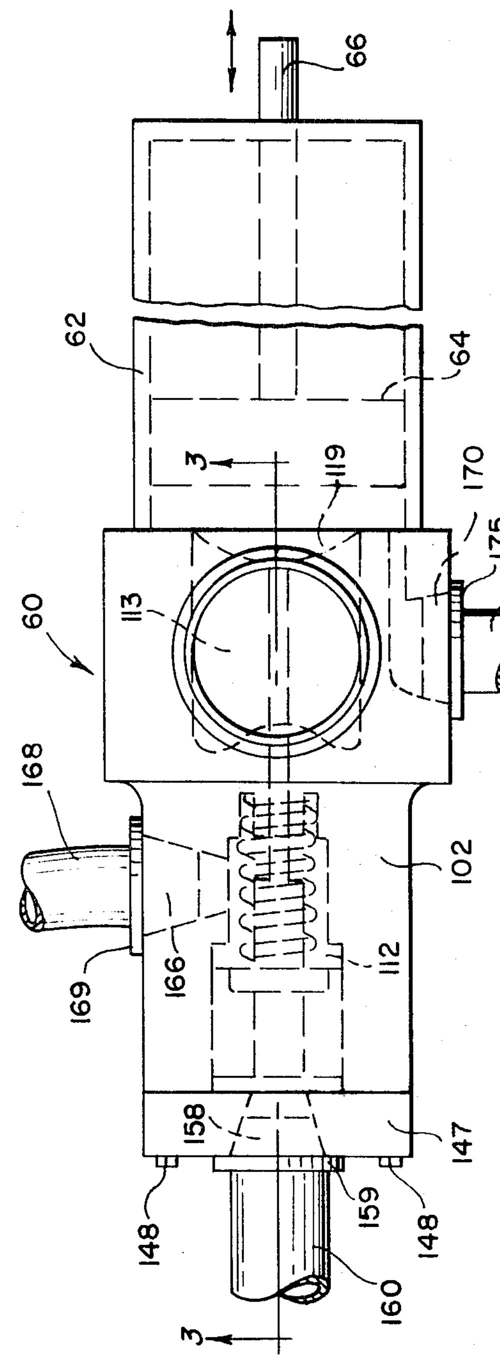


FIG. 1

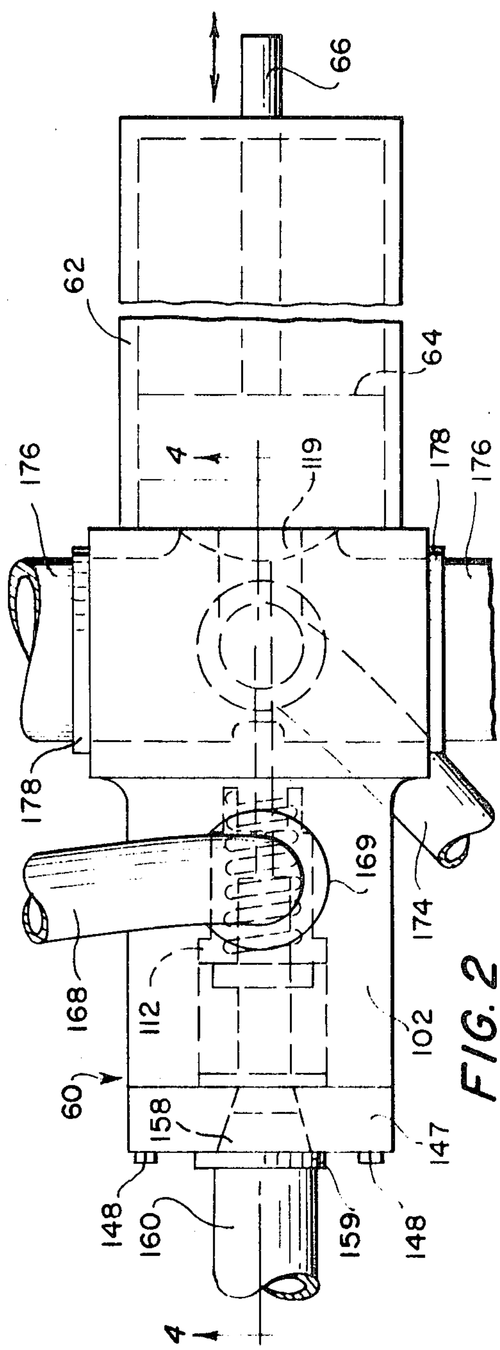


FIG. 2

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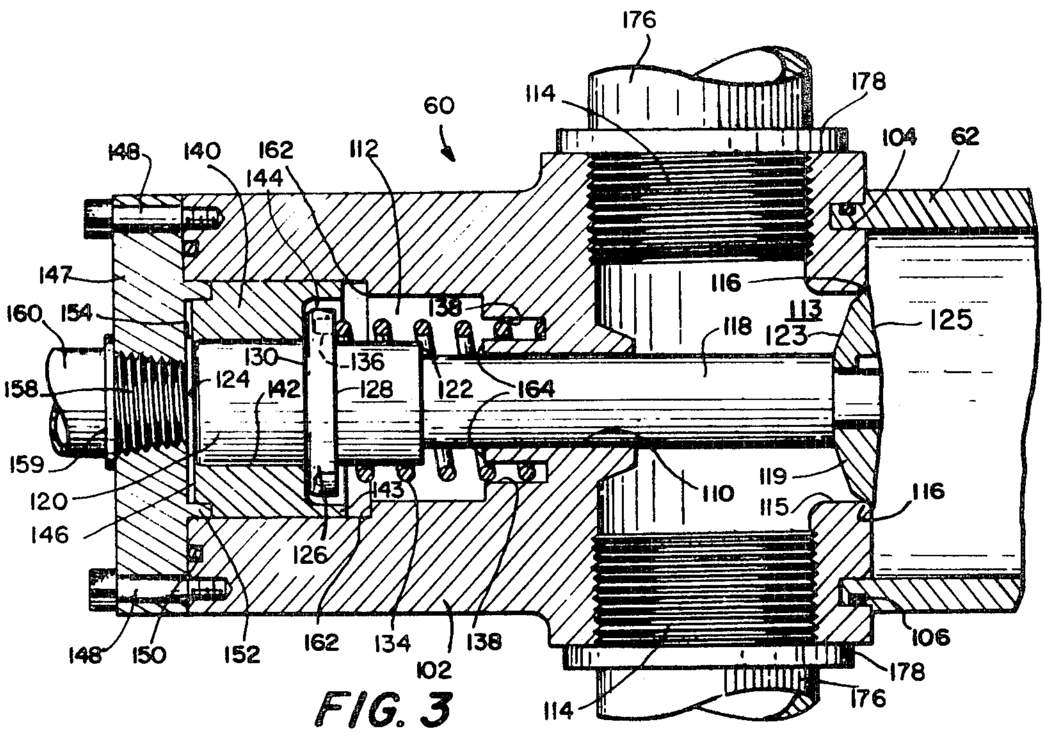


FIG. 3

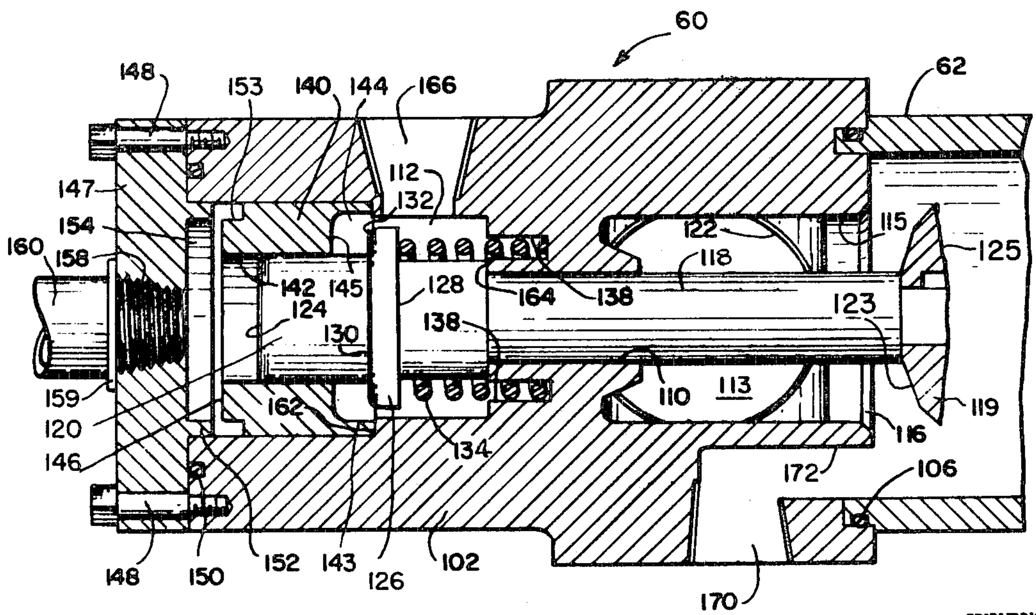


FIG. 4

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## FLUID-OPERATED VALVE

This application is a continuation-in-part of a copending application, Ser. No. 22,425, filed on Mar. 25, 1970, and entitled "Acoustic Pulse Generating System."

The present invention relates to a fluid-operated valve and, more particularly, to a fluid-operated valve for controlling the flow of pressurized fluid to and from a fluid-operated device, such as a hydraulic cylinder.

In fluid-operated systems, it is frequently desirable to employ a fluid-operated valve which initially produces a relatively large operating force to open the valve and subsequently produces a lesser operating force to move the valve to its fully open position. This type of fluid-operated valve is particularly useful in controlling the flow of high-pressure fluid to and from fluid-operated devices. For example, if it is desired to discharge fluid from a device containing fluid under high pressure through a normally closed valve, an operating mechanism which initially exerts a relatively large force on the valve to overcome the pressure exerted on the valve by the high-pressure fluid is preferred. Once the normally closed valve is open, however, it is no longer necessary to exert a large force on the valve to maintain it in an open position. Thus, it is desirable to provide a fluid-operated valve including an operating mechanism which produces an initially large operating force to open the valve and, thereafter, a lesser operating force to move the valve to its fully open position and to maintain the valve in that position.

At the same time, a valve which conserves the amount of pressurized fluid required for its operation is desirable. By conserving pressurized fluid required to operate the valve, the expense of operating a fluid system can be reduced. In addition, the time required for the system to respond to a change in pressure is minimized.

The fluid-operated valve of the present invention incorporates a valve-actuating mechanism which initially produces a large operating force to open the valve and subsequently produces a lesser operating force to move the valve to its fully open position. In addition, the fluid-operated valve is designed to conserve the amount of pressurized fluid required for its operation. The valve-actuating mechanism of the fluid-operated valve includes a fluid control chamber to which pressurized fluid can be supplied to determine the pressure required to operate the valve.

In accordance with the present invention, a fluid-operated valve includes a housing in which a fluid chamber and a fluid passage are formed. A valve stem is slidably mounted for movement relative to the housing and has a first end extending into the fluid passage and a second end extending into the fluid chamber. A poppet valve is mounted for movement with the first end of the valve stem and normally closes the fluid passage. The valve also includes a piston slidably disposed within the fluid chamber and having an axially extending opening for receiving the second end of the valve stem to permit the piston to move relative to the valve stem. Means connected to the fluid chamber are provided for supplying pressurized fluid to the fluid chamber to act on the piston and the second end of the valve stem to urge the poppet valve into an open position. In addition, means are provided for transmitting the force exerted on the piston by the pressurized fluid to the valve stem to move the valve stem and displace the poppet valve from its normally closed position.

In a preferred embodiment, a slot is formed in the housing extending from the fluid passage to the fluid chamber. The valve stem is slidably mounted within the slot. In addition, the housing has a valve seat formed in the fluid passage and biasing means are provided for urging the poppet valve into engagement with the valve seat to maintain the poppet valve in a normally closed position. The poppet valve is mounted on the first end of the valve stem and the biasing means comprises a coil spring mounted in the fluid chamber and having one of its ends connected to the valve stem and its opposite end engaging the housing.

The preferred embodiment also includes a flange formed on the valve stem and located in the fluid chamber for engaging the piston to transmit the force exerted on the piston to the valve stem. A first end of the piston is normally in contact with the flange, and a second end of the piston is located adjacent to the second end of the valve stem. The pressurized fluid supplied to the fluid chamber applies pressure to the second end of the valve stem and the second end of the piston to force the piston against the flange and to move the valve stem and poppet valve against the biasing means to displace the poppet valve from the valve seat.

In addition, the preferred embodiment includes first stop means located in the fluid chamber for limiting movement of the piston relative to the housing to permit the valve stem to move relative to the piston under the action of the pressurized fluid on the second end of the valve stem. The preferred embodiment also includes second stop means located in the fluid chamber for limiting movement of the valve stem relative to the housing to define the fully open position of the valve. The first and second stop means are arranged so that the valve stem cannot move out of the axial opening formed in the piston.

The piston and the flange of the preferred embodiment provide an actuating mechanism for the valve which applies an initially large operating force to the valve stem. In addition, this arrangement conserves the amount of fluid required for the operation of the valve because the valve stem remains within the axial opening formed in the piston during operating of the valve.

Additional features and advantages of the present invention are set forth in the description which follows and, in part, will be obvious from the description of the invention.

The accompanying drawings illustrate a preferred embodiment of the invention and, together with the description, serve to explain the principles of the invention.

Of the drawing:

FIG. 1 is a side elevation view of a fluid-operated valve constructed in accordance with the principles of the present invention for controlling the flow of pressurized fluid to and from a hydraulic cylinder;

FIG. 2 is a plan view of the fluid-operated valve of FIG. 1;

FIG. 3 is an enlarged sectional view of the fluid-operated valve taken along line 3—3 of FIG. 1; and

FIG. 4 is an enlarged sectional view of the fluid-operated valve taken along line 4—4 of FIG. 2.

In the following description, a fluid-operated valve constructed in accordance with the principles of the present invention is described in conjunction with a hydraulic cylinder. It is to be understood, however, that the applications for the fluid-operated valve are not limited to operating a hydraulic cylinder and that the valve of the present invention can be used in any fluid system in which it is desirable to control the flow of pressurized fluid to and from a fluid-operated device.

Referring to FIGS. 1 and 2, a fluid-operated valve 60 constructed in accordance with the principles of the present invention is illustrated in combination with a hydraulic cylinder 62. The valve is secured by welding or other conventional means at one end of hydraulic cylinder 62. The hydraulic cylinder includes a piston 64 slidably disposed within and in sealing engagement with the inner cylindrical wall of the hydraulic cylinder. An output shaft 66 is connected at one end to piston 64, and its opposite end extends outward from the hydraulic cylinder. Shaft 66 can be connected to a device, e.g. an acoustic pulse generator, to be operated by the hydraulic cylinder.

Referring to FIG. 3, valve 60 includes a generally cylindrical valve housing 102 having a circular slot 104 formed at one end thereof for receiving the cylindrical sidewall of hydraulic cylinder 62. An O-ring seal 106 is mounted in a groove formed in the exterior sidewall of hydraulic cylinder 62 to provide a seal between valve housing 102 and the hydraulic cylinder. The valve housing can be secured to the hydraulic cylinder by conventional means such as by welding.

In accordance with the invention, the fluid-operated valve includes a valve housing in which a fluid chamber and a fluid passage are formed. In a preferred embodiment, a slot is formed in the housing extending from the fluid passage to the fluid chamber. As here embodied and shown in FIG. 3, valve housing **102** has an elongated slot **110** which extends from a generally cylindrical fluid chamber **112** to a fluid passage **113** formed in the housing. Fluid passage **113** includes a pair of ports **114** located on opposite sides of valve housing **102** having internal threads for receiving threaded coupling members for hydraulic tubes.

In a preferred embodiment of the invention, the valve housing has a valve seat formed in the fluid passage. As shown in FIG. 3, fluid passage **113** includes an axially extending portion **115** which terminates at the end surface of valve housing **102**. A valve seat **116** is formed on the valve housing at the end of axially extending portion **115** of fluid passage **113**. The valve seat is annular in shape and, as shown in FIG. 4, has a beveled surface.

The invention includes a valve stem slidably mounted for movement relative to the valve housing and having a first end extending into the fluid passage and a second end extending into the fluid chamber. In a preferred embodiment, the valve stem is slidably mounted within the slot formed in the housing. As here embodied, a cylindrical valve stem **118** (FIG. 3) is slidably mounted within slot **110**. A first end of valve stem **118** extends into fluid passage **113** and a second end of the valve stem extends into fluid chamber **112**.

In accordance with the invention, a poppet valve is mounted for movement with the first end of the valve stem for normally closing the fluid passage. In the preferred embodiment, the poppet valve is mounted on the first end of the valve stem and normally engages the valve seat to close the fluid passage. Referring to FIG. 3, circularly shaped poppet valve **119** is mounted at the first end of the valve stem. As shown in FIGS. 3 and 4, the periphery of an inner surface **123** of poppet valve **119** is beveled to conform to the beveled surface of valve seat **116** so that when the poppet valve is in contact with the valve seat fluid passage **113** is closed. Poppet valve **119** also includes an outer surface **125**.

Valve stem **118** has an enlarged cylindrical portion **120** formed on its second end and located in fluid chamber **112** which defines a shoulder **122** on the valve stem. In addition, the enlarged cylindrical portion of valve stem **118** provides an enlarged end surface **124** on the valve stem.

As shown in FIG. 3, an annular flange **126** projects from enlarged cylindrical portion **120** of valve stem **118** into fluid chamber **112**. The flange has opposed annular surfaces **128** and **130** to which fluid pressure can be applied by fluid admitted into fluid chamber **112**. As shown in FIG. 4, the periphery of flange **126** adjacent to annular surface **130** is curved inwardly to provide a contoured edge **132** on the flange. The purpose of flange **126** is explained below.

In a preferred embodiment of the invention, biasing means are provided for urging the poppet valve into a normally closed position. The biasing means urge the poppet valve into engagement with the valve seat to maintain the poppet valve in its normally closed position. As embodied, the biasing means comprises a coil spring **134** mounted in fluid chamber **112** with one end engaging flange **126** to connect the coil spring to valve stem **118** and its other end engaging the valve housing. As shown in FIG. 3, flange **126** has an annular slot **136** for receiving one end of coil spring **134**. The other end of the coil spring is received in an annular recess **138** formed in valve housing **102**.

Coil spring **134** biases valve **60** into a normally closed position by urging poppet valve **119** into contact with valve seat **116**. With the poppet valve in this position, the interior of hydraulic cylinder **62** is closed to fluid flow through ports **114**. In its open position (FIG. 4), poppet valve **119** is moved away from valve seat **116** and the interior of hydraulic cylinder **62** is open to fluid flow through ports **114**.

The fluid-operated valve of this invention includes a piston slidably disposed within the fluid chamber and having an axially extending opening for receiving the second end of the valve stem to permit relative movement between the piston and valve stem. In a preferred embodiment, a first end of the piston is normally in contact with the flange, and a second end of the piston is normally located adjacent to the second end of the valve stem. As embodied, a piston **140** (FIGS. 3 and 4) is slidably disposed within fluid chamber **112** and its periphery is in sealing engagement with the interior walls of housing **102** which define fluid chamber **112**. The piston is provided with an axially extending cylindrical opening **142** for receiving enlarged portion **120** of valve stem **118** and for permitting relative axial movement between the enlarged portion of valve stem **118** and the piston. The periphery of the enlarged end of valve stem **118** is in sealing engagement with the inner cylindrical wall of piston **140** provided by axial opening **142**.

Referring to FIGS. 3 and 4, a first end **143** of piston **140** has a circular recess **144** for receiving flange **126** of the valve stem. As shown in FIG. 4, circular recess **114** terminates in a flat surface **145** for engaging annular surface **130** of flange **126**. As shown in FIG. 3, flat surface **145** of piston **140** is normally in contact with annular surface **130** when valve **60** is in its closed position.

A second end **146** of piston **140** is normally located adjacent to enlarged end surfaces **124** of valve stem **118**. As shown in FIGS. 3 and 4, this second end of piston **140** has the configuration of a flat annular surface.

Valve **60** is provided with a cover plate **147** secured to cylindrical valve housing **102** by a plurality of bolts **148** which extend through the cover plate and into threaded openings formed in the valve housing. Cover plate **147** and valve housing **102** constitute the housing of valve **60**. An O-ring seal **150** is mounted in an annular slot formed in valve housing **102** to provide a seal between cover plate **147** and the valve housing.

In a preferred embodiment of the valve, a projection is formed on the housing and extends into the fluid chamber for engaging the second end of the piston to limit movement of the piston relative to the housing to provide a minimum spacing between the second end of the piston and the housing. As here embodied, an annular ridge **152** (FIG. 3) is formed on cover plate **147** and extends into the interior of valve housing **102** to provide a stop for piston **140**. Piston **140** is provided with a peripheral notch **153** (FIG. 4) formed as its second end for receiving annular ridge **152**. The annular ridge and peripheral notch are dimensioned so that with the poppet valve in its closed position (FIG. 3) the ends of valve stem **118** and piston **140** are slightly spaced from the interior wall of cover plate **147**. Thus, when the poppet valve is closed, end surface **146** of piston **140**, enlarged end surface **124** of valve stem **118**, and the interior wall of cover plate **146** define a small fluid-receiving space **154**.

In accordance with the invention, means connected to the fluid chamber are provided for supplying pressurized fluid to the fluid chamber to act on the piston and the second end of the valve stem to urge the poppet valve into an open position. In the preferred embodiment, the pressurized fluid supplied to the fluid chamber applies pressure to the second end of the valve stem and the second end of the piston to force the piston against the flange and move the valve stem and poppet valve against the biasing means to displace the poppet valve from the valve seat. As here embodied, the means for supplying pressurized fluid to the fluid chamber comprises a first inlet port **158** (FIGS. 1 and 3) formed in cover plate **147** through which pressurized fluid can be applied to enlarged end surface **124** of the valve stem and to end **146** of piston **140** to open poppet valve **119**. Inlet port **158** has internal threads for receiving a threaded coupling member for a hydraulic tube. As shown in FIGS. 3 and 4, a hydraulic tube **160** is connected to inlet port **158** by a threaded coupling member **159**, and it can be used to supply pressurized fluid to fluid receiving space **154**.

The fluid-operated valve of the present invention includes means for transmitting the force exerted on the piston by the pressurized fluid to the valve stem to displace the poppet valve from its normally closed position. In the preferred embodiment, this means comprises the flange (described above) formed on the valve stem for engaging the piston to transmit the force exerted on the second end of the piston to the valve stem. As embodied, flange 126 (FIG. 3) is normally located in recess 144 formed in first end 143 of piston 140. When pressurized fluid is admitted to fluid-receiving space 154 through inlet port 158, the force exerted on end surface 146 of piston 140 is transmitted to valve stem 118 by flange 126.

A preferred embodiment of the fluid-operated valve includes first stop means located in the fluid chamber for limiting movement of the piston relative to the housing to permit the valve stem to move relative to the piston under the action of the pressurized fluid on the second end of the valve stem. This first stop means comprises a shoulder formed on the valve housing which projects into the fluid chamber for engaging the piston to limit movement of the piston relative to the valve housing and the valve stem. Referring to FIGS. 3 and 4, a shoulder 162 is formed on valve housing 102 and projects inward from the interior walls of fluid chamber 112. As shown in FIG. 3, first end 143 of piston 140 is spaced from shoulder 162 when valve 60 is in its closed position. When pressurized fluid is admitted to fluid-receiving space 154 through inlet port 158, piston 140 moves rightward until its end 143 engages shoulder 162.

In addition, the preferred embodiment includes second stop means located in the fluid chamber for limiting movement of the valve stem relative to the housing to define the fully open position of the valve. As embodied, housing 102 is provided with an annular surface 164 which is located in fluid chamber 112. When valve 60 is operated by applying pressurized fluid to fluid-receiving space 154, shoulder 122 of valve stem 118 moves into engagement with annular surface 164 to terminate movement of the valve stem and to define the fully open position of poppet valve 119.

Referring to FIG. 3, the interior walls of valve housing 102, valve stem 118, and first end 143 of piston 140 establish a fluid control chamber within fluid chamber 112. Flange 126 of valve stem 118 is located in this fluid control chamber. Housing 102 is provided with a second inlet port 166 which extends through housing 102 into the fluid control chamber. Inlet port 166 can be provided with internal threads for receiving a threaded coupling member.

A hydraulic tube 168 (FIGS. 1 and 2) is connected to inlet port 166 by a threaded coupling member 169. Pressurized fluid is supplied to the fluid control chamber through inlet port 166 to counteract the forces exerted on the ends of piston 140 and valve stem 118 by the pressurized fluid supplied to fluid-receiving space 154 to determine the pressure required to open poppet valve 119.

Valve 60 includes a third inlet port 170 (FIGS. 1 and 4) formed in valve housing 102, for admitting pressurized fluid into the fluid-operated device controlled by the valve. As shown in FIG. 4, inlet port 170 has an axial portion 172 which extends to the end of housing 102 and opens into the interior of hydraulic cylinder 62. Inlet port 170 can also be provided with internal threads.

Referring to FIG. 1, hydraulic tube 174 is connected by a threaded coupling member 175 to inlet port 170. Pressurized fluid can be supplied to the interior of hydraulic cylinder 62 through hydraulic tube 174 and inlet port 170 to displace piston 64 and shaft 66 rightward, as viewed in FIGS. 1 and 2.

As shown in FIGS. 2 and 3, a pair of large diameter hydraulic tubes 176 are connected to ports 114 by a pair of threaded coupling members 178. The large diameter hydraulic tubes permit fluid flow to and from the hydraulic cylinder to occur at a relatively large rate.

The fluid-operated valve of the present invention is particularly suitable for use in controlling the operation of an acoustic pulse generator of the type described in copending application, Ser. No. 22,425, filed on Mar. 25, 1970. This type of generator is designed to be submerged in a body of water and to generate an acoustic pulse in the water. The generator includes an expandable and collapsible structure, e.g., a piston slidably disposed within a cylindrical housing having an open end and a closed end, and a hydraulic cylinder having its output shaft connected to the piston for the generator for displacing the piston relative to the cylindrical housing. A compressible fluid is confined within the interior of the cylindrical housing by the piston of the generator.

In the operation of the generator, pressurized fluid is supplied to the hydraulic cylinder to move its output shaft to an extended position to displace the piston of the generator relative to the cylindrical housing against the pressure of the fluid medium. Then the pressure within the hydraulic cylinder is rapidly decreased to allow the ambient pressure of the fluid medium to drive the piston toward the closed end of the cylindrical housing. The piston of the generator is driven toward the closed end of the cylindrical housing to compress the fluid located in the generator. After this fluid is compressed, the piston rebounds way from the closed end of the cylindrical housing to create an acoustic pulse in the fluid medium. As the piston rebounds, pressurized fluid is admitted into the hydraulic cylinder to prevent a subsequent collapse (inward movement) of the piston toward the closed end of the cylindrical housing.

The fluid-operated valve of the present invention is useful in controlling the flow of pressurized fluid to and from the hydraulic cylinder of an acoustic pulse generator. The valve is not limited, however, to such use and can be used to control the flow of pressurized fluid to and from any fluid-operated device. The valve is particularly useful in fluid-operated systems where it is desired to obtain a rapid discharge of fluid from a device and to automatically control recharging of the device with pressurized fluid.

The operation of the fluid-operated valve is described in connection with the control of fluid flow to and from a hydraulic cylinder of an acoustic pulse generator of the type described above. It is to be understood, however, that this description is merely illustrative of a particular application of this valve and, that the description is not intended to limit the potential applications of the valve of the present invention.

In the operation of valve 60, pressurized fluid is initially supplied to the interior of hydraulic cylinder 62 through inlet port 170. The pressurized fluid forces piston 64 to move rightward, as viewed in FIGS. 1 and 2, to move output shaft 66 to an extended position relative to hydraulic cylinder 62. In the acoustic generator, the piston of the generator is displaced toward the open end of the cylindrical housing against the ambient pressure of the fluid medium.

When it is desired to discharge the pressurized fluid from hydraulic cylinder 62, the pressure of the fluid applied to hydraulic tube 174 is decreased, and pressurized fluid is supplied to fluid-receiving space 154 through inlet port 158 and hydraulic tube 160. The pressurized fluid supplied to fluid-receiving space 154 (FIG. 3) acts against enlarged end surface 124 of valve stem 118 and end surface 146 of piston 140. The resultant force on piston 140 is transmitted to valve stem 118 by flange 126. Thus, the total (rightward) force acting on the valve stem to open poppet valve 119 is the sum of the forces applied to the end surfaces of valve stem 118 and piston 140.

The rightward force acting on valve stem 118 to open poppet valve 119 is opposed by the leftward force exerted on flange 126 by coil spring 134 and the leftward force exerted on poppet valve 119 by the pressurized fluid in the hydraulic cylinder. In addition, when pressurized fluid is supplied through hydraulic tube 168 and inlet port 166 to the fluid control chamber, a leftward force is exerted on shoulder 122 of valve stem 118. Since annular surface 130 of flange 126 is in contact with flat surface 145 of piston 140, a pressure differential force is exerted on flange 126 by the pressurized fluid in the fluid control chamber. Contoured edge 132 of flange 126 determines the difference in areas of annular surfaces 128 and 130 of the flange and this difference determines the magnitude of the differential force on the flange.

In addition, a leftward force is exerted on piston 140 as a result of the pressurized fluid in the fluid control chamber acting on the exposed surfaces of end 143 of piston 140. Thus, the pressure required in fluid-receiving space 154 to open poppet valve 119 is determined by leftward forces exerted on valve stem 118 and piston 140 by coil spring 134 and the pressurized fluid in the fluid control chamber. The required pressure can be varied by adjusting the fluid pressure in the fluid control chamber.

When the pressure of the fluid supplied to fluid-receiving space 154 is sufficient to overcome the opposing forces on valve stem 118 and piston 140, the piston and valve stem move rightward, as viewed in FIG. 3, to displace poppet valve 119 from valve seat 116. Thus, an initially large operating force is applied to valve stem 118 to partially open the poppet valve. With the poppet valve in a partially open position, the remaining pressurized fluid in hydraulic cylinder 62 is permitted to discharge through ports 114 and hydraulic tubes 176. The pressurized fluid is discharged from the hydraulic cylinder as piston 64 moves leftward under the action of the force supplied to output shaft 66 from the acoustic pulse generator. The pressure acting on outer surface 125 of poppet valve 119 is decreased because of the fluid flow around the poppet valve.

Piston 140 is limited in its rightward movement by shoulder 162 (FIG. 3). Valve stem 118 is also limited in its rightward movement by shoulder 122 formed on enlarged portion 120 of the valve stem. Thus, piston 140 and valve stem 118 move rightward simultaneously until piston 140 engages shoulder 162. Thereafter, the pressure applied to end surface 146 of the piston is no longer transmitted to valve stem 118, and the only rightward force acting on the valve stem results from the pressure applied to its end surface 124.

After the initial opening of poppet valve 119, the pressure required to move the poppet valve to its fully open position decreases because of the discharge of pressurized fluid from hydraulic cylinder 62. Thus, the initially large operating force applied to valve stem 118 which includes the force exerted on piston 140 is not needed to move poppet valve 119 to its fully open position. Shoulder 162 limits the movement of piston 140 relative to housing 102 to conserve the amount of pressurized fluid required to operate valve 60.

Although the movement of piston 140 is terminated, valve stem 118 continues to move rightward as a result of the force applied to its enlarged end surface 124. When flange 126 moves out of contact with piston 140, the pressure differential force exerted on the flange disappears so that the only remaining leftward forces acting on valve stem 118 are the forces applied to the valve stem by coil spring 134 and by the pressure in the fluid control chamber acting on shoulder 122 and the force on poppet valve 119 from the decreased pressure in hydraulic cylinder 62. Valve stem 118 continues its rightward movement until shoulder 122 contacts annular surface 164 on valve housing 102. The movement of valve stem 118 is thus terminated and poppet valve 119 is maintained in its fully open position by the pressure of the fluid in fluid-receiving space 154.

Piston 140 (FIG. 3) of valve 60 permits an initially large operating force to be applied to valve stem 118 to open the poppet valve 119. After the initial opening of the poppet valve, a reduced operating force is applied to valve stem 118 to move the valve to its fully open position.

The valve design conserves the amount of fluid required to open the valve by permitting valve stem 118 to be driven a greater distance than piston 140. Furthermore, fluid is also conserved because enlarged portion 120 of valve stem 118 is in sealing engagement with the inner wall of piston 140 and it does not move out of axial opening 142 in the piston during operation of the valve.

After hydraulic cylinder 62 is discharged, pressurized fluid is again supplied to the hydraulic cylinder through port 170. At the same time, the fluid previously discharged through ports 114 is allowed return to the hydraulic cylinder through ports 114 and fluid passage 113. In addition, the pressure of the fluid applied to fluid-receiving space 154 is decreased so that the pressure in the fluid control chamber drives piston 140 leftward to its original position, as shown in FIG. 3. At the same time, valve stem 118 moves slightly leftward to move shoulder 122 out of engagement with annular surface 164, but it does not return to its original position since the pressure of the fluid flowing into the hydraulic cylinder through fluid passage 113 and acting on outer surface 125 of poppet valve 119 is sufficient to balance the forces exerted on the valve stem in the opposite direction by coil spring 134 and by the pressure in hydraulic cylinder 62.

As hydraulic cylinder 62 is recharged, the pressure in the hydraulic cylinder gradually increases and the flow of fluid into hydraulic cylinder 62 through ports 114 and fluid passage 113 gradually decreases. An increasing force is applied to outer surface 125 of poppet valve 119 by the pressurized fluid in the hydraulic cylinder to urge valve stem 118 leftward. When the leftward forces acting on valve stem 118, i.e., the force exerted on valve stem 118 by coil spring 134, the force applied to shoulder 122 by the pressurized fluid in the fluid control chamber and the force applied to outer surface 125 of the poppet valve, exceed the rightward force exerted on poppet valve 114 by virtue of the fluid flow from fluid passage 113 to the interior of the hydraulic cylinder, valve stem 118 is returned to its original position, as shown in FIG. 3. Thus, poppet valve 119 is closed to prevent further fluid flow through fluid passage 113 into the hydraulic cylinder.

The closure of the poppet valve occurs automatically during the rightward movement of piston 64 in hydraulic cylinder 62. The pressure at which the poppet valve closes is determined by the strength of coil spring 134 and the pressure in the fluid control chamber acting on shoulder 122.

The fluid-operated valve of the present invention permits fluid lines having a low-pressure rating to be used where large fluid flow rates occur at low pressure and where small fluid flow rates occur at high pressure. Thus, hydraulic tubes 176 can have a low-pressure rating since the large fluid flow rate through these tubes occurs at a low pressure. In addition, hydraulic tubes 160, 168, and 174 can also have a low-pressure rating since only a small volume of fluid flows through these tubes at high pressure.

The invention in its broader aspects is not limited to the specific details shown and described, and modifications may be made in the details of the fluid-operated valve without departing from the principles of the present invention.

What is claimed is:

1. A fluid-operated valve comprising:

a housing having a fluid chamber and a fluid passage formed therein;

a valve stem slidably mounted for movement relative to said housing and having a first end extending into said fluid passage and a second end extending into said fluid chamber,

a poppet valve mounted for movement with said first end of said valve stem and normally closing said fluid passage;

a piston slidably disposed within said fluid chamber and having an opening extending axially therethrough for receiving said second end of said valve stem to permit said piston to move relative to said valve stem;

means connected to said fluid chamber for supplying pressurized fluid to said fluid chamber to act on said piston and said second end of said valve stem to urge said poppet valve into an open position; and

means for transmitting the force exerted on said piston by the pressurized fluid to said valve stem to move said valve stem and displace said poppet valve from its normally closed position.

2. The fluid-operated valve of claim 1, which includes;

biasing means for urging said poppet valve into a normally closed position.

3. The fluid-operated valve of claim 2, wherein:

said housing has a valve seat formed thereon and located in said fluid passage; and said biasing means urges said poppet valve into engagement with said valve seat to maintain said poppet valve in a normally closed position.

4. The fluid-operated valve of claim 2, wherein:

said poppet valve is mounted on said first end of said valve stem; and

said biasing means comprises a coil spring mounted in said fluid chamber and having one of its ends connected to said valve stem and its opposite end engaging said housing.

5. The fluid-operated valve of claim 1, wherein the means for transmitting the force exerted on the piston by the pressurized fluid to the valve stem comprises:

a flange formed on said valve stem and located in said fluid chamber for engaging said piston to transmit the force exerted on said piston to said valve stem.

6. The fluid-operated valve of claim 1, which includes:

first stop means located in said fluid chamber for limiting movement of said piston relative to said housing to permit said valve stem to move relative to said piston under the action of the pressurized fluid on said second end of said valve stem.

7. The fluid-operated valve of claim 6, which includes:

second stop means located in said fluid chamber for limiting movement of said valve stem relative to said housing to define the fully open position of the valve.

8. The fluid-operated valve of claim 7, wherein:

said first stop means comprises a shoulder formed on said housing and projecting into said fluid chamber for engaging the piston to limit movement of the piston relative to said housing and said valve stem; and

said second stop means includes a shoulder formed on said valve stem for engaging said housing to terminate movement of the valve stem and to define the fully open position of the poppet valve.

9. The fluid operated valve of claim 1, wherein:

said housing has a slot formed therein extending from said fluid passage to said fluid chamber; and

said valve stem is slidably mounted within said slot.

10. A fluid-operated valve for controlling the flow of pressurized fluid to and from a fluid-operated device, which comprises:

a housing having a slot, a fluid chamber, and a fluid passage formed therein, said slot extending from said fluid passage into said fluid chamber;

said housing also having a valve seat formed thereon and located in said fluid passage;

a valve stem slidably mounted within said slot and having a first end extending into said fluid passage and a second end extending into said fluid chamber;

a poppet valve mounted on said first end of said valve stem for engaging said valve seat to close said fluid passage;

a flange formed on said valve stem and located in said fluid chamber;

biasing means for urging said poppet valve into engagement with said valve seat to maintain said poppet valve in a normally closed position;

a piston slidably disposed within said fluid chamber and having an opening extending axially therethrough for receiving said second end of said valve stem to permit said piston to move relative to said valve stem, said piston having a first end normally in contact with said flange and a second end adjacent to said second end of said valve stem; and

means for supplying pressurized fluid to said fluid chamber to apply pressure to said second end of said valve stem and said second end of said piston to force said piston against said flange and move said valve stem and poppet valve against said biasing means to displace said poppet valve from said valve seat.

11. The fluid-operated valve of claim 10, wherein:

said housing has a shoulder formed thereon which projects into said fluid chamber to limit the movement of said piston relative to said housing and to said valve stem.

12. The fluid-operated valve of claim 10, wherein the biasing means comprises:

a coil spring mounted in said fluid chamber, one end of said spring engaging said flange and the other end of said spring engaging said housing.

13. The fluid-operated valve of claim 10, wherein:

said valve stem has a shoulder formed thereon and located in said fluid chamber for limiting its movement relative to said housing.

14. The fluid-operated valve of claim 10, wherein:

said housing includes a first inlet port formed therein for admitting pressurized fluid into said fluid chamber to act on said second end of said piston and said second end of said valve stem.

15. The fluid-operated valve of claim 14, wherein:

said housing, piston, and valve stem establish a fluid control chamber within said housing in which said flange is received; and

said housing has a second inlet port formed therein through which pressurized fluid is supplied to or released from said fluid control chamber to counteract the forces exerted on said piston and said valve stem by the pressurized fluid supplied to said fluid chamber through said first inlet port to determine the pressure required to open said poppet valve.

16. The fluid-operated valve in claim 15, wherein:

said housing includes a third inlet port formed therein for admitting pressurized fluid into the fluid-operated device controlled by the valve.

17. A fluid-operated valve for producing an initially large operating force to open the valve and a subsequent lesser operating force to move the valve to its fully open position and for automatically closing the valve when a predetermined back pressure is exerted on the valve, which comprises:

a housing having a slot, a fluid chamber, and a fluid passage formed therein, said slot extending from said fluid passage into said fluid chamber;

said housing also having a valve seat formed thereon and located in said fluid passage;

a valve stem slidably mounted within said slot and having a first end extending into said fluid passage and a second end extending into said fluid chamber;

a flange formed on said valve stem and projecting into said fluid chamber;

a poppet valve mounted on said first end of said valve stem for engaging said valve seat to close said fluid passage;

biasing means for urging said poppet valve into engagement with said valve seat to maintain said poppet valve in a normally closed position;

a piston slidably disposed within said fluid chamber in sealing engagement with said housing, said piston dividing said fluid chamber into a fluid control chamber located adjacent to a first end thereof and a fluid receiving space located adjacent to a second end thereof and having an opening extending axially therethrough for receiving said second end of said valve stem and for permitting said piston to move relative to said valve stem;

means for supplying pressurized fluid to said fluid-receiving space to apply pressure to said second end of said valve stem and said second end of said piston to force said piston against said flange to move said valve stem and poppet valve against said biasing means and to displace said poppet valve from said valve seat;

a shoulder formed on said valve stem and located in said fluid control chamber; and

means for admitting or releasing pressurized fluid to said fluid control chamber to act against said flange and said shoulder to determine the pressure required in said fluid-receiving space to displace said poppet valve from said valve seat.

18. The fluid-operated valve of claim 17, wherein:

said housing has a surface in said fluid chamber for engaging said shoulder formed on said valve stem to limit movement of said valve stem relative to said housing and to define the fully open position of the valve.

19. The fluid-operated valve of claim 17, wherein:

said housing has a projection formed thereon and extending into said fluid chamber for engaging said second end of said piston to limit movement of said piston relative to said housing to provide a minimum spacing between said second end of said piston and said housing.

20. The fluid-operated valve of claim 17, wherein:

said biasing means comprises a coil spring mounted within said fluid chamber;

said flange has an annular slot formed therein for receiving one end of said coil spring, and

said housing has an annular recess formed therein for receiving the other end of said coil spring.

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