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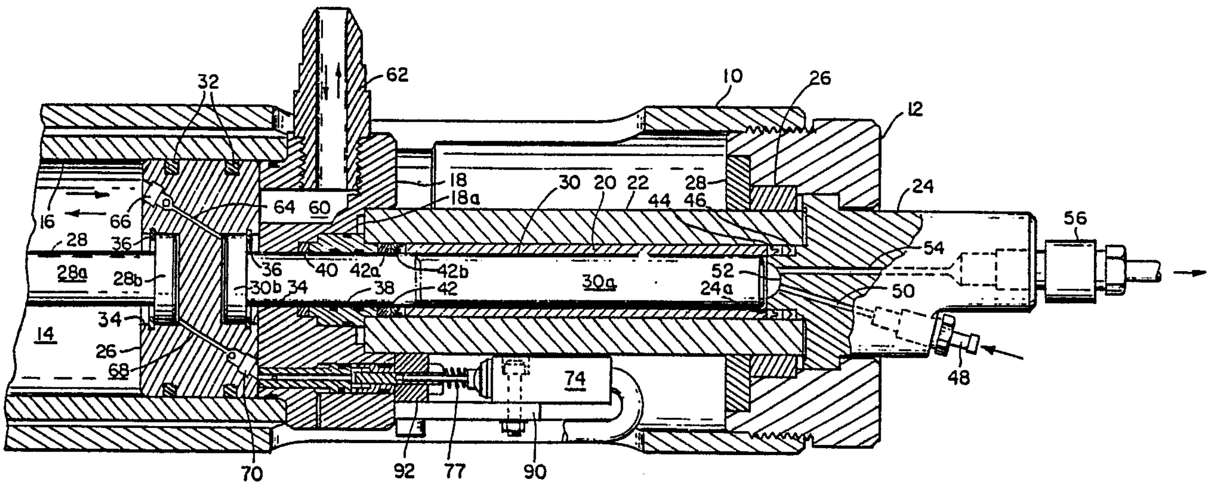


(57) Abstract

A fluid pressure-intensifying apparatus of the double-acting type has an elongated cylindrical housing that encloses the low pressure (14) and high pressure chambers (20) and compressively position and restrains the elements that make up the low and high pressure chambers under operating conditions. Hydraulic working fluid 4-way control valve solenoids are actuated by an actuating piston assembly (72) mounted in fluid communication with the low pressure working fluid chamber. An inlet/outlet check valve (52) is mounted at each end of the elongated housing.

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# FLUID PRESSURE INTENSIFIER

## Field of the Invention

This invention relates to high pressure fluid intensifier systems. More particularly, this invention relates to double-acting hydraulic intensifiers.

## Background of the Invention

In a typical high pressure fluid intensifier system, hydraulic fluid acts on a reciprocating double-acting, low pressure -- high pressure piston assembly to compress water to several thousand psi. The piston assemblies of such systems are exposed to hydraulic fluid pressures on the order of 3,000 psi and to water pressures on the order of 20-60,000 psi. These assemblies must be designed to withstand tremendous pressure fluctuations while at the same time maintain hydraulic fluid/water separation.

The pressure chambers within which such a piston assembly works, and the various pressure seals incorporated in the assembly are severely stressed. The pressure chambers are often made up of members that are screwed and/or bolted together to resist cyclic pressure buildup and release. Replacement of the high pressure seals periodically is difficult because of the attachment of the various members making up the intensifier pressure chambers and piston assembly. Usually, the intensifier must be completely dismantled to reach and repair or replace internal elements.

Summary of the Invention

The intensifier of this invention comprises an assembly having a central low pressure chamber flanked at each side by a high pressure chamber axially aligned with the low pressure chamber, a low pressure - high pressure piston assembly contained within the pressure chambers, a housing containing the axially-aligned pressure chambers, inlet/outlet valve-mounting end retainers screwed into each end of the housing to position and secure the internal elements making up the pressure chambers, and inlet/outlet valve bodies mounted by the end retainers in fluid communication with the adjacent high pressure chambers. The entire assembly fits together in such a way that removal of the end retainers permits easy disassembly and repair or replacement of worn parts. Portions of the housing may be cut away to afford access to the elements making up the pressure chambers. Within these access openings, low pressure fluid fittings may be extended for fluid communication with the low pressure chamber.

Another aspect of the invention is the provision of a low pressure fluid control valve actuator. This actuator involves a piston assembly, in fluid communication with the low pressure chamber, coupled to an external limit switch. Two such activators are provided, one on each side of the low pressure chamber, for actuating the low pressure fluid control valve. The piston assembly of each actuator extends into one end of the low pressure chamber and is shifted by the low pressure piston to activate the external limit switch and effect a change in the flow direction of the low pressure fluid. As a consequence, the low pressure piston will be moved out of contact with the actuator piston and low pressure fluid will act on the piston to extend it back into the low pressure chamber and out of contact with the external limit switch. As the low pressure piston travels to the opposite side of the low pressure chamber, the process will be duplicated with respect to the other low pressure fluid control valve actuator. These actuators are mounted by cylinder blocks that also define the adjacent end boundaries of the low and high pressure chambers. The activators are accessible through housing cut outs.

## Brief Description of the Drawings

Figure 1 is a front elevation of the right half of the intensifier of this invention in partial cross section; and

Figure 2 is an enlarged front elevation of a portion of the Figure 1 intensifier in partial cross-section.

Figure 3 is another partial front elevation of the intensifier of this invention illustrating a preferred check valve assembly;

Figure 4 is an enlarged cross-section of the preferred check valve assembly depicted in Figure 3;

Figure 5 is a view similar to Figure 4 illustrating the preferred check valve assembly.

## Description of the Invention

The intensifier of this invention utilizes hydraulic fluid (oil) to drive a high pressure - low pressure piston assembly to produce a high pressure water flow. The intensifier shown in Figure 1 is double-acting. It comprises a housing 10 in the form of an elongated steel cylinder. One half, the right half, is shown in Figure 1. The left half is a duplicate. Each end of the housing mounts an end retainer ring 12, the end of housing 10 being internally threaded to mate with external threads on end retainer ring 12 as shown. Within housing 10, a low pressure chamber 14 is provided by a steel cylinder 16 fitted onto a cylindrical end cap 18 at each end (the right hand cap being shown; the left hand end cap is an opposite hand duplicate). Also within housing 10, a left hand and a right hand high pressure chamber are provided (the right hand high pressure chamber 20 being shown; the left hand high pressure chamber is a duplicate), each by an elongated steel barrel cylinder 22 fitted at its inner end into end cap 18 and at its outer end onto a valve body 24 of an inlet/outlet water check valve assembly. Sleeve and ring bearings, 26 and 28, center the outer end of barrel cylinder 22 in end retainer 12.

The outer surface of end cap 18 conforms to the inner surface of housing cylinder 10, with a small allowance for a slip-fit clearance. Tightening the end retainers 12 places the pressure chamber elements in longitudinal compression and the housing cylinder 10 in longitudinal tension. When one or both end retainers 12 are removed, however, these elements may be removed from the housing in a very expeditious manner. The low pressure and high pressure cylinders, 16 and 22, are mounted in axial alignment with the housing cylinder 10 by the end caps 18 and the retainer rings 12. Because of the relative dimensions of the elements thus far described, the pressure chamber elements are confined against any lateral or longitudinal movement.

The low pressure - high pressure piston assembly comprises a low pressure piston 26 and left and right hand high pressure pistons 28 and 30. The low pressure piston is a cylindrical disk contained within low pressure chamber 14. Its outer surface conforms to the inner surface of low pressure cylinder 16, with a small allowance for a slip-fit clearance, and mounts appropriate hydraulic pressure seals 32 to seal one side of low pressure chamber 14 from the other. The high pressure pistons are connected to opposite faces of the low pressure piston 26 and extended through the respective cylinder block 18 into high pressure chamber sleeve 20.

Each high pressure piston is a one piece element machined to provide an elongated solid cylindrical rod 30a having a diameter slightly smaller than the inside diameter of sleeve 20, and to provide a cylindrical flange 30b at its inner end having a diameter larger than its rod. The high pressure piston flange 30b is fitted within a cylindrical counter bore 34 machined in the respective face of the low pressure piston 26. The flange 30b is held in place by a retaining ring 34, the latter being retained in a groove machined in the counterbore for that purpose. The cylindrical passage in end cap 18, through which the high pressure piston rod 30a extends, has a diameter slightly larger than the piston rod diameter. The high pressure side of the cylinder block 18 is machined to provide a stepped cylindrical counterbore 18a of inwardly-reducing diameters, the outermost portion to fit high pressure cylinder 22, the middle to fit a cylindrical piston rod centering ring 38, and the innermost to fit an appropriate high pressure static seal 40.

The centering ring 38 is machined to provide a middle portion that conforms to the diameter of the middle portion of counterbore 18a and an inner extension that conforms to the diameter of the innermost portion of counterbore 18a. The inner extension of centering ring 38 bears against and retains hydraulic seal 40 in place. Centering ring 38 also has an outer extension that extends outward beyond the middle portion of counterbore 18a and conforms to the inner diameter of high pressure cylinder 22. The high pressure cylinder 22 abuts the outermost portion of counterbore 18a in load bearing contact, and also abuts the outer extension of centering ring 38 to hold it in position. The reactive hydraulic force of the fluid working in low pressure chamber 14 is transmitted through the end cap 18 and high pressure cylinder 22 into the end retainer 12 and the internal threads of housing cylinder 10.

The centering ring 38 is made of a non-ferrous metal, such as beryllium-copper or an aluminum-nickle-bronze alloy. It serves as a bushing for the high pressure piston rod 30a as well as a retainer for hydraulic seal 40. It also holds high pressure cylinder 22 concentric with high pressure piston rod 30a. It also provides a metal back up for a high pressure dynamic seal group 42.

The opposite end of high pressure cylinder 22 fits over a stub that protrudes from the check valve body 24. Valve body 24 is machined to provide a cylindrical stub 24a for that purpose. The end of the stub is machined to provide a smaller cylindrical end surface as a seat for a high pressure dynamic seal group 44. The stepped transition between the high pressure cylinder - mounting stub and the high pressure seal seat provides a metal back up for seal group 44. The end diameter of stub 24a corresponds to the diameter of high pressure piston rod 30a as shown.

High pressure piston rod 30a reciprocates within the sleeve 20 inside of the cylinder 22 between the position shown and a position indicated by the dotted line adjacent seal group 42 that depicts the end of piston rod 30 in full retracted position. Seals groups 42 and 44 maintain the high pressure integrity within cylinder 22 as piston rod 30a reciprocates back and forth. Seal group 42 comprises a delrin dynamic back-up seal ring 42a that abuts center ring 38 and a polyurethane lip type seal 42b. Seal group 44 is composed of the same commercial lip seal 44a abutting a delrin ring 44b in turn abutting a non ferrous back up ring 44c.

As high pressure piston rod 30a is retracted from the position shown, low pressure water is drawn into high pressure chamber 20 through an inlet check valve 48, mounted by valve body 24, with passage 50 to valve body opening 52. When piston rod 30a is driven back to the position shown, inlet check valve 48 closes, water is compressed to a high pressure and then forced out through valve body opening 52, outlet passage 54 and through outlet check valve 56, mounted by valve body 24.

Reciprocation of the high pressure piston is effected as a consequence of hydraulic fluid being pumped into low pressure chamber 14 on one side of low pressure piston 26 or the other. Each end cap 18 is ported as at 60 to provide for hydraulic fluid flow into and out of low pressure chamber 14. An inlet tube 62 is screwed into port 60 for connection to a hydraulic fluid supply. When hydraulic fluid is pumped through port 60 into chamber 14, low pressure piston will be driven leftward from the position shown, thus retracting the right hand high pressure piston rod 30a and extending the left hand high pressure piston rod 28a. Concurrently, hydraulic fluid will be vented through the hydraulic fluid port in the left hand cylinder block, and water in the left hand high pressure chamber will be compressed and forced out through the left hand valve body. When low pressure piston 26 reaches the left end of low pressure chamber 14, hydraulic fluid flow will be reversed and low pressure piston 26 will be driven rightward. Hydraulic fluid will be vented through right hand cylinder block port 60 and water in high pressure chamber 20 will be compressed and forced out through valve body 24.

As low pressure piston 26 reciprocates, hydraulic fluid will accumulate between high pressure piston flange 30b and the low pressure piston counterbore 34. To prevent undue pressure buildup behind flange 30b, the base of counterbore 34 is vented through vent passage 64 and check valve 66 to the opposite side of the low pressure piston 26. High pressure piston flange 28b and its mating counterbore 34 are likewise vented through vent passage 68 and check valve 70. By this arrangement, a relatively loose fit can exist between the high pressure piston flanges and their respective counterbore seats, and the high pressure pistons can be easily retained by their respective counterbore seat snap rings 36.

A limit switch 74 for signaling a hydraulic fluid control valve is mounted adjacent each end cap 18. The signal condition of each switch is affected by the reciprocal movement of an actuator piston assembly which is slidably mounted in the adjacent cylinder block 18 as shown. It is contemplated that a solenoid-operated 4-way directional control valve will be provided to control hydraulic fluid flow into and out of low pressure chamber 14. Each limit switch 74 would actuate one of two control valve solenoids.

With respect to the right hand assembly shown, rightward travel of an actuator shifter pin 72 toward the outer side of end cap 18 is effected by mechanical contact with low pressure piston 26, and leftward travel of shifter pin 72 toward the inner side of end cap 18 is effected by hydraulic fluid from low pressure chamber 14.

When low pressure piston 26 begins to travel leftward from the position shown, hydraulic fluid will enter chamber 70 and force shifter pin 72 leftward to effect a change in the signal condition of limit switch 74. Chamber 70 is defined between shifter pin 72, a seal ring 73 and a cylindrical passage provided in end cap 18. This passage has an outer portion of larger diameter than its inner portion, and the stepped surface 86 between them provides a stop to limit the leftward travel of shifter pin 72. Shifter pin 72 comprises a cylindrical member that is machined to the configuration of the passage and has a smaller diameter inner end portion and a large diameter middle portion with the stepped surface 78 between them provided to engage surface 76 to limit leftward travel of the pin. Shifter pin 72 has a smaller diameter outer end portion that extends through seal ring 73 toward limit switch 74 and mounts limit switch actuating plunger 77.

Shifter pin 72 contains an axial passage 80 extending from its inner end and an interconnecting diametral passage 82 providing fluid communication between low pressure chamber 14 and chamber 70. The stepped surface 84 between the middle portion and the smaller diameter outer portion of shifter pin 72 provides a piston face 84. The diameter of the pin outer portion is sufficiently reduced so that the area of piston face 84 is greater than the area of the inner pin end 86. When piston 26 travels leftward from the position shown, hydraulic fluid from low pressure chamber 14 enters chamber 70 through passages 80 and 82 in shifter pin 72. The hydraulic fluid in chamber 70 acts against piston face 84. Because the area of piston face 84 is greater than the area of the inner end 86 of shifter pin 72, the hydraulic fluid in chamber 70 will drive shifter pin 72 leftward, until travel of shifter pin 72 is stopped by contact between the stepped surface 78 and surface 76 in end cap 18.

When piston 26 is reversed and travels rightward to the position shown, piston 26 will contact the protruding piston pin end 86 and drive the pin rightward to the position shown. The chamber 71 between stepped surfaces 76 and 78 is vented through passage 79 to the ambient atmosphere. The inner and middle portions of shifter pin 72 are provided with appropriate hydraulic fluid seals as shown to substantially prevent hydraulic fluid from entering chamber 71.

Plunger 77 comprises an elongated rod 77a loosely fitted within an axial passage provided in the outer portion of pin 72. The outer end of plunger 77 is capped by a switch contact 77b. A coil spring 75 extends between the end of the pin outer portion and plunger contact 77b to urge plunger 77 rightward. As piston 26 drives shifter pin 72 rightward to the position shown, spring 75 is compressed and urges plunger 77 into effective contact with limit switch 74. When piston 26 travels leftward and pin shifter 72 is driven leftward from the position shown, shifter pin 72 travels relatively to plunger 77. This relative movement relieves the compressive force on spring 75 and permits plunger 77 to release from effective contact with limit switch 74. The loose, sliding connection between pin 72 and plunger 77 affords some leeway in the positioning of switch 74 during installation and protects the limit switch from damage if pin 72 should overtravel.

By providing a cutout in housing 10 as shown, limit switch 74 can be mounted within the confines of housing 10 and still be accessible. Switch 74 is bolted to a mounting bracket

90. Bracket 90 is bolted at one end to a mounting plate 92 which itself is bolted to end cap 18. Mounting plate 92 has a passage machined through it that fits over the outer end portion of pin shifter 72. Mounting plate 92 also closes the outer end of the actuator pin passage provided in end cap 18, and abuts the outer end of sealing ring 73 to hold it in place against the reactive force of hydraulic fluid acting in chamber 70.

An intensifier arrangement utilizes hydraulic fluid (oil) to drive a high pressure - low pressure piston assembly to produce a high pressure water flow. The intensifier shown in Figure 1 is double-acting. It comprises a housing 10 in the form of an elongated steel cylinder. One half, the right half, is shown in Figure 1. The left half is a duplicate. Each end of the housing mounts an end retainer ring 12, the end of housing 10 being internally threaded to mate with external threads on end retainer ring 12 as shown. Within housing 10, a low pressure chamber 14 is provided by a steel cylinder 16 fitted onto a cylindrical end cap 18 at each end (the right hand cap being shown; the left hand end cap is an opposite hand duplicate). Also within housing 10, a left hand and a right hand high pressure chamber are provided (the right hand high pressure chamber 20 being shown; the left hand high pressure chamber is a duplicate), each by an elongated steel barrel cylinder 22 fitted at its inner end into end cap 18 and at its outer end onto a valve body 24 of an inlet/outlet water check valve assembly. End retainer 12, acting through valve body 24, centers the outer end of cylinder 22.

The outer surface of end cap 18 conforms to the inner surface of housing cylinder 10, with a small allowance for a slip-fit clearance. Tightening the end retainers 12 places the pressure chamber elements in longitudinal compression and the housing cylinder 10 in longitudinal tension. When one or both end retainers 12 are removed, however, these elements may be removed from the housing in a very expeditious manner. The low pressure and high pressure cylinders, 16 and 22, are mounted in axial alignment with the housing cylinder 10 by the end caps 18 and the retainer rings 12. Because of the relative dimensions of the elements thus far described, the pressure chamber elements are confined against any lateral or longitudinal movement.

The low pressure - high pressure piston assembly comprises a low pressure piston 26 and left and right hand high pressure pistons 28 and 30. The low pressure piston is a cylindrical disk contained within low pressure chamber 14. Its outer surface conforms to the inner surface of low pressure cylinder 16, with a small allowance for a slip-fit clearance, and mounts appropriate hydraulic pressure seals 32 to seal one side of low pressure chamber 14 from the other. The high pressure pistons are connected to opposite faces of the low pressure piston 26 and extended through the respective cylinder block 18 into high pressure chamber sleeve 20.

The outer end of high pressure cylinder 22 fits over a pilot or shoulder that protrudes from the check valve body 24. Valve body 24 is machined to provide a cylindrical pilot 24a for that purpose. The end of the pilot is machined to provide a smaller cylindrical end surface as a seat for a high pressure static seal group 44. The stepped transition between the high pressure cylinder-mounting pilot and the high pressure seal seat provides a metal back up for seal group 44. The end diameter of pilot 24a corresponds to the diameter of high pressure piston rod 30 as shown.

As high pressure piston rod 30 is retracted from the position shown, low pressure water is drawn into high pressure chamber 20 through inlet passage 50 in inlet/outlet water check valve assembly 25. When piston rod 30 is driven back to the position shown, water is compressed to a high pressure and then forced out through outlet passage 54 in check valve assembly 25. Water flow into and out of high pressure chamber 20 is controlled by a water pressure-influenced poppet-type check valve mechanism 52.

Inlet/outlet water check valve assembly 25 comprises valve body 24, low pressure water inlet manifold 51 communicating with low pressure water inlet passage 50, poppet check valve mechanism 52, high pressure outlet water line adapter 53 communicating with high pressure water outlet passage 54, and manifold lock nut 55 receiving manifold 51 to valve body 24. The outer end of valve body 24 is externally threaded and lock nut 55 screwed thereon to position manifold 51. Low pressure inlet water line 56 is attached to manifold 51 and high pressure outlet water line 57 is attached to adapter 53. The inner face of manifold 51 is machined to provide an annulus 58 for distribution of inlet water from inlet line 56 to inlet passage 50.

The check valve mechanism 52, as shown in enlarged detail in Figures 2 and 3, comprises an inlet poppet 100, an outlet poppet 102, a valve stem 104 connecting the two poppets, a high pressure poppet seat 106, and an enlarged abutment end 108 of stem 104 to retain and secure outlet poppet 102. The stem 104 extends through high pressure water outlet passage 54 and mounts the poppets at opposite ends. The inner end or head 110 of stem 104 is machined to provide an inner annular groove 111 for a return coil spring 114 and a spring retainer "E" ring clip 112 for retaining poppet 100. The mechanism is so arranged that inlet poppet 100 seats on the inner end surface of pilot 24a to seal low pressure water inlet passage 50, and outlet poppet 102 seats on high pressure seat element 106 to seal high pressure water outlet 54. Inlet poppet 100 is slidably mounted by and is axially moveable on the inner end of stem 104. Outlet poppet 102 is slidably mounted by and is axially movable on the outer end of stem 102 and retained thereon by enlarged stem end 108. The length of stem 104 between head 110 and the end 108 is sufficient to enable outlet poppet 102 to be unseated (as shown in Figure 2) when high pressure water bears against head 110 and shifts stem 104 as far outward as head 110 permits. Head 110 and the inner end portion of stem 104 are axially counterbored to provide a passage 115 that communicates with one or more diametric passages 116 cross-bored in stem 104. The outer end of stem 104, just inward of outlet poppet 102, is shaped to provide a passage 118 between that portion of stem 104 and the bore through valve body 24 high pressure water outlet passage 54.

The intermediate length of stem 104 is shaped to provide a passage 120 between that portion of stem 104 and the bore through valve body 24, which bore provides high pressure water outlet passage 54. Passage 120 interconnects cross-bore 116 and passage 118 to enable high pressure water to pass through water outlet passage 54 when outlet poppet 102 is lifted from its seat 106 to the position shown in Figure 2. Adapter 53 is provided with an inner cavity 122 that extends from seat element 106 to the high pressure outlet water line 57 and encloses outlet poppet 102 and enlarged stem 108 with space to spare for high pressure water travel around poppet 102 and end 108 from passage 54 to outlet line 57. Adapter 53 has a beveled annular surface 124 at the base of cavity 122. Surface 124 bears against a corresponding beveled surface on seat element 106 to secure seat 106 in a recess 126 provided therefore in the outer end of valve body 24, when adapter 53 is screwed onto valve body 24. Inlet poppet 100 is provided with an annular recess 128 that communicates with inlet water passage 50 when inlet poppet 100 is seated against the end surface 130 of stub 24a. Spring 114 seats in a depression machined in the adjacent face of inlet poppet 100.

When water has been compressed by the high pressure piston rod to a pressure sufficient to overcome the spring force of spring 114, valve stem 105 is shifted to the position shown in Figure 2 by water pressure acting on valve stem head 110. Prior to that point in time, water pressure acting on inlet poppet 100 would have closed inlet poppet 100 against surface

130 on valve body plug 24a to seal off low pressure inlet water passage 50. With valve stem 104 positioned as shown in Figure 2, outlet poppet is raised from its seat element 106 and high pressure water is forced by the high pressure piston rod through passages 114, 116, 120 118 into cavity 122 and out through line 57. When the high pressure piston rod reaches the end of its pressurization cycle, reverses, and begins to retract, the spring force of spring 110 and the reverse force of high pressure water in line 57 forces valve stem 104 to the position shown in Figure 3, seating outlet poppet 102 against seat element 114 to close off the high pressure outlet to line 57. As the high pressure piston rod is retracted, the force of low pressure water from passage 50, acting concentrically within annular recess 128 on inlet poppet, lifts poppet 110 from its seat 130 on pilot 24a and flows around poppet 100 into the high pressure chamber. The spring force of spring 114 is sufficiently small that the force of low pressure water acting on the opposite side of poppet 100 will shift poppet 100 along valve stem 104 from the position shown in Figure 3 toward valve stem head 110 to release water from passage 50 into the high pressure chamber. The travel length of poppet 100 is limited by spring clip 112.

Of the two poppet sealing surfaces, the sealing surface 132 associated with outlet poppet 102 incurs much more severe stress. Consequently, seat element 124 is provided as a replaceable element. Moreover, the mating surfaces of poppet 102 and seat element 124 undergo wear, necessitating that these surfaces must be periodically polished to avoid high pressure water back leakage from line 57. The configuration and arrangement of adaptor 53 permits convenient handling of these matters. Without dislodging or disassembly of any part of the rest of the system, adaptor 53 can be unscrewed and removed from valve body 24 to expose seat element 106, poppet 102 and enlarged stem end 108. Poppet 102 can be removed to permit polishing of the sealing surfaces, replacement of the seat element 106 or poppet 102, or whatever else may be required in connection with the high pressure outlet check valve mechanism by removing the assembly and disconnecting clip 112. High pressure outlet line 57, typically a stainless steel tubing, is preferably coiled in the vicinity of adapter 53 and screwed thereto by means of a coupling that permits adapter 53 to be turned relative to line 57. The resiliency of the coiled tubing permits the removal of adapter 53 away from the valve body 24 for working on the exposed mechanism.

While a preferred embodiment of an intensifier, made in accordance with the principles of the present invention, has been described and illustrated, certain changes may be made without departing from the scope of the invention.

What is Claimed Is:

1. A fluid pressure-intensifying apparatus which comprises a low pressure -- high pressure cylinder means providing a cylindrical low pressure chamber and a pair of elongated cylindrical high pressure chambers, the high pressure chambers extending from opposite ends of said low pressure chamber; low pressure -- high pressure piston means having a double acting low pressure piston section mounted for reciprocal movement in said low pressure chamber, and having a pair of elongated high pressure piston sections connected to opposite sides of said low pressure piston section and extending from said low pressure chamber into an adjacent high pressure chamber for reciprocal movement therein; cylindrical housing means enclosing and constraining said low pressure -- high pressure cylinder means to position and maintain said pressure chambers in alignment; and fluid inlet-outlet means mounted by said housing means in fluid com- munication with said high pressure chambers to simultaneously introduce fluid to be pressurized to one high pressure chamber and withdraw pressurized fluid from the other high pressure chamber; and working fluid inlet-outlet means mounted in fluid communication with said low pressure chamber such that working fluid may alternately work against one side or the other of said low pressure piston section to cause said low pressure -- high pressure piston means to reciprocate.

2. The intensifier of claim 1 wherein said low pressure -- high pressure cylinder means includes a low pressure cylinder and end caps fitted together to define said low pres-

sure chamber, a pair of high pressure cylinders each fitted to and extending outward from an end cap in alignment with said low pressure cylinder to define said high pressure chambers, each end cap being provided with a bore through which a high pressure piston section extends, said low pressure -- high pressure cylinder means being so constructed and arranged that said high and low pressure cylinders are compressively fitted to said end caps by said cylindrical housing means.

3. The intensifier of claim 2 wherein said fluid inlet-outlet means includes a pair of check valve bodies each fitted to the outer end of one of said high pressure cylinders and so constructed and arranged to be compressively fitted to said high pressure cylinders by said cylindrical housing means.

4. The intensifier of claim 3 wherein said housing means includes a housing cylinder having threaded end sections, a pair of threaded retainers each provided with a bore in which one of said valve bodies is fitted, said housing means being so constructed and arranged to compressively engage each valve body with the adjacent one of said high pressure cylinders, when said end retainers are screwed to said housing cylinder, with sufficient force to hold together and position aforesaid intensifier elements under operating conditions.

5. The intensifier of claim 1 including working fluid inlet-outlet means mounted in fluid communication with said low pressure chamber such that working fluid may alternately work against one side or the other of said low pressure piston section to cause said low pressure -- high pressure piston means to

reciprocate; and working fluid flow control actuating means for actuating a working fluid flow control means to change the direction of working fluid flow through said working fluid inlet-outlet means, said actuating means including actuating piston means mounted in fluid communication with said low pressure chamber for reciprocal movement and so constructed and arranged to be shifted from a first, inert position to a second, actuating position by contact with said low pressure piston section and to be returned to said first position by working fluid in said low pressure chamber.

6. The intensifier of claim 5 wherein said low pressure -- high pressure cylinder means includes a pair of low pressure chamber end caps defining opposite ends of said low pressure chamber, each end cap being provided with a bore in which an actuating piston means extends; and each actuating piston means includes a shifter pin having an inner end exposed to said low pressure chamber, an outer end extended outward from said end cap, and a mid portion providing a piston face in fluid communication with said low pressure chamber, said shifter pin being so constructed and arranged that the area of said piston face is greater than the area of said inner end whereby pressurized working fluid in said low pressure chamber acting on both said pistons face and said inner end will effect movement of said shifter pin into said low pressure chamber.

7. The intensifier of claim 6 wherein said actuating piston means includes a spring-loaded switch-contacting plunger telescopically mounted in the outer end of said shifter pin for

actuating contact with a switch when said actuating piston means is shifted to its actuating position.

8. The intensifier of claim 3 wherein each valve body is provided with a longitudinal axial fluid passage opening at one end into an adjacent high pressure piston chamber and opening at the other end into a cavity provided in an adjacent high pressure outlet line coupling; wherein said fluid inlet-outlet means includes a valve mechanism for each valve body, each such valve mechanism comprising an elongated valve stem extended through said axial fluid passage into the high pressure chamber at the inner end and the coupling cavity at the outer end and being so configured as to enable high pressure fluid passage into said coupling cavity; an outlet seat element exposed to said coupling cavity and through which said coupling passage, an outlet poppet mounted by said valve stem outer end within said coupling cavity and so configured as to be able seat against said outlet seat element to seal said axial fluid passage from high pressure fluid backflow out of said coupling cavity.

9. The intensifier of claim 8 wherein said fluid inlet/outlet means includes a low pressure fluid inlet distributor mounted by each valve body; wherein each valve body is provided with an elongated inlet fluid passage opening at one end into an adjacent high pressure piston chamber and opening at one end into an adjacent low pressure fluid inlet distributor; wherein each valve mechanism includes an inlet poppet slidably mounted on the inner end of said valve stem within said high pressure chamber and being so configured as to overlay and seal

off the inlet fluid passage opening into said high pressure fluid chamber exceeds the force exerted by inlet fluid within said inlet fluid passage.

**AMENDED CLAIMS**

[received by the International Bureau on 31 August 1987 (31.08.87); original claims 2-4 amended; other claims unchanged (3 pages)]

1. A fluid pressure-intensifying apparatus which comprises a low pressure--high pressure cylinder means providing a cylindrical low pressure chamber and a pair of elongated cylindrical high pressure chambers, the high pressure chambers extending from opposite ends of said low pressure chamber; low pressure--high pressure piston means having a double acting low pressure piston section mounted for reciprocal movement in said low pressure chamber, and having a pair of elongated high pressure piston sections connected to opposite sides of said low pressure piston section and extending from said low pressure chamber into an adjacent high pressure chamber for reciprocal movement therein; cylindrical housing means enclosing and constraining said low pressure --high pressure cylinder means to position and maintain said pressure chambers in alignment; and fluid inlet-outlet means mounted by said housing means in fluid communication with said high pressure chambers to simultaneously introduce fluid to be pressurized to one high pressure chamber and withdraw pressurized fluid from the other high pressure chamber; and working fluid inlet-outlet menas mounted in fluid communication with said low pressure chamber such that working fluid may alternately work against one side or the other of said low pressure piston section to cause said low pressure--high pressure piston means to reciprocate.

2. The intensifier of claim 1 wherein said low pressure--high pressure means includes a low pressure cylinder, a pair of end caps fitted to opposite ends of said low pressure cylinder to define said low pressure chamber, and a pair of

centering rings; each end cap having a longitudinal passage therethrough for receiving one of said high pressure piston sections for reciprocal movement therein, each such passage being counterbored for containing one of said centering rings; a pair of high pressure cylinders defining said high pressure chambers, each fitted over a portion of one of said centering rings, and fitted to and extending outward from an end cap whereby each centering ring maintains the adjacent high pressure cylinder inner end in alignment with said low pressure cylinder and with said cap longitudinal passage.

3. The intensifier of claim 2 wherein said fluid inlet-outlet means includes a pair of check valve bodies each having a portion fitted into the outer end of one of said high pressure cylinders whereby the adjacent outer ends of said high pressure cylinders are maintained in alignment with said low pressure cylinder.

4. The intensifier of claim 3 wherein said housing means includes a housing cylinder having threaded end sections, and including a pair of threaded retainers each provided with a bore in which one of said valve bodies is fitted, each end retainer being so constructed and arranged to compressively engage an adjacent valve body with the adjacent one of said high pressure cylinders, when said end retainers are screwed to said housing cylinder, with sufficient force to hold together and position the aforesaid intensifier elements under operating conditions.

5. The intensifier of claim 1 including working fluid inlet-outlet means mounted in fluid communication with said low

pressure chamber such that working fluid may alternately work against one side or the other of said low pressure piston section to cause said low pressure--high pressure piston means to

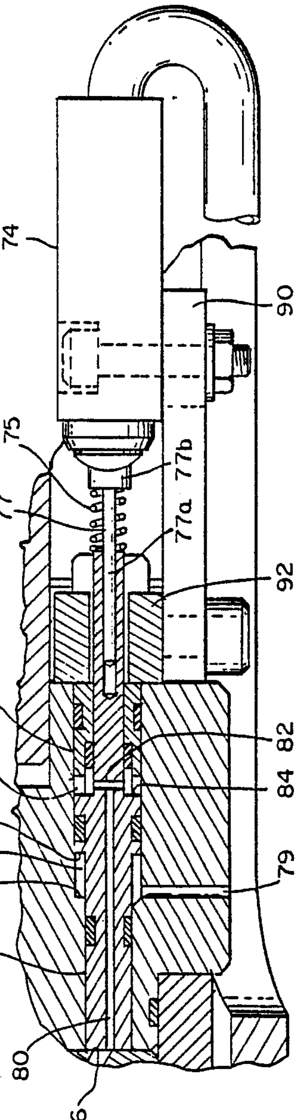
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FIG. 2

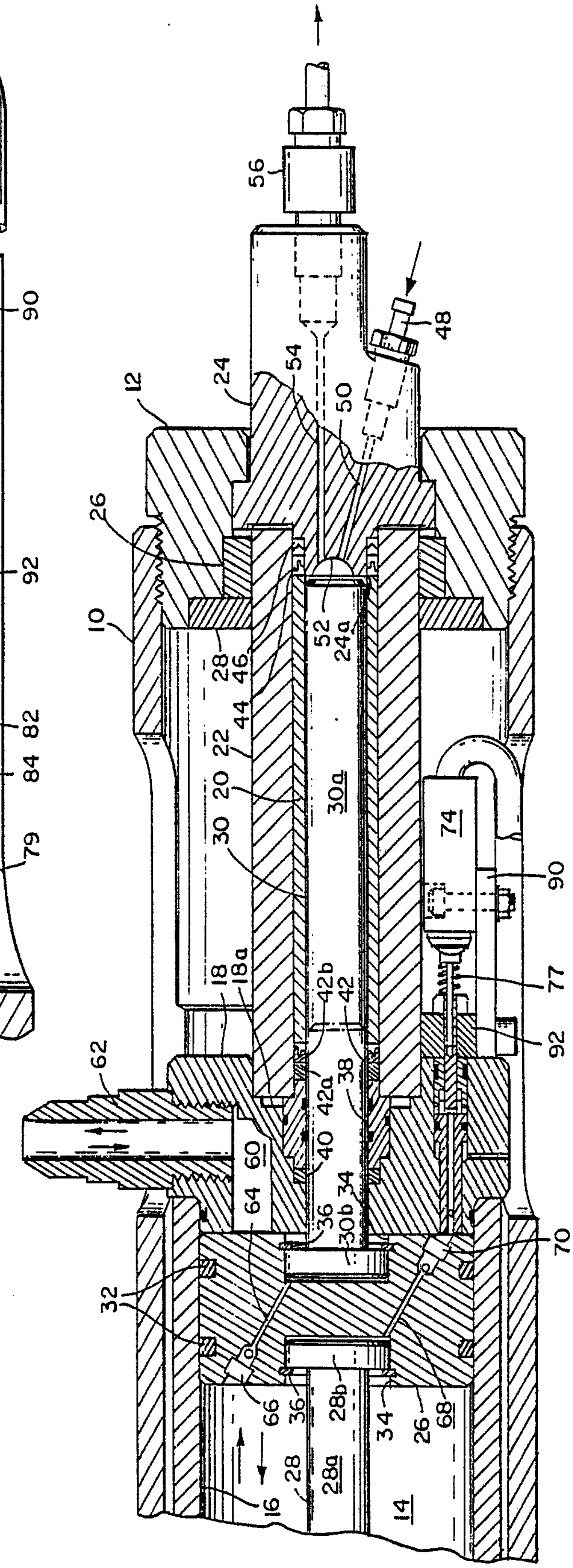
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FIG. 1

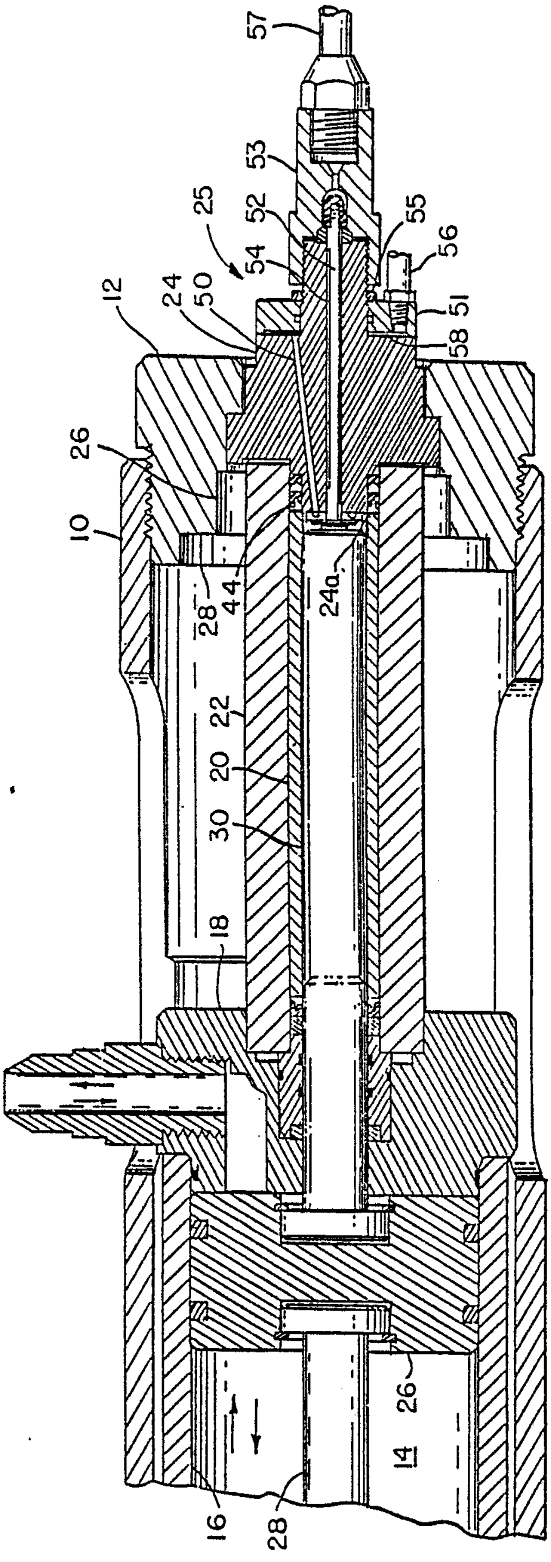
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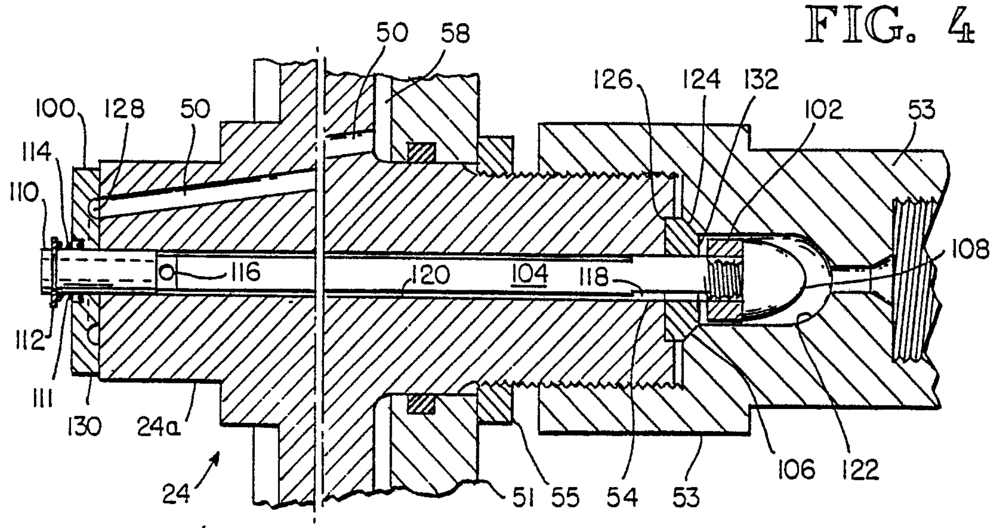
FIG. 3

FIG. 4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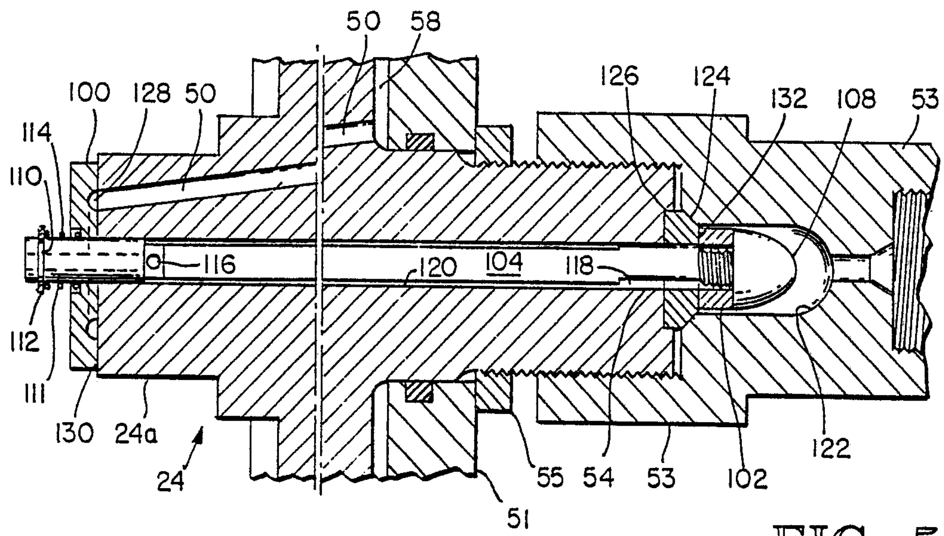
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FIG. 5

# INTERNATIONAL SEARCH REPORT

International Application No PCT/US 87/00884

**I. CLASSIFICATION OF SUBJECT MATTER** (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (4): F04B 9/10
U.S. CL. 417/397; 91/275; 137/512.5, 512.3

**II. FIELDS SEARCHED**

Minimum Documentation Searched [4]

| Classification System | Classification Symbols |
|---|---|
| U.S. | 417/569,567,571,397,396,393<br>91/275<br>137/512.5, 512.3 |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [6]

**III. DOCUMENTS CONSIDERED TO BE RELEVANT** [14]

| Category * | Citation of Document, [16] with indication, where appropriate, of the relevant passages [17] | Relevant to Claim No. [18] |
|---|---|---|
| Y | US, A, 3,070,023 (GLASGOW) 25 December 1962 See entire document. | 5,6 |
| Y | US, A, 2,949,098 (FLICK) 16 August 1960 See column 2, lines 21-64. | 5,6 |
| Y | US, A, 3,702,624 (FRIES) 14 November 1972 See column 2, lines 25-60. | 7 |
| Y | US, A, 3,746,483 (HINDEL et al) 17 July 1973 See column 4, lines 19-59. | 7 |
| A | US, A, 3,382,770 (BERNINGER et al) 14 May 1968 | |
| A | US, A, 3,309,013 (BAUER) 14 March 1967 | |
| A | US, A, 3,771,912 (CONLEE) 13 November 1973 | |
| A | US, A, 4,382,750 (ROBERTSON) 10 May 1983 | |

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

**IV. CERTIFICATION**

| Date of the Actual Completion of the International Search [2] | Date of Mailing of this International Search Report [2] |
|---|---|
| 3 JUNE 1987 | 02 JUL 1987 |
| **International Searching Authority [1]** | **Signature of Authorized Officer [20]** |
| ISA/US | Leonard E. Smith |

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

| Category * | Citation of Document, [16] with indication, where appropriate, of the relevant passages [17] | Relevant to Claim No [18] |
|---|---|---|
| A | DE, A, 3018625 (HOTGER) 26 November 1981 | |