March 31, 1953 C. A. BALTON 2,632,999

HYDRAULIC SYSTEM WITH AN ATMOSPHERIC PRESSURE CONTROLLED ACCUMULATOR

Filed Jan. 30, 1952 3 Sheets-Sheet 1

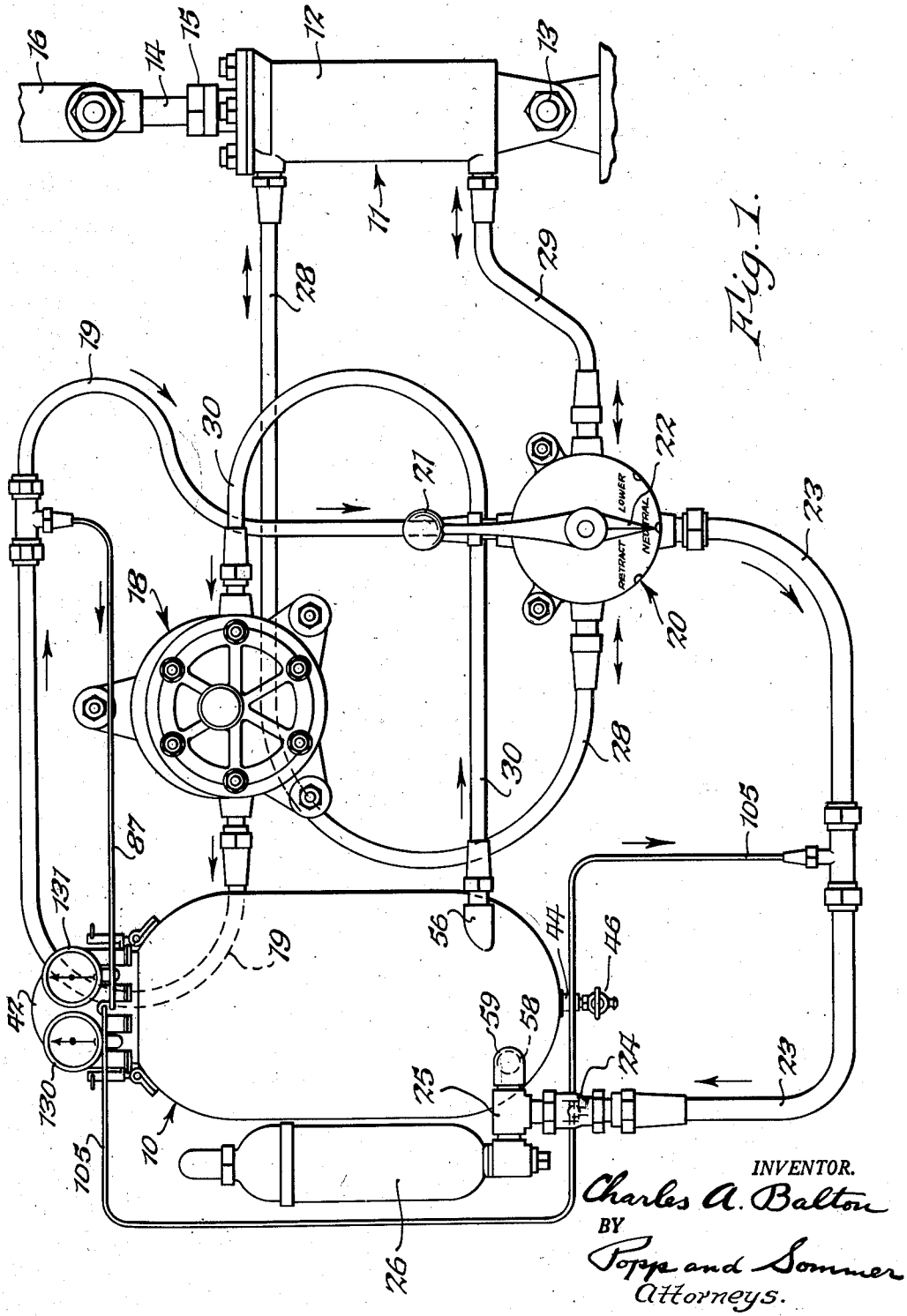


Fig. 1.

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Fig. 2.

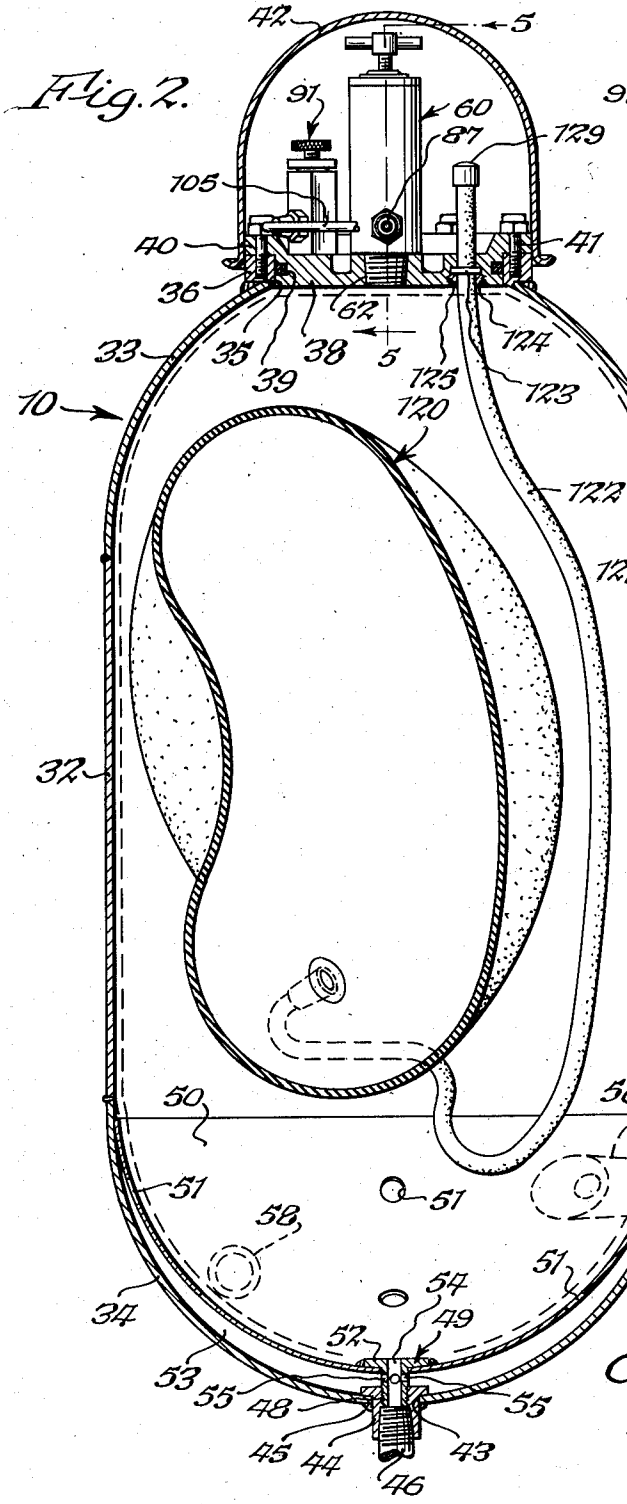


Fig. 3.

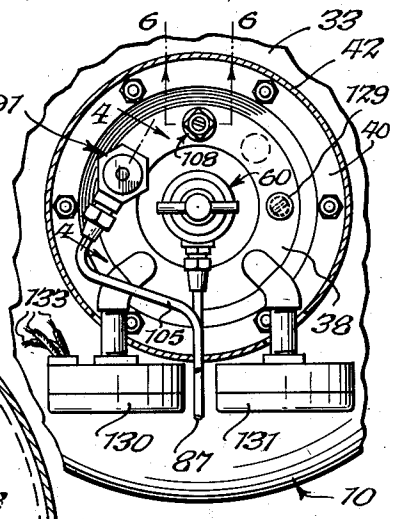
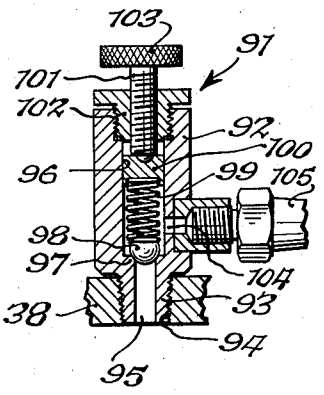


Fig. 4.



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Fig. 5.

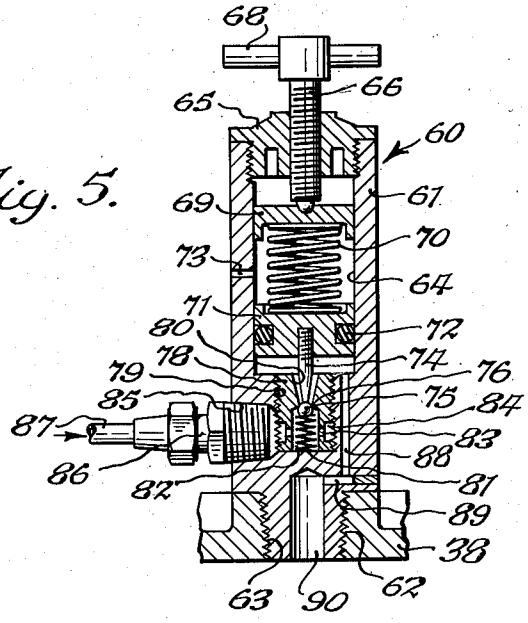
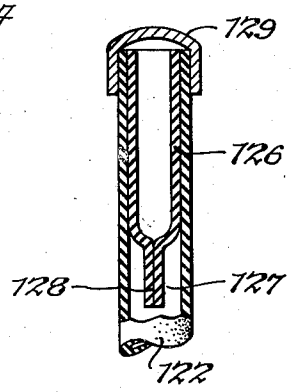


Fig. 7.



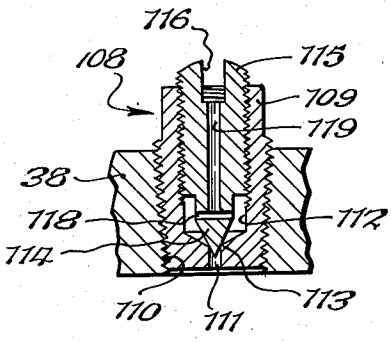


Fig. 6.

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UNITED STATES PATENT OFFICE

2,632,999

HYDRAULIC SYSTEM WITH AN ATMOSPHERIC PRESSURE CONTROLLED ACCUMULATOR

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Application January 30, 1952, Serial No. 269,094

8 Claims. (Cl. 60—52)

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This invention relates to an accumulator for liquids under pressure and more particularly to such an accumulator in which the pressure impressed on the liquid is varied to correspond to atmospheric pressures. Such accumulators are useful in hydraulic control circuits for the rudders, elevators and ailerons of airplanes where at higher elevations the air presents less resistance to movement and also the lower pressure presents less resistance to the projection of piston rods from the control cylinders.

One of the principal objects of the present invention is to provide such an accumulator for liquid under pressure which is of simple, low cost construction and at the same time is reliable in operation to provide liquid under a pressure varying directly with atmospheric or other pressure.

Another object is to provide such an accumulator in which the air in the accumulator is out of contact with the liquid thereby to avoid the occlusion of air in the liquid.

Another object of the invention is to provide such an accumulator having a large potential air space confined to expand and contract under varying liquid pressures, and thereby to avoid abrupt changes in pressure.

Another object is to provide such an accumulator which is rugged in construction and which will stand up under conditions of severe and constant use without getting out of order or adjustment and requiring repair.

Other objects and advantages of the invention will be apparent from the following description and drawings in which:

Fig. 1 represents a control circuit for the actuator, of, say, an aileron of an airplane and containing an accumulator embodying the present invention.

Fig. 2 is a vertical central section through the accumulator forming the subject of the present invention.

Fig. 3 is a fragmentary top plan view thereof with the cover or cap shown in section.

Fig. 4 is an enlarged fragmentary vertical section taken on line 4—4, Fig. 3.

Fig. 5 is an enlarged vertical section taken on line 5—5, Fig. 2.

Fig. 6 is an enlarged vertical section taken on line 6—6, Fig. 3.

Fig. 7 is a longitudinal section through the valve at the end of the rubber tube leading to the inflatable bladder included in the accumulator.

The accumulator forming the subject of the present invention is indicated generally at 10 and

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is shown as contained in a hydraulic control circuit for the actuator 11 of, say, an aileron (not shown), this actuator comprising a cylinder 12 pivotally connected, as at 13, to the body structure of the airplane and containing a piston rod 14 sliding in a gland 15. This piston rod 14 is shown as pivotally connected to a link 16 leading to the aileron.

The liquid for moving the piston rod 14 is supplied under pressure by a high pressure pump 18, the high pressure outlet line 19 of which connects with a four-way valve 20 having a handle 21 and a pointer 22 movable to "retract," "neutral" and "lower" positions.

The low pressure return line 23 from this four-way valve 20 leads to the accumulator 10 forming the subject of the present invention. This line 23, at the accumulator 10, includes a check valve 24 which opens toward the accumulator and which discharges into one branch of a T-fitting 25. Another branch of this T-fitting connects with an auxiliary accumulator 26 and the third branch connects with the accumulator 10 as hereinafter described.

In the "retract" position of the valve 20 the high pressure pump outlet line 19 is connected with a line 28 leading to the upper end of the actuator cylinder 12, as viewed in Fig. 1, and the low pressure line 23 to the accumulator 10 is connected with a line 29 at the lower end of this actuator cylinder. In the "lower" position of the valve 20 the high pressure pump outlet line 19 is connected with the line 29 and the line 28 is connected with the low pressure line 23 to the accumulator 10. In "neutral" position the lines 28 and 29 are disconnected from the lines 19 and 23. It will accordingly be seen that the liquid for moving the actuator 11 is supplied by the high pressure pump 18 under control of the manual four-way valve 20 to move the piston rod 14 of the actuator 11 so as to either retract or lower the aileron.

The hydraulic control circuit is completed by a line 30 connecting the accumulator 10 with the inlet of the high pressure pump 18.

The accumulator 10 to which the present invention is particularly directed comprises a sheet metal shell 31 preferably having a vertical cylindrical central section 32 to the upper and lower ends of which are welded hemispherical end heads 33 and 34. The upper hemispherical end head 33 is provided with a central opening 35 and around this opening a ring 36 is welded to provide a neck. A removable end head 38 is fitted within the neck ring 35 and a sealing gasket 39 is preferably provided in the periphery

of this removable end head 38 to seal the joint between it and the neck ring 36. The removable end head 38 is provided with an upwardly offset radially projecting annular flange 40 which rests on top of the neck ring 36 and the removable end head 38 is secured to the neck ring 36 by an annular series of screws 41 extending through the rim 40 of the removable end head 38 and into the neck ring 36. A dome-shaped removable cap or cover 42 is shown as fitted over the peripheries of the neck ring 36 and removable end head 38.

The bottom hemispherical end head 34 is provided with a central opening 43 through which a fitting 44 extends. This fitting is preferably welded to the lower hemispherical end head, as indicated at 45. The lower end of this fitting is threaded to receive a drain cock 46 and the upper end of this fitting is internally threaded to receive the threaded stem 48 of a mushroom shaped support 49 for a hemispherical perforated basket 50, the perforations being designated at 51. The stem 48 of the mushroom shaped support 49 extends through an opening in the bottom of the hemispherical perforated basket 50 and its enlarged head 52 is arranged against the upper or inner face of this basket and welded thereto.

The hemispherical basket is shown as being of the same radial dimension as the lower end head 34 and is supported by the mushroom shaped member 49 so as to provide a space 53 which is moon-shaped in section, as illustrated in Fig. 2, between the perforated basket 50 and the lower end head 34. The mushroom shaped member 49 is provided with a vertical through bore 54 leading from the interior of the hemispherical basket 50 to the drain cock 46 and the space 53 is drained through a plurality of radial ports 55 leading to this bore 54.

The purpose of the hemispherical perforated basket 50 is to prevent turbulence within the accumulator induced by the flow of liquid therethrough. Thus the lower hemispherical head 34 is provided with a tangential outlet nipple 56 having a threaded bore leading to the space 53 between the perforated basket 50 and the hemispherical lower end head 34 and this inlet nipple is connected by a fitting with the return line 30 to the high pressure pump 18. This lower hemispherical end head 34 is also provided with a tangential inlet nipple 58 connected by an L-fitting 59 with the third branch of the T-fitting 25 in the low pressure line 23 leading from the four-way control valve 20. It will be seen that the liquid pumped into the accumulator from the low pressure line 23 from the four-way valve 20 and passing to the return line 30 to the high pressure pump 18 is substantially confined within the space 53 between the hemispherical perforated basket 50 and the lower hemispherical end head 34 so as to avoid turbulence of the main body of liquid within the accumulator. At the same time the perforations 51 in the hemispherical basket 50 permit the passage of liquid from the tangential inlet nipple 58 into the main body of liquid in the accumulator and also permit the escape of this liquid through the outlet nipple 56.

A main control valve, indicated generally at 60, is mounted on the removable end head 38 of the accumulator. This valve is responsive to atmospheric pressure to adjust the fluid pressure within the accumulator to vary directly with the atmospheric pressure and is also manually adjustable as to the range of pressures maintained in the accumulator. As best shown in Fig. 5 this main control valve comprises a cylindrical casing or housing 61 having an axially extending externally threaded nipple 62 at one end and which screws into a threaded opening 63 through the removable end head 38. The upper end of the body is bored to provide a large coaxial cylindrical chamber 64 the upper end of which is closed by an externally threaded bonnet 65 screwed into the internally threaded upper end of the large bore or cylindrical chamber 64. A threaded coaxial adjusting stem 66 works in a threaded opening through this bonnet, the upper end of the stem having laterally extending arms 68 for manually turning the same. The lower end of this stem bears against a cylindrical follower 69, this follower being held against this stem by a helical compression spring 70. The lower end of this helical compression spring bears against a piston 71 slidable in the bore or cylindrical chamber 64 and preferably having an O-ring seal 72 in its periphery to prevent the escape of liquid. This piston 71 is responsive to atmospheric air pressure and for this purpose the bore or cylindrical chamber 64 is provided, intermediate the follower 69 and piston 71, with an air vent 73.

The piston 71 is shown as carrying a downwardly projecting pin 74 arranged to engage a ball 75. This ball seats upwardly against a seat 76 provided in a screw plug 78 inserted into a threaded bore 79 at the bottom of the bore or cylindrical chamber 64. The pin 74 engages the ball 75 through an opening 80 in this plug and the ball is biased upwardly by a helical compression spring 81 contained within the ball chamber 82. This ball chamber 82 is connected by laterally extending ports 83 to a channel 84 provided in the periphery of the screw plug 78. This channel 84 is in communication with a laterally extending threaded opening 85 containing a fitting 86 for a high pressure line 87. The opposite end of this high pressure line 87, as best shown in Fig. 1, connects with the outlet line 19 of the high pressure pump 18.

The outlet from the ball chamber 82 comprises a longitudinal bore 88 from this chamber, a lateral plugged bore 89, an axial bore 90 communicating with the interior of the shell 31 of the accumulator 10, all being provided in the body or casing 61 of the master control valve.

An adjustable pressure relief valve 91 is also mounted on the removable upper end head 38. As best shown in Fig. 4 this manual pressure control valve comprises a cylindrical body 92 having a reduced threaded end nipple 93 screwed into a threaded opening 94 through the removable end head 38. A vertical bore extends axially through the valve body 92, this bore having a reduced lower end 95 in communication with the interior of the accumulator shell 31 and an enlarged part 96 above the reduced bore part 95 so as to provide a valve seat 97 for a ball 98. This ball is held against its seat by a helical compression spring 99 the upper end of which is engaged by a follower 100 slidingly mounted in the enlarged part 96 of the bore. The position of this follower, and hence the degree of compression of the spring 99, is determined by a manual adjusting screw 101 having its lower end contacting the follower 100 and threadedly mounted in an internally threaded bushing 102 which also has external threads screwed into the upper end of the upper part 96 of the bore. The screw 101 is shown as having a knurled head 103 by means of which it can be turned.

The valve body 92 is provided with a port 104 leading from the enlarged part 96 of the bore to

a line 105 which, as shown in Fig. 1, connects with the low pressure line 23 from the four-way valve 20 to the accumulator 10.

A combined filling plug and manually operable air vent is indicated generally at 108, is mounted on the removable end head 38 of the accumulator. As best shown in Fig. 6 this filling plug and air vent is in the form of an externally threaded tapered plug 109 which is screwed into a taper threaded opening 110 extending through the removable end head 38. The plug 109 is provided with an axial through bore having a reduced part 111 at its lower end and an enlarged part 112 at its upper end to provide a seat 113 for a vent valve pin 114. This vent valve pin is integral with a screw plug 115 screwed into the upper threaded end of the enlarged part 112 of the bore. This screw plug 115 has a screw driver slot 116 at its upper end so as to adjust the valve pin 114 toward and away from its seat. Venting, on lifting the valve pin 114 from its seat, is through a transverse bore 118 in the valve pin 114 and which communicates with a vertical bore 119 through the screw plug 115 and which latter bore is open to the atmosphere.

A feature of the invention resides in the provision of an air space within the body 31 of the accumulator 10 in such a manner that the air is out of contact with the liquid thereby to avoid occlusion of the air in the liquid. This air is contained within an expansible bladder 120 in the body of liquid contained within the shell 31 of the accumulator and is made of rubber or the like so as to be expansible against the walls of the shell 31, as indicated by the dotted lines 121, if the liquid pressure in the accumulator were to be completely relieved. When pressure is applied to this liquid, the bladder 120 is compressed and reduced in size as illustrated in Fig. 2. Since the liquid in the accumulator is normally under pressure, air is supplied to the bladder 120 under an initial pressure. This pressurizing of the bladder is effected through a rubber tube 122 connected at one end to the interior of the bladder 120 and having its other end extending out through the removable end head 38. Any suitable means can be provided for sealing the joint between the rubber tube 122 and the end head, the rubber tube being shown as having for this purpose an outwardly projecting annular shoulder or rim 123 fitting in a threaded socket 124 in the bottom of the removable end head 38 and a screw ring 125 being screwed into the socket to compress the shoulder 123 against the inner end of the socket and providing a leak tight seal.

Any suitable form of check valve can be provided for maintaining the air pressure in the bladder 120, the valve shown in detail in Fig. 7 being preferred. As there shown this valve comprises a rubber tube 126 fitted and sealed in the outer end of the tube 122 and having a reduced flattened end 127 projecting into the tube 122 toward the bladder 120. This reduced flattened end 127 is provided with an axial flat slit 128 opening at one end to the interior of the tube 120 and at its opposite end opened to the atmosphere throught the interior of the valve tube 125. It will be seen that when air pressure is applied to the interior of the valve tube 126 it will distend the walls of the flattened end projection 127 and open the slit 128 so as to pass air through the tube 122 into the bladder 120. When this pressure is withdrawn the pressure within the tube 122 against the sides of the flattened end 126 closes the slit 128 so as to prevent the escape of air. A metal cap 129 can be applied over the end of the tube 120 so as to protect the tube valve 126 against dust and dirt.

Pressure gages can be provided on the removable end head 38 of the accumulator and responsive to the pressure therein. One, indicated at 130, can be calibrated in units of pressure and the other, indicated at 131, can be calibrated in units of volume of the liquid in the circuit. Electrical connections 133 can be provided for remote indicators, such as corresponding electrical gages on the instrument board.

In the operation of the accumulator, to render the accumulator operative, the dome-shaped cover or cap 42 is first removed as well as the cap 129 for the end of the rubber tube 122 projecting out of the removable end head 38 of the accumulator. Air pressure is then applied to this projecting end of the tube 122. This air pressure distends the walls of the flattened part 127 of the tube valve 126 and air passes through its slit 128 into the interior of the bladder to distend the same against the walls of the accumulator shell 31 as indicated by the dotted lines 121, Fig. 2. The pressure in the bladder 120 will depend on the range of working pressure of the control system. When the air filling pressure applied to the tube valve 126 is discontinued, the pressure within the tube 120 will compress the walls of the flattened end 127 of the tube valve 126 and close the slit 128 against the escape of air.

The system is then filled with oil or liquid at approximate ground level working pressure, say 60 p. s. i., such filling being either through the threaded opening 110 provided on removal of the filling plug 109 or through the auxiliary accumulator 26. As the working liquid pressure builds up to the assumed 60 pounds pressure, the bladder 120 contracts to the condition shown in Fig. 2 in which its size is substantially less than the internal volume of the shell 31 of the accumulator 10.

After the control system has been filled with liquid to approximately the required working pressure, any air occluded in the oil will collect in the top of the shell 31 of the accumulator 10. This air can be removed by unscrewing the threaded valve stem 115, in the filling plug 109, this cracking or lifting this valve stem 115 from its seat 113 and permitting air from the top of the shell 31 of the escape. After the air has been removed from the top of the accumulator casing 31, the valve stem 115 is screwed down to prevent escape of the liquid.

In the operation of the control system, the four-way valve 20 is moved to control the actuator 11, the valve being moved to admit liquid from the high pressure pump 18, which can be assumed to deliver pressure at 1500 p. s. i., to either the upper or lower end of the cylinder 12 of the actuator. While connecting either end of this cylinder 12 with the pump outlet line 19, the four-way valve 20 connects the opposite end of the actuator cylinder 12 with the line 23 leading to the accumulator 10 embodying the present invention.

The liquid entering the accumulator 10 from the line 23 past the check valve 24 and T-fitting 25 enters the space 53 between the perforated basket 50 and the hemispherical bottom 34 of the shell 31 of the accumulator. This liquid flows through this space 53 to the return line 30 to the high pressure pump 18.

It will be seen that the back pressure to movement of the actuator 11 is provided by the ac-

cumulator 10 and that this back pressure is cushioned by the body of air contained within the bladder 120, this bladder expanding and contracting to compensate for such inequalities in the system as occasioned, for example, by the extension and withdrawal of the piston rod 14.

The back pressure in the body 31 of the accumulator 10 is in part supplied by high pressure liquid from the outlet line 19 of the high pressure pump 18 passing through the line 87, annular channel 84, ports 83, ball chamber 82, past the ball 75 partly lifted from the seat 76 through bores 88, 89 and 90 to the interior of the accumulator 10. To supply such back pressure the high pressure pump 18 operating at, say, 1500 pounds pressure, is placed in operation so as to produce high pressure liquid in its outlet line 19, a part of this oil from the high pressure outlet line passing through the master control valve 60 into the shell 31 of the accumulator 10, and thence through the outlet nipple 56 back to the high pressure pump 18 through the pump return line 30. The passage of this high pressure liquid through the master control valve 60 from the pump outlet line 19 is also through the annular channel 84, ports 83, ball chamber 82 past partly open ball 75, opening 74, cylindrical chamber 64 and bores 88, 89 and 90 to the interior of the accumulator 10.

When the airplane rises to a higher than ground elevation, it is desirable to lower the back pressure provided by the accumulator 10 since the resistance of the air to movement of the airfoil surfaces being controlled is less and also since there is less pressure resisting the outward movement of the piston rod 14. The main control valve 60 operates to reduce the liquid pressure in the accumulator 10 in response to lowering atmospheric pressures to balance the back pressure of the accumulator 10 to the lowering atmospheric pressure and, conversely, to raise the back pressure of the accumulator 10 in response to rising atmospheric pressures as the airplane comes back to ground level.

As lower atmospheric pressure is encountered, the reduced atmospheric pressure, through the vent 73, Fig. 5, on the piston 71 of the main control valve 60 lifts the pin 74 to a proportionate degree and hence permits movement of the ball 75, biased by the spring 81, toward its seat 76. Accordingly the flow of high pressure liquid flowing from the pump outlet line 19 through the master control valve 60 into the body 31 of the accumulator 10 as above described, is reduced thereby to reduce the pressure in the accumulator. As the airplane gains further elevation the further reduced atmospheric pressure, through the vent 73, on the piston 71 of the master control valve 60 lifts the pin 74 still further and hence effects a further closing movement of the ball 75 toward its seat 76. Accordingly the flow of high pressure liquid flowing from the pump outlet line 19 through the master control valve 60 into the body 31 of the accumulator 10 is still further reduced thereby to still further reduce the pressure in the accumulator 10.

Conversely, as the airplane descends and encounters higher atmospheric pressure, this higher atmospheric pressure, through the vent 73, progressively depresses the piston 71 to open progressively the ball 75 against the resistance of its spring 81 thereby to increase progressively the amount of high pressure liquid admitted from the outlet line 19 of the high pressure pump 18 through the line 87, annular groove 84, ports 83, ball chamber 82, valve seat and orifice 76, 74, cylindrical chamber 64 and bores 88, 89 and 90 to the interior of the accumulator shell 31 thereby to build up a back pressure in this shell corresponding to the atmospheric pressure.

In the event the pressure in the shell 31 of the accumulator 10 exceeds a safe value, this pressure will lift the ball 98 of the pressure relief valve 91 (Fig. 4) and permit the liquid to escape from the accumulator through the line 105 to the low pressure line 23.

From the foregoing it will be seen that the present invention provides a very simple and reliable accumulator in which the pressure is regulated to correspond to changing atmospheric pressures and of particular use in hydraulic control circuits for the movable airfoils of airplanes and the like.

I claim:

1. In combination with a hydraulic circuit having a pump with an inlet and an outlet line, an actuator cylinder, and a four-way valve arranged to connect either end of said actuator cylinder with said pump outlet line and the opposite end of said actuator cylinder with a low pressure line, the combination therewith of an accumulator comprising a shell connected with said low pressure and pump inlet lines, a master control valve having its inlet communicating with said pump outlet line and its outlet opening to the interior of the shell, and means responsive to atmospheric pressure and arranged to move said master control valve toward open position on rising atmospheric pressure and to move said master control valve toward closed position on falling atmospheric pressures.

2. In combination with a hydraulic circuit having a pump with an inlet and an outlet line, an actuator cylinder, and a four-way valve arranged to connect either end of said actuator cylinder with said pump outlet line and the opposite end of said actuator cylinder with a low pressure line, the combination therewith of an accumulator comprising a shell connected with said low pressure and pump inlet lines, a master control valve having its inlet communicating with said pump outlet line and its outlet opening to the interior of the shell, means responsive to atmospheric pressure and arranged to move said master control valve toward open position on rising atmospheric pressure and to move said master control valve toward closed position on falling atmospheric pressures, a ball check valve in said low pressure line and opening toward said shell and a pressure relief valve having its inlet communicating with the interior of said shell and its outlet connected with said low pressure line on the side of said check valve remote from said shell.

3. In combination with a hydraulic circuit having a pump with an inlet and an outlet line, an actuator cylinder, and a four-way valve arranged to connect either end of said actuator cylinder with said pump outlet line and the opposite end of said actuator cylinder with a low pressure line, the combination therewith of an accumulator comprising a shell connected with said low pressure and pump inlet lines, a master control valve having its inlet communicating with said pump outlet line and its outlet opening to the interior of the shell, means responsive to atmospheric pressure and arranged to move said master control valve toward open position on rising atmospheric pressure and to move said master control valve toward closed position on falling at-

mospheric pressures, and a gas inflated bladder within said shell and providing a gas filled space therein.

4. In combination with a hydraulic circuit having a pump with an inlet and an outlet line, an actuator cylinder, and a four-way valve arranged to connect either end of said actuator cylinder with said pump outlet line and the opposite end of said actuator cylinder with a low pressure line, the combination therewith of an accumulator comprising a shell connected with said low pressure and pump inlet lines, a master control valve having its inlet communicating with said pump outlet line and its outlet opening to the interior of the shell, means responsive to atmospheric pressure and arranged to move said master control valve toward open position on rising atmospheric pressure and to move said master control valve toward closed position on falling atmospheric pressures, a gas inflated bladder within said shell and providing a gas filled space therein, and a filling tube leading from said bladder to the exterior of said shell.

5. In combination with a hydraulic circuit having a pump with an inlet and an outlet line, an actuator cylinder, and a four-way valve arranged to connect either end of said actuator cylinder with said pump outlet line and the opposite end of said actuator cylinder with a low pressure line, the combination therewith of an accumulator comprising a shell connected with said low pressure and pump inlet lines, a master control valve having its inlet communicating with said pump outlet line and its outlet opening to the interior of the shell, means responsive to atmospheric pressure and arranged to move said master control valve toward open position on rising atmospheric pressure and to move said master control valve toward closed position on falling atmospheric pressures, a gas inflated bladder within said shell and providing a gas filled space therein, a filling tube leading from said bladder to the exterior of said shell, and a check valve in said filling tube and opening toward said bladder.

6. In combination with a hydraulic circuit having a pump with an inlet and an outlet line, an actuator cylinder, and a four-way valve arranged to connect either end of said actuator cylinder with said pump outlet line and the opposite end of said actuator cylinder with a low pressure line, the combination therewith of an accumulator comprising a shell connected with said low pressure and pump inlet lines, a master control valve having its inlet communicating with said pump outlet line and its outlet opening to the interior of the shell, means responsive to atmospheric pressure and arranged to move said master control valve toward open position on rising atmospheric pressure and to move said master control valve toward closed position on falling atmospheric pressures, a gas inflated bladder within said shell and providing a gas filled space therein, a filling tube leading from said bladder to the exterior of said shell, and a rubber tube valve fitted and sealed in the end of said filling tube projecting from said shell, the end of said tube valve projecting toward said bladder being flattened to provide a slit through which gas under pressure can be forced into said bladder from the end of said filling tube and the walls of said flattened portion being compressed by the pressure in said bladder to prevent escape of gas therefrom.

7. In combination with a hydraulic circuit havinga pump with an inlet and an outlet line, an actuator cylinder, and a four-way valve arranged to connect either end of said actuator cylinder with said pump outlet line and the opposite end of said actuator cylinder with a low pressure line, the combination therewith of an accumulator comprising a shell, a perforated wall in said shell and forming a space between said wall and shell, means connecting one part of said space with said low pressure line and another part of said space with said pump inlet line, a gas inflated bladder in said shell on the side of said wall opposite said space, a master control valve having its inlet communicating with said pump outlet line and its outlet communicating with the interior of said shell, and means responsive to atmospheric pressure and arranged to move said master control valve toward open position on rising atmospheric pressure and to move said master control valve toward closed position on falling atmospheric pressure.

8. In combination with a hydraulic circuit having a pump with an inlet and an outlet line, an actuator cylinder, and a four-way valve arranged to connect either end of said actuator cylinder with said pump outlet line and the opposite end of said actuator cylinder with a low pressure line, the combination therewith of an accumulator comprising a shell having a hemispherical lower end head and an opening at its top, a removable end head in said opening, a perforated hemispherical basket fitted in said shell in generally conforming relation to said hemispherical end head and forming a space between said basket and hemispherical end head, means connecting one part of said space with said low pressure line and another part of said space with said pump inlet line, a gas inflated bladder in said shell, on the side of said basket opposite said space, a filling tube from said bladder extending through said removable end head, a check valve in said filling tube and opening toward said bladder, a manually openable vent valve in said removable end head and having its inlet in communication with the interior of said shell, a master control valve having its inlet communicating with said pump outlet line and its outlet communicating with the interior of said shell, and means responsive to atmospheric pressure and arranged to move said master control valve toward open position in response to rising atmospheric pressure and toward closed position in response to falling atmospheric pressure.

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No references cited.