

Feb. 25, 1964

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ACCUMULATOR

3,122,169

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3 Sheets-Sheet 1

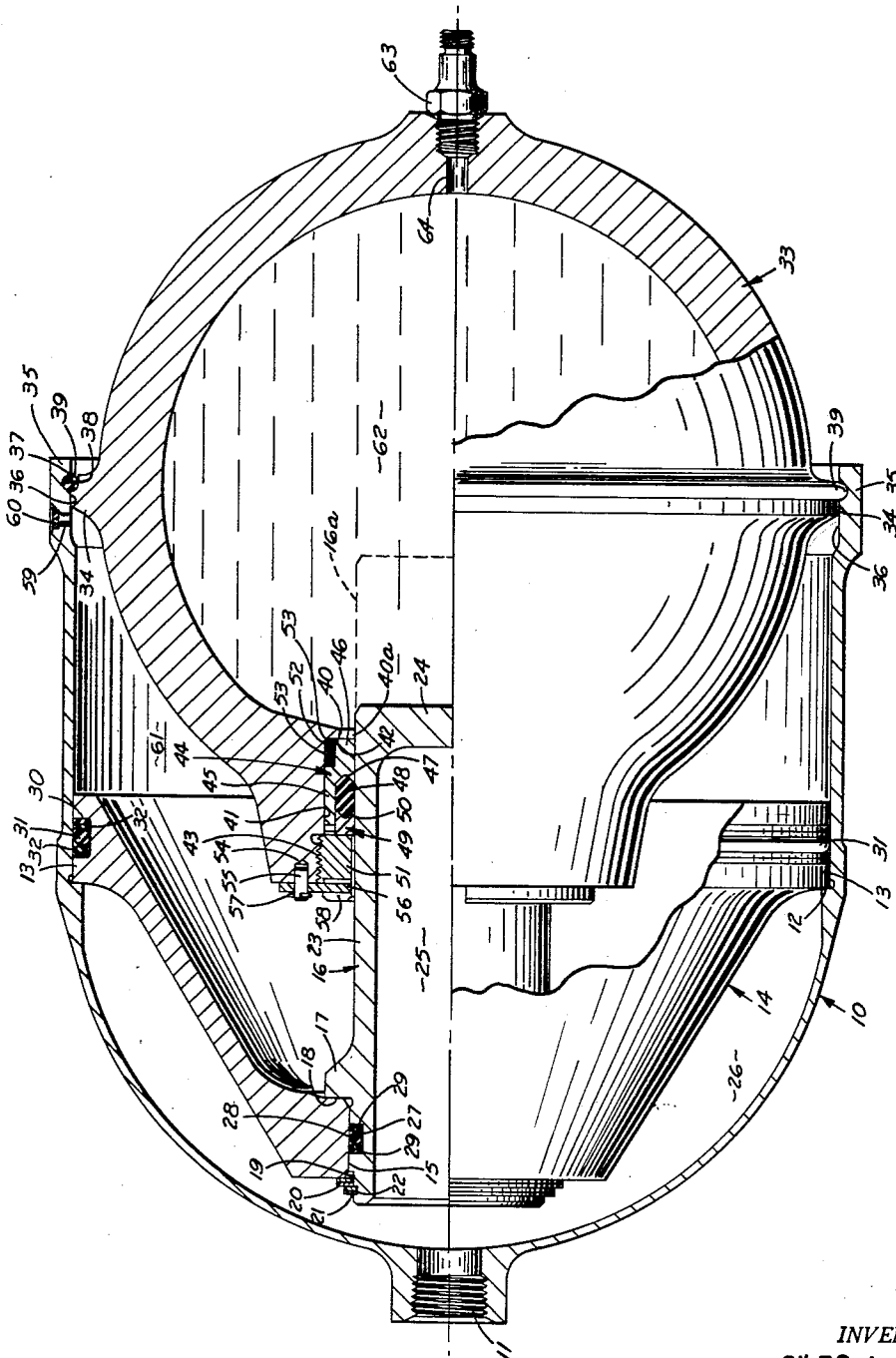


FIG. 1

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3 Sheets-Sheet 2

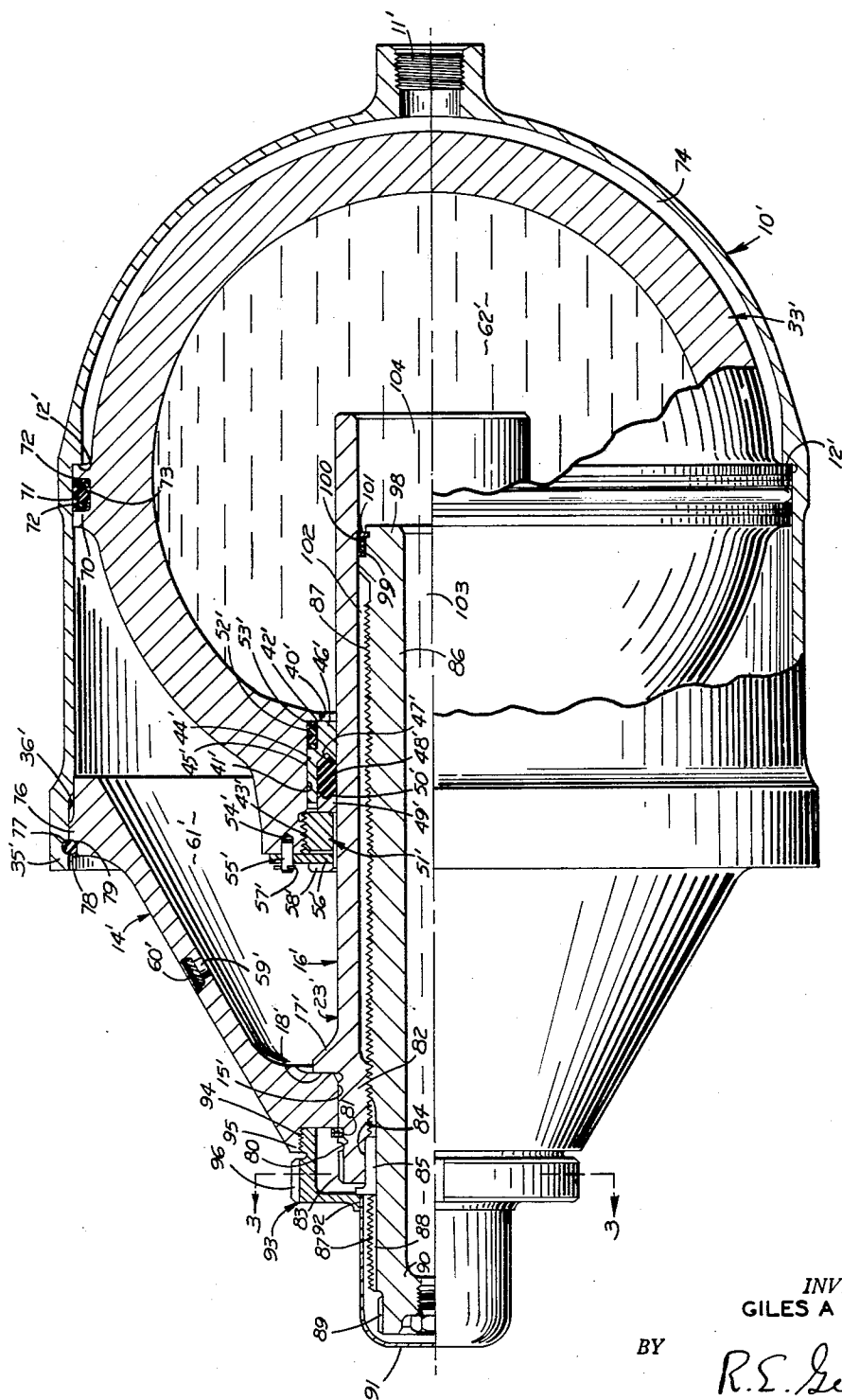


FIG. 2

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3 Sheets-Sheet 3

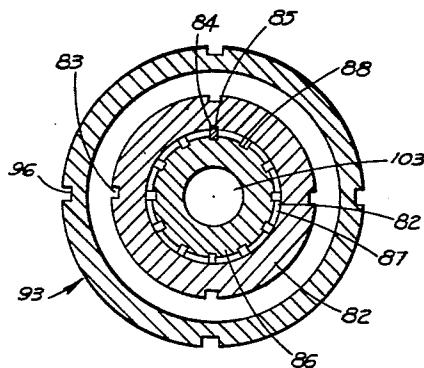


FIG. 3

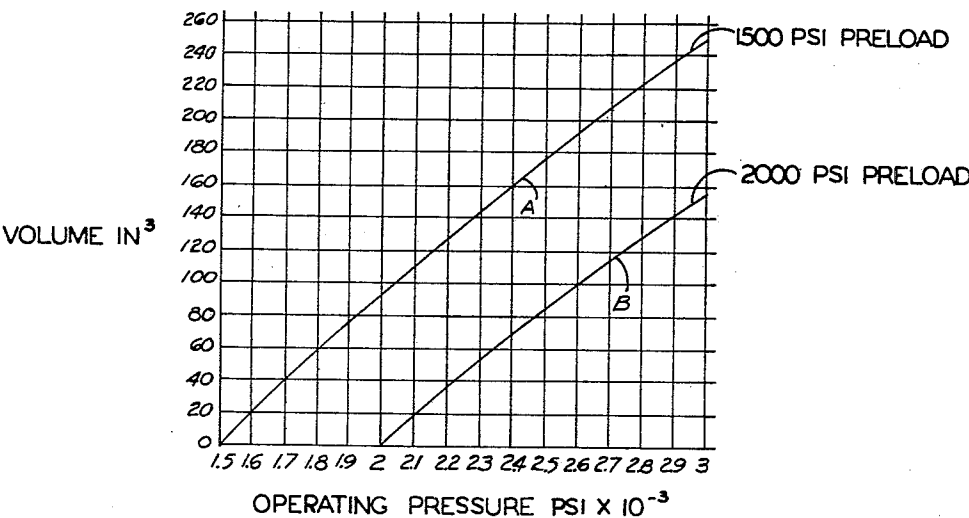


FIG. 4

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4 Claims. (Cl. 138—31)

This invention relates to an accumulator and more particularly to an accumulator for hydraulic systems, said accumulator utilizing a compressible solid or liquid as the loading medium for the hydraulic fluid.

Present accumulators for hydraulic systems may utilize either a mechanical spring or compressed air as the means for loading the hydraulic fluid stored in the accumulator. When air is utilized, the air leaks into the hydraulic fluid since it is difficult to seal the space containing the air under pressure. The addition of air to the fluid makes the fluid spongy and the system will be unstable because of this contamination of the hydraulic fluid. When mechanical springs are utilized, the allowable system pressure is limited since mechanical springs are physically too large to be used in compact, high pressure systems.

The present invention utilizes a compressible solid or liquid so that high system pressure can be reached in an accumulator which is much smaller in size than would be required if a mechanical spring were utilized. Also, since a solid or fluid can be more effectively sealed than a gas at high pressures, the solid or fluid will not leak into the hydraulic fluid. The working medium for the accumulator is preferably contained in a spherical container so that the medium can be stored in a container of optimum shape and minimum weight. In one form of the invention, a piston is moved by the hydraulic fluid pressure into the spherical container to increase the pressure of the medium and in another form of the invention, the spherical container is bodily moved relative to the piston. The initial pressure of the medium can be varied by changing the charging pressure in the first form or by mechanically changing the initial amount of penetration of the piston into the medium in the container of the second form. In the latter case, no auxiliary equipment is required to initially supply the medium under pressure, such as is necessary in a pneumatic accumulator when the initial charge of air must be supplied by an air compressor. Various compressible solids and liquids, such as silicone rubbers and silicone liquids, can be used in the spherical container to store the hydraulic fluid under pressure. Thus, the present accumulator is lighter and more compact than spring loaded accumulators, and more reliable and serviceable than air loaded accumulators. Also, the spherical volume of the compressible solid or liquid medium can be larger without consuming excessive space so that a smaller plunger can move a considerable distance into the medium for a given permissible pressure rise in the medium. This movement of the plunger can be of approximately the same amount as is common in air accumulators wherein the plunger and a cylinder have the same cross section. Because of the larger volume of the medium in the present invention, the percentage compressibility of the medium need not exceed 10–15 percent while storing a sufficient volume of hydraulic fluid.

It is therefore an object of the present invention to provide an accumulator which utilizes a compressible solid or liquid as the loading medium.

Another object of the invention is to provide an accumulator in which the initial loading of a compressible solid or liquid medium can be accomplished without separate means to pressurize the medium.

Another object of the invention is to provide an accumulator in which a compressible solid or liquid loading

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medium is stored in a spherical container having minimum weight and volume.

A further object of the invention is to provide an accumulator that has a volume of solid or liquid loading medium which is larger relative to plunger size so that considerable plunger stroke is permissible without exceeding the pressure limit of the accumulator.

These and other objects of the invention not specifically set forth above will become readily apparent from the accompanying description and drawings, in which:

FIGURE 1 is a longitudinal sectional view, partly in elevation, of one form of the invention in which the piston moves into the spherical container.

FIGURE 2 is a longitudinal sectional view, partly in elevation, of another form of the invention in which the spherical container moves along the piston.

FIGURE 3 is a transverse section along line 3—3 of FIGURE 2 showing the locking pin, and

FIGURE 4 is a graphical illustration of the variation of pressure with volume change within the spherical container for a typical compressible solid.

Referring to the form of the invention shown in FIGURE 1, a cup-shaped housing 10 contains a port 11 at its bottom and the port is connected by a suitable line (not shown) to a hydraulic system. Thus, the housing 10 is stationary and can be supported by other supporting means (not shown) in addition to the passage leading to the hydraulic system. The interior surface of the housing has a step 12 which engages and positions the outer edge 13 of a conical shaped piston member 14 when the member is inserted into the housing. The piston member or head 14 contains a central opening 15 for receiving the end of a plunger 16. The plunger 16 has an annular projection 17 providing a face 18 for engaging one side of piston member 14. Also, the plunger 16 has a reduced portion 19 which receives a ring 20 located adjacent the opposite side of piston member 14. The ring 20 is held against piston member 14 by a snap ring 21 located in a groove 22 in plunger 16. Thus, the piston member 14 and the plunger 16 will move together as a unitary structure. The plunger 16 has a cylindrical side 23 and an end 24 defining an interior plunger space 25 which communicates with space 26 located between the housing 10 and the piston member 14. The surface of plunger 16, which is received by opening 15 in piston member 14, contains a groove 27 for a flexible sealing ring 28. Two backup rings 29 are located on each side of ring 28 to prevent extrusion of the ring into the clearance at opening 15. Also, the outer edge 13 which is received by housing 10, has a groove 30 which contains a flexible sealing ring 31 and backup rings 32.

A spherical container 33 has a circular projection 34 around its circumference and the lip 35 of housing 10 contains an enlarged interior surface 36 which snugly receives the projection 34. The surface 36 and the projection 34 contain cutouts 37 and 38, respectively, each of which receives a portion of a retainer ring 39 which is assembled after the projection 34 has been inserted into lip 35 beyond the cutout 37.

The spherical container 33 contains an opening for plunger 16, said opening comprising smooth cylindrical surfaces 40 and 41 separated by a step 42 and a threaded surface 43. A high pressure seal comprises an L-shaped member 44 having a side 45 snugly received by surface 41 and an end 46 abutting the step 42. The end 46 has a V-shaped surface 47 positioned adjacent one end of flexible sealing material 48. A ring 49 is received between side 45 and cylindrical side 23 and has a V-shaped surface 50 adjacent the opposite end of the sealing material 48. The ring 49 is forced against the sealing material by retaining nut 51 which is threaded into surface 43. A sealing ring 52 having backup rings 53 on opposite

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sides, serves to provide a stationary seal in the clearance between surface 41 and member 44. Also, the container 33, adjacent the threaded surface 43, contains an opening 54 which receives a pin 55 with a press fit. A key 56 is retained on pin 55 by a locking wire 57, and the key is inserted into one of a plurality of slots 58 located around the outer surface of nut 51 in order to retain the nut in a position to provide the desired initial compression of sealing material 48. A port 59 is located in housing 10 adjacent lip 35 and contains a filter 60. The internal space 61, defined by housing 10, piston member 14, plunger 16 and container 33, is connected to atmosphere through port 59 so that relative movement between the piston member 14 and container 33 will not be affected by air trapped in space 61.

The interior space 62 of spherical container 33 is charged with a compressible solid or liquid introduced through a charging valve 63, located in a passage 64 and connected with a source (not shown) of the solid or liquid under pressure. The pressure developed in space 62 will move the edge 13 of the piston member into engagement with step 12 and will move the projection 34 against ring 39 since the internal pressure will move the plunger 16 into its fully extended position shown in full line in FIGURE 1. The internal charging pressure, imparted to the medium in space 62, will determine the preload on the hydraulic system and the internal charging pressure can be varied to vary the preload. If the accumulator of FIGURE 1 is to operate in a 3000 p.s.i. system, it can be preloaded to a high pressure, such as 1500 p.s.i. or 2000 p.s.i. Obviously, the higher the preload pressure, the less compression of the material can take place before the compressible medium reaches 3000 p.s.i.

As previously stated, various compressible solids or liquids can be utilized in space 62, such as silicone rubbers and silicone liquids. The silicone rubbers are produced from dimethyl polysiloxanes in which various vulcanizing agents are incorporated to attain various degrees of hardness and compressibility. Such materials produced by Dow Corning are called "silastics" and are produced in a wide range of unit shear strength and compressibility. A suitable silicone solid and a suitable silicone liquid are designated respectively as Dow Corning RTV-501 and F-4029. Also, natural or synthetic rubber compounds and hydraulic fluids can be utilized.

In operation, hydraulic fluid from the system will be stored in space 26 and as the pressure in the system increases over the preload of the medium in space 62, the fluid acting on piston member 14 and plunger 16 will force the plunger into the container 33. The fluid force always holds the piston member 14 against face 18 and the container 33 against ring 39 while the housing 10 is rigidly supported. When the plunger 16 reaches the dotted line position 16a of FIGURE 1, maximum insertion of the plunger into the container 33 has resulted and the medium within the container has reached the maximum pressure of the hydraulic system. At intermediate positions of the plunger, the pressure in container 33 is between the preload pressure and the maximum pressure, depending upon the amount of compression of the medium by the plunger. Thus, the accumulator provides a means of storing hydraulic fluid in space 26 under pressure. The displacement of plunger 16 causes a reduction in volume of the compressible medium resulting in storing of energy in the medium so that the accumulator can receive, store and deliver a quantity of hydraulic fluid under pressure.

By utilizing a spherical container of large volume for the compressible solid or liquid medium, a small plunger can have the same amount of displacement as the plunger in an air loaded accumulator wherein the plunger and cylinder are of the same cross section. However, in the present invention, this amount of displacement amounts to a smaller percentage of compressibility while producing the same energy absorption. Thus, the spherical container provides a larger volume to permit substantial

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displacement of the plunger so that the required volume of hydraulic fluid can be stored in space 26 without exceeding the maximum system pressure. At the same time, the spherical container requires minimum space for a given volume of the compressible medium and the accumulator can be of substantially less size for a given capacity than one utilizing mechanical spring loading.

The compressible medium, either solid or liquid, is effectively sealed by sealing material 48. The space 40a between surface 40 and the plunger applies the pressure of the medium to the area of end 46 and the total pressure on end 46 is resisted by the smaller area of ring 49. Thus, the unit pressure on material 48 is greater than the unit pressure of the medium trying to squeeze past the sealing material and effective sealing results against liquids as well as solids.

A second embodiment of the invention is shown in FIGURE 2. The cup-shaped housing 10' contains a port 11' which is connected to a hydraulic line of the hydraulic system in the same manner as in the prior embodiment so that the housing 10' is rigidly supported with the hydraulic line. The interior surface of the housing has a step 12' which engages and positions an enlarged ring projection 70 on spherical container 33'. A sealing ring 71 and backup rings 72 are contained in a groove 73 in the projection so that no leakage will occur when the container 33' moves relative to the housing 10' in response to the pressure of hydraulic fluid introduced to space 74 between the container and the housing. Lip 35' of housing 10' has an enlarged surface 36' to receive the circular enlargement 76 on member 14'. The surface 36' and enlargement 76 contain cutouts 77 and 78, respectively, each of which receives a portion of retainer ring 79 which is assembled after the enlargement 76 has been inserted into lip 35' beyond the cutout 77.

The member 14' contains a central opening 15' for receiving the end of a plunger 16'. The plunger 16' has an enlarged annular projection 17' providing a face 18' for engaging one side of piston member 14'. Also, the plunger 16' contains a groove 80 containing a ring 81 which engages the opposite side of the piston member 14', so that the piston member 14' is locked to the plunger 16'. The plunger 16' comprises a cylindrical sleeve 23' having an interior threaded portion 82 and a spline section 83 located at the end adjacent to portion 82. A slot 84 is located in threaded portion 82 for receiving a portion of a retaining pin 85.

An inner sleeve 86 has a threaded surface 87 along its entire length which coacts with threaded portion 82 to secure sleeve 86 within sleeve 23'. A plurality of slots 88 are located in the end of said inner sleeve 86 so that the slot opposite slot 84 can receive a second portion of locking pin 85 in order to lock the sleeves together. A spline section 89 is located on end 90 of the inner sleeve 86 and the end 90 is normally covered by a cup-shaped member 91 having its rim secured in an opening 92 of a cap member 93. A threaded portion 94 of cap member 93 is secured in a threaded recess 95 of member 14' and the cap member 93 has a spline section 96.

When the cap member 93 is removed, suitable tools can be applied to the spline portion 83 and 89 of the cylindrical and inner sleeves, respectively, to cause relative movement of the sleeves and position the end of the inner sleeve within the container 33'. After the inner sleeve is positioned, a slot 88 is located opposite slot 84 and the key 85 is inserted, as illustrated in FIGURE 2, to lock the sleeves together. Thereafter, the cap member 93 can be attached by a tool applied to spline section 96, so that it engages the end of key 85 and places cover member 91 around the end of sleeve 86. The end 98 of the inner sleeve 86 normally located within container 33', has a step 99 in which is located a sealing ring 100 retained by backup rings 101. The sealing ring 100 prevents passage of the working medium into space 102 between the cylindrical sleeve 23' and the threaded sur-

face 87 of inner sleeve 86. As will be later described, the positioning of the inner sleeve 86 within the cylindrical sleeve 23' can be accomplished to preset the initial preload pressure within the loading medium in container 33'.

The spherical container 33' contains an opening for sleeve 16', said opening comprising smooth cylindrical surfaces 40' and 41' separated by a step portion 42', and a threaded surface 43'. A high pressure seal comprises an L-shaped member 44' having a side 45' snugly received by surface 41' and an end 46' abutting the step 42'. The end 46' has a V-shaped surface 47' positioned adjacent one end of flexible sealing material 48'. A ring 49' is received between side 45' and cylindrical sleeve 23' and has a V-shaped surface 50' adjacent the opposite end of the sealing material 48'. The sealing ring 49' is forced against the sealing material by retaining nut 51' which is threaded into surface 43'. A sealing ring 52' having backup rings 53' on opposite sides serve to provide a stationary seal in the clearance between the surface 41' and member 44'. Also, the container 33' adjacent the surface 43' contains an opening 54' which receives a pin 55' having a pressed fit. A key 56' is retained on pin 55' by a lock wire 57', and the key is inserted into one of a plurality of slots 58' located around the outer surface of nut 51', in order to retain the nut in a position to provide the desired initial compression of the sealing material 48'. A port 59' is located in the piston member 14' and contains a filter 60'. The internal space 61' between container 33' and piston 14' is connected to atmosphere through port 59' so that relative movement between the piston member 14' and container 33' will not be affected by air trapped in space 61'.

The interior space 62' of spherical container 33' is charged with a compressible solid or liquid which is initially introduced through the opening in the spherical container for the cylindrical sleeve 23'. Thereafter, the cylindrical sleeve 23', together with the inner sleeve 86, are inserted into the spherical container 33'. At the time of the insertion, the end 98 of the inner sleeve has been threaded into portion 82 of the cylindrical sleeve 23' so that a large interior space 104 exists in the cylindrical sleeve 23' to receive working medium displaced by the insertion of the sleeve 23' into the space 62'. Thus, the piston member 14' can be moved into the housing 10' far enough to permit the assembly of retaining ring 77. With the piston member 14' secured and the cap member 93 removed, the inner sleeve 86 can be rotated relative to the cylindrical sleeve 23', by suitable tooling applied to spline sections 83 and 89, in order to move the inner sleeve 86 into the container 33'. The interior space 103 of sleeve 86 is smaller in cross section than space 104 and the pressure of the working medium in space 62' will increase as the inner sleeve is moved into the container space 62'. In other words, the reduction in volume of container 33' caused by the insertion of the end of sleeve 86 is not compensated for by the volume of space 103 in the inner sleeve after the space 103 is filled. Thus, the initial charging pressure of the medium in space 62' can be initially set by relative rotation of the sleeves to provide a predetermined preload on the hydraulic system and no auxiliary equipment, such as air compressors or other pressure sources requested to obtain a selected preload.

If the accumulator of FIGURE 2 is used in a 3000 p.s.i. system, it can be preloaded to a pressure, such as 1500 p.s.i. or 2000 p.s.i., by simply adjusting the position of the sleeve 86. As illustrated in FIGURE 2, the slot 88 in the inner sleeve 86 terminates at a position where the lowest desired preload pressure is obtained. Therefore, the key 85 can maintain the relative positions of the sleeves at the lowest preload and at all higher preloads in which the sleeve 86 could be further inserted into container 33'. The cover 91 is sufficiently large to receive the projecting end 90 of sleeve 86 in the lowest

preload position of FIGURE 2. The container 33' can contain the same types of compressible solids or liquids as described for the space 33 in the previous embodiment.

In operation, hydraulic fluid from the system will be stored in the space 74 and as the pressure in the system increases over the preload pressure in space 62', the fluid acting on the container 33' will force the container toward the piston member 14' which is held by the retaining ring 77. This movement will cause a compression of the loading medium within the container 33' and the maximum stroke of container 33' will be determined by the maximum permissible pressure of the hydraulic system. At intermediate positions of the container 33', the pressure of the medium will be intermediate the preload pressure and the maximum permissible pressure.

The graphical illustration of FIGURE 4 illustrates the performance of the embodiment of FIGURE 2 in a 3000 p.s.i. system, when the container 32' contains a silicone solid, such as RTV-501. The compressibility of this medium is approximately $6.45P^{-.73}10^{-5}$ where "P" is pressure in pounds per square inch and the compressibility is in terms of volume change per unit pressure change. As indicated by curve A, the maximum storage volume in space 74 is approximately 230 cubic inches with a preload of 1500 p.s.i., and curve B shows a lesser volume change when the preload pressure is 2000 p.s.i. It is apparent from FIGURE 4 that a large volume of working medium in a spherical container permits a small percentage compressibility of the medium while affording considerable stroke. Further, in FIGURE 2, it is possible to obtain adjustment of the preload by the adjustment of the components of the device itself, so that an external supply of medium under pressure is not required.

It is therefore apparent, that the present invention provides a novel accumulator which is rugged in construction and easy to service. The accumulator can be made of any size required for a given energy storage. Also, the sealing problems are a minimum since no high pressure gases need be sealed to prevent contamination of the hydraulic fluid. While the invention is particularly adaptable to accumulators, it is understood that it can be utilized as a damper to damp all types of forces. Various container shapes can be utilized although the spherical shape is preferred. Various other modifications are contemplated by those skilled in the art without departing from the spirit and scope of the invention, as hereinafter defined in the appended claims.

What is claimed is:

1. An accumulator for a hydraulic system comprising a spherical container for storing a volume of compressible working medium less compressible than a gas, an opening at one location in said container, a plunger having one end inserted through said opening into said container, a piston member secured to the other end of said plunger and having an inner wall adapted to encompass said container, a cup-shaped housing member slidably receiving said piston member, and having a lip at its open end, retaining means at the lip of said housing member for securing said container around its circumference, a fluid storage chamber defined between the bottom of said cup-shaped housing member and said piston member, and port means connected with said fluid chamber for introducing fluid from said hydraulic system, said plunger being movable relative to said container by said hydraulic fluid to vary said fluid chamber.

2. An accumulator as defined in claim 1 having a charging port located in said container, and connecting means in said port for connecting the interior of said chamber to a source of working medium under pressure in order to preload the container with working medium.

3. In an accumulator for a hydraulic system, relatively movable means comprising substantially spherical container means for storing a compressible working medium

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less compressible than a gas and plunger means extending into said container means, said plunger means comprising a substantially conical shaped piston head located exteriorly of said container means, said piston head having an open base adapted to encompass said container means, cup-shaped housing means receiving said container means and piston head and guiding one of said movable means during said relative movement, a storage space located between said housing means and said one of said relatively movable means, and means connected with said housing means for supplying fluid from said hydraulic system to said space in order to store the hydraulic fluid by varying the volume of said working medium.

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4. In an accumulator as defined in claim 3 having means for adjusting the preload on said working medium, said adjusting means comprising a charging valve for connecting said container means with a source of working medium under pressure.

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