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Greer

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[54] **HYDRO-PNEUMATIC FLEXIBLE BLADDER ACCUMULATOR**

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[52] **U.S. Cl.** **138/30**
[51] **Int. Cl.** **F16l 55/04**
[58] **Field of Search** 138/30; 239/96

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[57] **ABSTRACT**

A flexible separator type of hydro-pneumatic accumulator is provided which incorporates a thimble-shaped flexible bladder. The bladder is constructed and mounted so that it has the capability of turning inside-out as the liquid pressure within the accumulator is increased, so that the bladder can force all of the gas out of the gas chamber of the accumulator without twisting or wrapping. This construction permits the accumulator to have the high volumetric efficiency characteristics of the prior art bladder-type accumulators, and yet to have the high differential pressure ratio capabilities of the prior art diaphragm-type accumulators, this being achieved without the need for any extraneous components which would add to the expense and complexity of the unit. The bladder is mounted within the container of the accumulator to permit a cap to be welded to the container without excessive heat reaching and damaging the bladder. This is achieved by mounting the bladder substantially midway along the length of the container by means of a thin metal tube which holds the open end of the bladder spaced from the inner surface of the container. The metal tube has sufficient length, and it is sufficiently thin, to limit the heat conducted to the bladder from the heat generated during the welding operation to a level insufficient to cause damage to the bladder.

9 Claims, 4 Drawing Figures

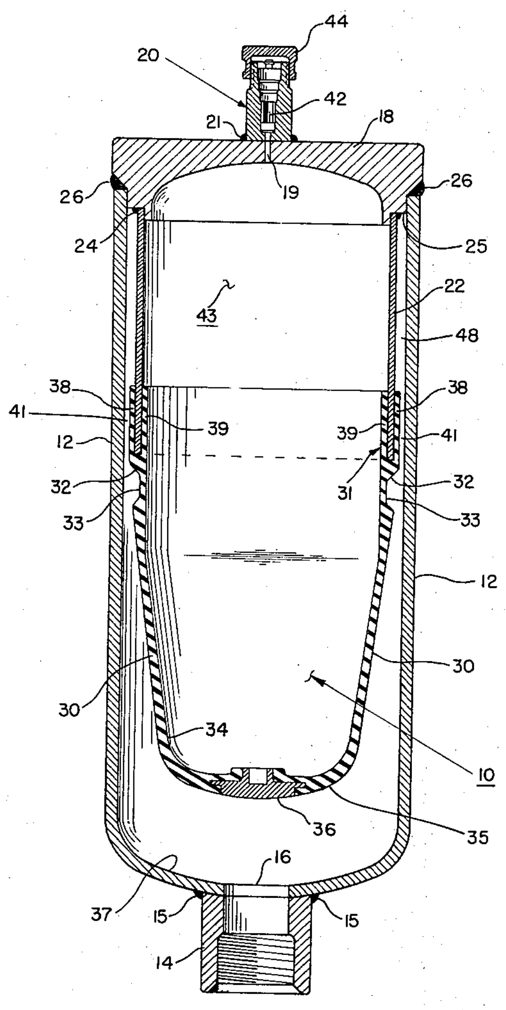

FIG. 1

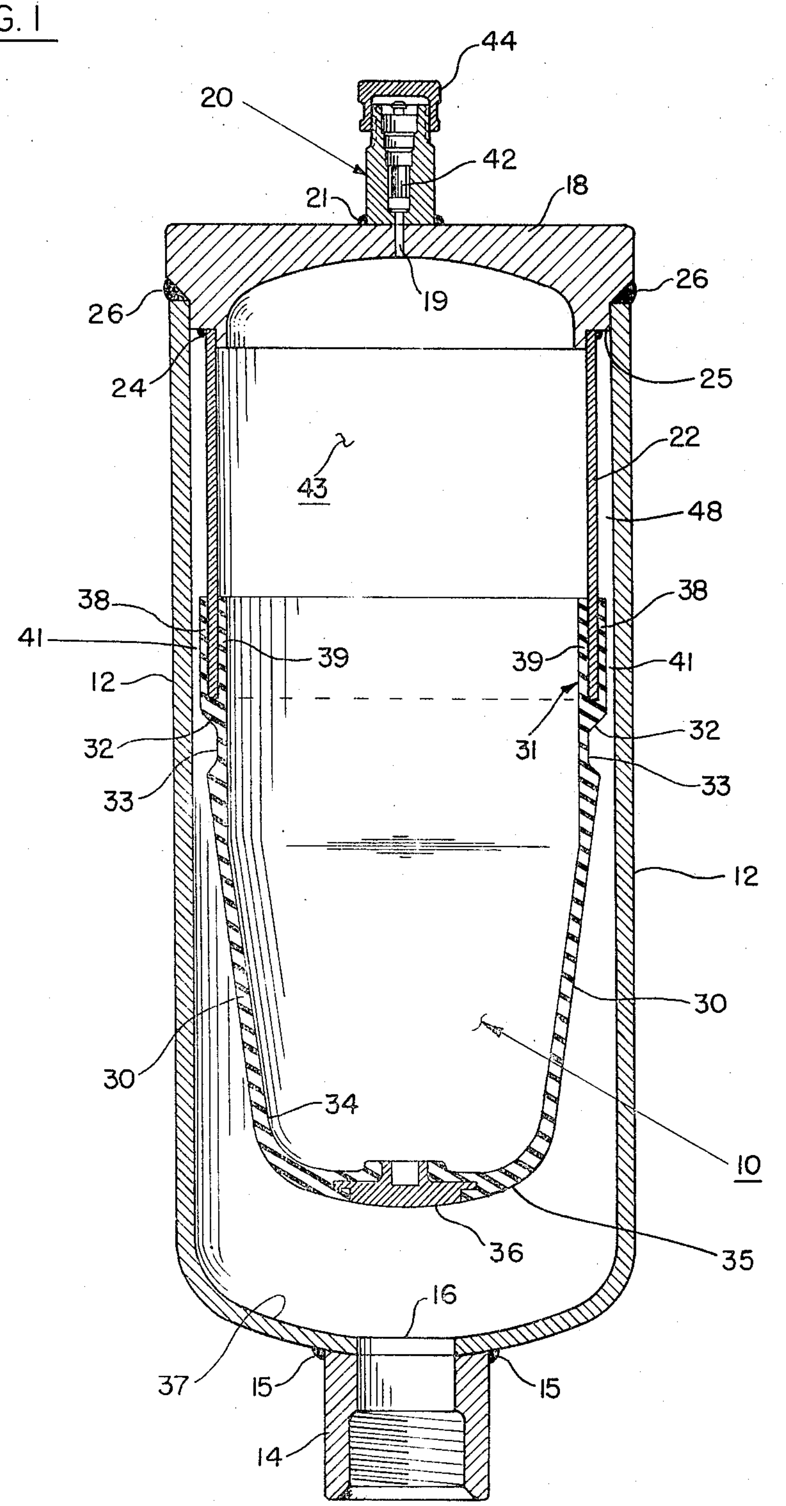
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FIG. 2

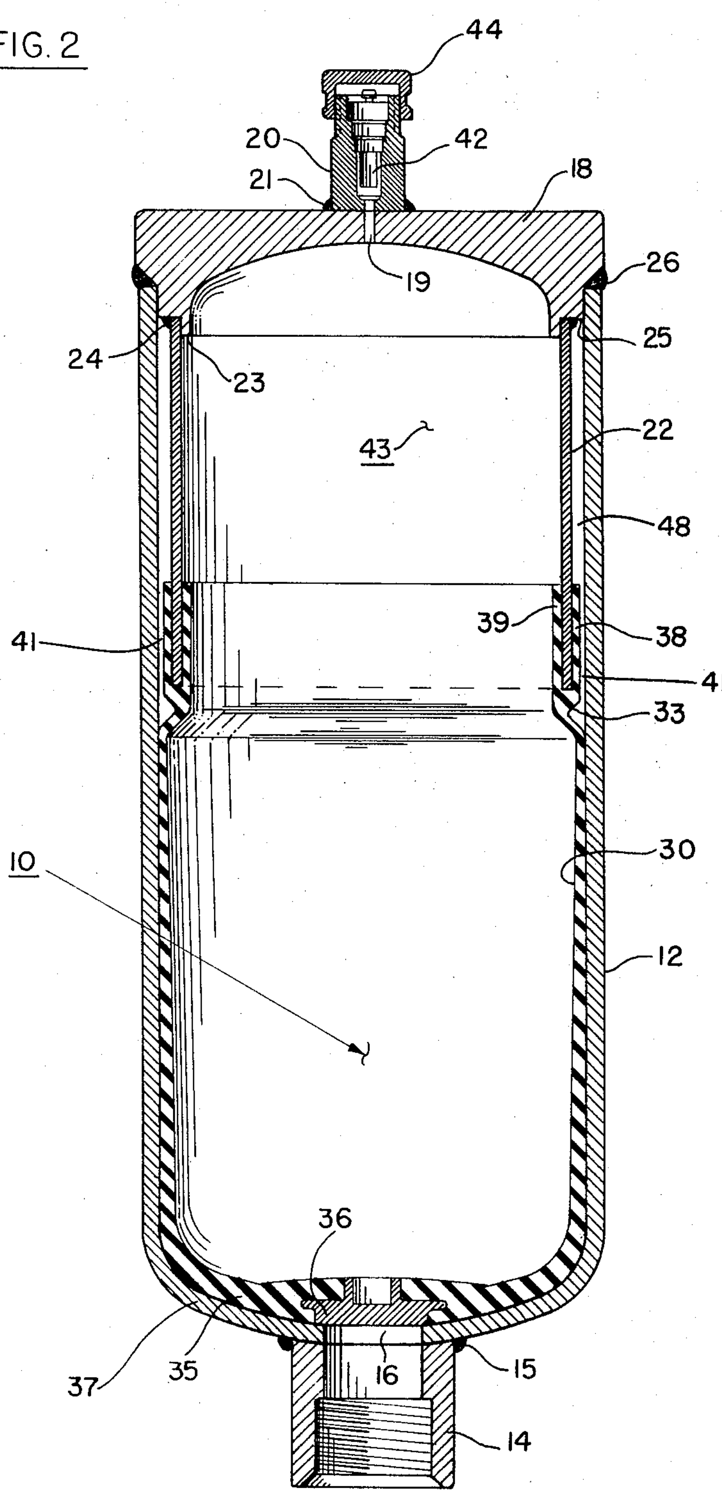
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FIG. 3

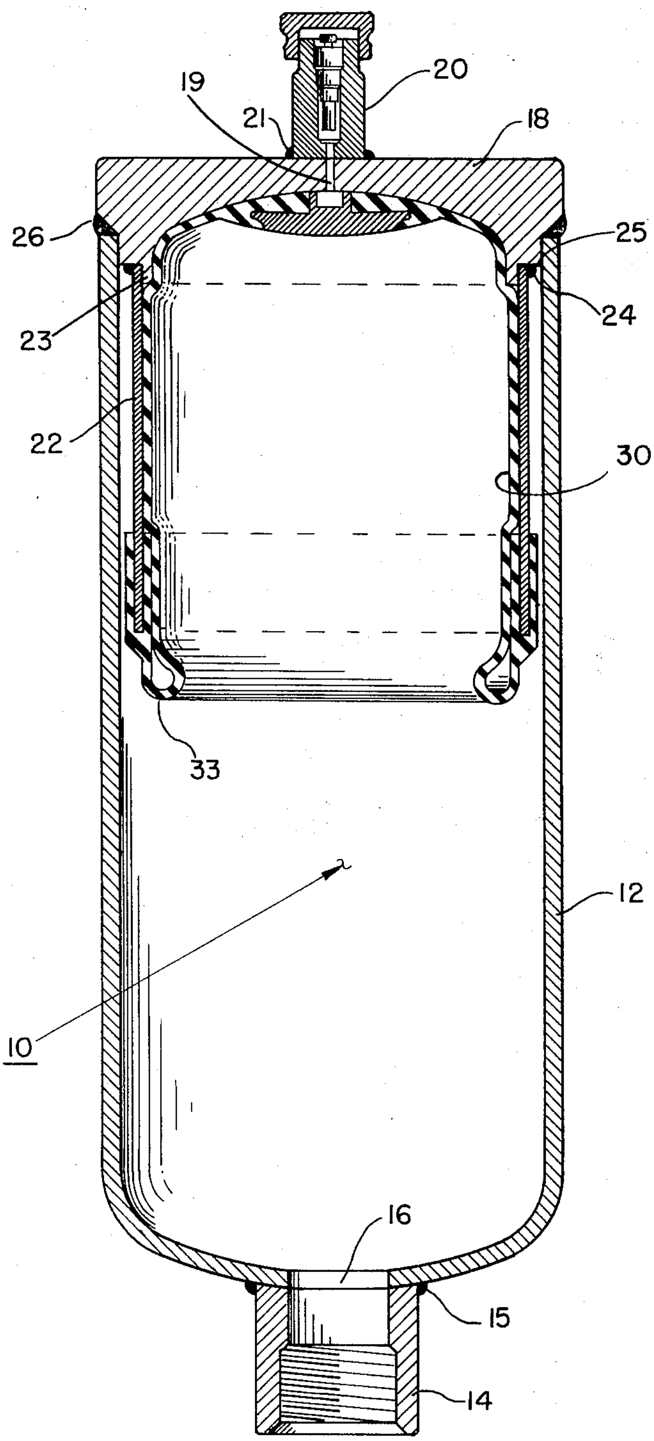
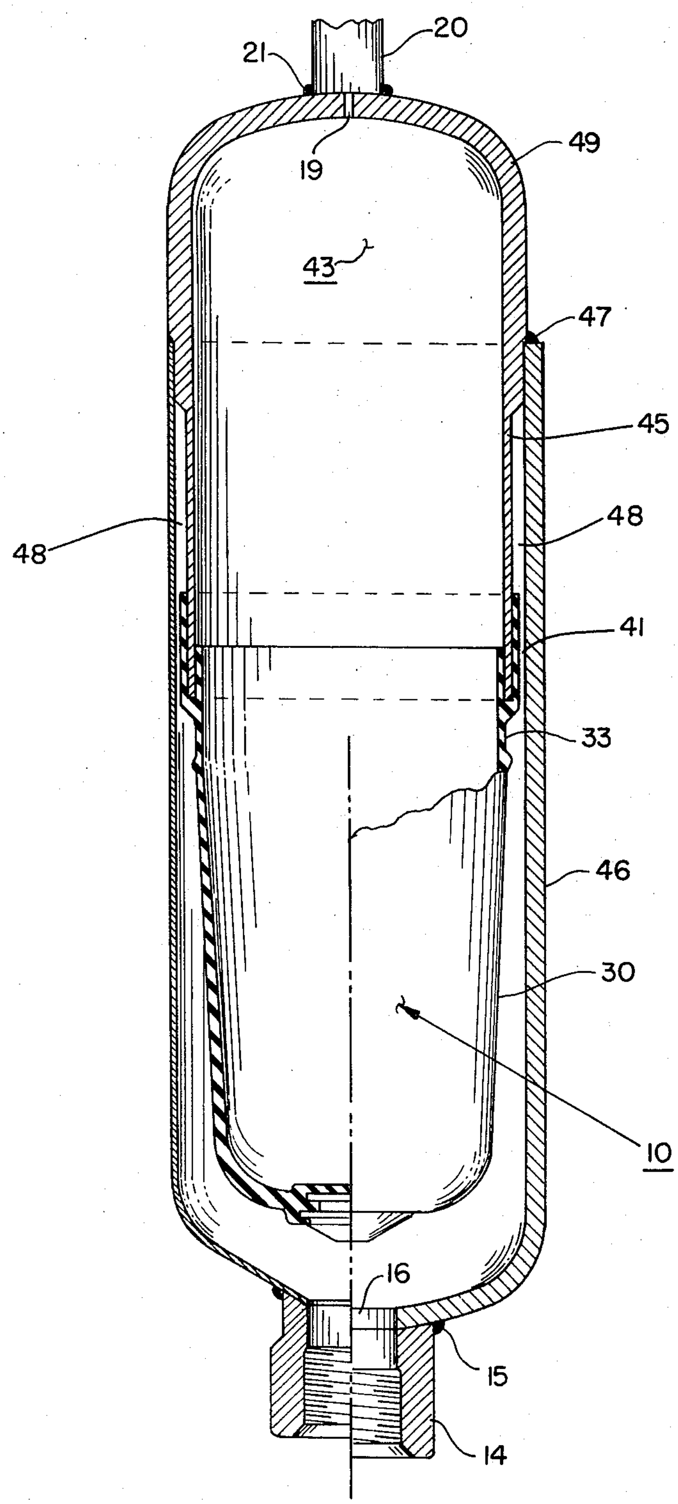


FIG. 4



HYDRO-PNEUMATIC FLEXIBLE BLADDER ACCUMULATOR

BACKGROUND OF THE INVENTION

Hydro-pneumatic accumulators are being widely used in hydraulic systems in many industries throughout the world, and have been so used since at least as early as 1935. Greater and more efficient types of such accumulators are continuously in demand and are being continually introduced to the industry to satisfy this demand. There are two distinct types of hydro-pneumatic accumulators utilized at the present time. These are the floating piston type, wherein a sealed rigid piston slides reciprocally in a smooth and closely fitting cylinder, the cylinder having a cap at each end, one cap being fitted with a gas valve and the other cap being fitted with a fluid port. The other type of present day accumulator is known as the flexible separator type, and this latter type may include either a thimble-shaped flexible bladder, or a flexible diaphragm.

The flexible separator of the separator type hydro-pneumatic accumulator divides the accumulator into two chambers which are sealed from one another. One chamber is connected to a liquid port, and it constitutes the "liquid" chamber of the accumulator; and the other chamber, constituting the "gas" chamber of the accumulator, is connected to a gas valve resembling an automobile tire valve. A compressible gas, such as nitrogen, is permanently charged and compressed under high pressure and sealed through the gas valve into the gas chamber of the accumulator; then, an incompressible hydraulic liquid under high pressure is pumped into the opposite liquid chamber. The flexible separator is gradually forced into the gas chamber as the liquid is pumped into the liquid chamber, thereby further compressing the gas in the gas chamber until a balanced high pressure is reached in both the liquid and gas chambers. In this way, energy is stored or absorbed into the gas chamber of the accumulator, which acts as a spring to force the incompressible hydraulic liquid out of the liquid chamber, and thereby causing the hydraulic liquid to do useful work.

Although both the flexible separator and floating piston type of accumulator are in general use throughout the hydraulic industry, the flexible separator types are used more extensively because of their lower cost, longer life, and lower maintenance and repair requirements. As mentioned above, the present invention is concerned with the flexible separator type accumulator.

It is recognized that as the pressure is raised in the hydraulic liquid chamber in a flexible separator type of accumulator, the gas pressure in the gas chamber will vary continuously in an exactly proportionate relationship. Therefore, the pressure on both sides of the flexible separator is identical at all times.

It has also been recognized in the prior art that when the flexible separator is in the form of a thimble-shaped bladder, then, as the hydraulic liquid is expelled from the accumulator, the side wall of the bladder will gradually make contact with the side wall of the container, gradually squeezing the hydraulic liquid out of the liquid chamber until all the liquid is expelled. This is due to the basic law of physics that stress or stetch on the side wall of an essentially cylindrical shaped member is equal to the internal pressure times the diameter divided by twice the wall thickness. It is due to this law of physics that bladder-type accumulators having a flexible thimble-shaped bladder, which has a wall thickness that increases gradually as the bladder diameter decreases, has proven over the past many years to have a volumetric efficiency approaching 100 percent.

The usual prior art flexible diaphragm type of accumulators, on the other hand, do not exhibit the desired high volumetric efficiency of the bladder-type accumulators. This is because the diaphragm separator, regardless of its molded-in convolutions, tends to entrap substantial amounts of liquid fluid, so that the volumetric efficiency cannot be accurately determined, and is relatively low. Radial ribs, extruding buttons and other mechanical devices have been utilized with some benefits in the prior art diaphragm accumulators in order to increase the volumetric efficiency. However, these devices add to the complication and cost of the assembly.

Although the prior art bladder type accumulator exhibits high volumetric efficiency, as compared with the prior art diaphragm type accumulator, during the discharge of the hydraulic liquid; the diaphragm accumulator has certain advantages over the bladder type accumulator during the cycle in which the hydraulic liquid is pumped into the gas chamber of the accumulator, and as the separator is displaced further and further into the gas chamber by the hydraulic liquid. During this cycle, the flexible separator will convolute into the gas chamber along its greatest axis, which occurs diametrically when the separator is a diaphragm, and longitudinally when the separator is a thimble-shaped bladder. In the case of the bladder, the separator has a tendency to twist and wrap onto itself until all the gas is squeezed out of the gas chamber; and eventually the bladder will rupture or tear, or take a permanent set, rendering it inoperative. The diaphragm, on the other hand, is not subject to twisting or wrapping as it is forced into the gas chamber and eventually against the side walls of its housing.

Generally speaking, bladder accumulator manufacturers in the prior art recommend a maximum pressure differential of the order of 6:1. This means that the maximum pressure that a prior art bladder type accumulator may be subjected to may not exceed six times the initial gas precharge pressure, since there are a great many conditions in industry where most or all the fluid in the gas chamber must be squeezed out of the gas chamber by pressure from the hydraulic system. This occurs, for example, where a separate gas bottle is coupled to the gas chamber of the accumulator to increase its effective capacity.

A specialty accumulator of the bladder type has been introduced into the prior art in which a perforated tube, or other mechanical means, is mounted to extend through the center of the gas chamber, thus limiting the amount of twisting and squeezing together of the side walls of the bladder, thereby giving it more life assurance. This specialty accumulator is known to the industry as a bladder-transfer barrier type, and it has gained acceptance in the industry. The barrier type accumulators are used extensively to separate different liquids, where pressure in the hydraulic system will force the second liquid out of the "gas" chamber of the accumulator. However, the bladder-transfer barrier type accumulator is relatively expensive.

The present invention provides a hydro-pneumatic accumulator of the flexible bladder type which has the high volumetric efficiency in the expulsion cycle of the hydraulic liquid from the liquid chamber as experienced in the prior art bladder-type accumulator, and which also exhibits the characteristics of the prior art diaphragm-type accumulator during the cycle of compression of gas in the gas chamber, in that it is not subject to wrapping and twisting, and it is not limited to any specific permissible pressure differential, this being achieved without the need for any extraneous components.

In the construction of accumulators of the type under consideration, it is necessary to position the bladder in the metal container between fluid ports at opposite ends of the container. Normally the container is open at one end, and the open end substantially enclosed by a metal closure cap. The closure cap is normally welded to the metal container, which creates high temperatures at the welding seam during the welding operation, and which are conducted at diminishing temperatures along the length of the side wall of the container. Since the bladder is normally secured to the container prior to welding the closure cap in place, the high temperatures involved in welding the closure cap to the container are normally conducted through the container structure to the bladder, and can damage the bladder.

Because the container is entirely enclosed, it is often difficult to detect damage to the bladder until after the accumulator is placed in operation. However, whether the bladder damage is discovered initially, or later during the operation of the accumulator, the construction of the accumulator is such that this damage results in the entire accumulator being useless and normally nonrepairable.

Therefore, it is of major importance for the bladder to be mounted within the container in a manner such that it will not be susceptible to damage when the cap is welded or brazed to the container. The construction of the accumulator to be described is such that the housing and cap can be welded together without the heat developed during the welding operation having any tendency to damage the bladder.

In one embodiment of the invention to be described, a hydro-pneumatic accumulator is provided which comprises a metal tubular container having a liquid port at one end and a metal cap at the other end welded to the container. A gas valve is mounted on the cap, in conjunction with a gas port which extends through the cap into the interior of the container. A thimble-shaped bladder of appropriate resilient, deformable material is mounted within the container between the liquid port and the gas port, and this bladder defines the liquid chamber and the gas chamber of the assembly.

The assembly has an open end facing the gas port. A thin-walled open-ended metal tube serves to mount the bladder in the container, one end of the metal tube being secured to the cap and the other end being secured to the open end of the bladder. In a second embodiment, as will be described, the tube is formed integral with the cap. The metal tube has sufficient length so that the open end of the bladder is positioned to be about midway along the length of the assembly.

The outer diameter of the metal tube is made less than the inner diameter of the container, so that at least a portion of the length of the tube, and the open end of the bladder, may be spaced radially inwardly from the inner surface of the container. Thus, the only direct heat path to the bladder is through the metal tube, and the tube is made sufficiently thin and sufficiently long so that heat developed during the welding of the cap to the container cannot reach the bladder with sufficient intensity to damage the bladder.

As mentioned above, the bladder separator in the embodiments of the invention to be described, is generally thimble-shaped, and open at one end. The bladder is formed with a thickened portion adjacent its open mouth, and with a deep peripheral channel formed in the thickened portion which receives the annular end of the metal tube. The bladder is cemented firmly to the inner and outer surfaces of the portion of the metal tube received in the peripheral channel. An alpha cyanoacrylate adhesive marketed by the Pearl Chemical Co. of Tokyo, Japan under the trademark "Permabond" is suitable for the purpose.

The bladder is shaped so that the aforesaid thickened mouth portion tapers abruptly to a thin wall section, and then gradually the wall thickness increases towards the closed end of the bladder. By such a configuration and mounting of the bladder, the accumulator has the desired volumetric efficiency which is characterisitic of bladder-type accumulators, and it also has a desired characteristic in that high pressures can be exerted against the bladder by the hydraulic liquid to force all the gas out of the gas chamber, this being achieved without any danger of twisting or wrapping the bladder, since the bladder is constructed to turn inside-out, as will be explained, during this latter phase.

Specifically, since the reduced thickness portion of the bladder is positioned substantially midway along the length of the accumulator assembly, and since the enlarged thickness band at the mouth of the bladder is just adjacent the reduced thickness portion, and on the gas port side thereof, the resulting structural shape of the bladder permits greater flexure of the bladder while maintaining a stable point. Therefore, the closed end of the bladder is able to move from one end of the container to the other, with the major flexing of the bladder taking place in the thin wall section adjacent the thick band portion, allowing the closed end of the bladder to move through its mouth in an inside-out configuration and traverse the entire length of the container, forcing all of the gas out of the gas chamber, without twisting or wrapping on itself.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side section of one embodiment of the invention in which the internal bladder is supported in the container on a length of thin-walled open-ended metal tubular support member which is welded to the cap, the view of FIG. 1 showing the assembly prior to gas or liquid pressurization;

FIG. 2 is a section of the accumulator of FIG. 1 with all the hydraulic liquid exhausted, and the bladder expanded to the walls of the container, under conditions where the hydraulic pressure of the accumulator is zero and the gas volume is maximum;

FIG. 3 is a side section of the embodiment of FIG. 1, after the pre-charged volume of the gas in the gas chamber has been reduced to zero either by ultimate compression, or loss of the gas, and with maximum volume of liquid having been pumped into the liquid chamber, the section of FIG. 3 showing the bladder in its inside-out condition; and

FIG. 4 is a side composite section, showing a second and third embodiments of the invention, in which the metal tubular support member for the bladder is formed integral with the cap.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

As shown in FIGS. 1–3, for example, a hydro-pneumatic accumulator assembly **10** is provided, which comprises an elongated metal cylindrical container **12** having a liquid opening **16** formed at one end. A fitting **14** is welded, or otherwise attached to the container **12** about the opening **16** by means, for example, of a weld designated **15.** A metal closure cap **18** is mounted to the other end of the container **12** by means, for example, of a weld **26.** A gas port **19** extends through the cap **18,** and a gas charging valve assembly **20** is affixed to the external surface of the cap to surround the port **19** by means, for example, of a weld **21.**

As shown in FIG. **1,** for example, the cap **18** defines a peripheral shoulder **25** at its inner end, and a thin-walled open-ended metal tubular support member **22** has one end fitted against the shoulder **25** and affixed to the cap, by means, for example, of a weld **24.** The cap **18** also has a further section of reduced outer diameter which receives the open end of the container **12,** and which is affixed to the open end by means, for example, of a weld **26.**

It will be noted that the outer diameter of the thin-walled metal tubular support member **22** is less than the inner diameter of the container **12,** so that the tubular member **22** is spaced radially inwardly from the inner surface of the container. The length of the tubular member **22** is such that the member extends approximately midway of the length of the assembly, as shown.

A bladder **30,** formed of an appropriate stretchable, resilient, deformable material, such as synthetic rubber, and having a thimble-like configuration, is mounted on the end of the metal tubular member **22,** in such a way that the thin wall portion **33** of the bladder **30** is positioned approximately midway along the length of the assembly. The bladder **30** has a band of thickened material adjacent its mouth, which is designated **31.** Immediately to the right of the band of thickened material, the wall of the bladder tapers abruptly as at **32** to a thinned wall portion **33.** Then the wall of the bladder, as designated **34,** tapers with a gradually increasing thickness as better illustrated in FIG. **4,** to the closed end wall of the bladder.

An anti-extrusion button **36** is bonded to the closed end wall **35** of the bladder, and this button functions both as a seat against the opening **16,** and to prevent the end of the bladder from extruding into the opening with resulting destruction of the bladder. Because of the close ratio of the length of the maximum inside diameter of the bladder **30** and the tapered side wall construction of the bladder, the side wall **34** elongates and stretches sufficiently to move the button **36** to abut against the closed wall **37** of the container **12** at the opening **16,** as best shown in FIG. **2.**

A relatively deep peripheral groove is formed into the thickened band **31** at the mouth of the bladder **30** which divides the bladder wall into two thin portions designated **38** and **39.** The end of the metal tubular member **22** is received in the groove, and the bladder is cemented, or otherwise attached to the tubular member **22** by applying adhesive material to the surface of the groove, and by then inserting the end of the tubular member into the groove.

In the construction of the unit, as shown in FIGS. **1–3,** the metal tubular member **22** is first attached to the cap **18** by means, for example, of a weld **24.** The bladder **30** is then adhesively, or otherwise attached to the other end of the tubular member **22.** The subassembly comprising the cap **18,** the tubular member **22** and the bladder **30,** is then inserted into the open end of the metal container **12,** and the cap **18** is attached to the container by means, for example, of the weld **26** to complete the assembly.

The tubular member **22** spaces the mouth of the bladder **30** inwardly from the inner surface of the container **12** heaving a radial gap **48.** Also, the bladder **30** is spaced inwardly from the container leaving a radial gap **41.** Therefore, the only direct path for heat to the mouth of the bladder during the welding of the cap **18** to the container is through the tubular member **22.** As mentioned above, the tubular member is made thin enough and long enough, so that it constitutes a very restricted heat path, and sufficient heat is dissipated before it reaches the mouth of the bladder, so that no damage occurs to the bladder or to the cemented joint between the bladder and the tubular member **22.** Heat is dissipated in the annular space between the tubuler member **22** and the inner surface of the container **12,** and in the air space within the tubular member **22.**

The gas valve **20** contains a tire-type valve core **42** which is threaded into the valve, so that gas pre-charged into the gas chamber **43** of the assembly is entrapped and cannot leak out even at high pressure. A high pressure commercial gas valve cap **44,** containing a secondary seal, may be screwed tightly onto the stem of the valve **20,** insuring that there will be no loss of gas pressure within the gas chamber **43.**

After installation in an hydraulic system, the accumulator **10** is connected to an hydraulic pressure line by the fitting **14,** and after dry nitrogen, for example, has been pre-charged into the inner gas chamber **43,** and sealed, the bladder will expand in diameter gradually from the largest diameter and the thinnest wall to the smallest diameter and thickest wall, and then it will stretch and elongate until the button **36,** and the enclosed end wall portion **35** of the bladder, impinge against the inner surface of the container, as shown in FIG. **2.** The action of the bladder **30** against the inner surface of the container **12** acts as a squeegee pushing all the hydraulic oil out of the liquid chamber of the accumulator.

Conversely, as hydraulic oil is pumped into the liquid chamber of the accumulator through the liquid port **16,** the gas in the gas chamber will be gradually compressed with a resulting reduction in gas volume. The bladder **30** will then first assume its molded configuration such as shown in FIG. **1,** and it will then fold in several places around its periphery along its centerline, or major axis, as the liquid pressure increases, until the thin wall **33** adjacent to the thickened mouth portion **31,** which is further supported by the rigid metal tube **22,** will collapse inwardly. Thereafter, the bladder **30** effectively acts as a diaphragm, and folds along the diametric axis formed by the rigid inside diameter of the mouth of the bladder **31.** As the liquid pressure is further increased, with resulting decrease in gas volume, the bladder will eventually turn inside-out entrapping the gas further and further until a volume-to-gas volume ratio approaches **10**:**1**, the ultimate position of the bladder being shown in FIG. **3.**

The construction of FIG. **4** is generally similar to that of FIGS. **1–3,** and like elements have been designated by the same numbers. However, in the embodiment of FIG. **4,** the metal tubular member **22** is formed integral with the cap **18.** Specifically, the cap **49** of the assembly of FIG. **4** is provided with an elliptical closed end, on which the valve **20** is mounted, and through which the gas port **19** extends. The cap extends down into the container **46** an amount corresponding to the length of the tubular member **22** in the preceding embodiment. The end of the cap, designated **45** is provided with a reduced outer diameter, and the bladder **30** is cemented to that end, in a manner similar to the previous embodiment, to be displaced from the inner surface of the wall of the container **46.**

The construction of FIG. **4** permits the container **46** to be considerably shortened with respect to the container **12** of the previous embodiment. In the construction of the embodiment of FIG. **4,** the cap **18** and bladder **30** are cemented together, and the cap and bladder sub-assembly are inserted into the container **46.** The container **46** is then attached to the cap by means, for example, of a weld **47.** A thin-walled section **45** of the cap provides a restricted heat path to the mouth of the bladder **10,** so that the bladder and its cemented joint are protected during the welding operation. Also, the thin-walled section of the cap spaces the mouth of the bladder inwardly from the inner surface of the container to form the annular space **48,** as in the previous embodiment. The operation of the assembly of FIG. **4** is similar to the operation of the assembly of FIGS. **1–3.**

As noted above, the representation of FIG. **4** is a composite representation of a second and third embodiment of the invention. The two embodiments are alike, except that in the second embodiment the outer container **46** is welded to the cap **49** by the weld **47,** as shown, and in the third embodiment the container **46** has a somewhat thinner wall, which extends over the rim of the cap **49,** as shown, so that the outer surfaces of the container and of the cap are essentially flush.

The invention provides, therefore, an improved hydropneumatic accumulator which is relatively simple and inexpensive to construct, and which has all the desirable features of the prior art bladder-type accumulator, and all of the features of the prior art diaphragm-type accumulator. The accumulator of the invention is constructed so that the cap section may be welded to the container section without any likelihood of heat damage to the bladder, or to its joint with respect to its tubular mounting member within the container.

The annular space **48** between the tubular member **22** and the inner surface of the container **46,** and the annular space **41** between the bladder **30** and the inner surface of the container, allows a pressure balance between the inner and outer surfaces of the tubular member, and also allows the flow of hydraulic oil around the tubular member to pick up thermal changes developed in the expansion-compression of the gas which tends to keep the temperature constant. The use of the relatively long tubular member, in addition to the advantages described above, also substantially shortens the required length of the bladder **30.** A lower length/diameter ratio of the bladder results in a smaller lower cost mold, and better tolerance contol on the walls to prevent a misshapen expansion of the bladder. The rigid mount of the bladder **30** on the cap **18** by the tubular member **22,** and the relatively short bladder assures that the button **36** will travel along the centerline of the assembly to the port **19** and makes possible the turnover condition of the bladder.

It will be appreciated that while particular embodiments of the invention have been shown and described, modifications may be made. It is intended in the claims to cover the modifications that fall within the spirit and scope of the invention.

What is claimed is:

1. A hydro-pneumatic accumulator comprising: an elongated container having a first fluid port on one end and a second fluid port on the other end; an integrally connected tubular elongated member closed by an end cap and mounted at one end of the container and extending into the container and having a length such that its inner end is positioned substantially midway along the length of the container, the outer surface of said tubular member being spaced radially inward from the inner surface of said container providing a heat dissipating space therebetween and aiding in limiting heat transfer during fabrication of the accumulator; and a thimble-shaped bladder of resilient, deformable material mounted on the inner end of said tubular member in said container between the first port and the second port, said bladder having a thickened open mouth end portion, said open mouth end portion having a grooved portion in the bladder, said inner end of said tubular member being secured in said grooved portion of the bladder, with the end portion of the bladder extending over and surrounding the inner end of said tubular member, said thickened open mouth end portion forming a relatively thick outer peripheral band section adjacent the thickened mouth end portion, and an outer peripheral groove between the outer peripheral band section and the thickened open mouth end portion and forming a relatively thin walled peripheral band section therebetween, thereby to cause the bladder to expand to the inner surface of the container in the presence of increased gas pressure through the first fluid port, and to collapse and bend inwardly in the presence of increasing liquid pressure through the second fluid port around the inner end of said tubular elongated member and turn itself inside-out as the liquid pressure increases.

2. The hydro-pneumatic accumulator defined in claim **1,** in which said grooved portion is a deep peripheral channel extending longitudinally for receiving the inner end of the tubular member and dividing the mouth of the bladder into inner and outer peripheral walls.

3. The hydro-pneumatic accumulator defined in claim **1,** in which the thickness of the wall of said bladder is progressively thicker from said thin-walled peripheral band section to the closed end thereof.

4. The hydro-pneumatic accumulator defined in claim **2,** in which said bladder is cemented to the end portion of said tubular member.

5. The hydro-pneumatic accumulator defined in claim **1,** in which said container includes said cap member at one end thereof, and said tubular elongated member is an open-ended cylindrical member affixed to the inner surface of said cap member, said openended cylindrical member having an outer diameter less than the inner diameter of saidcontainer so as to inhibit the heat transfer from the container to the bladder.

6. The hydro-pneumatic accumulator as defined in claim **5**, in which said bladder as affixed to said cap member has an outer diameter less than the inner diameter of said container so as to inhibit heat transfer from the container to the bladder.

7. The hydro-pneumatic accumulator defined in claim **1**, in which said container includes a cap member at one end thereof, and said tubular elongated member is integral with said cap member, at least the end portion of said tubular member having an outer diameter less than the inner diameter of said container to inhibit heat transfer from the container to the bladder.

8. The hydro-pneumatic accumulator defined in claim **1**, in which said tubular member has a relatively thin wall as compared with the thickness of the wall of the container so as to inhibit the transfer of heat along said tubular member.

9. The hydro-pneumatic accumulator defined in claim **1**, in which said container includes said cap member at one end thereof and welded thereto, said tubular member having a selected length and wall thickness to dissipate any heat from the weld so as to protect the bladder.

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