United States Patent [19]

Bisciglia

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[54] **CONTROL FOLD LIQUID EXPULSION BLADDER**

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[52] **U.S. Cl.** ....**222/94,** 220/20, 220/85 B, 222/95

[51] **Int. Cl.** **B65d 35/22**

[58] **Field of Search**.......222/386.5, 389, 94, 95, 395; 220/85 B, 20

[56] **References Cited**

UNITED STATES PATENTS

2,836,963	6/1958	Fox	222/386.5 X
3,070,265	12/1962	Everett	222/386.5
3,286,878	11/1966	Schadt et al.	220/85 B
3,404,813	10/1968	Waxman	222/386.5

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[57] **ABSTRACT**

A means to control the collapse of a liquid expulsion bladder is disclosed which comprises one or more bladder lobes identical in cross-section having a variable wall thickness. When external gas pressure is applied to the bladder it begins to collapse in the thin wall section, at its center, propagating towards the thicker side walls and ends. The bladder sequentially collapses towards a concave support structure with a contour matching the bladder shape, during the last stage of liquid expulsion, expulsion is complete with the bladder conforming to the concave surface of the structure free of double folds and tears.

9 Claims, 8 Drawing Figures

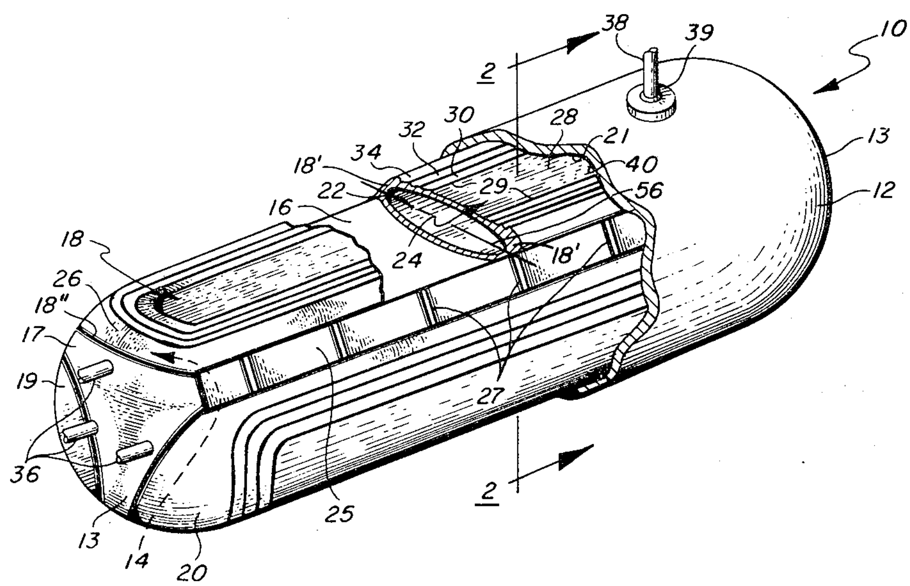
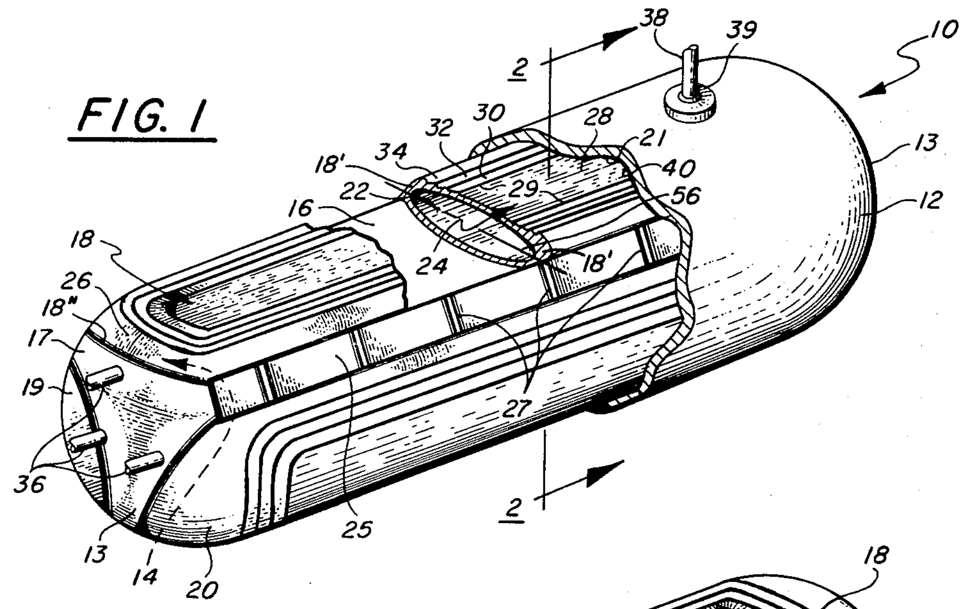


FIG. 1



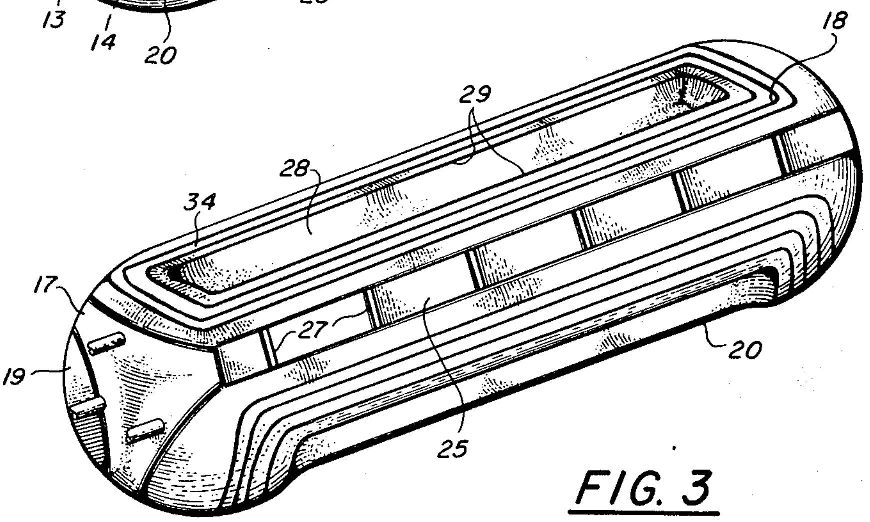


FIG. 3

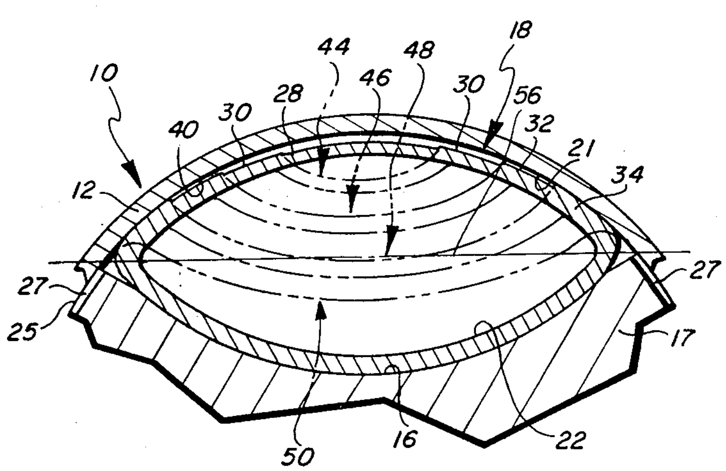


FIG. 2

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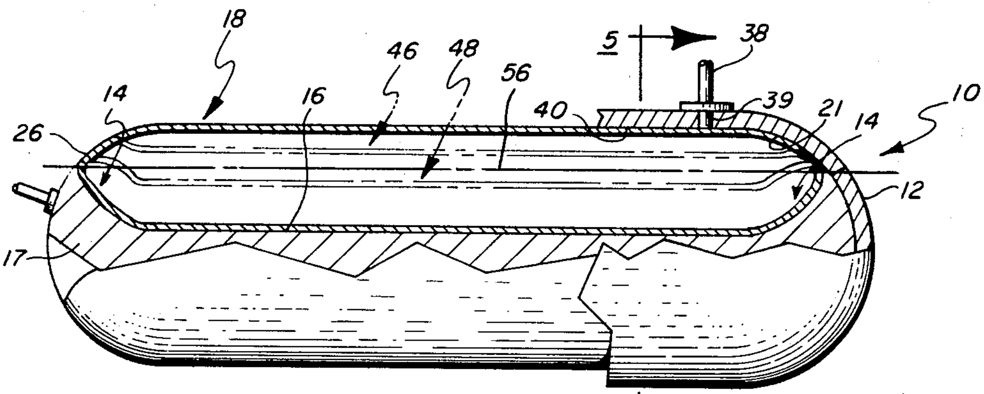

FIG. 4

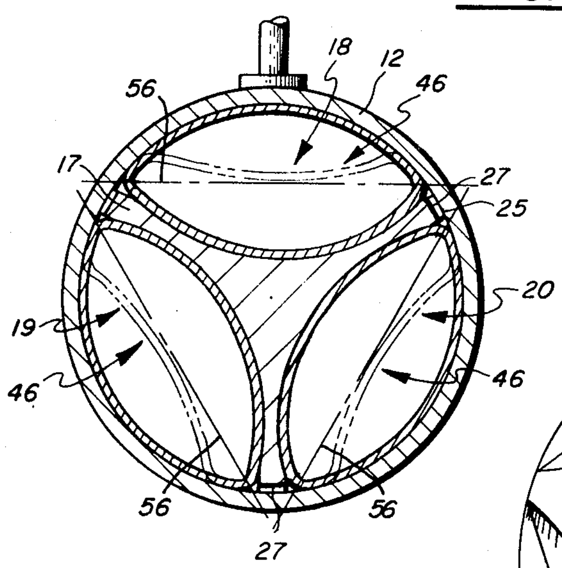

FIG. 5

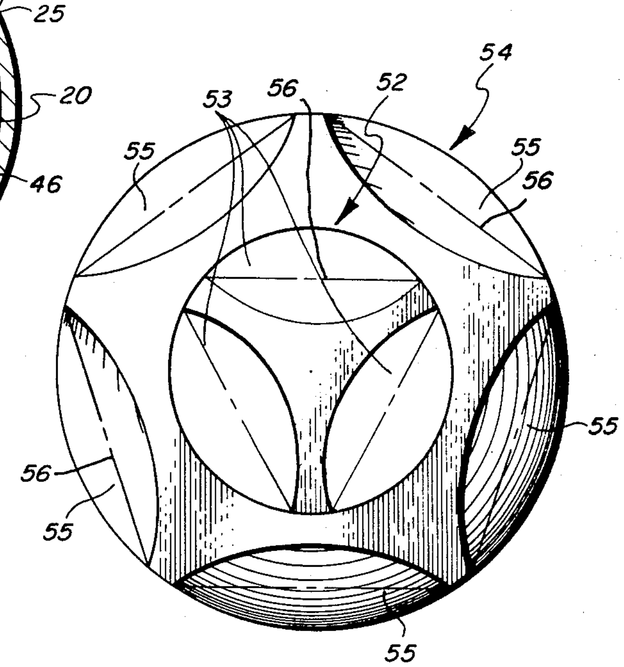

FIG. 6

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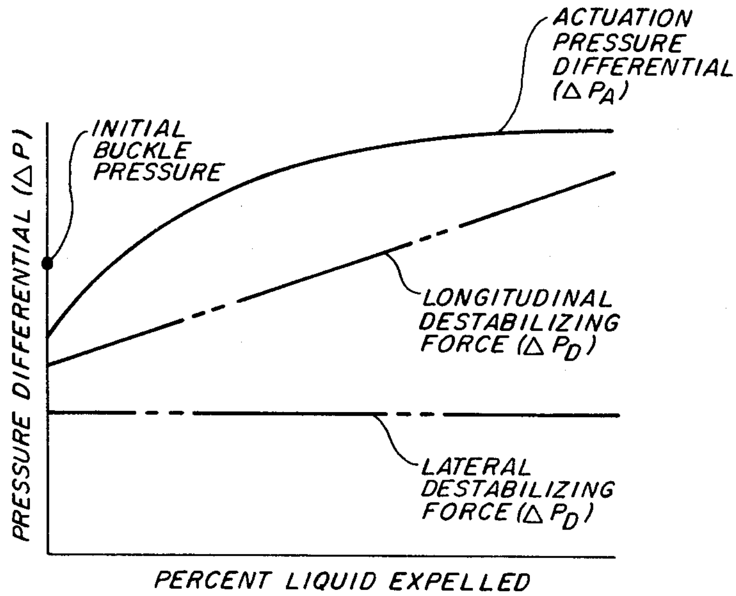

FIG. 7

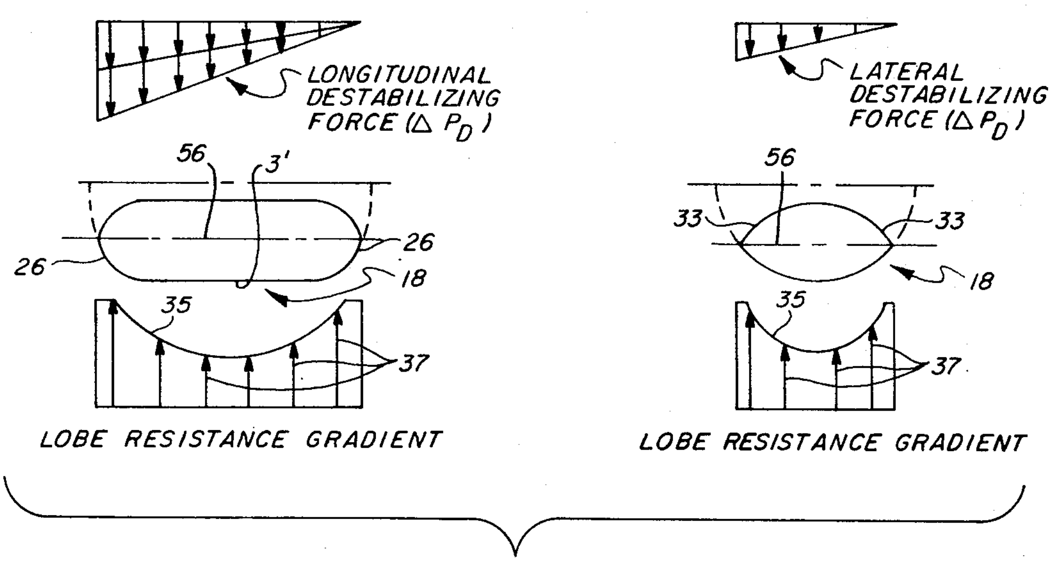

FIG. 8

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CONTROL FOLD LIQUID EXPULSION BLADDER

BACKGROUND OF THE INVENTION

Liquid expulsion devices have become increasingly important in the aerospace industry especially where long term storage of liquid propulsion systems are concerned. Present and future tactical and interceptor prepackaged liquid propulsion missiles require precise means to deliver liquid propellants to a propulsion engine with a minimum of variance. These prepackaged systems must be relatively impervious to the possible deteriorating effects of the propellants contained therein. Thus, the containment and expulsion bladder must be completely compatible with the particular propellants utilized. These systems require an external source of gas pressure to squeeze the liquid out of the bladder. Usually the bladder is contained within a tank shell and the gas pressure is subjected to the area between the inner wall of the shell and the outer wall of the bladder thereby collapsing the bladder and forcing the liquid propellant into the feed lines to the rocket engines.

There are many types of propellant expulsion bladders in the prior art. Among these include, for example, U.S. Pat. No. 3,286,878 which discloses a means to control the fold of a bladder when it is expelling liquid. A Teflon cigar-shaped bladder is formed over a pair of finger-like supports internally of and at opposite ends of the bladder so as to control the ultimate shape of the bladder when the propellant is expelled from the bladder.

U.S. Pat. No. 3,115,162 is an accumulator which basically is a tank with an intermediate rubberized bladder contained therein. A central support structure is positioned inside the bladder having four radially extending webs which control the ultimate shape of the bladder as it expells liquid through a central conduit. An external supply of gas pressure is directed into the accumulator between the interior wall of the accumulator and the outside wall of the bladder to force the liquid out of the accumulator.

U.S. Pat. No. 3,424,201 is similar to the foregoing patent in that it deals with an accumulator having an interior bladder with a central cross-shaped axially aligned support structure therealong. The bladder as it becomes depleted conforms to the shape of the internal structure.

All of the foregoing prior art patents suffer a common disadvantage in that the rigid support structures positioned within the flexible bladders merely control the ultimate shape of the expulsion bladders when they have expelled all of the liquid from the interior thereof. There is no control of the collapse of the expulsion bladder during the initial and intermediate stages of the expulsion process. Therefore, the bladder takes on any number of random shapes during this early expulsion cycle especially when the missile is subjected to maneuvering acceleration forces. Liquid is oscillated from one side to the other or skewed while a missile or the like is subjected to translational or pitching maneuvers along its flight path.

A still further disadvantage is that there is no means to prevent the bladders from reversing themselves under, for example, a very high "G" forces thereby causing additional problems to the expulsion system as well as the missile guidance system. Whenever there is a random uncontrolled collapse of an expulsion bladder, double and three-corner folds can occur causing unusually high stresses to the bladder material and subsequent failure. High terminal pressure drops also may occur due to the unpredictable folding of the bladders.

Accordingly, it is an object of this invention to provide a controlled collapse of an expulsion bladder.

More specifically, it is an object of this invention to provide a liquid expulsion bladder having programmed controlled collapsing modes.

SUMMARY OF THE INVENTION

The control-fold expulsion bladder basically consists of a liquid expulsion tank having two or more liquid containing lobes circumferentially placed around the interior of a tank. For example, a three lobe expulsion tank comprises an inner support structure forming three bays, each bay having a concave shape which is symmetrical about a reflection plane midway between the outer tank wall and under the support structure. Between the inner wall of the tank and the wall of the support structure are located, for example, three metallic bladders that conform to the shape of each lobe of the tank. Each of these bladders is filled with liquid propellant and the bladders conform to the walls of the central support structure and the inner wall of the outside containing tank. Gas under pressure is admitted to the area between the inner wall of the tank and the outer wall of the bladder so as to cause the bladders to deflect or buckle radially inwardly toward the center of the support structure. A gas passageway is provided to assure that pressurizing gas reaches each of the bladder lobes. In order to control the collapse of each of these bladders when they are subjected to external gas pressure, the wall thickness of the bladder is varied. The varying thickness is on the bladder surface that is juxtaposed to the inner surface of the tank. One way of varying the thickness of the bladder is by chemically milling sections of the bladder so as to provide controlled stages of expulsion. The chemical milling process is shown in U.S. Pat. No. 2,739,047. For example, there is a definite bladder configuration for each stage of the expulsion sequence. Since the bladder is symmetrical about the reflection plane the last stage of the expulsion mode ultimately terminates (collapses) in a "mirror image" of the lobe in its "full" (expanded) configuration, thus conforming to the concave shape of the tank support structure. Secondary buckles and double folds inherent in the prior art are avoided. Experience has shown that such double folds of the bladders during operation give rise to severe strains and result in reduced fatigue life and subsequent failure of the bladders. A varying wall thickness profile is designed to prevent bladder skewing or reversing during missile maneuvers which can subject the liquid to severe inertia or "G" forces. In addition, an escalating actuation gas pressure differential is provided greater than the destabilizing pressure gradients which would result during missile maneuvers. The increased pressure ultimately serves to prevent bladder reversal during the sequential depletion of each of the bladders.

An advantage over the prior art is the elimination of any chance for secondary buckles or double folds which can occur in random uncontrolled collapse of an expulsion bladder.

Another advantage over the prior art is the close control of each stage of expulsion of liquid from the interior of the bladder so as to maintain absolute control over the expulsion process.

DESCRIPTION OF THE DRAWINGS

The above noted objects and advantages of the present invention will be more fully understood upon a study of the following detailed description in conjunction with the detailed drawings in which:

FIG. 1 is a partially cutaway perspective view of the preferred embodiment of the invention illustrating one of the bladder lobes in cross-section;

FIG. 2 is a partially cutaway cross-section taken along lines 2—2 of FIG. 1 illustrating a lobe of the expulsion bladder in various alternative positions during the expulsion cycle;

FIG. 3 is a perspective view of the expulsion device illustrating the initial buckle of the bladders;

FIG. 4 is a partially cutaway section of the preferred embodiment showing one lobe of the three lobe expulsion device illustrating alternative positions of the bladder as it is being depleted of liquid;

FIG. 5 is a section taken along lines 5—5 of FIG. 4 illustrating the positions of the three lobes of the expulsion device;

FIG. 6 is an alternative embodiment illustrating concentric tanks wherein the inner tank contains a three lobe device and the outer tank contains a five lobe device;

FIG. 7 is a simplified graph illustrating the ΔP or pressure differential of the actuating gas pressure necessary to cause the bladders to sequentially collapse in a controlled manner during operation; and

FIG. 8 is a diagram of the external pressure differential against the bladder versus the destabilizing forces generated when the bladder is subjected to inertia forces.

Referring now to FIG. 1, the expulsion device generally designated as **10**, comprises an outer tank shell or container **12** having an inner support structure **17**. The elongated shell **12** shown has ellipsoidal shaped ends **13**. The support structure **17** is designed to accept, for example, three metallic bladders **18**, **19** and **20**. Symmetry about the reflection (median) plane **56** places the Concave surface **16** of support structure **17** equal in size to the inner surface **21** of tank shell **12**. Each of the bladders **18** through **20** nest within the shape defined by the inner wall **21** of tank **12** and the outer (concave) surface **16** of support structure **17** so that when the bladders **18** through **20** are collapsed, they form a configuration corresponding to the shape of that portion of the bladder juxtaposed to the concave surface **16**. To prevent a random collapse of each of the bladders, the outer surface **24** of bladder **18** is designed with a thickness profile which provides controlled steps of sequential collapse during the expulsion mode of the bladder. The thinnest section **28** of surface **24** is at the apex of bladder **18** and each of the intermediate steps **30**, **32** and the relatively thick section **34** propagate towards edges **18′** and ends **18″** of support structure **17**. The inner surface **22** adjacent surface **16** of support structure **17** is of a constant thickness comparable to the thickness of step **34** on outer surface **24**. The ends **26** of each of the bladders **18** through **20** conform to a concave surface towards the end **13** of support structure **17** so as to form a smooth sloping surface for the bladders to fold against.

In operation, each of the bladders **18** through **20** are filled with an incompressible liquid. During the expulsion mode, gas under pressure enters through conduit **38** and opening **39** into annular space **40** defined by the inner wall **21** of container **12** and the outer skin of the expulsion bladders. The gas pressure is increased until an initial buckle occurs in each lobe of the bladder as it is indicated in FIG. 3. The relationship of buckle pressure vs. percent of liquid expelled will be discussed later on in the specification. By providing a thin section **28**, the buckle initially occurs in this section and is encouraged to propagate towards the ends **13** by following the ridge lines **29** running parallel to each other longitudinally down the length of the tank **12**. It should be noted here that the ridge lines can take on any number of designs depending upon the desired collapse modes and particular design parameters to be met. The initial stage of the expulsion mode occurs in section **28** down its entire length as is indicated more clearly in FIG. 3. FIG. 2 illustrates the initial buckle **44** as well as subsequent modes or stages **46**, **48** and **50**. As the escalating pressure increases in annular space **40** the second mode or stage of expulsion occurs at alternative position **46**, again being controlled by the ridge or thickness separation lines as is indicated at **29**. Thus, it can be seen there is a simultaneous and controlled collapse through various stages designed into each of the bladders **18** through **20**. To insure that each of the three bladders is subjected to the same actuating gas pressure, passageways or openings **27** are notched into surfaces **25** of support structure **17** as shown in FIGS. **1**, **2**, **3** and **5**. Referring again to FIG. **2**, the last stage when virtually all of the liquid is expelled from the bladder is indicated in the alternative position **50** of the bladder **18**. The collapse of the bladder eliminates any possibility of overstressing the bladder material caused by double folds sometimes resulting in catastrophic failures of the bladders.

Turning to FIG. **4** the sectional view illustrates the expulsion device **10** basically depicting how the ends **26** of bladder **18** conform to a symmetrical section taken from a median reflection plane **56** formed between the concave portion **14** of the support structure **17** and the outer cylinder **12**. The bladder **18**, being symmetrical in shape about a median reflection plane **56** in both the end cross-section and the side cross-section, assures that the outer surface of the bladder can fold against itself forming a "mirror image" of the bladder.

As each of the bladders goes through its expulsion modes, the escalating pressure differential of ΔP assures that each step occurs simultaneously and, as the bladders **18** through **20** reach their depletion state, the pressure differential need not be as high as during the initial buckle phases since the folds of each of the stages of expulsion are controlled, thus less pressure is needed to finally deplete each of the three lobes. Since each lobe is collapse controlled as it is expelling liquid there is no need for an increased pressure to compensate for a double fold condition with can build in a tremendous resistance to bladder expulsion as is the case in uncontrolled bladder liquid expulsion. A randomly folding bladder requires a very high pressure to make it expel liquid; the more depleted the bladder becomes, the more severe the folds become, consequently requiring a much larger pressure differential to overcome the double and triple folds of the bladder. Thus, it is a unique feature of the instant invention in that the pressure differential actually goes down or tapers off towards the depletion stage of each of the lobes of the bladders.

Experimental tests have shown 90 to 98 percent liquid expulsion efficiencies in the bladders of the present invention.

Turning now to FIG. 5, it can be seen that the three lobes **18**, **19** and **20** are positioned approximately 110° apart within tank shell **12**, each of the lobes conforming to support structure **17**. Each of the bladder lobes **18** through **20** being in communication with annular space **40** via channels **27** are equally and simultaneously depleted of liquid as is indicated in alternative positions **46**.

A typical bladder lobe **18** may be formed, for example, from 1,100–0 aluminum, have a longitudinal dimension of from 35 to 40 inches long and have a radius of from 8 to 10 inches. The lobe is preferably chemically etched to the following dimensions: the thinnest section **28** to 0.030 inch; section **30** to 0.045 inch; section **32** to 0.075 inch and section **34** to 0.125 inch. The external actuation gas pressure feeding into conduit **38** through opening **39** into annular space **40** of tank **12** can, for example, range from a low of 45 psid to a high of 80 psid to expel liquid from a tank lobe fitting the dimensional tolerances just described. The pressure differential is sufficient to assure complete collapse of the bladders, as will be more fully explained with reference to FIGS. **7** and **8**.

Referring now to FIG. **6**, an alternative embodiment illustrates concentric tanks that may be used in a bipropellant propulsion system of a missile. The inner tank is filled with an oxidizer while the lobes of the outer concentric tank contain a fuel. The inner tank indicated as **52** comprises a three lobe bladder system **53** as previously described while the outer concentric tank generally designated as **54** is comprised of a five lobe bladder tank system, each of the lobes indicated as **55**. The number of lobes in the outer ring of the alternative embodiment is basically determined by the diameter or radius of the outer tank so that each of the lobes can be formed in a symmetrical manner.

A key feature of the controlled bladder design, combined with thickness programming, is escalation of actuation pressure differential (energy required to deflect or move the bladder). The combination is instrumental in controlling the sequence of bladder movement to provide simultaneous fluid flow from each lobe as well as counteracting inertia forces. FIG. **7** illustrates the relationship between pressure differential (ΔP) and percentage fluid expelled (bladder movement). The solid curved line depicts the escalating actuation pressure differential (ΔP_A) required for bladder movement (radially inward) and resistance to inertia forces (that can cause bladder skewing or reversing). Design equations have been derived which enable prediction of ΔP_A. Design then resolves itself to selecting a sequence of controlled bladder movements and programming a thickness profile to attain the desired escalating ΔP_A. Inertia loads (resulting from missile maneuvers) superimpose a destabilizing pressure gradient, equal to the pressure head (ρGh), on the liquid pressure within the bladder. The destabilizing pressure gradients (ΔP_D) are shown as dotted lines in FIG. **7**. The gradient increasing linearly with time (percent liquid expelled) is produced as the missile accelerates or decelerates along its flight path. The horizontal dotted line depicts the gradient produced by lateral displacement or pitching of the missile. Bladder skewing or reversing is prevented by designing ΔP_A to be greater than ΔP_D, thereby assuring control of the center of gravity.

FIG. **8** diagramatically shows the inertia or destabilizing forces (ΔP_D) both longitudinally and laterally that may be imparted to the expulsion bladder **18**. The curved line **35** with attending arrows **37** adjacent the side elevational and end view of the bladder **18** represent the resistance to the longitudinal and lateral destabilizing forces built into the bladder. The long arrows **37** represent a high resistance to the inertia forces (bladder is thicker in cross-section at end **26**) and the short arrows represent a low resistance at center **31** (thin cross-section). By programming the thickness of each stage or section of the bladder and by providing a sufficient pressure differential, it can be seen that any destabilizing tendency of the liquid within the bladder caused by external inertia forces is resisted regardless of the percent of liquid depleted or expelled from the bladder.

Since the bladder resists longitudinal and lateral destabilizing forces more towards its ends **26** and sides **33** than its center **31**, a shift in the change of the center of gravity is resisted obviating a serious problem (unstable center of gravity location) formerly associated with randomly collapsing liquid expulsion bladders.

Any drastic change of center of gravity could cause disastrous results necessitating destruction of the vehicle due to erratic flight. The controlled fold aspect of the invention prevents any shift in the center of gravity and also, more importantly, prevents any random folding which could cause a catastrophic failure in the bladders.

Obviously the lobes of the expulsion device could be contoured differently than described and the method of providing varying wall thickness could involve other techniques, for example, the lobes of the tank could be explosively formed into a mold pattern in such a manner as to cause the apex of the lobe to be thin, the wall gradually thickening towards its outer edge. In addition each lobe could be fabricated of a material other than metal.

I claim:

1. A liquid expulsion device comprising:

a cylindrical hollow container,

a support structure longitudinally disposed within said container, said support structure forming at least a concave wall paralleling the axis of said container, said concave wall and a portion of an inner wall of said container together forming an open bay which is symmetrical about a median plane, and

a collapsible bladder formed to nest within said bay, said bladder having a first wall with a varying wall thickness from thin to thick from a central area to edge areas thereof and a second wall of a constant wall thickness integral with and opposite to said first wall, said bladder when subjected to a source of external pressure being caused to buckle in a radial direction starting at the thinnest section of said first wall propagating towards the thicker section, thereby causing said first wall to fold against said second wall in a controlled manner to expel liquid contained in said bladder.

2. The invention as set forth in claim 1 further comprising:

means to connect the volume between the inner periphery of said container and the outer periphery of the bladder to said source of external pressure, said pressure being produced by gas, the gas being directed into said container between the inner wall of said container and the outer wall of said bladder to cause said bladder to buckle in a radial direction.

3. The invention as set forth in claim 1 wherein said first wall of said bladder is comprised of stepped sections having longitudinally extending ridges separating said sections, each successive section being thicker in cross-section as the wall descends from the apex of said bladder.

4. The invention as set forth in claim 3 wherein said bladder is comprised of aluminum, said aluminum being chemically milled forming said stepped sections.

5. The invention as set forth in claim 1 wherein said support structure forms three longitudinally extending bays, each of said bays containing bladders from 105° to 120° apart.

6. The invention as set forth in claim 1 further comprising a second cylindrical hollow container independent of and concentric with said first mentioned container, said second container being housed within said support structure of said first container, the second container having a support structure longitidinally disposed within the container, wherein an open bay is formed symmetrical about a median plane between said support structure and said second container which nests therein, a collapsible bladder having a varying wall thickness for the purpose of expelling a second liquid contained within said second container when said bladder is subjected to a source of external pressure.

7. A liquid expulsion device comprising:

a cylindrical hollow container,

a support structure longitudinally disposed within said container, said support structure forming three concave walls from 105° to 120° apart paralleling the axis of said container, each of said concave walls together with a portion of the inner wall of said container forming a bay which is symmetrical about a median plane, said inner wall of said container and said concave walls of said support structure forming three open bays,

a collapsible bladder formed to nest within each of said bays, said bladder having a first wall with a varying wall thickness from thin to thick from a central area to edge areas thereof and a second wall of constant wall thickness integral with and opposite to said first wall, and

means to connect the volume between the inner periphery of said container and the outer periphery of the bladder to a source of gas pressure, said gas pressure being directed into said container between the inner wall of said container and the outer wall of said bladder to cause said bladder to buckle radially inwardly starting at the thinnest section of said first wall propagating towards the thicker section thereby causing said first wall to fold against said second wall in a controlled manner to expel liquid contained in said bladder.

8. A liquid expulsion device comprising:

a hollow container,

a collapsible bladder within sad container, said bladder having at least one bladder wall with a varying wall thickness from thin to thick from a central area to edge areas thereof, said bladder wall being positioned adjacent an inner wall in said hollow container, said bladder when subjected to a source of external pressure being caused to buckle inwardly starting at the thinnest section propagating towards the thicker section thereby causing said bladder wall to fold in a controlled manner against an opposite inner wall of said container to expel liquid contained in said bladder.

9. The invention as set forth in claim 8 further including an internal support structure within said container and forming said opposite inner wall, said opposite inner wall being concave in curvature, said bladder having a second bladder wall of greater stiffness than said bladder wall of varying wall thickness, said second bladder wall being integral with said first bladder wall and nesting within the opposite concave inner wall, said inner wall together with said opposite inner wall forming a bay which is symmetrical about a median plane.

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