June 13, 1967 J. F. SCHIRTZINGER 3,324,917

EXPANSIBLE AND SELF-FOLDING CONTAINER

Filed Oct. 26, 1964

4 Sheets-Sheet 1

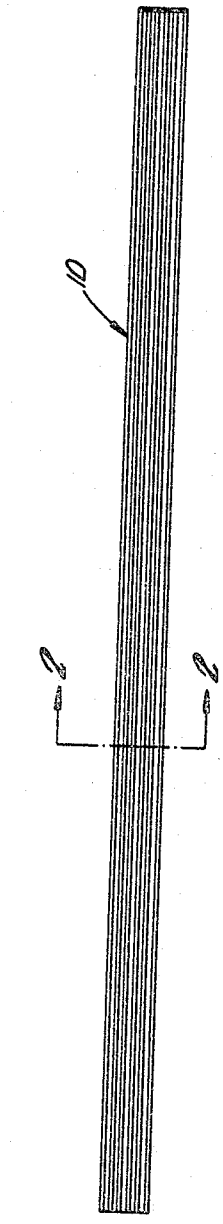


FIG. 1.

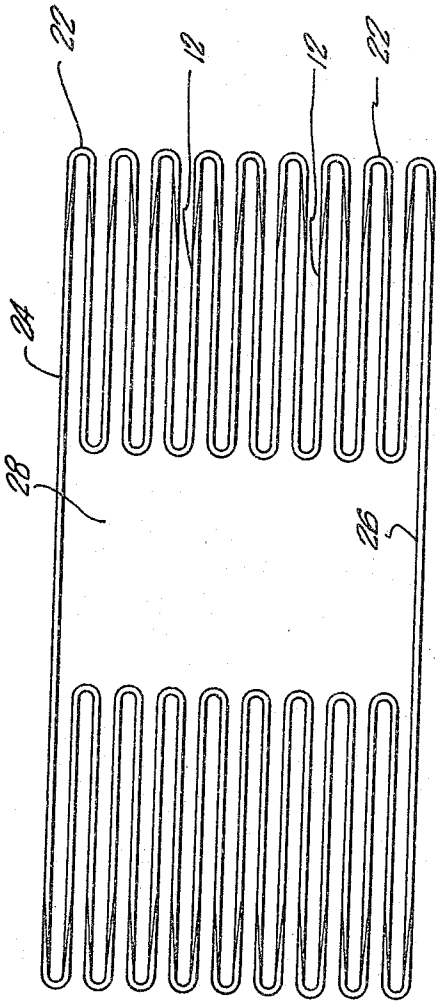


FIG. 2.

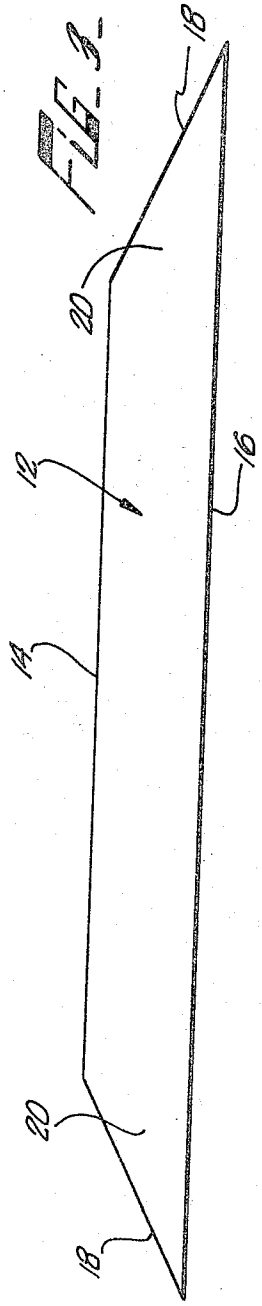


FIG. 3.

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4 Sheets-Sheet 2

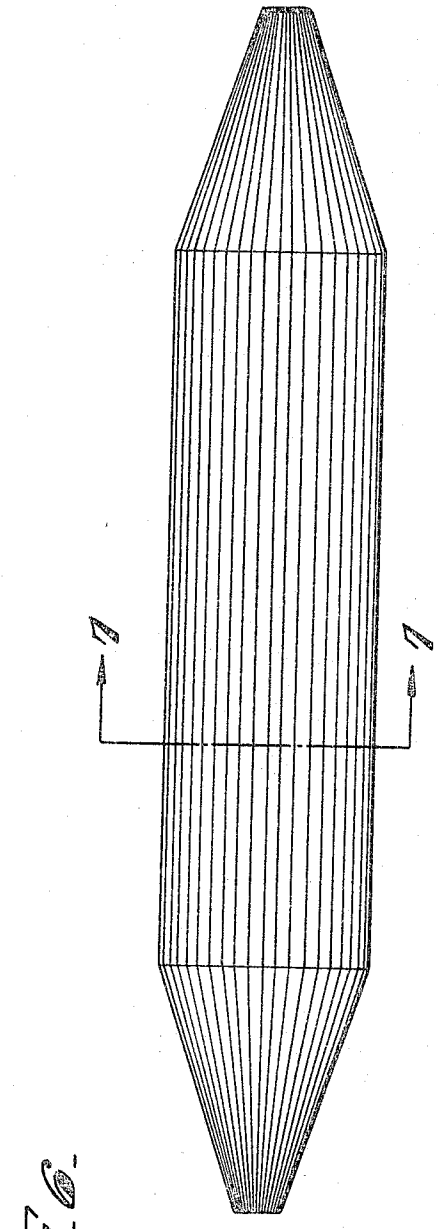


FIG. 6.

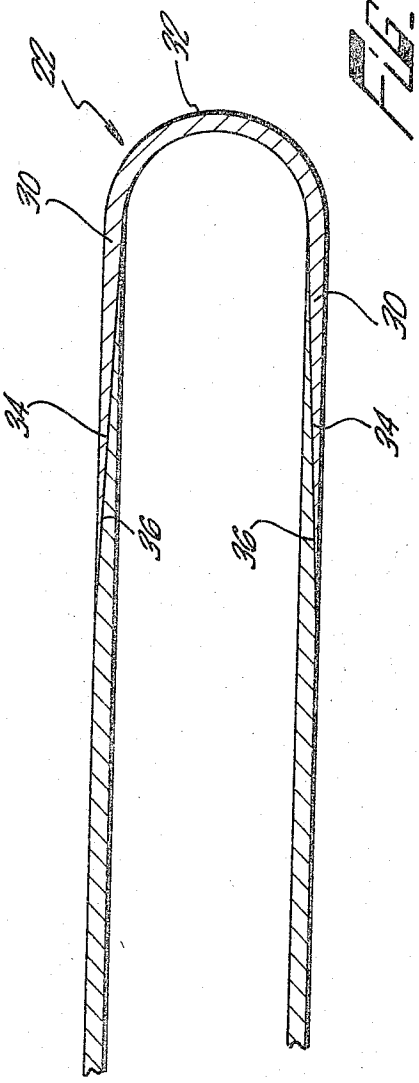


FIG. 4.

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4 Sheets-Sheet 3

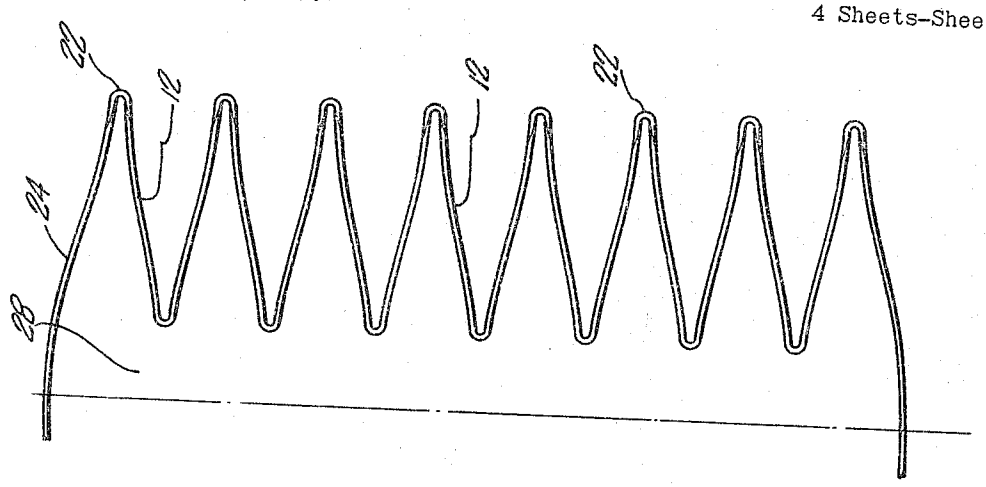


FIG. 5.

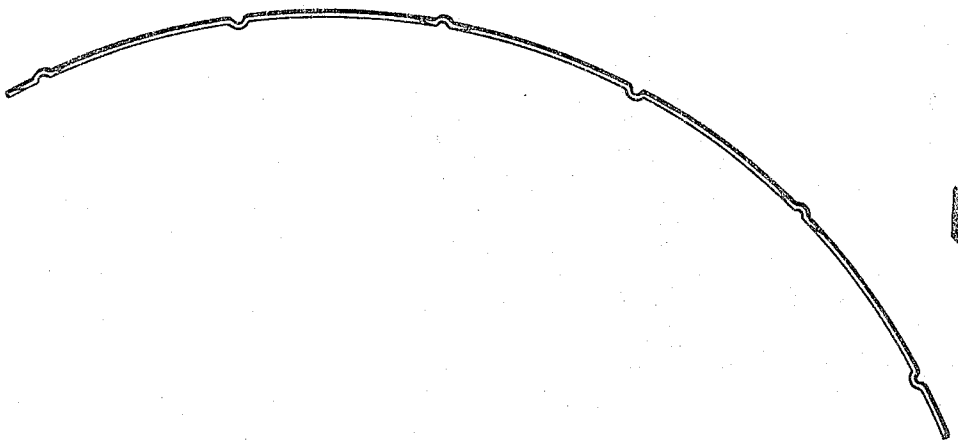


FIG. 7.

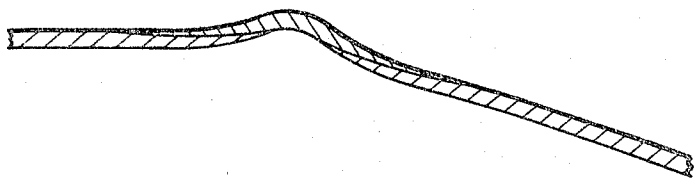


FIG. 6.

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4 Sheets-Sheet 4

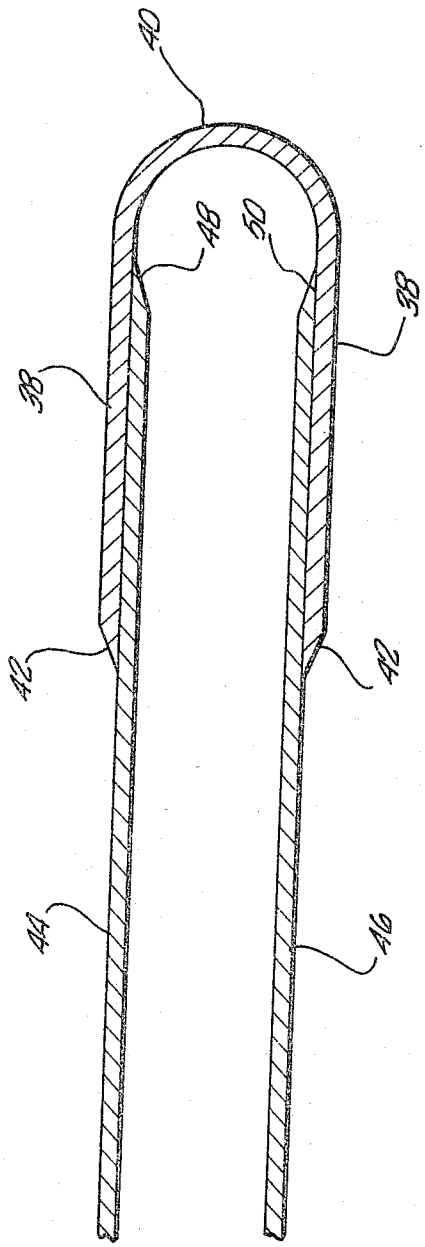


FIG. 9.

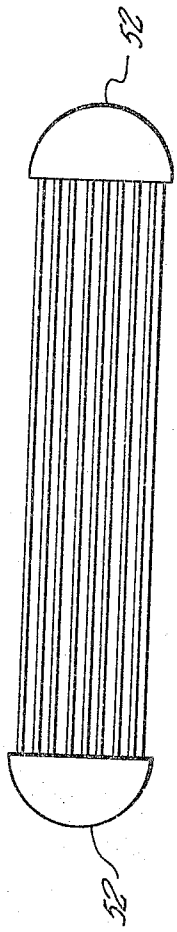


FIG. 10.

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3,324,917

EXPANSIBLE AND SELF-FOLDING CONTAINER

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Filed Oct. 26, 1964, Ser. No. 406,506
5 Claims. (Cl. 150—1)

This invention relates to containers and, more particularly, to containers which are expansible by pressure from within the container, and are self-folding upon removal of the pressure.

Containers which can be expanded to over-all dimensions sufficient to accommodate a large volume of material to be shipped, and can then be folded when empty to substantially reduce over-all dimensions, are utilizable in a variety of situations. Areal needs often require one-way material transport with the result that containers used to bring in a material must be returned empty. Where a large bulk of material is involved, as in the case of transport of liquids, such as petroleum products, chemical products, or fresh water, the economic disadvantages attendant upon return of empty containers retaining their filled dimensions can in many instances make the transport of such materials unfeasible. For example, water transport of liquids in towed containers can be rendered uneconomical if it becomes necessary to return the empty containers in their original dimensions to the point of departure. This is particularly true where the return trip involves adverse oceanic or river currents. Comparable situations exist in transport of liquids by air, truck and trailer, or rail.

The present invention provides a container of high structural strength which is expansible to large over-all dimensions and is self-folding as emptied so that it assumes substantially reduced over-all dimensions. Although its use is not so limited, the structural strength and self-folding characteristics of the container of the present invention make it particularly adaptable for water transport of liquids in large quantities not previously contemplated.

The present invention is an expansible and self-folding container comprising a plurality of sheets, each having two longitudinal edges. Plastic means are provided to join each edge of each sheet to an edge of another adjacent sheet to produce a substantially corrugated pattern of sheets in the folded position. At the ends of the sheets, means are provided to define with the sheets an enclosure. The joining means are of a plastic having a high ratio of tensile strength to tensile modulus of elasticity. Upon application of pressure within the enclosure, the joining means are opened and thereby enable the container to be expanded to a substantially elliptical cross-section without permanent deformation of the joining means. Its characteristics enable the joining means to return the container to the folded position upon removal of the pressure.

In one embodiment of the invention, the folded cross-section of the container consists of first and second pluralities of plastic sheets, each in a substantially corrugated pattern of sheets in the folded position. A wider first plastic sheet is joined at its longitudinal edges to an edge of the top sheet in each of the pluralities. A second plastic sheet, equal in width to the first sheet, is joined at its longitudinal edges to an edge of the bottom sheet in each of the pluralities. In this manner, the over-all dimensions of the folded container are reduced.

The materials from which the joining means of the containers of the present invention are made are characterized by a capability of storing energy without hysteresis loss. The structural requirement of a high ratio of tensile strength to tensile modulus of elasticity for the joining means is particularly found in filament-reinforced laminated thermosetting plastic materials. Reinforcement of

such materials is achieved by a parallel array of natural or synthetic filaments in each of the lamina. In the laminated structure, the filaments of a given lamina are oriented crosswise to the filaments in the overlying and/or underlying lamina. A preferred form of plastic material, sold under the mark "Stratoglas," consists of fiber glass filaments bonded together with an epoxy resin to provide a reinforced laminated plastic. The material possesses an unusual combination of structural strength and impact resistance. Its flexural characteristics and moldability permit forming of joints which produce longitudinal folds in the container as the contained liquid is withdrawn, and enable the container to assume an elliptical or circular cross-section as it is filled.

The container of the present invention and the manner of its use will be better understood from the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is an elevational view of one embodiment of the container of the present invention in a folded position;

FIG. 2 is an enlarged sectional view showing the container as seen along line 2—2 of FIG. 1 in a folded position;

FIG. 3 is a plan view of a plastic sheet removed from the container of FIG. 1;

FIG. 4 is an enlarged fragmentary view showing an embodiment of a joint used to join the plastic sheets of the container in FIG. 1;

FIG. 5 is an enlarged fragmentary sectional view generally taken along line 2—2 of FIG. 1 and showing a portion of the container in a partially expanded position;

FIG. 6 is a side elevational view of the container in its fully expanded position;

FIG. 7 is a fragmentary sectional view generally taken along line 7—7 of FIG. 6 after the container is in a fully expanded position;

FIG. 8 is an enlarged fragmentary view showing one of the joints and its associated sheets after the container is in a fully expanded position;

FIG. 9 is a fragmentary view showing another embodiment of a joint for joining the edges of the plastic sheets with the sheets in the folded position; and

FIG. 10 is a side elevational view of another embodiment of a container according to the present invention.

With reference to FIGS. 1 and 2, a container **10**, shown in its folded position, is formed from a plurality of flat sheets **12**, of which one is shown in plan view in FIG. 3. The sheets are preferably formed of the same reinforced plastic material as the joints, which will be described. Since the sheets are not subject to an unusual amount of bending upon expansion, other more rigid materials may be employed for some containers. However, for unusually large containers, the inherent structural characteristics of the reinforced plastic materials enable use of a thin wall structure which provides a basic economy in material costs.

As shown in FIG. 3, each sheet includes a longitudinal edge **14** and a longer parallel longitudinal edge **16**. The longitudinal edges are joined by angled edges **18** to provide a tapered end portion **20** at opposite ends of sheet **12**. It will be understood that edges **18** may also be curved to provide tapered end portions.

As particularly shown in FIGS. 1 and 2, each sheet **12** is joined along longitudinal edge **14** and angled edges **18** to the corresponding longitudinal edge and angled edges of an adjacent sheet by a joint **22**, to be described. Similarly, longitudinal edge **16** is joined to the corresponding longitudinal edge of another adjacent sheet. The sheets are joined to provide a series of longitudinal folds. In cross-section, as shown in FIG. 2, the structure appears as two pluralities of sheets, each in a substantially corrugated pattern. An upper sheet **24**, which is substantially wider

than sheets **12**, is joined at its longitudinal edges to a longitudinal edge of the uppermost sheet **12** in each of the pluralities. A lower sheet **26** is similarly joined to a longitudinal edge of the lowermost sheet **12** in each of the pluralities.

Joining of angled edges **18** of adjacent sheets at opposite ends of the sheets produces an envelope which defines an enclosure **28** within which fluids can be contained. The described structure can be made in a variety of sizes and may be utilized to provide containers of unusually large capacity. The container may be formed from reinforced plastic sheets, four to six feet in width and as long as required to meet the intended utilization.

The sheets are joined at their longitudinal edges by joints **22**, of which one embodiment is shown in enlarged detail in FIG. 4. This joint is molded from a reinforced laminated plastic material such as the product already described as sold under the trademark "Stratoglas." Sheets having an average thickness of about 1/16" (0.060") can be used, and such sheets, consisting of oriented lamina of parallel glass filaments bonded by an epoxy resin, provide a flexural yield strength as high as 180,000 p.s.i. in the direction of the filaments. The joint is formed by transversely folding a longitudinal strip upon itself to provide in cross-section a pair of parallel legs **30** extending from a curved closure **32**. A scarf **34** is formed in the interior surface of each of the legs, and a corresponding scarf **36** is formed in each of the longitudinal edges and angled edges of the plastic sheet. A scarf joint is produced between each leg of joint **22** and the plastic sheet longitudinal edges and angled edges by bonding the corresponding scarfs together with a suitable resin or the like.

It will be understood that joints corresponding in shape to joint **22**, as shown in FIG. 4, can be integrally formed with plastic sheets having the characteristics requisite for the joint material. With larger containers, however, it is more convenient to form the joints separately and secure them to the plastic sheets, as has been described.

As to the material from which the joints are formed, the ratio (δ_M/E) of the maximum bending stress (δ_M) to the modulus of elasticity (E) should be as high as possible. It can be shown that this ratio can be equated to the ratio (T/R) of the thickness of the material (T) to the radius of bend (R) of the joint. To meet many utilizations of the container of the present invention, the thickness must be great enough to provide the requisite strength while the radius of bend must be small enough to provide minimum over-all dimensions in the folded position of the container. Filament-reinforced laminated plastic materials of the type described meet these requirements. Their δ_M/E ratio is between 0.03 and 0.04. With a material thickness of 0.1", a radius of bend between 2.5" to 3.3" can be obtained with retention of the self-folding characteristic.

After enclosure **28** within the container is, in its unexpanded position, filled with liquid, the force exerted on the interior surfaces of plastic sheets **12** as additional liquid is forced under pressure into the chamber begins to expand the container. The sheets are moved outwardly between their longitudinal edges as the joints are opened. FIG. 5 shows the container in a partially expanded position. Continued addition of liquid expands the container to the fully expanded position shown in FIG. 7. The container has a substantially circular cross-section in this position. As particularly shown in FIG. 8, the flexural modulus of the joint material enables the joints to be opened so that each leg of the joint is displaced from each other almost 90° from its position when the container is in a folded position. However, even with this degree of bending, the yield point of the material is not exceeded so that no permanent deformation of the joints and sheets defining the enclosure takes place. Once the container has been transported to its destination and the enclosure is emptied, with attendant removal of pressure, the container

returns to the initial folded position shown in FIGS. 1 and 2.

Upon expansion of the container to its fully opened position, the angled edges of the adjacent sheets produce conical or tapered sections at opposite ends of the container. This is particularly shown in FIG. 6.

With reference to FIG. 9, an alternative embodiment of a joint for joining the longitudinal edges of the sheet is shown. The joint is formed by transversely folding a longitudinal strip upon itself to provide in cross-section a pair of parallel legs **38** extending from a curved closure **40**. A scarf **42** is formed in the exterior surface of each leg. A portion of the surface of a plastic sheet **44** adjacent a longitudinal edge is bonded to the interior surface of one leg, and another plastic sheet **46** is similarly bonded to the other leg. A scarf **48** is formed in the interior surface of sheet **44**, and a scarf **50** is formed in the interior surface of sheet **46**. The scarfs are not utilized to form joints but provide a smooth transitional joinder in the inner and outer surfaces of the container. The joint shown in FIG. 9 is made of the same type of material as has been previously described. The joint responds to pressure and exhibits a self-folding characteristic, as has already been described with reference to the joint shown in FIG. 4.

The data provided in the table below show the force in pounds per linear inch required to expand a container having its joints made from 0.1" thick Stratoglas filament reinforced laminated plastic to different degrees of expansion where the radius of bend of the joints is 3 inches:

Percent expansion of container:	Force lbs./linear inch
50	2.7
92	6.9
96	10.6
100	44

Although it is generally preferred that sheets be shaped so that a means for completing an enclosure is integrally formed, flat sheets without end portions **20** of FIG. 3 may be joined together, as already described. In such an embodiment, resilient diaphragms **52** are joined to the ends of the sheets, as shown in FIG. 10. A neoprene-nylon material can be used to form the diaphragms, which, when the container is in the collapsed position such as illustrated in FIG. 1, are folded in a manner similar to a folded parachute. Expansion of the sheets to the circular cross-section previously described acts to stretch the diaphragms. In the fully expanded position, the cylindrical container shown in FIG. 10 is obtained.

What is claimed is:

1. An expansible and self-folding container comprising:

(a) a plurality of sheets, each having two longitudinal edges;

(b) reinforced plastic means joining each edge of each sheet in the plurality to an edge of different adjacent sheets to provide a substantially corrugated pattern of sheets in a folded position; and

(c) means at the ends of the sheets to define a fluid-tight enclosure together with the sheets and the joint means;

(d) said plastic having a high ratio of tensile strength to tensile modulus of elasticity enabling the joining means to be opened to expand the container to a substantially elliptical cross-section by pressure from within the enclosure and further enabling the joining means to return the container to the folded position upon removal of the pressure.

2. An expansible and self-folding container comprising:

(a) a plurality of sheets, each including a longitudinal edge, a longer longitudinal edge and a tapered edge at each end joining the longitudinal edges;

(b) plastic means joining the longer longitudinal edges of adjacent sheets to provide an inward longitudinal

fold in a substantially corrugated pattern of sheets in a folded position;

(c) plastic means joining the longitudinal edge and the tapered edges of adjacent sheets to provide an outward fold in said corrugated pattern;

(d) said joined sheets forming an envelope defining an enclosure and having tapering closed ends in an expanded position;

(e) said plastic having a high ratio of tensile strength to tensile modulus of elasticity enabling the joining means to be opened to expand the container to a substantially elliptical cross-section by pressure from within the enclosure and further enabling the joining means to return the container to the folded position upon removal of the pressure.

3. Container in accordance with claim 2 wherein the plastic material is a reinforced plastic including lamina of parallel fiber glass filaments bonded by a resin.

4. An expansible and self-folding container comprising:

(a) a plurality of sheets, each having two longitudinal edges;

(b) a plastic joint including a pair of legs extending from a curved closure,

(i) each leg of the joint being joined to an edge of a sheet along its longitudinal extent to provide a plurality of alternating inward and outward longitudinal folds in a substantially corrugated pattern of sheets in a folded position; and

(c) means at the ends of the sheets to define a fluid-tight enclosure together with the sheets and the joints;

(d) said plastic having a high ratio of tensile strength to tensile modulus of elasticity enabling the joints to be opened to expand the container to a substantially elliptical cross-section by pressure from within the enclosure and further enabling the joints to return the container to the folded position upon removal of the pressure.

5. An expansible and self-folding container comprising:

(a) first and second pluralities of plastic sheets, each having two longitudinal edges;

(b) plastic means joining each edge of each sheet in each plurality to an edge of different adjacent sheets to provide a substantially corrugated pattern of sheets in a folded position;

(c) a first plastic sheet joined at its longitudinal edges to an edge of a sheet in each of the pluralities;

(d) a second plastic sheet joined at its longitudinal edges to an edge of another sheet in each of the pluralities;

(e) means at the ends of the sheets of the first and second pluralities and of the first and second sheets to define a fluid-tight enclosure with the sheets and joining means;

(f) said plastic having a high ratio of tensile strength to tensile modulus of elasticity enabling the joining means to be opened to expand the container to a substantially elliptical cross-section by pressure from within the enclosure and further enabling the joining means to return the container to the folded position upon removal of the pressure.

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