Oct. 22, 1968 R. G. JACKSON 3,406,858

CONTAINERS FOR COLD LIQUIDS

Filed Nov. 15, 1965 3 Sheets-Sheet 1

FIG. 1.

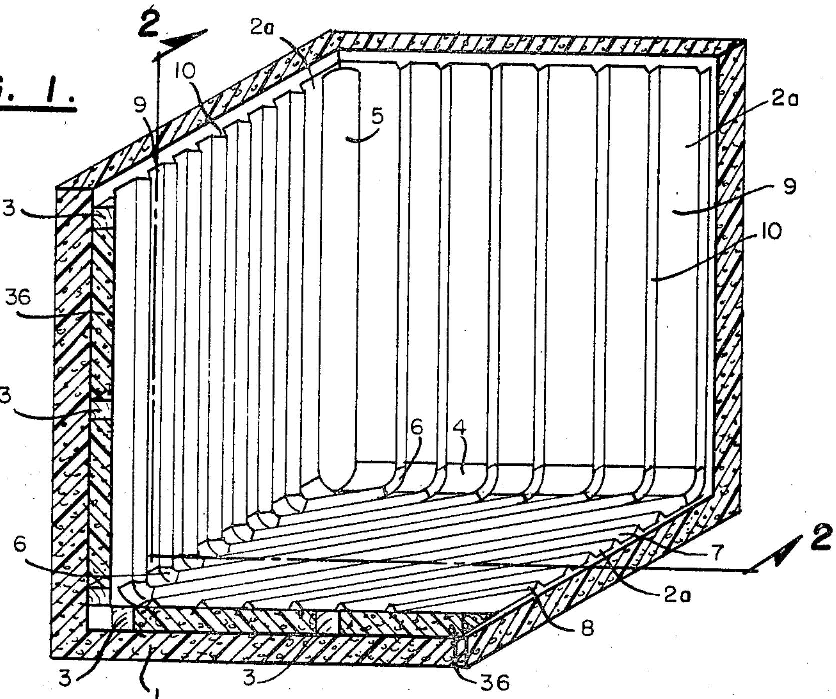
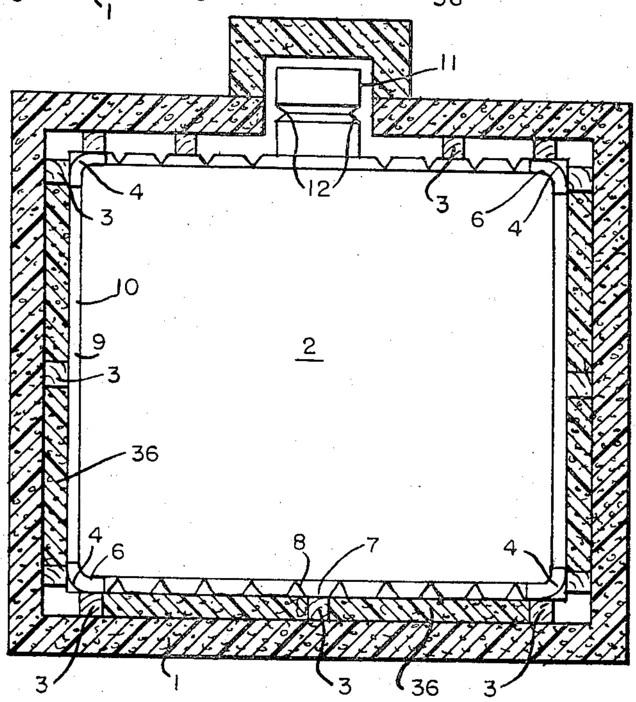


FIG. 2.



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CONTAINERS FOR COLD LIQUIDS

Filed Nov. 15, 1965 3 Sheets-Sheet 2

FIG. 4.

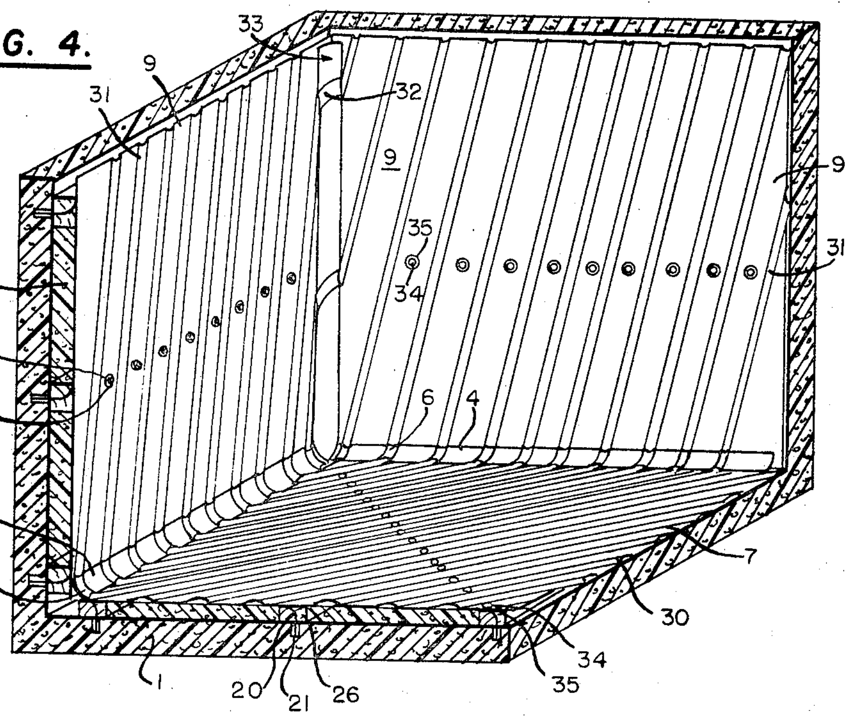


FIG. 1A.

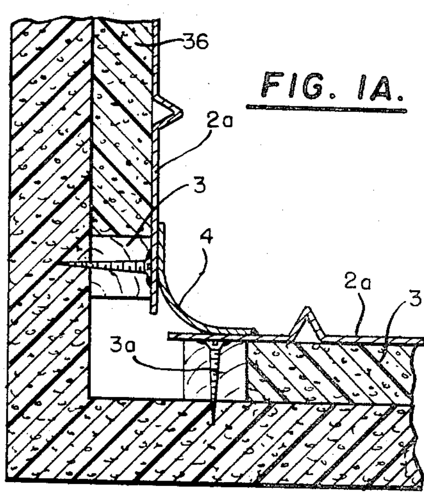
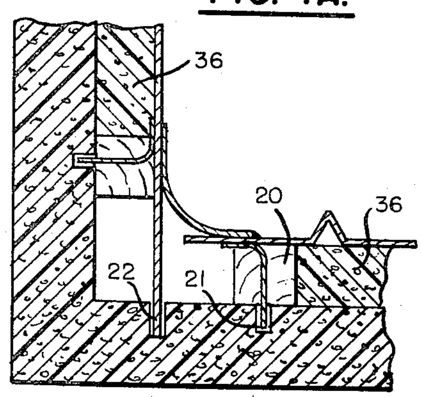


FIG. 4A.



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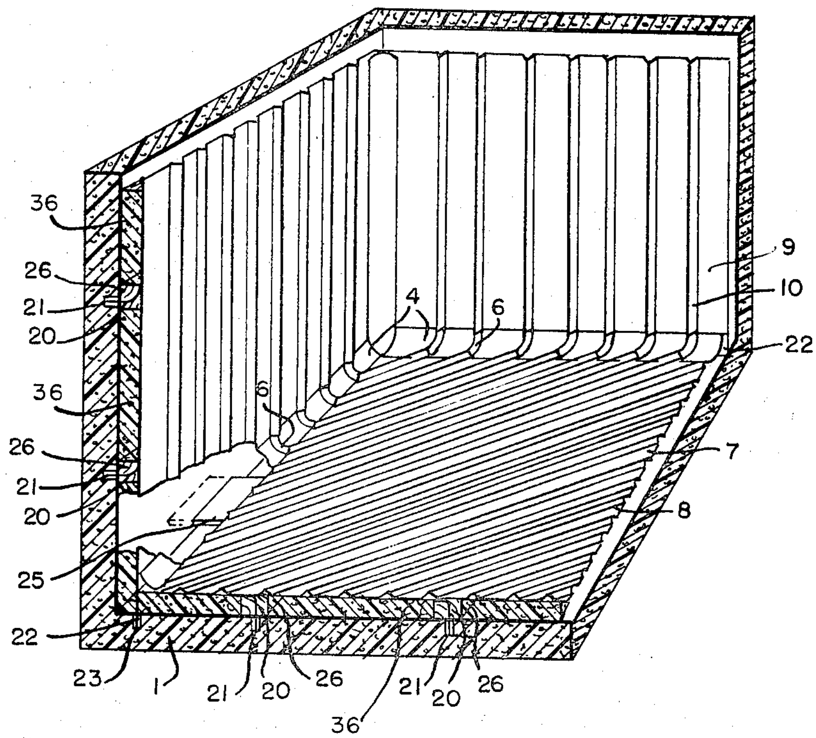
Oct. 22, 1968 R. G. JACKSON 3,406,858

CONTAINERS FOR COLD LIQUIDS

Filed Nov. 15, 1965 3 Sheets-Sheet 3

FIG. 3.



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CONTAINERS FOR COLD LIQUIDS

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12 Claims. (Cl. 220—9)

ABSTRACT OF THE DISCLOSURE

A membrane tank for cryogenic liquids, in which a metal membrane is fully supported by a layer of insulating material, and the membrane walls are of a material having a ratio of elastic stress to thermal stress (over the temperature range to which the tank is subjected) of at least one. The metal membrane walls have distributed thereon a plurality of spaced-apart generally parallel expansion-absorbing corrugations, with completely smooth wall areas between the corrugations, the corrugations in one wall meeting those in an adjacent wall through corner strips which have transverse corrugations engaging the wall corrugations so as to join them without interruption.

This invention relates to containers wherein a membrane tank is supported in an insulated housing, especially to containers for the storage of cold liquids, for example liquefied gases, such as liquefied natural gas.

Containers for very cold liquids have been proposed in the past where the tank housing the liquid is of the membrane type, i.e. is supported by an outer housing and is not self-supporting. It has been suggested that these membrane tanks be provided with a large excess of metal in all directions (such as transversely directed corrugations) which excess is taken up when the tank contracts from ambient temperature to the low temperature of the liquid. Such tanks are usually of fairly complicated construction and precautions have had to be taken to prevent excess stresses being set up at the intersections of corrugations and to prevent overstretching (with possible deformation or rupture) due to the effect of the hydrostatic load.

It has now been found that by making use of various metals where the ratio of elastic stress to thermal stress over the temperature range to which the metals are subjected, and particularly at low temperatures, is equal to or greater than one, the design of such tanks can be considerably simplified because it is only necessary to provide excess metal in the form of corrugations in only one direction in each of the walls of the tank.

According to this invention a container suitable for the storage of cold liquids comprises an outer housing of thermal insulating material wherein which is housed and fully supported, e.g., against hydrostatic loads, a membrane tank. A plurality of non-intersecting corrugations extends across the walls of the tank so as to cover substantially the whole of said walls, and so that the corrugations in one wall meet those in an adjacent wall at the corners. Angle strips are sealingly secured inside the tank to the walls along those corners where corrugations in the adjacent walls meet one another, and these strips have transversely arranged corrugations to engage with the corrugations in the walls.

The walls of the tank must be made of a material, e.g.

metal, having a ratio of elastic stress to thermal stress over the temperature range to which the tank is subjected of at least one. By elastic stress is meant the maximum stress to which the material can be subjected so that it returns to substantially its original dimensions when the load is removed. This in practice is very close to the yield stress, i.e. the stress beyond which the material becomes permanently deformed. By thermal stress is meant the stress imposed at the particular temperature by keeping the dimensions of the material the same when the material is subject to a cooling down from ambient temperature to that low temperature. Since for some materials the ratio of elastic stress to thermal stress might drop below one at the extremities of the temperature range, it is preferable that this ratio is greater than one, e.g., at least 1.2, to avoid any chance of this happening.

Examples of suitable metals having a ratio of elastic stress to thermal stress of at least 1.2 are most stainless steels, Invar, 9% Ni-steel, Inconel–X, K–Monel, and certain aluminum alloys. A typical thickness for the walls is between 0.5 and 1.0 mm.

The membrane tank, i.e. a tank made of a material having insufficient strength to support loads to which it is subjected, is preferably a hexahedron, or a hexadron in which the bottom portions of a pair of opposite side walls are tapered to meet the bottom wall. The tank may however be of other shapes, and could be a cylinder, but it cannot be a sphere.

The outer housing can be of wood, for example balsa wood, or quippo; or of plastic, for example predominately closed cell rigid or semi-rigid foamed plastics such as polyurethane, polystyrene, polyethylene, polyvinyl chloride, or foamed epoxy resin.

The tank must be fully supported within the insulating housing. This may be achieved by fastening members to the housing and to or near the edges of the walls of the tank. These members may, for example, be of wood or metal, and preferably there should be a plurality of members spaced at intervals near or along the edges of the walls. If the members are made of a material which has a relatively high coefficient of thermal expansion, these members should not be of too large a size so that they will not distort to any appreciable extent when the tank is in use. If the members are of wood small bolts or screws may be welded or fastened to or passed through the membrane tank, which bolts or screws can then be fastened to the members. If the members are of metal they may be welded or brazed directly to the membrane tank and may be in the form of angle brackets. The members can be readily secured to the outer housing by screws or bolts, or by other methods according to the nature of the housing.

Another method or additional method of supporting the membrane tank within the housing is for parts of adjacent walls of the tank to be extended beyond the corners so that the tongues formed by the extended parts of the walls are held between fixing members, or so that said tongues extend into slots formed in the outer housing. If desired of course where two walls meet, the whole of one of the walls may extend beyond the corner, this wall having slits at intervals near the extended edge thereof to allow passage of tongues from the other sheet. In order to minimize the flow of heat it is preferable if the extended parts be thermally insulated. If therefore the extended parts are held between fixing members, these members may be conveniently made of thermal insulating material, e.g. wood. If however the extended parts of the walls project into slots in the insulated housing, then the extended parts of the walls between the tank and the housing should be thermally insulated, e.g., by surrounding them by blocks of wood.

When the depth of the tank is comparatively great, e.g. greater than about 6 meters, it is preferable if support be given to the walls especially the side walls additional to that given to or near the edges of the walls. Thus for example, the outer housing may have a plurality of mounting blocks into which are screwed bolts or screws passing through holes in the central portions of the walls of the tanks. The holes in the walls of the tank may then be sealed by welding or brazing a cap over the head of the bolt or by using a bolt having a flange, the edge of which is welded or brazed to the wall. The provision of mounting blocks for supporting the inner regions of the walls is particularly desirable when it is required to mount various objects, for example pumps, in the tank. The bolt or fixing member may conveniently form the pump seat in such cases.

A plurality of non-intersecting corrugations extend across the walls of the tank so as to cover substantially the whole of said walls. In practice this means that generally for each wall of the tank the corrugations will be substantially parallel to one another. These walls do not have series of corrugations transverse, e.g., at right angles, to one another, as suggested in the prior art. In any case, the corrugations will not be confined to one part of the wall. In some cases however, e.g. when the wall is not square or rectangular, it may be desirable for the corrugations to be at a slight angle to one another, i.e. to have a splayed configuration.

The corrugations can have any desired profile, that is they can be symmetrical (e.g. simple folds or curved) or unsymmetrical (e.g. V-shaped in which one inclined face is wider than the other inclined face of the corrugation). Preferably, the corrugations project into the tank, but in some cases it may possibly be desirable for the corrugations to project out of the tank, when the clearance between the tank walls and the housing will have to be greater.

In order that the corrugations in one wall meet those in adjacent walls, at least one of the walls, for example the bottom wall, of the tank should preferably have corrugations arranged to terminate in all the edges of this wall. Thus, if this wall is of square or rectangular shape, the corrugations should be disposed at an angle to the edges thereof and not all of them can be parallel to one of the edges of the wall. If this wall is of other shapes, e.g. pentagonal, or hexagonal, in order that the corrugations shall terminate in all the edges thereof, the corrugations will also have to be angularly disposed to at least one of the edges, and in some cases, splayed slightly.

When one or more of the walls have corrugations arranged so that they terminate in all the edges thereof, the walls adjacent to said wall or walls generally need not have this special arrangement. In such adjacent walls the corrugations may often be parallel to a pair of opposite edges of the wall.

Preferably in none of the walls should a corrugation meet a corner when three sides meet, i.e. none of the corrugations in any wall should be a diagonal. This is because in such cases it is necessary for the corner between the two adjacent walls to be a corrugation, and this makes the fixing of the tank in the insulating housing rather difficult.

When making the membrane tank the walls can be assembled so that separate sheets are joined together along their corrugations. Thus, a series of sheets each with upturned edges along a pair of opposite edges may be joined together so that the corrugations are formed by the upturned edges welded together at their edges. If desired of course, such sheets may already have one or more corrugations extending across the sheet between the upturned edges. Alternatively, sheets having one or more corrugations may be joined together along either edges

so that in the assembled wall the joins are transverse to the corrugations or run between adjacent corrugations.

The angle strips are preferably of metal, and are secured inside the tank to adjacent walls in the corners. These strips are preferably secured by welding or brazing.

It is only necessary for angle strips to be provided along those corners where corrugations in the adjacent walls meet one another. However, the angle strips are preferably secured to the walls of the tank at all corners, because this makes the fixing of the tank in the housing much easier. At the corners where corrugations in adjacent sheets meet one another, in order that the angle strip should form a liquid-tight seal and in order that undue stresses are not set up, the strips must be provided with transversely arranged corrugations to engage with the corrugations in the walls. So that the stresses set up therein when the angle strips expand and contract are a minimum, and for ease of manufacture, these transverse corrugations should have the minimum or no deflection as they traverse the strip. Of course, as the strip itself is bent through an angle, usually 90°, the corrugations will also have to be bent similarly. It is therefore desirable when designing the tank, for the inclination of the corrugations in adjacent walls to be arranged so that the corrugations when traversing from one wall to the next change their direction as little as possible. In some cases this means that the corrugations in one of a pair of adjacent walls should be at right angles to longitudinal axis of the common corner, and at other times at an angle to said longitudinal axis.

In order to ensure that the corrugations are preserved during welding, or brazing, especially when securing the angle strips to the edges of the walls, it is preferable to insert a strip of non-fusible material, e.g. asbestos inside the corrugation at the place where the weld is to take place before carrying out the welding or brazing. This prevents the whole of the wall about the corrugation fuzing together, and making the corrugation inoperative.

If desired, the top wall of the membrane tank need not be integral with the side walls of the tank, and can for example be a wall of completely different design. In such cases it is necessary for the corrugations in the side walls to terminate within the walls before reaching the upper edges thereof. Also in such cases it is preferable if the bottom wall has corrugations terminating in all the edges thereof.

In other cases, for example when the tank has a trunk, the corrugations may if desired terminate in the top wall near the base of the trunk, and the trunk itself may have one or more peripheral corrugations. The other walls of such a tank would of course have non-intersecting corrugations extending across each wall to meet the corrugations in an adjacent wall.

The container of this invention is very suitable for the storage of a liquefied gas, that is a gas which boils below the ambient temperature at atmospheric pressure. Examples of such liquefied gases are liquid butane, liquid propane, liquid ethylene, liquid methane, liquid oxygen, liquid nitrogen, and liquid ammonia.

The invention is now described with reference to the accompanying drawings, in which

FIG. 1 shows a perspective view of part of the interior of a container of the invention;

FIG. 1A is an enlarged sectional view of a portion of a container showing details of the fastening means;

FIG. 2 shows a side elevation through the center taken on the line **2—2** of the container shown in FIG. 1;

FIG. 3 shows a perspective view of the interior of part of a different container from that shown in FIG. 1;

FIG. 4 shows a perspective view of the interior of part of a large container different from those shown in FIGS. 1 and 3; and

FIG. 4A is an enlarged view of the structure shown at the corner of FIG. 4.

Referring to FIGS. 1 and 2 of the drawings, the outer housing **1** of thermal insulating material comprises blocks of predominately closed cell polyurethane. The tank 2 having walls 2*a* made of 0.5 mm. thick Invar is supported within the housing 1 by means of wooden blocks 3 secured to the housing on the tank. The blocks are screwed onto the housing and screws 3*a* pass through the walls of the tank into the blocks 3. The heads of the screws are welded to the tank to form a seal. These blocks are secured at intervals only around the edges of the walls of the tank. The space between the blocks 3 is filled up with thermal insulating material 36 which may be the same as the material forming the outer housing. In this way the membrane tank is fully supported by the outer housing, any load on the walls being transferred to the outer housing by means of blocks 3 and insulation 36.

Inside the tank along all the edges of the wall thereof are angle strips 4 and 5 welded to the walls and completely covering the screws passing through the sheet into the blocks 3. The angle strips 4 are provided with transverse corrugations 6 which engage with the corrugations in the adjacent walls. In the vertically disposed angle strips 5 there are no transversely disposed corrugations as these strips do not have to engage with corrugations in the walls.

The bottom wall 7 of the tank has parallel corrugations 8 running at an angle across the wall and engaging with the corrugations 6 in the angle strips 4. The side walls have parallel vertically disposed corrugations 10 which also engage with the transverse corrugations 6 in the angle strips 4.

The corrugations are formed by having strips with upturned edges, and welding these strips together along their upturned edges. Thus corrugations having a V-shaped profile are formed along the edge of each adjacent sheet.

Referring to FIG. 2 of the drawings, the top of the tank is provided with a trunk 11 having a peripheral corrugation 12 in the side wall thereof. Passing through the top of the trunk are conduits and gas vents (not shown) so that a liquefied gas may be housed within the tank.

Referring to FIG. 3 of the drawings, similar numerals indicate similar features to those shown in FIG. 1 of the drawings. Also part of the tank and angle strip have been broken away to show the method of fixing the tank in the housing.

In this embodiment the method of fixing the walls of the tank to the housing 1 is different. Angle brackets 20 are welded at intervals along the edges of the walls 7 and 9 of the tank. These brackets are secured into slots 21 of the housing. As further support the ends of the wall are extended to form tongues which enter into slots in the housing 1. In the figure, tongues 22 are shown, and one of these tongues 22 is shown entering the slot 23 in the housing 1. In dotted lines is shown the extension of a tongue 24, extending from the bottom wall 8. This tongue 24 enters the slot 25 in the housing 1. Surrounding the brackets 20 are blocks of thermal insulation 26, the space left between the blocks 26 being filled with insulation 36, which may be the same as the material of blocks 26. Similar blocks of insulation surround the tongues 22 and 24, but for clarity these are omitted in the drawing.

Referring to FIG. 4 of the drawings, similar numerals indicate similar features to those shown in FIG. 3 of the drawings.

In this embodiment, the side walls of the tank have corrugations 31 inclined at an angle to the vertical. These corrugations and corrugations 30 in the bottom wall 7 are slightly different from those shown in FIGS. 1 and 3 in that their profile is curved and not V-shaped. The vertical angle strip 33 has one transverse corrugation 32. Additional support for the walls of the tank is achieved by means of the bolts 35. These bolts 35 pass through a hole in the wall and are screwed into a thread in a mounting block (not shown) fixed to the outer housing 1 behind the walls 7 and 9. To seal the wall the bolts have flanges 34, the edges of which are welded to the wall. In order to reduce the stresses set up due to thermal expansions and contractions, these bolts 35 are placed centrally in the separate sheets constituting the walls of the tank.

I claim:

1. A conductor comprising an outer housing of thermal insulating material within which is housed and fully supported a membrane tank, in which at least the side walls and the bottom wall of the tank are made of a material having a ratio of elastic stress to thermal stress over the temperature range to which the tank is subjected of at least one, a plurality of spaced apart non-intersecting corrugations extend across the walls of the tank so as to be distributed over substantially the whole of said walls, and so that the corrugations in one wall meet those in an adjacent wall at the corners, and in which angle strips are sealingly secured inside the tank to the walls along those corners where corrugations in adjacent walls meet one another, the strips having transversely arranged corrugations to engage with the corrugations in the walls, the said walls between all of said corrugations being smooth and uncorrugated.

2. A container as claimed in claim 1 in which said ratio of elastic stress to thermal stress is at least 1.2.

3. A container as claimed in claim 1 in which the tank is fully supported within the outer housing by members fastened to the housing and to or near the edges of the walls of the tank.

4. A container as claimed in claim 1 in which tongues are formed by parts of adjacent walls of the tank extending beyond the corners, and are held in the outer housing.

5. A container as claimed in claim 1 in which for each wall of the tank the corrugations are substantially parallel to one another.

6. A container as claimed in claim 5 in which the corrugations project into the tank.

7. A container as claimed in claim 1 in which in at least one of the walls of the tank the corrugations are arranged to terminate in all the edges of the wall.

8. A container as claimed in claim 7, in which the bottom wall of the tank has corrugations terminating in all the edges of the wall.

9. A container for liquids at very low temperatures comprising:

(a) an outer housing of thermal insulating material,

(b) a membrane tank within and fully supported by said housing, said tank having a plurality of thin metal walls,

(c) said metal walls having a plurality of pleated accordian-like corrugations which are spaced from each other and distributed over substantially the entire surface of the walls in generally parallel relationship to the adjacent corrugations so as to be non-intersecting with each other, so as to permit the walls of the membrane tank to expand and contract freely for a limited distance in a direction perpendicular to the corrugations, in bellows-like fashion, the metal wall between adjacent corrugations being smooth and uncorrugated.

10. A container as claimed in claim 9, said tank being generally prismatic in shape, with said corrugations being oblique to the edges of at least one of the walls.

11. A container as claimed in claim 9, including angle strips sealingly joining adjacent walls, said strips having transversely arranged corrugations aligned with the corrugations of the two sheets which they respectively join so that a given corrugation extends from one wall to an adjacent wall without interruption.

12. A container for liquids at cryogenic temperatures comprising:

(a) an outer housing of thermal insulating material,

(b) a membrane tank within and fully supported by said housing, said tank having a plurality of walls,

(c) the walls of said membrane tank being made of a material having a ratio of elastic stress to thermal stress over the temperature range to which the tank is subjected of at least one,

(d) a plurality of non-intersecting corrugations extending across the walls of the tank and spaced apart from each other so as to be distributed over substantially the whole of said walls, with a corrugation on one sheet meeting at its end a corresponding corrugation of an adjacent sheet so that a given corrugation continues from one sheet into the adjacent sheet, the wall space between adjacent corrugations being smooth and uncorrugated,

(e) angle strips sealingly joined adjacent walls, said strips having transversely arranged corrugations aligned with the corrugations of the two sheets which they respectively join so that a given corrugation extends from one wall to an adjacent wall without interruption.

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