United States Patent [19]

Hamilton

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[54] **STORAGE CONTAINERS FOR LIQUIDS**

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Jan. 22, 1971 Great Britain......................2,992/71

[52] **U.S. Cl.** ....**220/9 LG,** 114/74 A, 220/15, 220/72

[51] **Int. Cl.** **B65d 25/18**

[58] **Field of Search** ....220/9 LG, 10, 15, 72; 114/74 A

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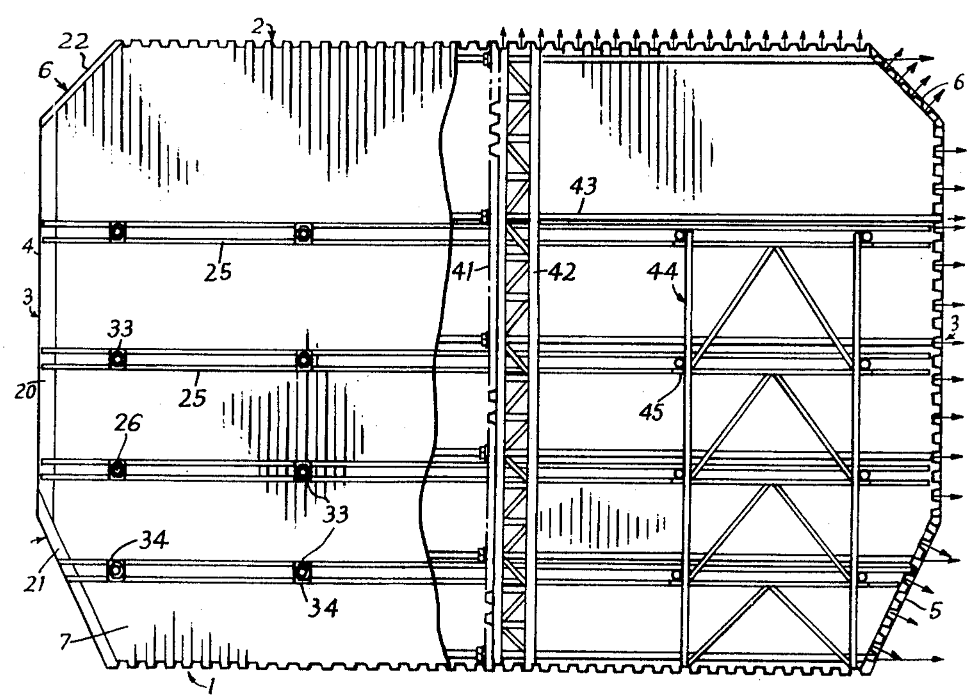
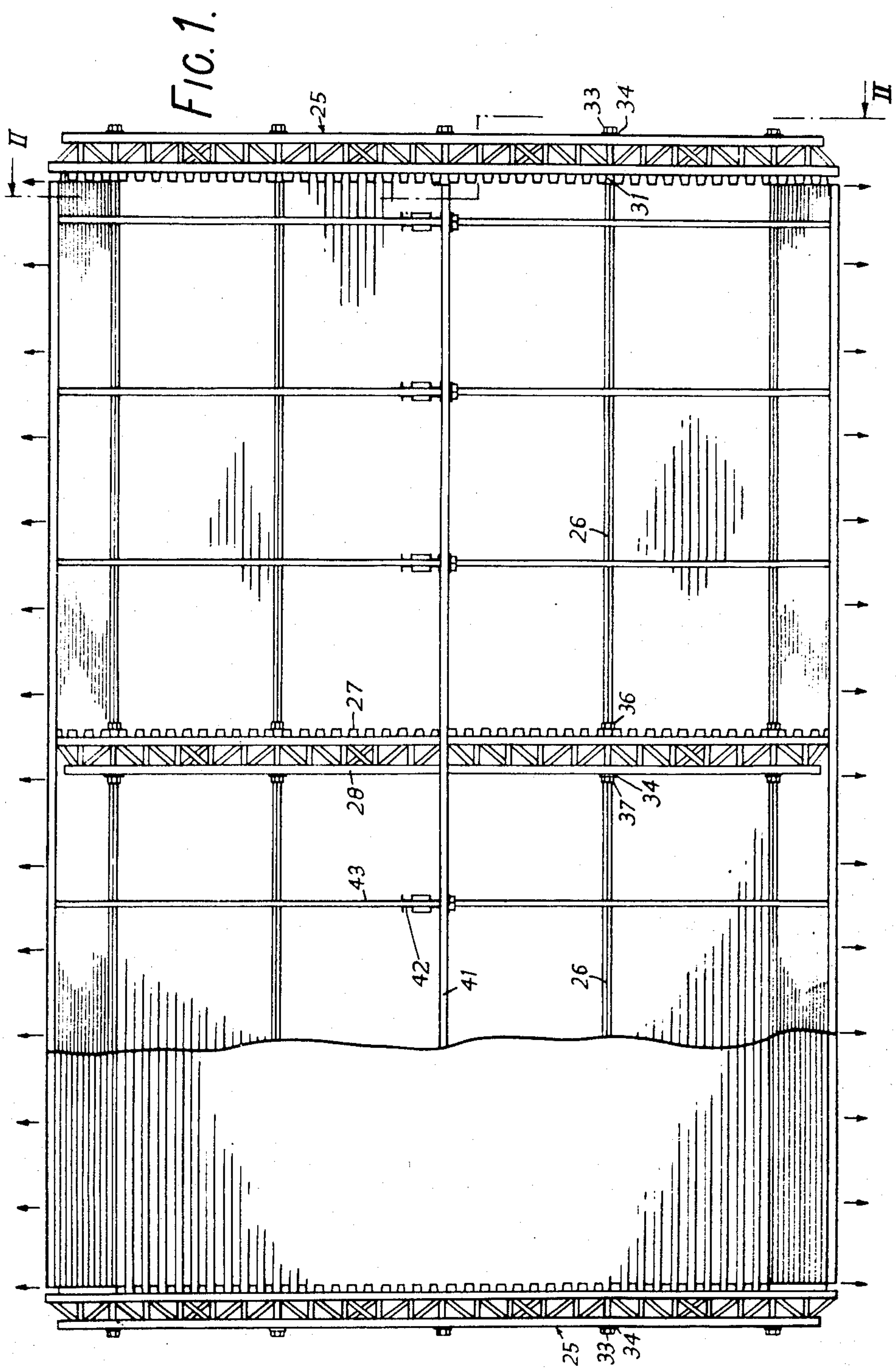
[57] **ABSTRACT**

A thermally insulated container for liquefied natural gas is constructed in a ship and has corrugated walls. The corrugations in the bottom, side and top walls extend longitudinally of the ship while those in the end walls extend vertically. The side and top walls are supported from the ship's structure by sliding connections, while the end walls are interconnected by tie-rods. Thermal contraction of the walls on filling the container is accommodated by a reduction in the length of the tank in the length direction of the corrugations and by deformation of the corrugated walls transversely of the corrugations. Vertical contraction and expansion of the end walls is accommodated by elastic deformation of the top wall which is left unsupported in the regions adjacent the end walls.

15 Claims, 18 Drawing Figures





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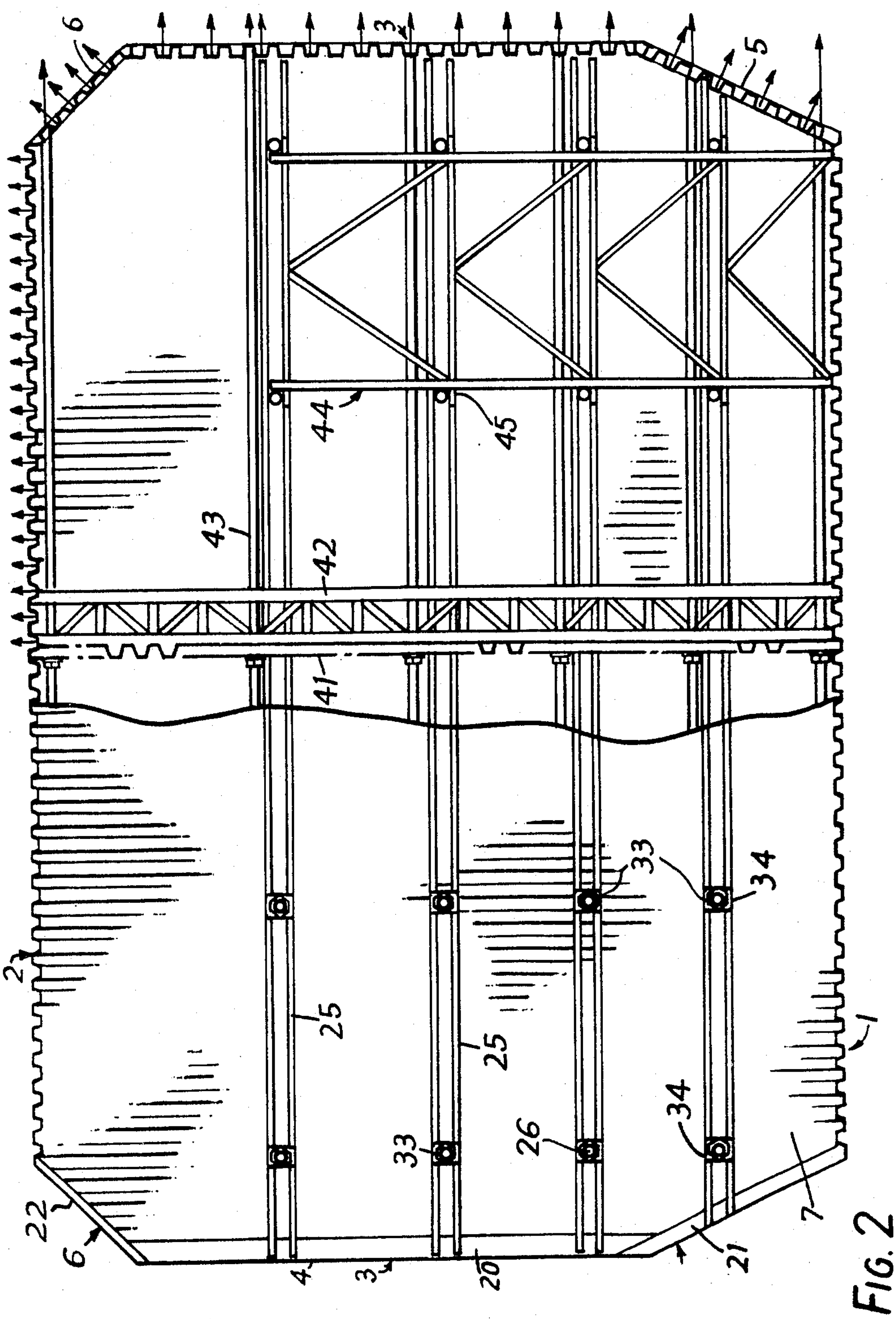

FIG. 2

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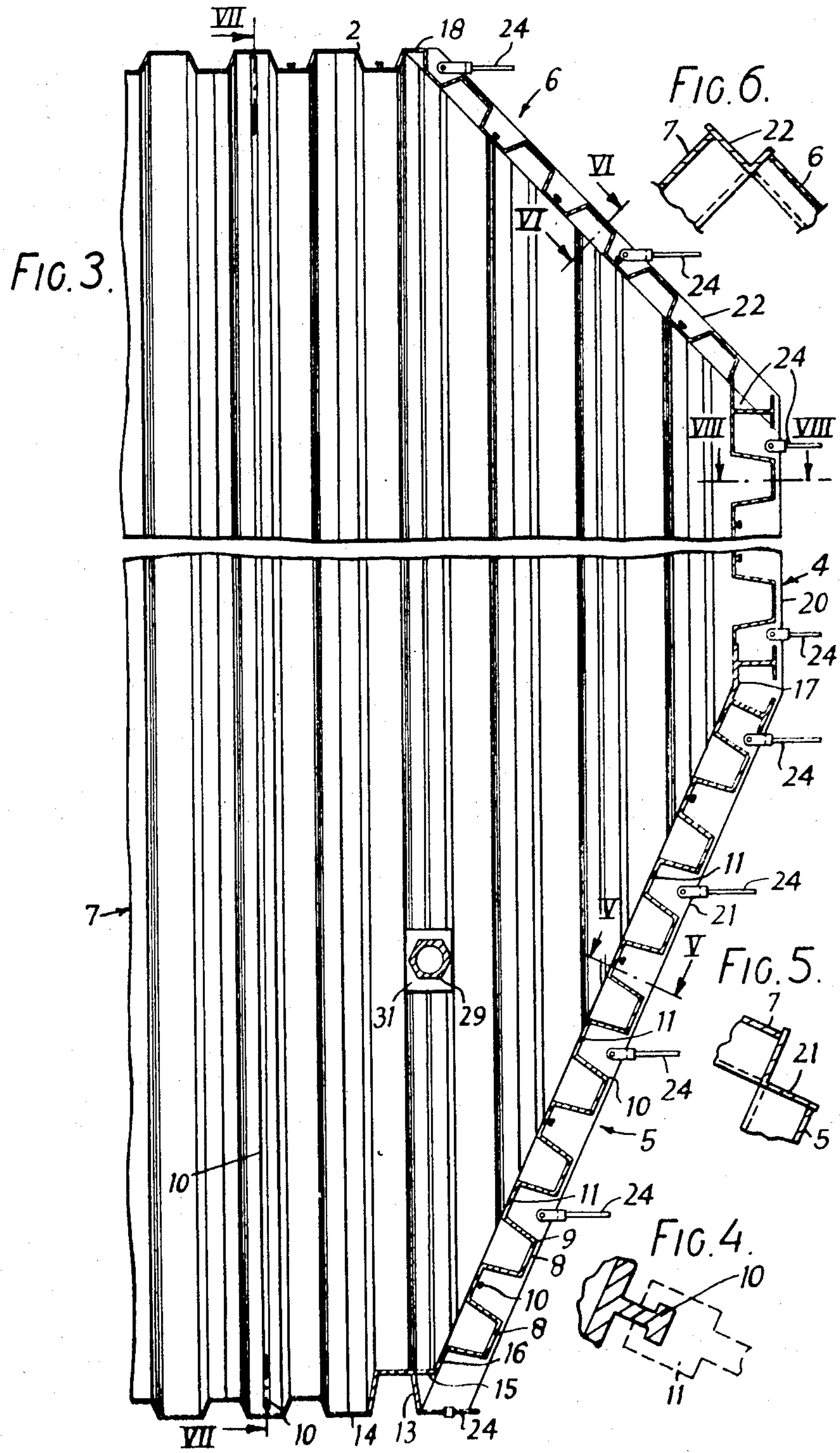

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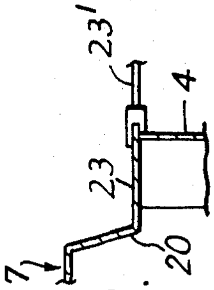

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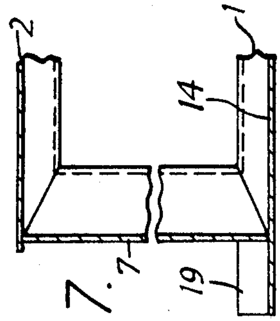

FIG. 7.

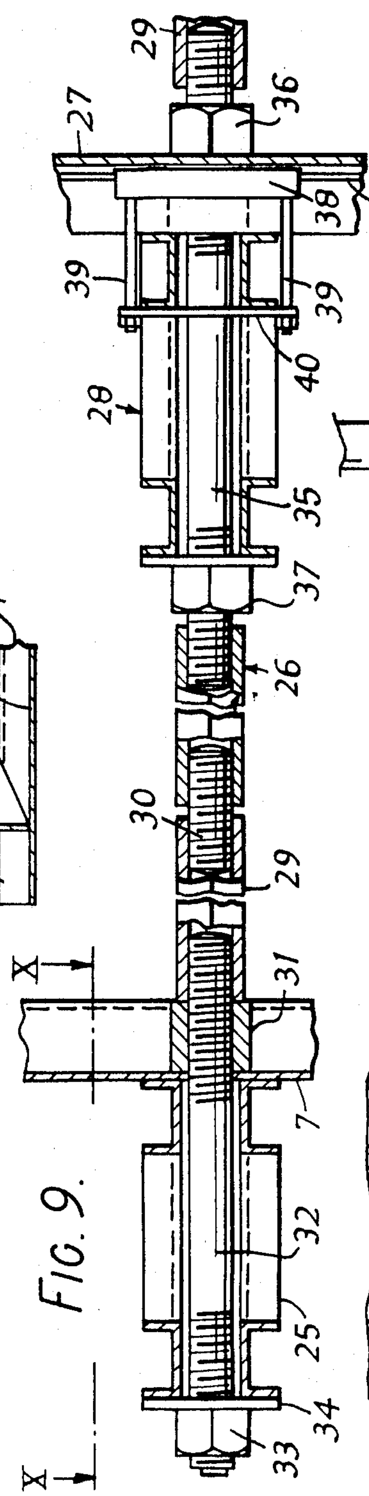

FIG. 9.

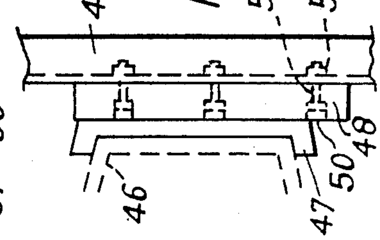

FIG. 11.

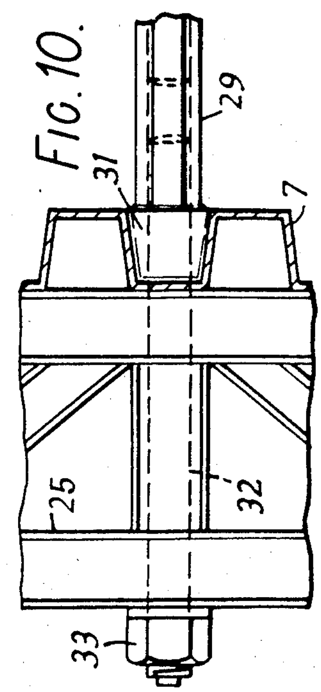

FIG. 10.

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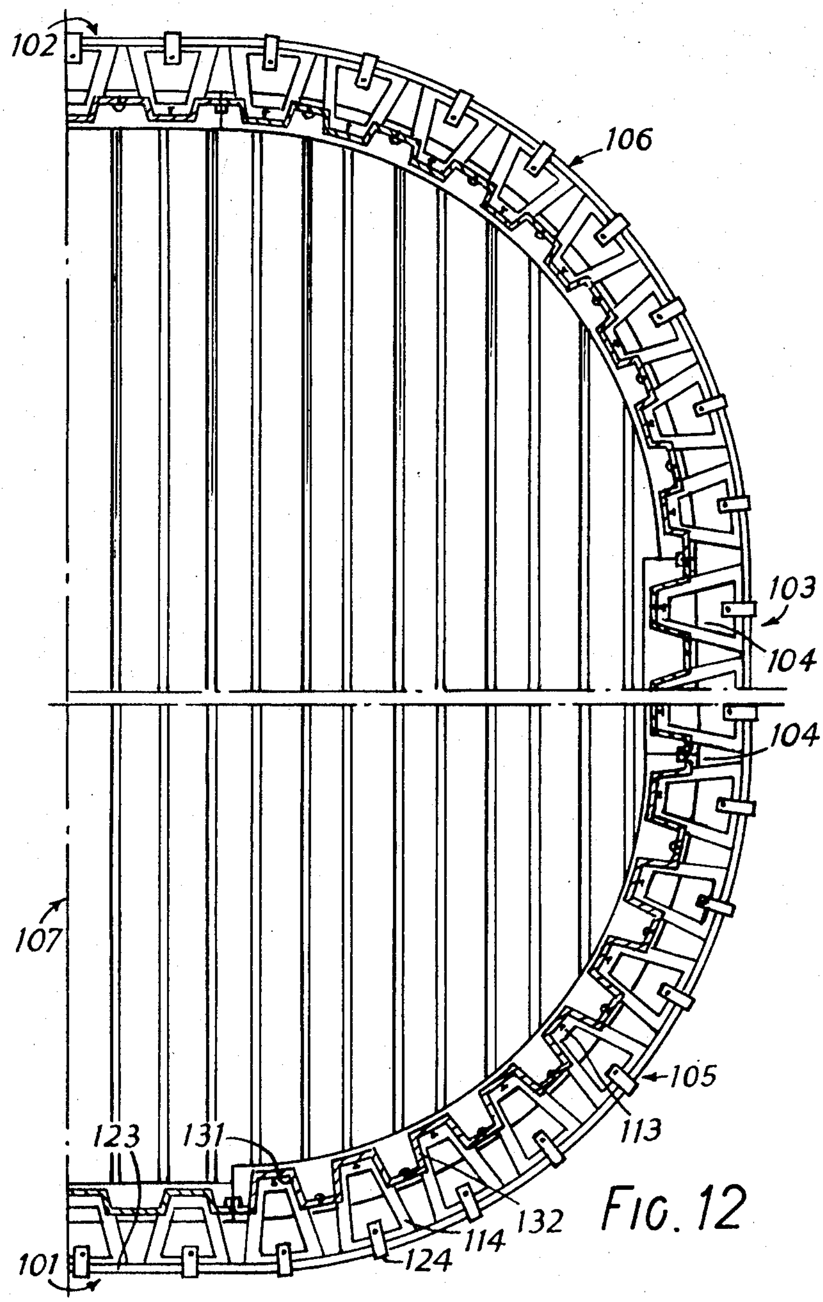

FIG. 12

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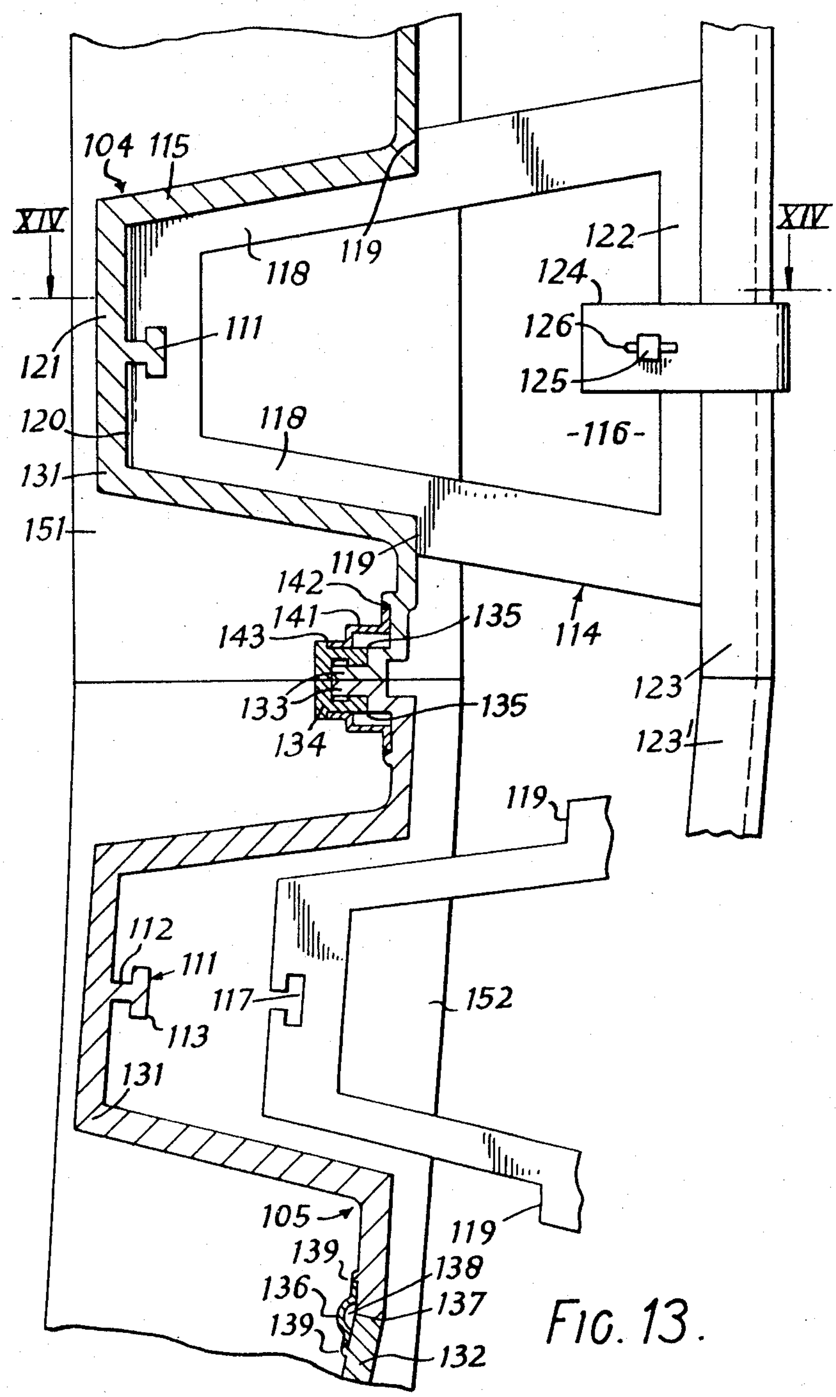

FIG. 13.

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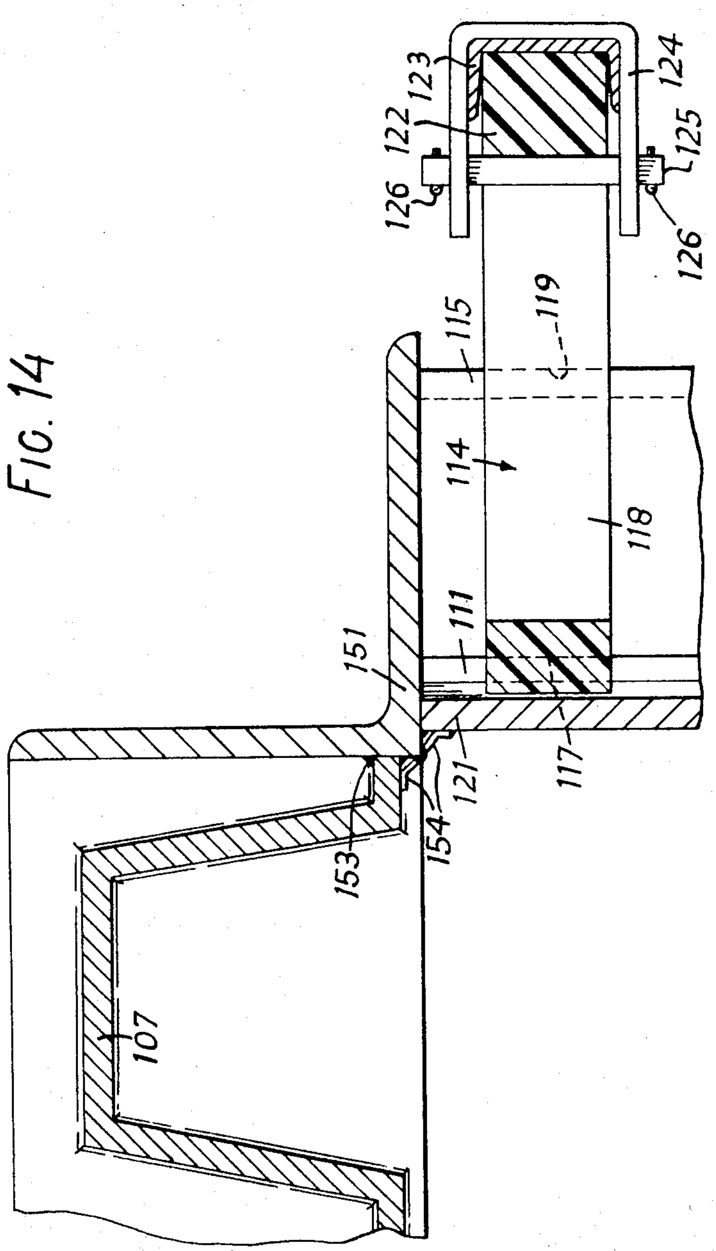
FIG. 14



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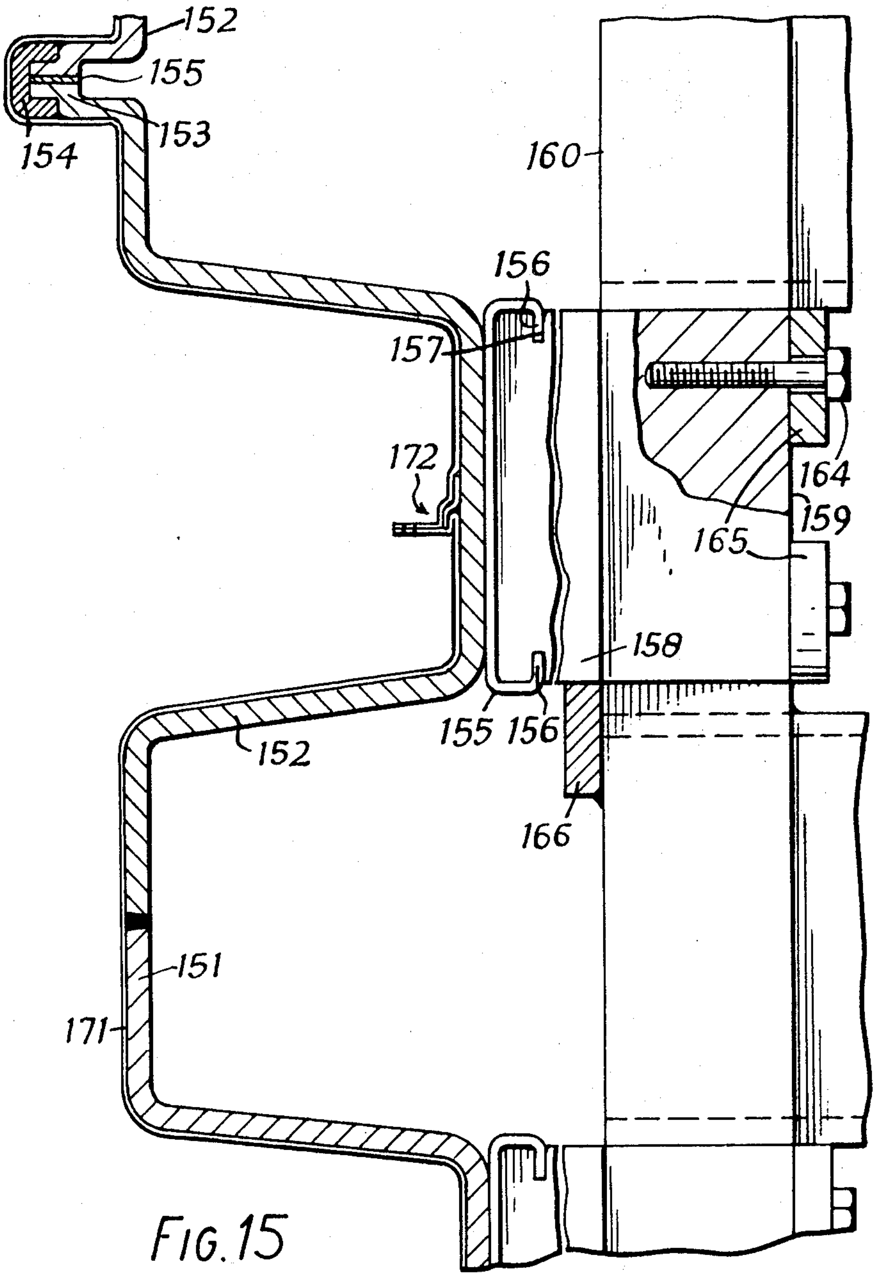

FIG. 15

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FIG. 16

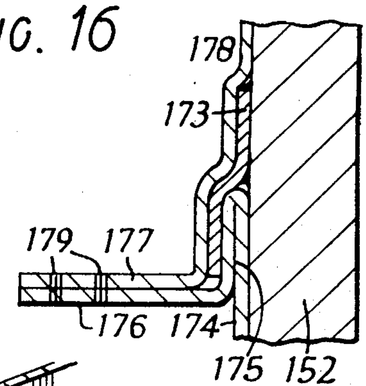


FIG. 17

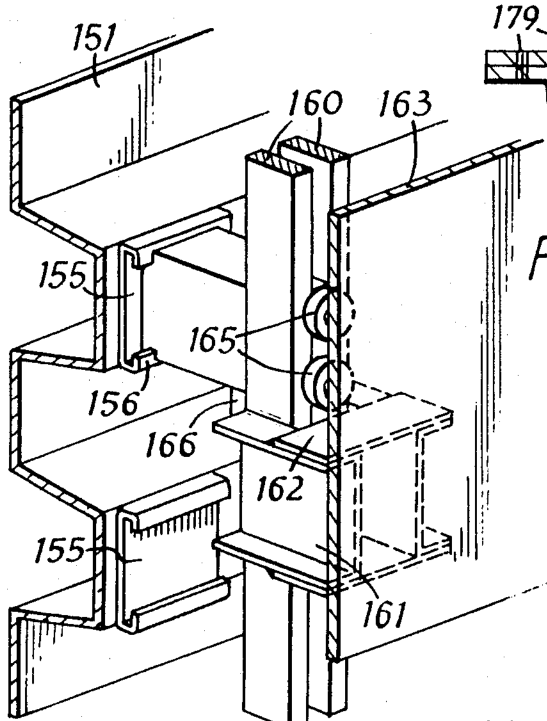
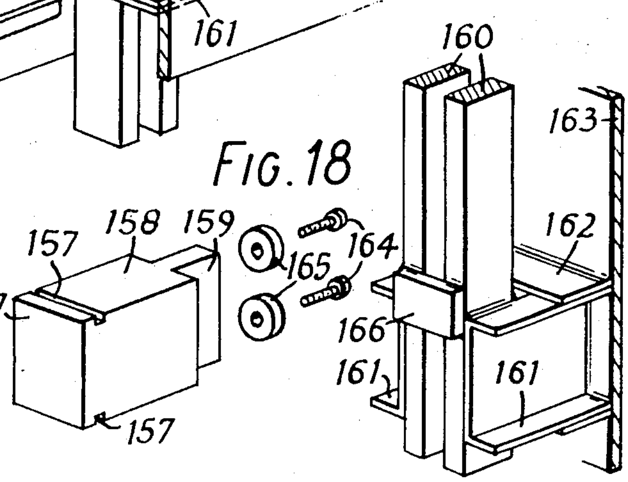


FIG. 18



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STORAGE CONTAINERS FOR LIQUIDS

The present invention relates to storage containers for cryogenic liquids such as liquified gas. Such storage containers may for example be installed in ships for carrying liquified natural gas in bulk.

The construction of storage containers for cryogenic liquids presents a number of difficulties as compared with conventional storage containers in which the contents can be at ambient temperature. When a storage container is filled with a cryogenic liquid, the large drop in temperature causes contraction of the walls, typically by several inches, unless the entire container is constructed of a material such as Invar which has a negligible co-efficient of thermal expansion. Storage containers constructed of Invar are necessary extremely expensive. While the walls of an Invar container can be anchored directly to some other structure, for example a ship's hull (with suitable insulation therebetween), this is not possible with other materials having normal co-efficients of thermal expansion. Accordingly, where it has been desired to avoid the expense of constructing the entire container walls of Invar, it has been necessary to make the container free standing or self-contained so that its walls can support the hydrostatic pressure of its contents without external assistance. In the case of containers installed in ships, the container walls must be sufficiently rigid to withstand not only the hydrostatic pressure but also the increased loads due to surging of the container contents during pitching and rolling of the ship. Thus, while cheaper materials may be used, a much more rigid construction is necessary with relatively small saving in cost.

In accordance with the present invention there is provided a low-temperature container for a ship, the container having corrugated top, bottom, side and end walls, characterized in that the corrugations in each wall are uni-directional, in that the corrugations of the end walls are vertical while the corrugations in all the other walls all run lengthwise of the ship, in that vertical thermal contraction and expansion of the end walls is accommodated by resilient distortion of the adjacent portions of at least the top and side walls secured thereto, and in that the side walls are secured to the ship's hull by spaced sliding connections permitting relative movement in the length direction of the corrugations in the side wall.

With this arrangement, there is no need to allow for expansion and contraction in the width direction. Additionally, the end walls are formed with corrugations which extend vertically so that again there is no need to allow for lateral expansion and contraction of the end walls. The side walls of the containers are supported by the ship's hull without having to allow for relative movement of the side walls of the container towards and away from the hull as a result of thermal contraction and expansion.

Where however it is desired that the top wall of the container should not be free to move bodily, the side walls may be formed with horizontally extending corrugations while the end walls have vertically extending corrugations. Provision must then be made for the vertical expansion and contraction of the end walls and it is preferred to accommodate this expansion and contraction by elastic deformation of the portions of the side and top walls which are adjacent the end walls while the intervening portions of the side and top walls are held against at least outward movement while permitting longitudinal movement.

In the case of larger containers the side, end and top walls are supported at intervals along the length of the corrugations. In the case of the end walls, this may be achieved by means of horizontal beams, corresponding beams at opposite ends of the container being interconnected by tie rods which extend through the container and are preferably of a material having the same or comparable co-efficient of thermal expansion as the material of the side walls of the container. Since no relative movement is required between the tie rods and the container walls through which they pass, the liquid-tight seal between the tie rods and container walls may be effected by welding. The side walls of the container may be supported by an external structure, such as a ship's hull, by means of support pads, with suitable thermal insulation. The support pads may be made of an insulating self-lubricating material such as polytetrafluoroethylene or Tufnol. Preferably wear pads carried by the walls are interposed between the walls and the support pads.

In one preferred form of embodiment, the corrugated walls are of a weldable cryogenic aluminum alloy. The wall thickness may for example vary from 1 inch to ⅝ inch in accordance with loading and the walls may be built up of panels each of which is formed by extrusion. It is believed that panels up to 4 feet wide can be formed by extrusion with existing equipment at least in the United States of America. Each panel may then for example form two complete corrugations.

In addition to the corrugations, the extruded panels may advantageously be formed with flanged projections extending along the length direction of the corrugations. These provide convenient anchoring points and also convenient lifting points for lifting prefabrication units into position on site.

Conveniently, the tie rods are also formed by extrusion. The tie rods may be formed of the same alloy and may be hollow and be joined together by screw-threaded stainless steel connecting pins screwed into the ends of adjacent tie-rod sections.

Alternatively, the panels may be rolled from appropriate material, for example 9 percent nickel steel.

Preferably, the panels are welded together under factory conditions into units which can be lifted into position on site for final assembly. In this way, the amount of on-site welding required is greatly reduced and the majority of the welding and weld-inspection can be carried out under the better conditions prevailing in the fabrication shop.

The container may have two adjacent corrugated walls which are inclined at an angle to each other and have their corrugations running in the same direction and the two walls may be joined by a curved section also formed with corrugations, the two walls being preferably tangential to the curved portion. With this construction, shrinkage in the material of the walls resulting from thermal contraction is more easily spread.

The curved portion may be fabricated from corrugated extrusions in the same manner as the walls described in my said earlier provisional specification.

Advantageously, the corrugations of the curved portion are supported by pads which have a nose portion seated in the external concavity of a corrugation and having a base portion engaged in a channel section member extending around the curved portion and spaced therefrom. Preferably, the base portions of the supported pads are free to slide in the channel member so that they can adopt a position in which they do not interfere with the local movements of the walls of the corrugations during expansion and contraction. At the same time they should permit free longitudinal movement of the corrugations. For this reason, it is preferred that they should be made of or coated with a material of low coefficient of friction such as polytetrafluoroethylene or Tufnol (Trade Mark). Such materials also act as thermal insulation.

In order to save material the supported pads may be of open-centered construction for example substantially in the shape of a trapezium, the base of which is held in the channel by a suitable clip which can allow sliding movement of the pad base in the channel.

When assembling such a container, the entire curved corner unit may be prefabricated to comprise not only the curved corrugated wall portion but also the support pads and curved channels and the complete assembly thus obtained may be lifted into position for example into a ship, and the curved corrugated wall portion and the curved channel members may be welded to the appropriate ends of the corresponding members of the adjacent wall portions.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawings, in which:

FIG. 1 is a plan view of a liquefied natural gas container to be constructed within a ship,

FIG. 2 is partly an end view and partly a sectional view on the line II—II of FIG. 1,

FIG. 3 shows a detail of an end view of the container of an enlarged scale,

FIG. 4 shows a detail of one of the fixtures for the container,

FIG. 5 shows in section on the line V—V of FIG. 3 a junction between an end wall and a lower sloping portion of a side wall of the container,

FIG. 6 is a view corresponding to FIG. 5 on the line VI—VI of FIG. 3,

FIG. 7 shows in vertical section the junctions of an end wall with the top and bottom walls of the container,

FIG. 8 shows the junction of an end wall and the portion of a side wall on the line VIII—VIII of FIG. 3,

FIG. 9 is an elevational view of a tie rod at its junctions with a wall of the container and a baffle wall within the container,

FIG. 10 is a plan view on the line X—X of FIG. 9,

FIG. 11 shows a detail of a supporting abutment for a corrugation in a wall of the container,

FIG. 12 shows an end view of the container in the regions adjacent top and bottom corners of the container with portions cut away,

FIG. 13 shows a detail of FIG. 12 on an enlarged scale,

FIG. 14 is a section on the line XIV—XIV of FIG. 13,

FIG. 15 shows a wall portion of another embodiment in section,

FIG. 16 shows a detail of FIG. 15 on an enlarged scale,

FIG. 17 is a perspective view of components shown in FIG. 15,

FIG. 18 is an exploded view of parts shown in FIG. 17.

The liquefied natural gas container shown in FIGS. 1 to 11 is constructed in the hull of a ship (not shown). As shown in FIG. 2, the container has a bottom wall 1, a top wall 2 and side walls 3 which comprise a vertical portion 4 and inclined lower and upper portions 5 and 6. The two ends of the container are closed by vertical end walls 7.

Each wall is built up from weldable cryogenic aluminum alloy panels which are preferably formed by extrusion in order to obtain the required corrugated profile and length. The individual extruded panels may be up to 4 feet wide and can thus contain two of the corrugations, for example those shown at 8 in the lower sloping wall portion 5 in FIG. 3. The extruded panel 9 containing the corrugations 8 is also formed with a small rail-like projection 10 between the two corrugations 8. This projection is shown on an enlarged scale in FIG. 4 and can be engaged by clips 11 by means of which the panel 9 can be anchored to a convenient point on the ship's hull or framework.

The wall portion 5 is prefabricated by welding together the adjacent panels 9 at their junctions 11. This welding can be carried out in the fabrication shop under closely controlled conditions and the welds can easily be inspected by any of the well-known techniques. The wall portion thus formed can be lifted into the ship in which the container is being constructed by means of clips similar to the clips 11 which are temporarily engaged with the rails 10.

The other wall portions of the container can be similarly prefabricated in the fabrication shop from appropriate extruded panels. In this way the amount of welding to be carried out and inspected within the ship is greatly reduced. As in the example shown in the drawings, it may be desirable to use different sizes of corrugations in the different walls in accordance with the various load pressures and bending moments which the walls have to withstand in service. Thus the bottom wall 1 can rest on a solid bed of insulation material (not shown) and can thus be uniformly supported over its whole area. Accordingly, the corrugations in the bottom wall 1 serve merely to accommodate the lateral thermal contraction and expansion of the bottom wall when the tank is filled with liquified gas or emptied. The end walls 7 however are free-standing and accordingly their corrugations are of much deeper section in order to provide the necessary stiffness to withstand the loads imposed by a body of liquified gas within the container. The bottom wall 1 is joined to the lower portions 5 of the side walls by means of a special-section corrugated extrusion 13 (FIG. 3) which has one flange 14 welded to the edge of the bottom wall 1 and a second flange 15 which is elbowed and is welded at 16 to the lower edge of the lower side wall portion 5. Correspondingly, other special sections, for example 17 and 18 may be employed for joining the upper inclined side wall portions 6 to the top wall 2 and the vertical side wall portions 4.

The corrugations in the top and bottom walls 1 and 2 extend lengthwide of the ship and have the same spacing as the corrugations of the end walls 7. Consequently, they can have their ends bevelled at appropriate angles as shown in FIG. 7 to fit together and be joined by welding without the need for further special extruded sections. As shown in FIG. 7, there is no need to bevel the corrugated panels of the bottom wall 1 which can therefore continue as shown at 19 to spread the weight of the vertical end wall 7 over a greater area of the underlying insulation material. The horizontal corrugations in the inclined portions 4 and 5 of the side walls 3 may be joined to the vertical corrugations of the end wall 7 by means of simple L-section extrusions 21 and 22 having the shapes shown respectively in FIGS. 5 and 6. With this arrangement there is no difficulty in accommodating the differences in the depths of the corrugations as shown for example in FIG. 6 where the corrugations in the end wall 7 are much deeper than those in the upper inclined side wall portion 6. As shown in FIG. 8, the vertical portions 4 of the side walls may be welded directly against the flat portion or flange 23 of a special section 20 of the end wall 7. Flanges of the special-section extrusions 13, 17, 18, 20, 21 and 22 are anchored to the ship's hull by tie-rods 24.

The end walls 7 are supported by horizontal nickel-steel or aluminum alloy beams 25 at spaced vertical intervals. Beams at opposite ends of the container are interconnected by tie rods 26 which pass through the end walls 7 and extend along the length of the interior of the container. The tie rods 26 also serve to support a transverse vertical baffle wall 27 which is built up of corrugated panels similar to those forming the end wall 7 and is further supported by horizontal beams 28 of similar construction to the beams 25. The construction of one of the tie rods 26 is shown in detail in FIGS. 9 and 10. The tie rod 26 is assembled from extruded lengths 29 of the same aluminum alloy as the container walls. The extruded lengths 29 are hexagonal in outer section and are hollow, having a cylindrical bore. At the ends of the section, the bore diameter is somewhat reduced and is internally screw-threaded to enable the section to be joined to the next section by means of a stainless steel screw-threaded peg 30.

At the place where the tie-rod passes through an end wall 7, the end of the adjacent section 29 is welded to a filler piece 31 of the same aluminum alloy and the filler piece 31 is welded to the walls of a corrugation in the end wall 7 so as to provide a reliable seal. A stainless steel bolt or stud 32 is screwed into the end of the section 29 and extends outwards through the filler piece 31 and a hole in the wall 7 and thence through the beam 25 to carry a nut or bolt-head 33 at its free end with a washer 34 between the nut or bolt-head and the beam 25.

Similarly, where the tie-rod 26 passes through the baffle wall 27 and supporting beam 28, a stainless steel stud 35 serves to secure the baffle wall 27 to the beam 28 by means of nuts 36 and 37 and its two ends are screwed into the adjacent ends of the extruded sections 29. It is preferred, as shown in FIG. 9, that the baffle wall 27 should also be formed with rails 10 on which are mounted clips 38 which are secured to the beam 28 by means of tie bolts 39 and straps 40.

As shown in FIG. 1, the container may if desired include a longitudinal baffle wall 41 supported by vertical beams 42 in the same way that the transverse baffle wall 37 is supported by the beams 28. The beams 42 are held in position by transverse tie-rods 43 which are of similar construction to the tie-rods 26 and pass out through the side walls 3 to be secured through stainless steel springs to the hull structure of the ship. In order to prevent the tie-rods 26 and 43 from sagging under their own weight, it is preferred, particularly in the case of large containers, to incorporate a light supporting framework as shown diagrammatically at 44 in FIG. 2. The tie rods 26 and 43 then rest on short spurs 45 projecting from the framework 44.

FIG. 11 shows a supporting abutment arrangement for one corrugation 46 of a side wall 3 or top wall 2 of the container. A wear plate 47, preferably of the same cryogenic aluminum alloy, is welded to the corrugation 46 and bears against a pad 48 of polytetrafluoroethylene which is secured to a member 49 attached to the ship's frame. The pad 48 may for example be formed with countersunk bores 50 to accommodate bolts 51 carrying nuts 52. The pad 48 both acts as a thermal insulator and minimizes friction between it and the wear pad 47.

Thus, the side walls 3 are anchored securely in position by the clips 11 (in positioning indicated by arrows) which hold the corrugations securely against the support pads 48. Movement of the side walls towards and away from the ship's hull is thereby prevented but the side walls are free to expand and contract longitudinally. The top wall 2 of the container is correspondingly anchored to a deck structure over its width and along the greater part of its length. However, the support pads 48 are omitted in the immediate vicinity of the junction of the top wall 2 with the end walls 7 and the end portions of the top wall 2 are then free to deform resiliently to accommodate the vertical movement impressed on them by the contraction and expansion of the end walls 7. Similarly, the support pads 48 may be omitted in the vicinity of the junctions of the upper inclined side wall portions 6 with the end wall 7.

As described above, the container shown in the drawings is assembled in the ship from prefabricated units. Thus for example the bottom wall may be preformed in two sections extending for the full length of the container and for half its width. They can then be lifted into the hull and placed on a bed of thermal insulation in which a narrow channel has been left to enable the weld joining the two sections to be carried out and inspected. Thereafter, this channel is filled with insulation material. Similarly, the tie-rods may be preassembled and lifted into position in lengths corresponding to the length between the baffle walls and the side or end walls.

In use, when the container is to be filled with a cryogenic liquid such as liquified natural gas, the container is first cooled by filling its interior with gas just above its liquefaction point. This causes the material of the container walls and tie rods to contract. The two end walls 7 are thus drawn towards each other but the side walls 3 and top wall 2 are securely anchored to the ship's frame and cannot therefore move bodily in the direction towards the center of the container. Instead all the resulting stresses are absorbed by resilient deformation of the corrugations of the respective wall portions. Thus it is only necessary to allow for contraction and expansion of the container walls in the length direction of the corrugations. In the case of the bottom, side and top walls, this results in an overall reduction in the length of the container. In the case of the end walls **7** however, the reduction in height of the walls on precooling is accompanied by resilient deformation of the top wall **2** and upper inclined side wall portions **6** adjacent their junctions with the end walls.

The container is then filled with liquified gas. In general, this will be at a temperature well below its boiling point and accordingly the bottom wall **1** will be further cooled before the remainder of the container structure. The resulting contraction of the bottom wall **1** is absorbed, in the transverse direction, by further deformation of its corrugations while its contraction in the length direction can cause some deformation of the end walls out of their planes. There is however no difficulty in designing the container in such a way as to ensure that such deformations which are produced during filling of the container with liquified gas are well within the elastic limit of the material of the walls.

The container construction shown in FIGS. **12** to **14** is of generally similar construction to that described above in that it comprises a bottom wall **101**, a top wall **102**, side walls **103** which comprise a vertical section **104** and lower and upper junction portions **105** and **106** and vertical end walls **107**.

Each wall is built up from weldable cryogenic aluminum alloy panels which are preferably formed by extrusion in order to obtain the required corrugated profile and length. The extruded panels are built up into wall sections by being welded together edge-to-edge by an automatic welding plant in the fabrication shop. In view of the great lengths of the extrusions, it is preferable to hold two adjacent panels side-by-side with an appropriate small gap between them and to run a router along the gap between them in order to dress their edges before welding. In this way, any minor irregularities due to the extrusions being not quite straight are removed and the adjacent edges to be welded to each other are properly conformed to each other. If desired, the edges of the panels may be dressed at the extrusion plant and the individual panels may then be transported, for example on rail cars or by ship to the fabrication shop in the shipyard where the ship is to incorporate the containers is being constructed. Obviously, the panels must be suitably marked to ensure that each panel is welded to the adjacent panel to which its edge has been conformed.

As can be seen in the drawings, each of the panels in the walls **102**, **104**, **105** and **106** has integrally formed therewith during the extrusion process a rail-like projecting rib **111** which consists of a stem **112** and a broader head **113** located in the center of the trough formed by each corrugation facing towards the exterior of the container.

The support pads **114** of generally trapezoidal shape have their apices or nose portions conformed to the inclined side walls **115** of the troughs formed by the corrugations. The pads **114** are formed of the resin-bonded fabric material available under the Trade Mark 'Tufnol' and have a central trapezoidal opening **116**. The wall at the apex of each pad **114** is formed with a T-shaped groove **117** by which it can be engaged on the rib **111** in the corrugation to which the pad is to be engaged and can be slid therealong to the required position. The sloping side walls **118** of each pad are shouldered at **119** to conform to the corrugated panels **115**. Preferably a clearance **120** is lift between the base **121** of each corrugation and the top edge of the pads **114**. The base **122** of each pad **114** is seated in a channel section member **123** secured to the ship's frame. In view of the thermally insulating material from which the pads **114** are made, it is not necessary for the channel sections **123** to be made of cryogenic material. The pads **114** are held in the channel sections **123** by clips **124** through which pass square section bars **125** in sliding contact with the base **122**. The bars **125** are suitably anchored against disengagement from the clips **124**, for example by means of split pins **126**.

In view of the relatively low co-efficient of friction between the material of the pads **114** and both the extruded panels and the channels **123**, the pads **114** can slide relative to both of these members during any movements caused by thermal expansion or contraction in order to adopt a position of minimum stress while at the same time supporting the panels against the loads exerted on them by the body of liquefied gas within the container.

It is envisaged that each of the curved walls **105** and **106** would be built-up in the fabrication shop as a complete unit. The pads **114** would then be engaged in each corrugation in the required numbers and the required spacing to carry the outward thrusts to which these container wall portions will be subjected in use and the curved channel section members **123'** will be engaged with the pads **114** and secured to them by the clips **124** and **125**. The complete assembly thus obtained is lifted into position and the curved channel members **123'** are secured to the ship's hull and to the adjacent straight channel members **123** of the bottom wall **101** and/or the vertical side wall **104**. The longitudinal edges of the corrugated wall portions **105** are secured to the longitudinally corrugated wall portions **101**, **104** and **102** by welding.

In order to facilitate the formation of suitable joints between the wall portions in situ in the ship despite minor variations and irregularities in the edges to be joined, it is preferred that the edge panel of each wall portion is formed by a specially extruded section shown at **131** in FIGS. **12** and **13**. The panels **131** differ from the other panels **132** in that one edge, which is to form the outermost edge of the prefabricated wall portion, carries a flange **133**. During assembly of the container, the flanges **133** are brought into contact as far as this is possible and this contact is then improved and made uniform by driving a channel section clamping member **134** over the two flanges **133** to force them into full contact. The clamping member **134** extends for the full length of the joint and is welded to the roots of the flanges **133** at **135**. The clamping member **134** is made sufficiently rigid to withstand the force of separation between the flanges to be encountered in use. Accordingly, the welds **135** are not subjected to great stresses but serve mainly as seals.

It may be preferred to weld a bridging member, e.g. the bridging members **136** (FIG. **13**), to each pair of members joined by a weld e.g. **137** and to introduce an inert gas such as nitrogen into the pocket **138** thus formed at a pressure somewhat greater than that which obtains within the container in use.

In this way, if the weld **137** or either of the welds **139** between the bridging member and the members **132** and **131** should leak, there is no loss of gas from within the container to the outside. Instead, some of the gas from the pocket **138** is lost and is replaced from a suitable source, at the same time giving an indication that there is a leak. Similar protection is afforded for the welds **135** by means of W-shaped bridging members **141** welded at **142** to the panels **131** and at **143** to the clamping member **134**.

The top, bottom and side wall portions **102** to **106** are joined to the ends walls **107** by angle sections, **151** in the case of the straight side wall portions and **152** in the case of the curved side wall portion, the angle sections **152** being suitably curved to follow the curvature of the curved wall portions. Again, pockets for pressurized inert gas are formed along the welds such as **153** by bridging members such as **154** (FIG. **14**).

When the container is filled with liquefied natural gas, the end walls will shrink in the vertical direction (normal to FIG. **14**). The angle section **151** will also shrink in the same direction thereby distorting the corrugations in both the straight and curved side wall portions **104**, **105** and **106**. This movement is accommodated by sliding movement of the bases **122** of the pads **114** in their channels **123** and by resilient deformation of the walls of the corrugations in the side wall portions. At the same time, the side wall portions themselves will shrink longitudinally so that the angle section member **151** will be pulled to the left as seen in FIG. **14**. This movement is readily accommodated by relative sliding movement between the apex or nose of the pads **114** and the sloping walls **115** and rails **111**. Accordingly, there are substantially no loads other than direct compressive loads acting on the pads **114**.

FIGS. **15** to **18** show an arrangement for tying back the corrugated walls of the container to the ship's hull in the case where it is not possible, or not convenient, to form a rail-section rib, such as the rib **111** of FIGS. **13** and **14**, on the corrugated panels. For example, the panels may be formed by rolling in manner similar to that used for conventional sheet piling. Clearly, it is impractical to extrude 9 percent nickel steel. While it might be possible to weld a continuous rail section of rib to the rolled panel, the arrangement shown in FIGS. **15** to **18** can be used instead.

In FIGS. **15** to **18**, the panels **151** and **152** are rolled from 9 percent nickel steel. Each wall section may comprise eight of the plain-edge sections **151** welded together edge-to-edge with two special-section panels **152** welded to the two edges of the assembly, the special panels **152** having a special configuration **153** at their free edges by means of which they may be secured to the corresponding configuration of an adjacent special section **15** of the adjacent wall section by means of a U-section clamping member **154** with a packing piece **155**.

In order to tie the corrugations back to the ship's hull while at the same time permitting the corrugated panels to expand and contract along the length of their corrugations, clips **155** are welded to the backs of the corrugated panels **151** and **152** at intervals corresponding to the frames of the hull. Each clip **155** is effectively a length of channel-section member, the free edges **156** of which are turned inwards and engage in grooves **157** in blocks **158** of an appropriately strong insulating material such as tufnol. The other end of each block **158** is formed as a tenon **159** which is a sliding fit between two rectangular-section rails **160** which follow the lines of the ship's frame and are secured to the ship's hull by means of channel members **161** interconnected by horizontal sealing plates **162** welded to both the channel sections **161** and the ship's hull structure **163**. The blocks **158** are secured in position by bolts **164** tapped into the tenon portion of the block, with washers **165** under the heads of the bolts **164** engaging the rear surfaces of the rails **160**. The blocks **158** are prevented from moving downwards under the weight of the wall sections formed by the panels **151** and **152** by means of horizontal stops **166** welded to the two rails **160** at the underside of each block **158** supporting side walls of the container.

When the container is full, its contents will exert an outward pressure maintaining the base surface of the clips **155** in contact with the end surface **167** of each block **158**. During filling, the container walls are free to contract in the longitudinal direction of the corrugations since the clips **155** are free to slide in this direction relative to the blocks **158**, being assisted by the self-lubricating properties of the material of blocks **158**. The interengagement of the clips **155** and the blocks **158** prevents relative movement in all other directions.

Where regulations require the container to present a double barrier against leakage of contents, the container may have a lining such as that shown at **171** in FIGS. **15** and **16**. The lining **171** may consist of 9 percent nickel steel one-sixteenth of an inch thick. The edges of the sheet portions of the lining **171** may be secured to the edges of adjacent portions and to the container panel such as **151** and **152** by the joint construction **172** shown in detail in FIG. **16**. A strip **173** of cranked-section 9 percent nickel steel extends along the full length of the panel **151** or **152** and is welded to it, for example by spot-welding. The edge of one sheet portion **174** is folded back on itself at **175** and the resulting fold is engaged under the free portion of the cranked-section **173** to hold it in position. The free edge **176** is brought out to extend perpendicular to the underlying wall of the panel **151** or **152**. The edge **177** of the adjacent lining portion **178** is then conformed to the outside of the cranked-section **173** and to the upstanding free edge of the portion **174**. The free edges **176** and **177** are then secured together by continuous resistance welding at **179**, preferably along at least two lines. With this construction, the joints between the lining portions **174** and **178** are reliably fluid-tight and are secured to the panels **152**, being preferably located in the trough of the corrugations to minimize the risk of damage during transport of prefabricated wall sections. It will be noted that the majority of the lining **171** may be applied to the prefabricated wall sections whey they are prefabricated, it being only necessary to instal in the ship the lining portions **178'** extending over the joints **154**.

As shown in the drawings, it is preferred that the corrugations should be formed by flat surfaces interconnected by relatively sharp angles.

The end walls may be anchored to bulk heads against surging of the container contents in rough seas, by tie-rods connected to the horizontal beams, such as the beams **25**, with lost-motion which is fully taken up when the container contracts as its temperature drops to that of its contents. When the container is empty at ambient temperatures, the forces acting on the end walls even in rough seas, will be much less and can be withstood by the stiffness of the end walls and cross beams.

I claim:

1. A low-temperature container for a ship, the container having corrugated top, bottom, side and end walls, in which the corrugations in each wall are unidirectional, the corrugations of the end walls are vertical while the corrugations in all the other walls all run lengthwise of the ship, and the side walls are secured to the ship's hull by spaced sliding connections permitting relative movement in the length direction of the corrugations in the side wall.

2. A container according to claim **1**, in which the end portions of the top wall are free to deform resiliently to accommodate vertical expansion and contraction of the end walls while the remainder of the top wall is supported against upward movement.

3. A container according to claim **1**, in which pads of load-bearing insulating material are interposed between walls of the container and adjacent portions of the ship's structure with freedom for sliding movement of the corrugated wall portions longitudinally of the corrugations.

4. A container according to claim **3** in which the pads have nose portions engaged in the corrugations.

5. A container according to claim **3** in which the pads make interlocking sliding connection with ribs extending longitudinally of the corrugations and projecting therefrom.

6. A container according to claim **3**, in which the outer ends of the pads bear slidably against guide channels secured to the ship's hull.

7. A container according to claim **1**, in which the corrugated walls of said container are built up from extruded panels, adjacent panels being welded together.

8. A container according to claim **1**, in which the corrugated walls are built up from rolled sheet panels having the corrugations rolled therein, adjacent panels being welded together.

9. A container according to claim **1** in which the two end walls are stiffened by transverse beams, the transverse beams at opposite ends being interconnected by tie-rods extending through the container.

10. A container according to claim **1**, in which two adjacent mutually inclined walls having their corrugations running in the same direction are joined by a curved section also formed with corrugations running in the said direction, said walls being tangential to said curved section.

11. A container according to claim **10**, in which the curved corrugated wall section is slidably supported on pads which in turn are slidably supported in curved guide channels secured to the hull.

12. A container according to claim **8**, in which the connections comprise channel-section clips having inwardly turned edges received in grooves in support pads.

13. A container according to claim **1** in which the corrugations in the walls comprise substantially plane front and rear walls interconnected by substantially plane sloping walls.

14. A container according to claim **1** and including an inner liner in said container, said liner being secured at joints in the liner to the inner walls of the container.

15. A container according to claim **14** in which a clip-section member is secured to an inner face of a wall of the container and extends longitudinally of the corrugations, one liner portion is folded back on itself and engaged under the clip section and the free edge is welded to the free edge of an adjacent portion of said liner.

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