

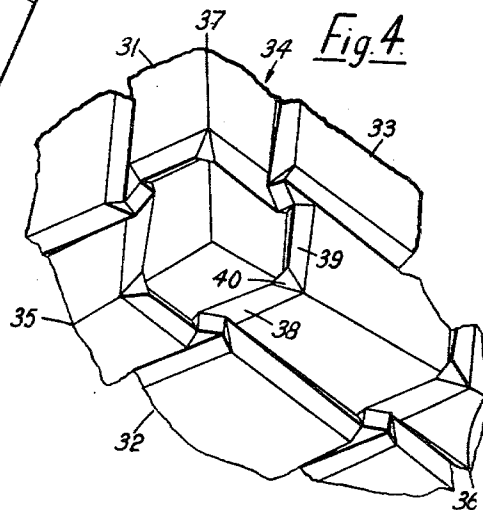
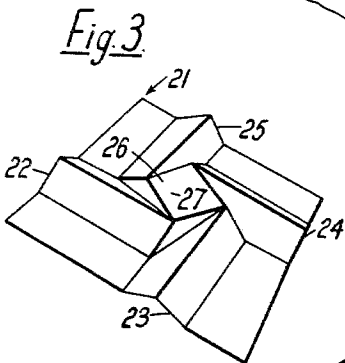
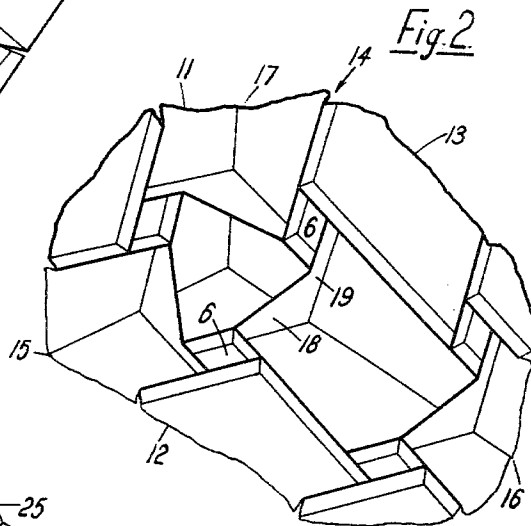
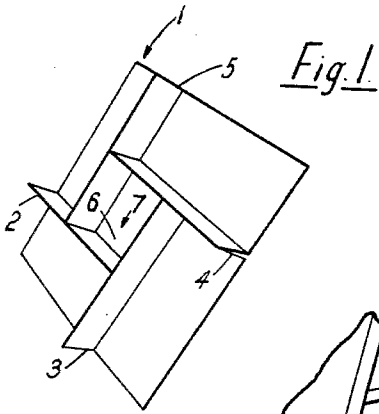
May 18, 1965

M. J. FRENCH ETAL
EXTENSIBLE METAL SHEETS

3,184,094

Filed June 4, 1963

3 Sheets-Sheet 1



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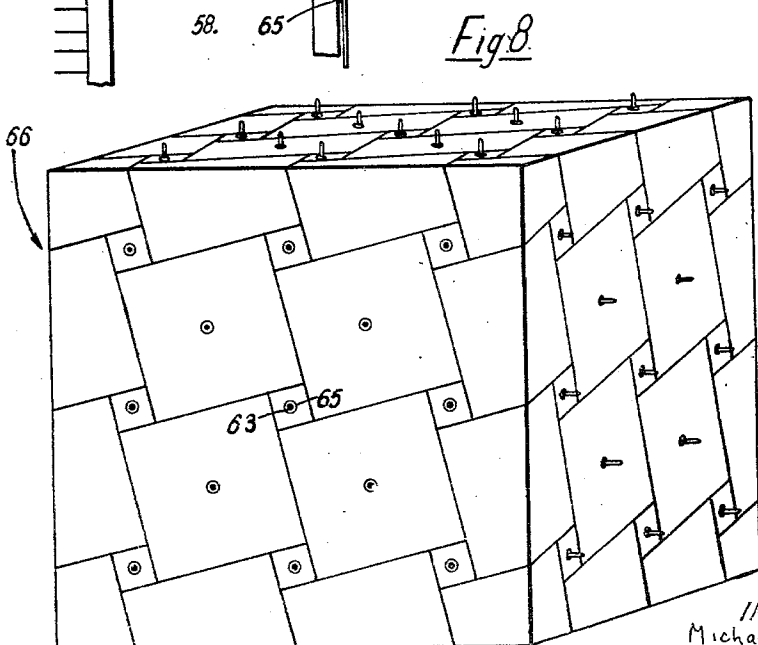
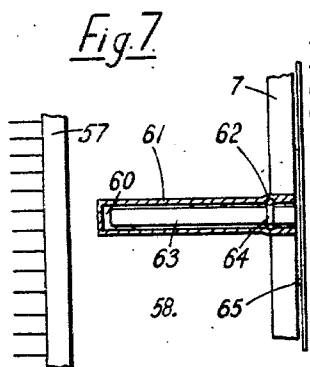
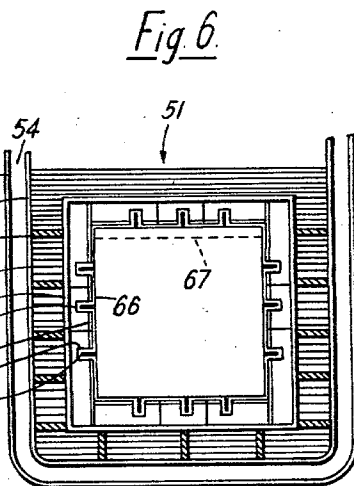
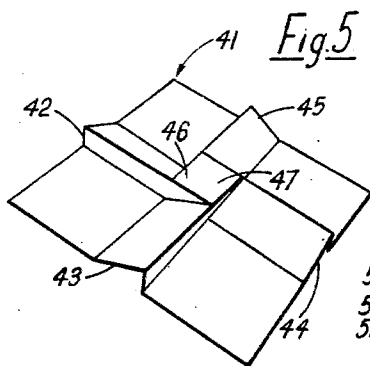
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M. J. FRENCH ETAL
EXTENSIBLE METAL SHEETS

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3 Sheets-Sheet 2



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M. J. FRENCH ETAL
EXTENSIBLE METAL SHEETS

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3 Sheets-Sheet 3

Fig. 9.

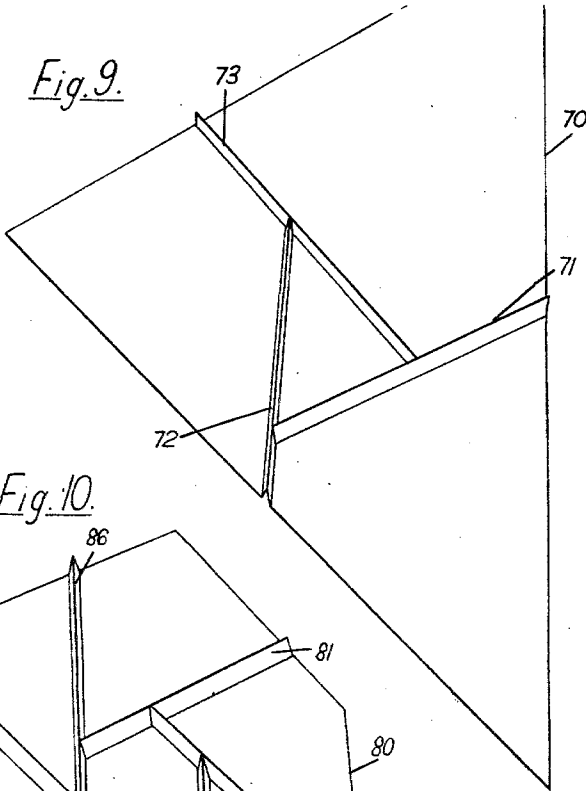


Fig. 10.

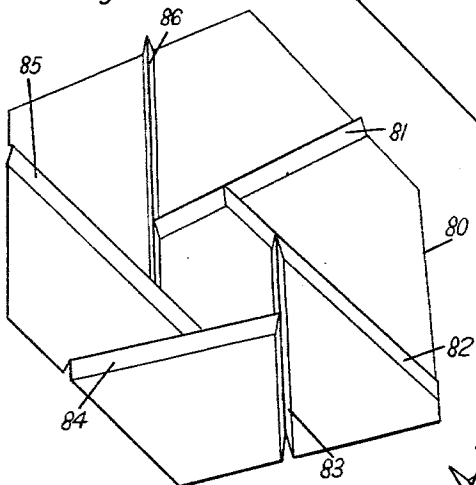
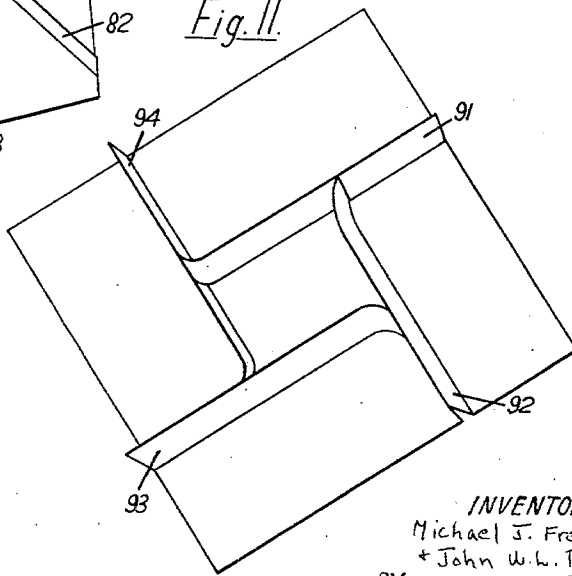


Fig. 11.



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3,184,094

EXTENSIBLE METAL SHEETS

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17 Claims. (Cl. 220—9)

This invention concerns extensible sheets, that is sheets which when fully restrained and subjected to low temperatures will not suffer any stress exceeding their elastic limit. In other words, these sheets are ones which when under stress will be more extensible than allowed by the modulus of elasticity of the material thereof. The invention also concerns a container suitable for the storage of a liquefied gas, in which one or more walls is or are fabricated from the extensible metal sheet, and a ship having such a container. By "liquefied gas" is meant liquid that boils at atmospheric pressure at a temperature below the ambient temperature, for example liquefied natural gas, methane, ethane, propane, air, hydrogen, nitrogen or oxygen.

A liquefied gas can be stored in a container fabricated of thin metal walls supported externally. However, use of such a container is complicated by need to relieve it to an acceptable level of stresses produced by contraction or expansion of its walls with changes in temperature; that is, it is necessary to relieve the container of most of the thermal stresses. The problem of relieving thermal stresses in the walls of the container becomes particularly acute at temperatures normally encountered in the handling of liquefied gases at atmospheric pressure, because the differences between the liquefied gas temperatures and ambient temperature can be very great, for example about 290° F. in the case of liquefied natural gas, which boils at atmospheric pressure at a temperature of about -258° F. Moreover, if the container is partly charged with a liquefied gas, a large temperature gradient can exist in the column of gas above the liquid level, which temperature gradient can induce additional thermal stresses in the walls of the container. Unless thermal stresses in the walls of the container are relieved, the stresses may cause the container to fail.

It has now been found that the thermal stresses described above can be relieved if one or more walls of the container is or are fabricated from an extensible metal sheet formed with corrugations extending in crossing directions and so disposed as to render the sheet extensible in all directions. A sheet metal simply corrugated in one direction is stiffened against flexing in all directions but one, namely that in which flexing to open or close the corrugations, occurs. This leaves the sheet extensible transversely to the corrugations, by opening of the corrugations. If the sheet is then simply corrugated with a second set of corrugations crossing the first set of corrugations, the stiffness produced by both sets of corrugations leaves the sheet so that extension in any direction is resisted. This is the difficulty that is overcome in accordance with the invention.

According to the invention an extensible sheet is one having an enclosed area bounded entirely by non-intersecting but meeting corrugations which corrugations extend linearly beyond the enclosed area. The term corrugation of course includes simple folds. This sheet will later be referred to as a defined sheet.

By these means, since the corrugations in any direction do not reach completely across the extensible metal sheet, they are not called on to extend longitudinally. Extension or contraction of the sheet in a direction parallel

to a corrugation is achieved by movement of each corrugation as a whole.

In the preferred embodiment of the invention (that is an extensible metal sheet formed with corrugations terminating within the sheet, in which the adjacent ends of any four adjacent corrugations enclose an area of metal so that each of said corrugations is offset relatively to its opposite corrugation and terminates in the periphery of the enclosed area), the ends of the corrugations terminating in the peripheries of the enclosed areas move relatively to one another. They are free to do this by reason of a rotational movement of the enclosed areas. The remaining corrugations transverse to the set of the corrugations discussed above do not impede the extension or contraction of the sheet but open or close to permit it. The same principles apply when the corrugations enclose areas other than quadrilaterals.

In the preferred embodiment, the adjacent corrugations can extend in suitable crossing directions, but preferably form two sets of corrugations at right angles to one another. Opposite corrugations terminating in the periphery of an enclosed area are preferably parallel i.e. the enclosed area is a rectangle, or preferably a square.

Adjacent corrugations can have any desired profile, which can be symmetrical or unsymmetrical. When corrugations terminating within the sheet to form a corner have unsymmetrical profiles, they are arranged so that the same sides of the profiles are in the clockwise direction and the other sides of the profiles are in the anticlockwise direction.

The area bounded by the corrugations can lie either in or out of the plane of the extensible metal sheet; that is, it can be bounded by the flanks of sides of the corrugations, or the crests of the corrugations. When adjacent corrugations are mutually at right angles to each other, the enclosed area can be a square or a square with triangular flanges. The enclosed area will rotate about its centre of area when the extensible sheet is contracted or expanded by stresses.

The enclosed area may be of any shape, having any number of sides. However, to minimise the stresses set up in the sheets when it contracts at low temperatures it is preferable, if the sides of the enclosed area are equal in length and also preferable if the enclosed area is in the centre of the sheet. Preferred shapes are triangles or hexagons and especially quadrilaterals e.g. squares.

The average of the ratios of the length of each corrugation bounding each enclosed area to the total length of each corrugation is preferably less than 1 to 2, e.g. about 1 to 4. The corrugations may if desired be curved before meeting an adjacent corrugation, preferably curved outwardly of the enclosed area. When referring to sheets substantially the same shape as the enclosed area, the curvature of the corrugations is for this purpose ignored i.e. the sheet is the same shape as the enclosed area but for the rounded corners. In order to obtain the best results the corrugations should extend linearly beyond the enclosed area to the sides of the sheet, or at least extend to nearly the sides of the sheet.

The extensible sheet, preferably metal, can be fabricated by suitably pressing a flat metal sheet or bending and welding together suitable metal sections. The extensible metal sheet can be of any thickness appropriate to the stresses to be taken by it and to the degree of extensibility required. Preferred extensible metal sheets are fabricated from steels, but other metals possessing desired structural strengths can be used, for example aluminum or alloys of aluminum.

One or more walls of a container suitable for the storage of a liquefied gas can be fabricated from any of the sheets of the invention. Such a container will normally

be used as a primary container supported by a secondary container of thermally insulating material capable of bearing the liquid load for which the primary container is designed. The primary and secondary containers may be kept in a housing.

The primary container can be fabricated by welding together suitable sections of the extensible sheet. It is preferable however, and often necessary for large walls, if the walls comprise sheets having a plurality of enclosed areas. Such sheets may be either a composite extensible sheet comprising a plurality of defined sheets spaced in side-by-side and end-to-end relationship so that each of the corrugations of each of the defined sheets is in line with and meets a corrugation in a contiguous sheet, or may be an extensible sheet comprising a plurality of zones, each having the features of and corresponding to the defined sheet, in which the zones are spaced in side-by-side and end-to-end relationship so that each of the corrugations of each zone is in line with, and meets a corrugation in a contiguous zone. Because of the geometry, the defined sheet or the zone corresponding to the defined sheet, also has to be one which is substantially the same shape as its enclosed area, one in which the corrugations extend to the sides of the sheet, and one in which the enclosed area is in the centre of the sheet and has sides which are equal in length. In the extensible composite sheet referred to above the individual defined sheets are preferably welded together. The extensible sheet comprising a plurality of zones (or the extensible composite sheet), may be made by welding sheets together along the corrugations. In this case corrugations which are curved outwardly of the enclosed area before meeting an adjacent corrugation are an advantage, because often the sheets which are welded together along the corrugations can be fabricated by stamping.

When the walls of the container are sheets having a plurality of enclosed areas and they meet one another directly at the edges and corners of the container it is essential that the edges do not pass through an enclosed area. This means in practice that if the enclosed area is a square, large containers at least, can only be a hexahedron in which the walls are squares or rectangles. If the enclosed areas are triangles, large containers at least, can only be pyramidal in shape.

It is not necessary for the top wall of the container to be a sheet with an enclosed area or a plurality of enclosed areas, and this wall therefore may be conventional design, thus cheapening the cost of the container.

If desired, the container can be so assembled that the wall or walls fabricated from the extensible sheet is or are under compression, so as to relieve the thermal stresses produced by charging the container with liquefied gas. The primary container can be located by attaching pegs to the outside of said container and rotatably securing the pegs in recesses in the walls of the secondary container, for example by spring rings. Preferably, the pegs are attached to the primary container at the centres of the enclosed areas of the sheets, the centres consequently acting as fixed points about which the areas can move. The use of the pegs has the advantage of dampening any vibrations in the walls arising from vibration of the enclosed areas. An additional advantage of the use of the pegs is that construction of the primary container from suitable sections having pegs already attached to them can be facilitated by first constructing the secondary container and then using the recesses in the walls of the secondary container as jigs in the construction of the primary container; individual sections of the primary container will be positioned for welding together by their being held in place by cooperation between the pegs and the recesses.

The secondary container can be any suitable thermally insulating material, for example asbestos, balsa wood faced with plywood, foamed glass, glass wool, granulated cork or particles of foamed elastomeric material, for instance polystyrene or polyurethane foam. Preferably,

it is a thermally insulating material that neither substantially contracts nor substantially expands with changes in temperature, for example balsa wood faced with plywood. The thermally insulating material can be in the form of blocks or in the form of a continuous layer. The face of the thermally insulating material presented to the outside of the primary container preferably has recesses to receive in rotating fit pegs fixed to the outside of the primary container as described above. When the pegs are metal pegs, any recess can have a nylon bush containing a spring ring to prevent longitudinal but allow rotational movement of the peg to be inserted in the recess. The secondary container, apart from supporting the primary container, provides, between the primary container and the housing, a barrier for cold liquid and gas that might escape from the primary container, as well as providing a thermally insulated space for the primary container.

The housing can be of any suitable material, for example aluminum or plywood. Its effect is to box in the primary and secondary containers.

If the composite container described above is to be used in the hold of a ship, it is preferably supported by spacers connected to the structure of the ship, so that stresses in the walls of the container can be transmitted to the structure of the ship. Any space between the housing and the hull of the ship is preferably filled with a thermally insulating material, which can be the same as that used for the secondary container. The total amount of thermally insulating material used in the composite container and to fill any space between the housing and the hull of the ship should be sufficient to keep the temperature of the hull above the embrittlement temperature of the hull when the primary container is charged with liquefied gas. This requirement is particularly necessary when the primary container is used for the storage of liquefied natural gas, which boils at atmospheric pressure at a temperature of about -258°F .

The invention will now be particularly described with reference to the accompanying drawings, in which:

FIGURE 1 is a view of an extensible metal sheet in which the enclosed area is a square;

FIGURE 2 is a view of the inside of a corner of a container having at least three walls fabricated from extensible metal sheets as described with reference to FIGURE 1;

FIGURE 3 is a view of another extensible metal sheet in which the enclosed area is a square;

FIGURE 4 is a view of the inside of a corner of a container having at least three walls fabricated from extensible metal sheets as described with reference to FIGURE 3;

FIGURE 5 is a view of another extensible metal sheet in which the enclosed area is a square;

FIGURE 6 is a section of a ship having a container suitable for the storage of a liquefied gas, in which the liquefied gas is stored in a primary container supported by a secondary container of thermally insulating material the primary container having its bottom, top and side walls fabricated from extensible metal sheets as described with reference to FIGURES 1 and 2, and both containers being kept in a housing;

FIGURE 7 is a section of a detail of FIGURE 6;

FIGURE 8 is a view of the outside of the primary container of FIGURE 6.

FIGURE 9 is a view of an extensible sheet in which the enclosed area is a triangle.

FIGURE 10 is a view of an extensible sheet in which the enclosed area is a hexagon.

FIGURE 11 is a view of a modification of the extensible sheet as shown in FIGURE 1.

In FIGURE 1, an extensible sheet 1 of stainless steel has four adjacent corrugations 2, 3, 4 and 5, which form two sets of corrugations at right angles to one another. The corrugations have symmetrical profiles, and the bottoms of sides of the adjacent ends of the corrugations en-

5

close a square area 6 whose plane lies in the plane of the extensible sheet. Opposite corrugations 2, 4 and 3, 5 respectively are offset relatively to one another, and each of corrugations 2, 3, 4 and 5 terminates in the periphery of square area 6.

Extensible sheet 1 was fabricated by bending and welding together suitable section of stainless steel, and was not heat treated after the welding.

When extensible sheet 1 is contracted or extended, corrugations 2, 3, 4 and 5 open or close, and bending moments about axes perpendicular to the plane of the sheet are induced in the sides of the corrugations at the corners of square area 6. The bending moments cause square area 6 to rotate about its centre of area 7, thereby enabling each corrugation to move longitudinally as a whole and the extensible sheet to be extensible in all directions.

In FIGURE 2, three walls 11, 12 and 13 fabricated from extensible metal sheets as described with reference to FIGURE 1 meet in a corner of a container 14 suitable for the storage of a liquefied gas. The walls terminate in edges 15, 16 and 17 of the container, and are butt-welded together. Alternatively the walls may be folded thereby avoiding welds at the edge joints. At each edge of the container, any corrugation 18 in one wall is deepened and made integral with a corresponding corrugation 19 in a second wall, so as to render the edge of the container longitudinally extensible.

In FIGURE 3, an extensible sheet 21 of stainless steel has four adjacent corrugations 22, 23, 24 and 25, which form two sets of corrugations at right angles to one another. In this case, the corrugations have symmetrical profiles, and the flanks of sides of the adjacent ends of the corrugations enclose an area 26 in the form of a square with triangular flanges. The enclosed area lies out of the plane of the extensible sheet. Opposite corrugations 22, 24 and 23, 25 respectively are offset relatively to one another, and each of corrugations 22, 23, 24 and 25 terminates in the periphery of area 26.

Extensible sheet 21 was fabricated by suitably pressing a flat sheet of stainless steel.

When extensible sheet 21 is contracted or extended, corrugations 22, 23, 24 and 25 open or close, and bending moments about axes perpendicular to the plane of the sheet are induced in the sides of the corrugations at the corners of enclosed area 26. The bending moments cause area 26 to rotate about its centre of area 27, thereby enabling each corrugation to move longitudinally as a whole and the extensible sheet to be extensible in all directions.

In FIGURE 4, three walls 31, 32 and 33 fabricated from extensible metal sheets as described with reference to FIGURE 3 meet in a corner of a container 34 suitable for the storage of a liquefied gas. The walls terminate in edges 35, 36 and 37 of the container, and are butt-welded together. At each edge of the container, any corrugation 38 in one wall is joined to a corresponding corrugation 39 in a second wall by a corner corrugation 40, so as to render the edge of the container longitudinally extensible.

In FIGURE 5, an extensible sheet 41 of stainless steel has four adjacent corrugations 42, 43, 44 and 45, which form two sets of corrugations at right angles to one another. The corrugations have unsymmetrical profiles, and the crests of the adjacent ends of the corrugations enclose a square area 46 whose plane lies out of the plane of the extensible sheet. Opposite corrugations 42, 44 and 43, 45 respectively are offset by reason of their profiles being reversed relatively to one another, and each of corrugations 42, 43, 44 and 45 terminates in the periphery of square area 46.

Extensible sheet 41 was fabricated by bending and welding together suitable sections of stainless steel, and was not heat treated after the welding.

When extensible sheet 41 is contracted or extended, corrugations 42, 43, 44 and 45 open or close, and bending moments about axes perpendicular to the plane of the

6

sheet are induced in the sides of the corrugations at the corners of enclosed area 46. The bending moments cause square area 46 to rotate about its centre of area 47, thereby enabling each corrugation to move longitudinally as a whole and the extensible sheet to be extensible in all directions.

In FIGURE 6, a ship 51 has an outer hull 52 and an inner hull 53 inwardly spaced therefrom, both hulls being fabricated from steel plates. Ballast water can be contained in space 54 between the hulls.

Inwardly spaced from inner hull 53 and separated therefrom by spacers 55 and glass wool 56 is a plywood housing 57; the spacers are rigidly secured to the inner hull and the housing.

Immediately within housing 57 are blocks of balsa wood 58 faced with plywood 59, each block having a recess 60 extending into the balsa wood. As shown in FIGURE 7, each recess 60 has a nylon bush 61 containing a spring ring 62. Passing into each recess 60 is a stainless steel peg 63 having a circumferential groove 64 adapted to receive a spring ring; cooperation between the groove and the ring allows the peg to rotate but prevents it moving laterally.

Each peg 63 is welded to a circular stainless-steel base plate 65 (FIGURES 7 and 8), which is welded to the outside of a stainless steel container 66 suitable for the storage of a liquefied gas. The container is shown in greater detail in FIGURE 8, and has its bottom, top and side walls fabricated from extensible metal sheets as described with reference to FIGURES 1 and 2. The pegs and their base plates are attached to the centres of area enclosed by the adjacent ends of any four adjacent corrugations. The attachment of the pegs to the outside of container 65 is shown in greater detail in FIGURE 7.

The optimum level for liquefied gas in container 66 is shown at 67. When liquefied gas is charged at atmospheric pressure into the container, thermal stresses produced in the bottom, top and side walls of the container are relieved by corrugations opening or closing. Any vibrations set up in the bottom, top and side walls of the container are damped by pegs 63. The weight of the liquefied gas is transmitted through facing 59, blocks 58, housing 57 and spacers 55 to inner hull 53.

In FIGURE 9, an extensible sheet 70 of stainless steel has three non-intersecting corrugations 71, 72 and 73. The corrugations have symmetrical profiles, and they meet to form an enclosed triangle.

In FIGURE 10, the extensible sheet 80 is similar to sheet 70 of FIGURE 9 except that there are six non-intersecting corrugations 81, 82, 83, 84, 85 and 86 meeting to enclose a hexagon.

FIGURE 11 shows a modified form of the sheet described with reference to FIGURE 1 in which each of the corrugations 91, 92, 93 and 94 are rounded outwardly of the enclosed square before meeting another corrugation.

The principle of operation of the sheets as shown in FIGURES 9, 10 and 11 is the same as that shown in FIGURE 1.

We claim:

1. An extensible unitary, continuous, fluid impermeable sheet including an enclosed area bounded entirely by non-intersecting but meeting corrugations in the sheet, which corrugations extend linearly beyond the enclosed area, and which corrugations are capable of flexing in response to thermal expansion and contraction of the sheet; a supporting structure for said sheet, spaced from said sheet, and a pivotal supporting connection between the center of said enclosed area and said supporting structure whereby said sheet expands and contracts in response to temperature changes by angular rotary movement about said pivotal connection due to the flexing of said corrugations.

2. A sheet as claimed in claim 1 in which the enclosed area is a quadrilateral.

3. A sheet as claimed in claim 1 in which the enclosed area is a triangle.

4. A sheet as claimed in claim 2 in which the sides of the enclosed area are equal in length.

5. A sheet as claimed in claim 2 in which the average of the ratios of the length of each corrugation bounding the enclosed area to the total length of each corrugation is about 1 to 4.

6. A sheet as claimed in claim 5 in which the sides of the enclosed area are equal in length.

7. A sheet as claimed in claim 2 in which the end portions of the corrugations are curved before meeting an adjacent corrugation.

8. A sheet as claimed in claim 6 in which the enclosed area is in the centre of the sheet.

9. A composite extensible continuous, gas impermeable sheet comprising a plurality of sheet units joined continuously at their edges, each sheet unit having in the centre of the sheet unit an enclosed area of the same geometric shape as the sheet unit, the enclosed area being bounded entirely by non-intersecting but meeting corrugations in the sheet unit, which corrugations extend linearly beyond the enclosed area and extend to the sides of the sheet unit, the sheet unit being spaced in side-by-side and end-to-end relationship so that each of the corrugations of each sheet unit is in line with and meets a corrugation in a contiguous sheet unit, said corrugations flexing in response to thermal expansion and contraction of the sheet units; and a pivotal support in the center of at least one of said enclosed areas, on which support the enclosed area is mounted for limited angular movement in response to thermal changes.

10. A composite sheet as claimed in claim 9 in which the sheet units spaced in side-by-side and end-to-end relationship are welded together.

11. An extensible sheet comprising a plurality of zones each zone having in the centre of the zone an enclosed area of the same geometric shape as the zone, the enclosed area being bounded entirely by non-intersecting but meeting corrugations, which corrugations extend linearly beyond the enclosed area and extend to the sides of the zone, the zones being spaced in side-by-side and end-to-end relationship so that each of the corrugations of each zone is in line with and meets a corrugation in a contiguous zone and a pivotal fixed support in the center of at least one of said enclosed areas for supporting said extensible sheet, said enclosed area being mounted on said fixed support for limited angular movement about said support in response to thermal changes.

12. A container suitable for the storage of a liquefied gas in which at least one of the walls of the container is fabricated from an extensible sheet as claimed in claim 9.

13. A container suitable for the storage of a liquefied gas in which at least one of the walls of the container is fabricated from an extensible sheet as claimed in claim 11.

14. A container suitable for the storage of a liquefied gas comprising a primary container in which at least one of the walls of the container is fabricated from an extensible sheet as claimed in claim 9, and a secondary container of thermally insulating material supporting said primary container.

15. A container suitable for the storage of a liquefied gas comprising a primary container in which at least one of the walls of the container is fabricated from an extensible sheet as claimed in claim 11, and a secondary container of thermally insulating material, supporting said primary container.

16. A container suitable for the storage of a liquefied gas comprising a primary container in which at least one of the walls of the container is fabricated from an extensible sheet as claimed in claim 9, a secondary container of thermally insulating material, there being a number of said pivotal supports comprising pegs that are rotatably secured within recesses in the walls of the secondary container and are attached to the primary container.

17. A container suitable for the storage of a liquefied gas comprising a primary container in which at least one of the walls of the container is fabricated from an extensible sheet as claimed in claim 11, a secondary container of thermally insulating material there being a number of said pivotal supports comprising pegs that are rotatably secured within recesses in the walls of the secondary container and are attached to the primary container.

References Cited by the Examiner

UNITED STATES PATENTS

1,799,234	4/31	Huff	220—9
2,020,630	11/35	Anderson	220—63
2,971,667	2/61	Benson et al.	220—10

FOREIGN PATENTS

525,687 9/40 Great Britain.

Theron E. Condon, *Primary Examiner*.