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J. O. JACKSON ET AL.

2,329,765

LOW TEMPERATURE STORAGE TANK

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2 Sheets-Sheet 1

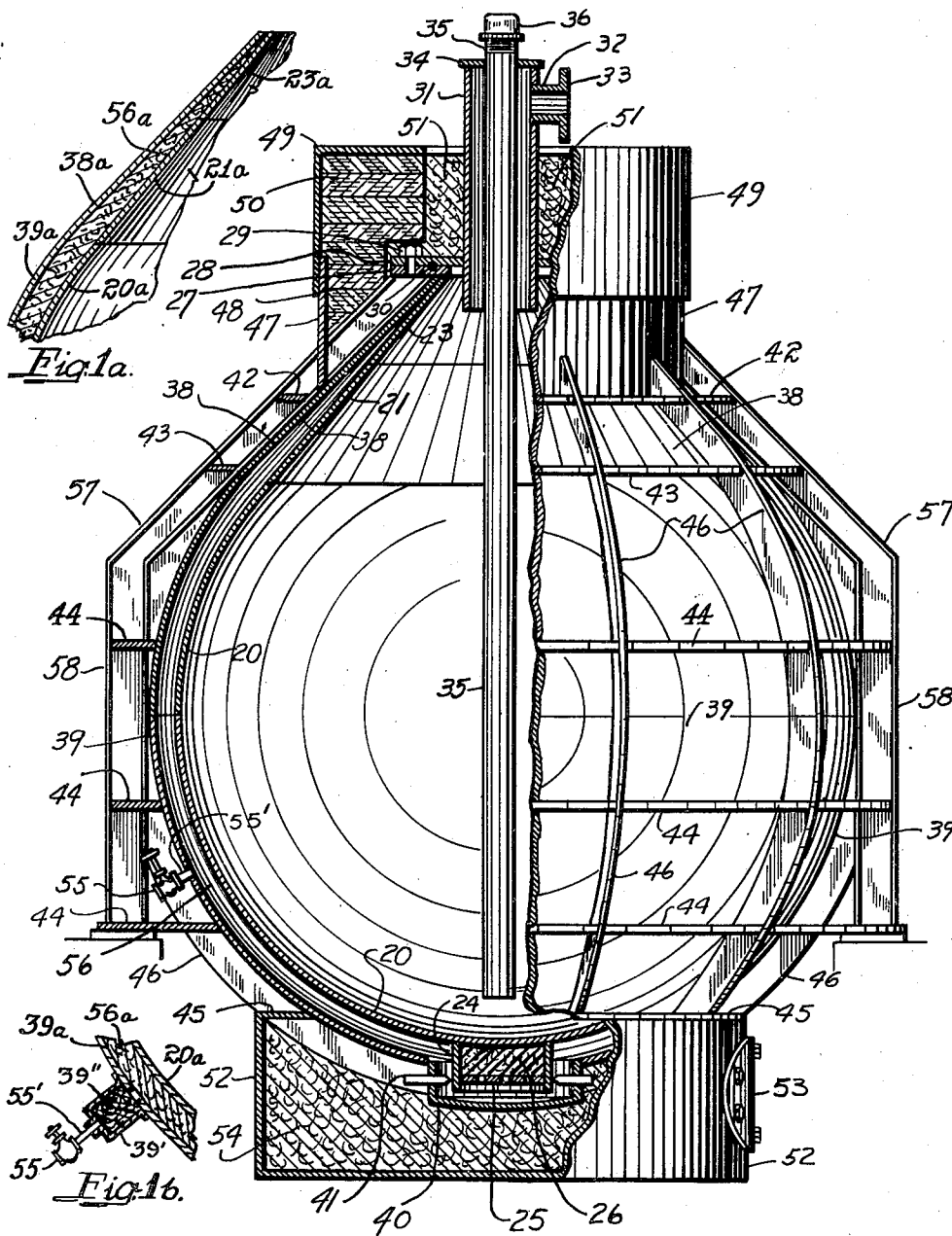


Fig. 1

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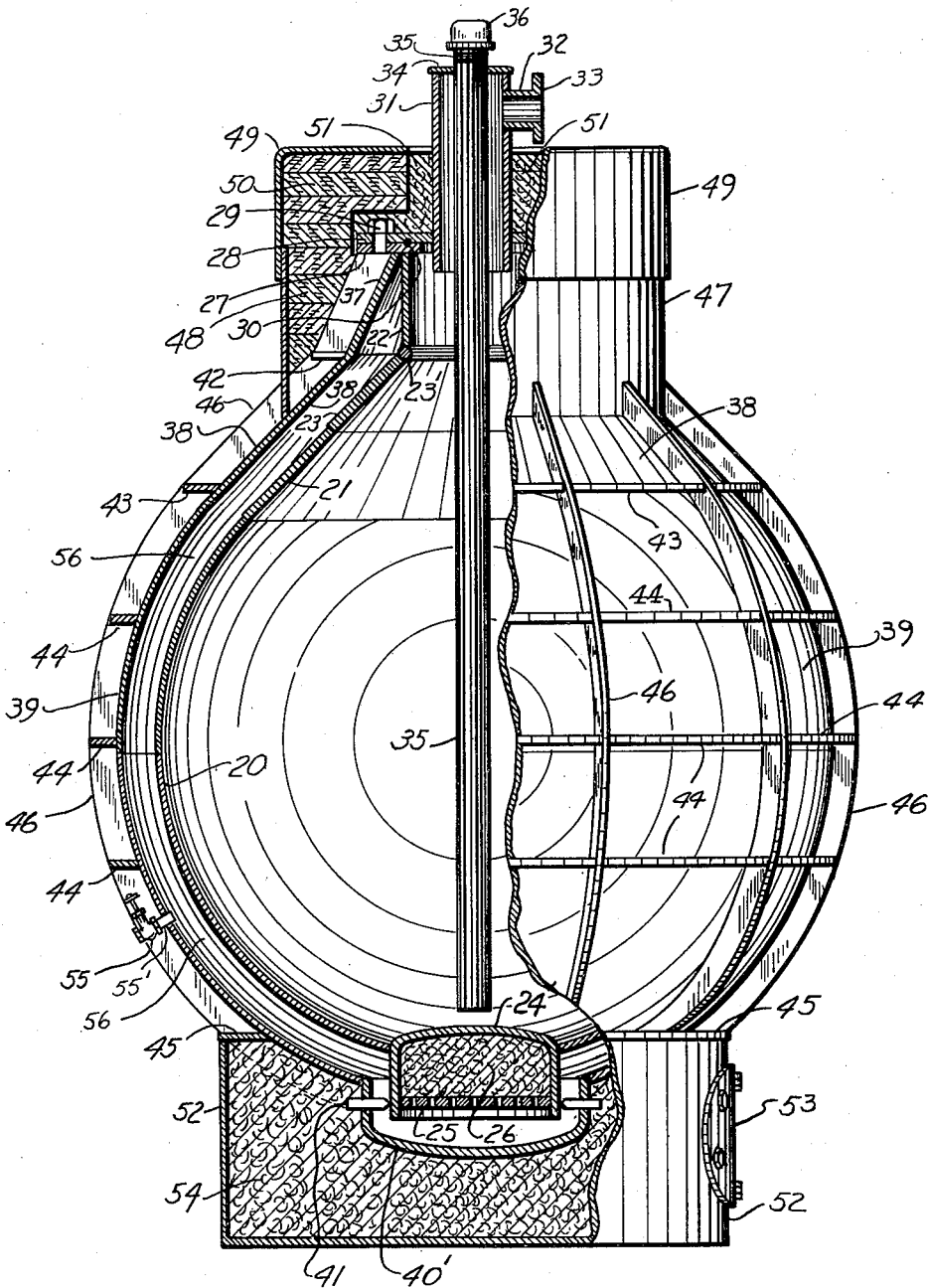


Fig. 2

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LOW TEMPERATURE STORAGE TANK

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11 Claims. (Cl. 220—9)

This invention relates to storage tanks and particularly to metallic tanks or containers for the storage of liquids and vapors (fluids) at low temperatures.

Containers consisting of double-walled glass or metallic vessels having an evacuated space between the double walls have been used for many years for the storage of extremely cold liquids and vapors such as liquid oxygen, liquid nitrogen, etc. These containers have, however, been of rather small capacity, the largest of which we have knowledge having a capacity of less than 10 gallons. To allow for internal expansion and contraction due to temperature changes and to ensure good insulating properties, such containers have invariably been constructed in such manner that the inner vessel is suspended at its neck from the neck of the outer vessel. For these reasons it has not been practicable to produce containers of this type which have larger volumetric capacity. In many cases buffers made of felt or other materials having good insulating properties have been placed at advantageous positions between the two vessels to assist in the support of the inner vessel but even under such conditions the practical limit of the present glass or metallic vacuum bottle has been definitely reached at about the capacity stated.

It is, therefore, one of the objects of this invention to provide a container which is capable of holding large amounts of fluids—either liquids or vapors—at low temperatures and particularly at the extremely low temperatures involved by liquid air, liquid oxygen, liquid nitrogen, etc.

Another object of the invention resides in the provision of a large container for low temperature fluids which is so constructed that it not only has the requisite strength but also has excellent insulating characteristics while at the same time making necessary provision for internal expansion and contraction due to temperature changes.

An additional object of the invention resides in the provision of a container which has a spherical body portion and a conical polar portion, the conical portion being arranged tangentially to the spherical portion.

A still further object of the invention resides in providing a large tank for low temperature fluids which has a spherical body portion and a tangentially disposed conical portion and wherein the said portions are provided with girders arranged in the manner of lines of latitude and meridians of longitude on the earth's surface.

A still further object of the invention resides in

a double-walled container for low temperature fluids, the inner wall of which is composed of an austenitic material such as chromium-nickel steel, particularly one containing approximately 18% chromium and 8% nickel, and the outer surface of which is highly polished.

Other and further objects and advantages reside in the various combinations, subcombinations and details hereinafter described and claimed and in such other and further matters as will be understood by those skilled in the art or pointed out hereinafter. Such include the provision of either an evacuated chamber or the use of a heat insulating medium between the spaced container walls.

In the accompanying drawings:

Fig. 1 illustrates a double-walled evacuated container for low temperature fluids responding to the present invention partially in elevation and partially in vertical section;

Fig. 1a is a fragmentary view of a modification of the invention in which the double-walled container is filled with heat insulating material between its walls;

Fig. 1b is a fragmentary view of a modified valve arrangement for the form of invention illustrated in Fig. 1a; and

Fig. 2 is a view similar to Fig. 1 of a structurally modified form of the invention.

Like numerals designate corresponding parts in the various views of the drawings.

Referring now to Fig. 1 of the drawings, the container there shown has an inner shell which consists of a hollow segmental spherical shell portion 20 formed of sheet metal parts united as by welding and a conical polar portion 21, 23 forming a continuation of the said spherical portion and united to it as by welding. Portion 21, 23 is composed of two integrally united parts but may equally well be a single unitary member. Both variations are deemed to be a part of the invention. At the lower polar portion of spherical portion 20 a relatively heavy flanged ring-like member 24 is strongly attached as by welding. Member 24 is provided with a perforated closure 25 also secured in place as by welding. This arrangement provides a compartment or chamber 26 which is loosely packed with a material which is capable of absorbing a relatively large quantity of gas, especially at low temperatures. A number of materials can be employed with success and we mention, purely by way of example, activated carbon, silica gel, and charcoal derived from woods and shells among which beechnut shell charcoal is particularly effective.

The upper edge of conical portion 21, 23 is firmly secured, as by welding, to a relatively thick horizontally disposed centerless annular flange member 27. Superimposed on flange 27 is a cover plate 28 secured to flange 27 by fastening means such as the cap screws 29. The joint between members 27 and 28 is gas-tight, being sealed by a ring gasket 30 of suitable material.

In containers of the present type some slight heat infiltration inevitably occurs which causes vaporization. In the present construction such vapors can escape by way of tubular member 31 and branch pipe 32 located laterally near the top of member 31. Member 31 passes vertically through and is attached to cover plate 28 which is provided with a central aperture for such purpose. The uniting of member 28 and 31 may be by welding. Tubular branch pipe 32 terminates in a flange 33 to which may be bolted a continuation of the vent pipe which may carry the vented vapors through a line provided with proper safety valves to special condensing machinery for the purpose of re-liquefying and conserving such vented vapors.

End piece 34 closes the upper end of tube 31 and is attached thereto as by welding. Member 34 has a central opening through which tube 35 extends downwardly nearly to the bottom of the container. Members 34 and 35 are united in gas-tight relationship, preferably by welding. The contents of the container may be withdrawn through tube 35 by removing the cap 36 normally in place thereon and connecting tube 35 to a pipe or hose or other suitable conduit. By applying sufficient pressure through branch pipe 32 the contents of the container may be forced up through tube 35 and directed to any desired point.

Attached to flange 27, as by welding, and extending downwardly and outwardly therefrom is the conical sheet metal portion 38 which is very close to or in contact with portion 23 at its top but which thereafter diverges therefrom so as to produce an annular chamber or space 56 between the inner spherical member 20 and the outer spherical member 39 of the container, the member 39 being composed of sheet metal parts assembled and secured as by welding. The lower polar portion of member 39 is cut out and member 40 secured thereto as by welding. Member 40 is made up of a cylindrical portion and a lower concavo-convex closure of disc shape which is welded or otherwise secured to the cylindrical portion. A plurality of angularly disposed short bar-like members 41 extend radially inwardly through the vertical cylindrical portion of member 40 and are welded in such position. Members 41 terminate in truncated conical ends which are slightly spaced from the outer surface of the vertical cylindrical member 24. Thus member 24 is incapable of appreciable lateral movement, being held thereagainst by members 41, but is enabled to move vertically without undue restriction.

A plurality of horizontal continuous sheet metal rings 42, 43, 44 and 45 are attached, as by welding, to outer shell 38, 39. A plurality of vertical bar-like sheet metal ribs 46 are disposed around the periphery of the outer shell and are attached to it and to the horizontal rings 42, 43, 44 and 45 and member 40 as by welding. The purpose of these bar-like members is to strengthen or stiffen the outer shell against collapse due to the pressure of the atmosphere on the external surface thereof after the space 56 has been evacuated. It will be noted that the horizontal rings

and vertical ribs are arranged in the manner of lines of latitude and meridians of longitude on the earth's surface. Depending upon the size of the tank, the sections of metal employed, etc., the members 46 may be omitted where their strengthening effect is not essential.

A thin cylindrical sheet metal shell 47 is suitably attached to the outer shell and extends vertically to about the level of flange 27. This cylindrical shell is spaced from the periphery of flange 27 and hence forms an annular opening between the upper end of member 38 and the said cylindrical shell. This opening is filled with a heat insulating material 48, such as cork blocks. A cover member 49 consisting of a hollow cylindrical shell having an annular substantially flat top forming a roof which fits loosely over member 47 in telescoping fashion. Cover member 49 encloses an annular body of solid heat insulating material 50, such as cork blocks, cemented in place to the cover member. The interior portion 51 of the cover member the sides of which are defined by the solid insulating material 50 is filled after the cover member is in position with a loose granular or fibrous heat insulating material such as granulated cork. The purpose of the space 51 is to permit the cap to be withdrawn over tube 31 and flange 33 so that bolts 29 may be removed, whenever necessary, to gain access to the interior of the container.

A cylindrical sheet metal shell 52, having a substantially flat bottom, is attached as shown to the exterior shell as by welding it to ring 45. This sheet metal shell is provided with a number of openings each of which is normally closed by a bolted-on closure plate 53 through which the chamber 54 may be filled with a granular or fibrous heat insulating material such as granulated cork. Communicating with the space 56 between the two shells and attached to the outer shell, as by welding, is hermetically tight needle valve 55 provided at one end with a copper tube connection 55', which is substantially or entirely leak-proof.

It will be observed that the modified structure of Fig. 2 is fundamentally the same as that of Fig. 1 already described. This will be apparent by the use of the same numerals to designate like parts. In Fig. 2, however, the inner shell 20 is secured to a frusto-conical shell portion 21, 23 which terminates in a vertical cylindrical inner neck 22, the juncture between 22 and 23 being provided with a girder-like ring member 23'. Since the entire weight of the inner shell is suspended by neck 22 this latter member is made of adequate strength and thickness to prevent damaging stresses and strains from arising in the structure.

Further, outer shell 39 of Fig. 2 has the frusto-conical portion 38 as a continuation thereof, the shell terminating in a converging cylindrical collar-like outer neck 37 which rises to meet flange 27 and is welded thereto. In this case, horizontal ring 42 is welded in place at the juncture of parts 38 and 37. In Fig. 2 also the parts 24' and 40' are a little different from parts 24 and 40 as will be readily ascertainable upon inspection. In other respects there is no material difference between the two containers such as would alter the nature of the inventive concept.

In designing the container we proportioned the interior surfaces to resist an internal pressure equal to one atmosphere (due to the evacuation of the space between the two shells) plus the weight of the liquid at its highest elevation plus

whatever pressure might have to be applied in order to remove the liquid from the vessel. The spherical portion of the interior shell is proportioned as for spherical surfaces, using commonly known methods for obtaining the stress caused by the weight of the stored liquid and also that caused by the atmospheric and imposed inside vapor pressures. The conical portion is designed the same as the spherical portion except that the cone radius is used in the customary way in determining the maximum stress.

The horizontal circular reinforcing ring 23' is proportioned to withstand the horizontal component of the radial stress in cone portion 21, 23 at its juncture with ring 23'. The exterior shell is designed so that in cooperation with the bar-like stiffeners, when used, it will have sufficient strength to resist the external atmospheric pressure on the entire outer shell. Members 24 and 24' are designed so as to safely resist the internal pressure and weight of the contents and the depending flanges thereof are proportioned so as to safely transmit to bar-like members 41 any horizontal forces which may be present. Members 40 and 40' are designed to resist the external pressure and to receive the reactions from bars 41 and to transmit the same into the outer shell with the cooperation of vertical stiffeners 46, when used.

Our vacuum containers may be used either for stationary storage purposes or as a component part of trucks, railroad cars, barges, ships, airplanes, etc. for the transportation of the stored contents. The design is considered especially suitable for use in barges and ships where the longitudinal and transverse bulkheads are partitions of the ships and could be rigidly attached, as by welding, to the vertical stiffeners 46 which would not only form an excellent support for the vacuum vessels themselves but which, because of their very great rigidity, would act to stiffen the vessels and to divide the interior of the vessels or barges into bulkheaded spaces, which is considered desirable in boat building.

In the use of our vacuum tank we have found that even though extreme care is taken in making all of the welded joints, after a period of use there will be some infiltration of air or gases, perhaps through very tiny pores in the sheet metal itself or perhaps from gas entrapped in the metal during its manufacture. We, therefore, provide a gas absorbing material, such as activated carbon, which has the property of absorbing gas, especially at the very low temperature of the fluid which we contemplate storing. This gas-absorbing material is, therefore, placed in contact with the inner vessel so that it will be maintained at a very cold temperature where its efficiency in absorbing gases is the greatest. Under certain conditions it might be desirable to further evacuate the space 56 between the two vessels. For example, in a barge containing several of our tanks, a vacuum pump might be provided and connected with very tightly sealed copper tubing to needle valve 55 so that a very high vacuum could be maintained at all times.

We have determined that a vacuum of the order of $\frac{1}{400}$ of a millimeter of mercury (absolute pressure) will reduce the heat infiltration from the outer to the inner shell by conduction or convection through any possible remnant of unevacuated gases to almost zero. There remains, however, heat infiltration from the outer to the inner shell through the neck and through the lateral stabilizing members 41. We have found that

these losses may be greatly reduced by increasing the distance over which the heat must travel in reaching the inner shell. For example, (referring now to Fig. 2) for heat to reach the inner shell through the neck it must travel the entire length of the path from the intersection of members 47 and 38 up through the outer neck to the intersection with flange 27, then down the inner neck 22, then down 21, until contact with the liquid is established. Since the heat conductivity of a metal is inversely proportional to the length of the metal path through which the heat must travel, it is apparent that this method of insulation is very effective in reducing neck heat losses.

The same thing is true of the insulation at the bottom of the vessel and, in addition, the special construction of members 41 further reduces the heat infiltration at this point. The bar-like members 41 have a body of sufficient diameter to enable them to carry the stresses imposed upon them as a column. The ends, however, are truncated and the extreme ends may be hard-faced so as to provide a very high unit bearing value. Likewise, the spots on the vertical flanges of members 24 and 24' against which members 41 bear may also be hard-faced so as to provide a corresponding high unit bearing on that member. As a result of this construction the actual metal to metal contact between members 24 and 24' and 41 is not large and, since when member 24 cools it tends to contract somewhat there is normally no actual contact except when the vessel is tilted slightly so that the weight of the contents tends to force member 24 or 24' to press against one or more of the members 41.

The remaining source of heat infiltration is the black body radiation from the outer to the inner shell. This may be considerable especially if the temperature of the contents being stored is several hundred degrees Fahrenheit below the temperature of the outside shell. In order to reduce this loss to a minimum we construct the inner shell 20 of sheet metal having a very high polish on the exterior surface, which effectively reflects any radiated heat back to the outer shell. We have found that austenitic stainless steel containing from about 8-24% chromium and about 2½-12% nickel with the remainder iron and the usual impurities is entirely satisfactory, and we prefer to use so-called 18-8 which has a chromium content of approximately 18% and a nickel content of approximately 8% for the construction of the inner shell. These steels, being austenitic in nature, do not become brittle at low temperatures and satisfactory welds may be made, using welding rods of the same or slightly higher chromium and nickel content, e. g., 9-25% chromium and 2-12½% nickel, which welds also are satisfactory at low temperatures. We, therefore, construct the entire inner shell from material of the above range of composition as well as the outer neck and the outer conical portion down to approximately the juncture with 41. We also use stainless steel of the composition stated or an alloy consisting of approximately 3½% nickel, the balance ordinary mild steel, for tubes 31 and 35 and connecting parts. We have found cork board to be the best insulating material for the neck insulation and granulated cork the best for the insulation in spaces 51 and 54, although there are other materials which are entirely satisfactory.

The form of the invention illustrated in Fig. 1a is the same as that of Fig. 1 except that in addi-

tion to employing an evacuated space 56 between the shells and necks we fill such space with a suitable heat insulating medium 56a such as granulated cork, charcoal or pulverized balsa wood. In such case it is to be understood that valve 55 and tube 55' are modified as shown in Fig. 1b to provide a chamber 39' filled with a straining or filtering material 39'' such as coarse steel wool to prevent loss of insulating material into the evacuating line. A polished outer surface on the inner shell is unessential and therefore may be dispensed with. This form of container is less expensive and for many purposes entirely satisfactory. The heat insulating medium above mentioned also acts to prevent black body heat radiation into the inner shell in the same manner that a polished surface, provided on the outer surface of the inner shell, prevents such by reflecting heat back toward the outer shell. Such constitutes another effective mode of realizing the present results. It should further be understood that the construction of Fig. 2 may likewise be modified to utilize a filling of insulating or radiation blocking material in accordance with Fig. 1a.

We have described two particular forms of the invention, with the understanding that other and further additions, omissions, substitutions and variations may be made both as to construction and as to materials of construction. The invention is rather that defined by the appended claims.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent is:

1. An insulated container comprising inner and outer metal shells having substantially spherical spaced apart lower portions and upper portions which are attached to said lower portions and which converge to a common line of contact, said upper portions being substantially conical at their lines of attachment to their lower portions and substantially tangent thereto, said outer shell being reinforced by stiffening means adapted to enable it to support the weight and contents of said inner shell, said stiffening means being attached to the upper extremities of said shells at said common line of contact.

2. In an insulated container, an outer metal shell having a substantially spherical lower portion and a substantially conical upper portion which is substantially tangent thereto, an inner metal shell having a substantially spherical lower portion spaced from the spherical portion of the outer shell and a substantially conical portion above said spherical portion and which is substantially tangent thereto; the upper extremities of the outer and inner shells being in contact one with the other and attached to a metal member which extends laterally beyond the outer periphery of the upper extremity of the outer shell, said outer shell being reinforced by stiffening means attached to its outer surface and to said metal member.

3. An insulated container comprising inner and outer metal shells having substantially spherical spaced apart lower portions and upper portions which are attached to said lower portions and which contact one with the other at their upper extremities, said upper portions being substantially conical at their lines of attachment to the lower portions and substantially tangent thereto, a metal member to which the upper extremities of both shells are attached, said outer shell being reinforced by vertically and horizontally extend-

ing stiffening means adapted to enable it to support the weight and contents of said inner shell, said vertically extending stiffening means being attached to the metal member to which the upper extremities of both shells are attached.

4. In an insulated container, an outer metal shell having a substantially spherical lower portion and a substantially conical upper portion which is substantially tangent thereto, an inner metal shell having a substantially spherical lower portion spaced from the spherical portion of the outer shell and a substantially conical portion above said spherical portion and which is substantially tangent thereto; the upper extremities of both shells being in contact one with the other and attached to a metal member which extends laterally beyond the upper extremity of the outer shell, said outer shell being reinforced by stiffening means attached to its outer surface and to said metal member and means carried partially by each shell adjacent its lower polar region for limiting relative horizontal movement between the shells at such regions while permitting relative vertical movement of the same.

5. In an insulated container, an outer shell having a substantially spherical lower portion and a substantially conical upper portion substantially tangent thereto, an inner shell having a substantially spherical lower portion spaced from the spherical portion of the outer shell and a substantially conical portion above said spherical portion and which is substantially tangent thereto, a laterally extending member to which the upper extremities of said shells are attached as by welding, stiffening means welded to the exterior of the outer shell and to such laterally extending member, means carried partially by each shell adjacent its lower polar region for limiting relative lateral movement of said shells at such region while permitting relative vertical movement of the same and heat insulating means carried by the outer shell and surrounding said movement limiting means.

6. In an insulated container, inner and outer metal shells having substantially spherical spaced apart lower portions and upper portions which are substantially conical and which at their upper extremities are in contact one with the other, a metal member to which the upper contacting extremities of the shells are attached, which extends laterally beyond such extremities and has an opening extending vertically there-through giving access to the interior of the inner shell, a closure element removably attached to said member and carrying a tubular member which extends through said opening and has its lower end open to the interior of the inner shell, a walled compartment which surrounds the upper end of the outer shell, extends upwardly from said shell to a position adjacent said removable element and has a removable cover provided with an opening in its top around said tubular member and heat insulating material within said compartment.

7. A container as defined in claim 2 in which the terminal upper portion of the inner shell is cylindrical and the terminal upper portion of the outer shell while conical is of a steeper angle than the conical portion which is substantially tangent to the spherical portion of the outer shell.

8. A container as defined in claim 5 in which that part of the movement limiting means carried by the inner shell is hollow, has a perforated closure positioned in its lower end and contains

a body of gas absorbing material which contacts with the inner shell and is in communication with the space between the shells.

9. A container as defined in claim 4 in which the outer shell adjacent its lower polar region carries means for heat insulating the means for limiting relative horizontal movement between the shells at the lower polar regions thereof.

10. A container as defined in claim 4 in which the outer shell in addition to the stiffening means which are attached to the metal member to which the upper extremities of both shells are attached, is provided with spaced horizontal outwardly extending rings welded thereto and arranged in

the manner of lines of latitude of the earth's surface.

11. A container as defined in claim 5 in which the outer shell carries heat insulating means which surrounds the upper extremities of the shells and the laterally extending member to which such upper extremities are attached, and the outer shell adjacent the lower polar region thereof carries heat insulating means which surrounds the means for limiting the relative lateral movement of the shells at the lower polar regions thereof.

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