Oct. 16, 1945. J. O. JACKSON 2,386,958

SPHERICAL TYPE INSULATED CONTAINERS FOR LIQUEFIED GASES

Filed Jan. 8, 1942 7 Sheets-Sheet 1

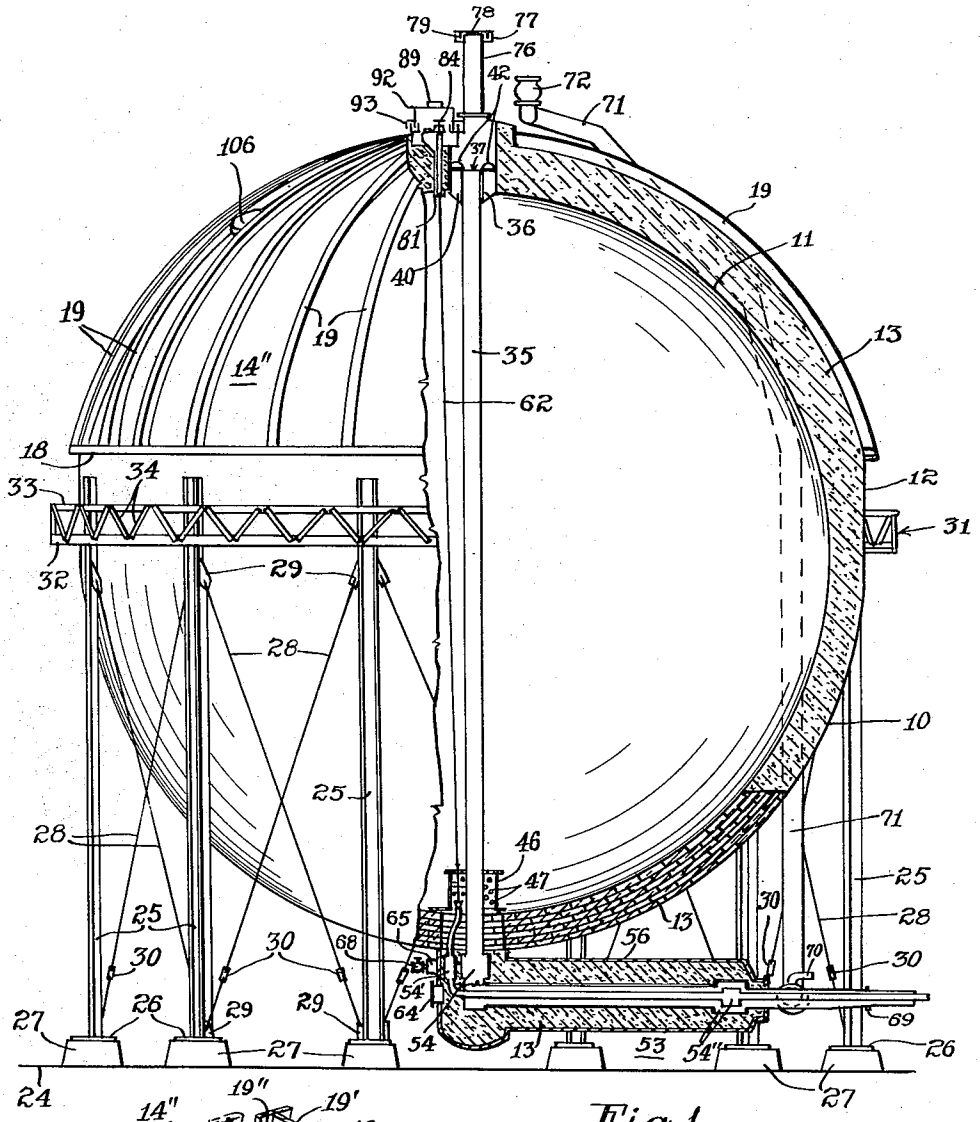


Fig. 1.

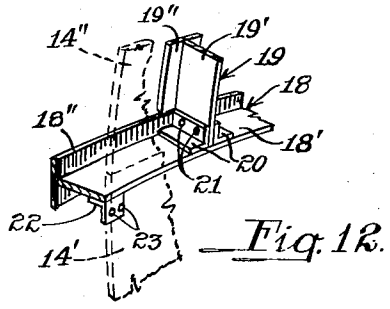


Fig. 12.

INVENTOR
James O. Jackson
By Green & McCallister
His attorneys

Oct. 16, 1945. J. O. JACKSON 2,386,958

SPHERICAL TYPE INSULATED CONTAINERS FOR LIQUEFIED GASES

Filed Jan. 8, 1942 7 Sheets-Sheet 2

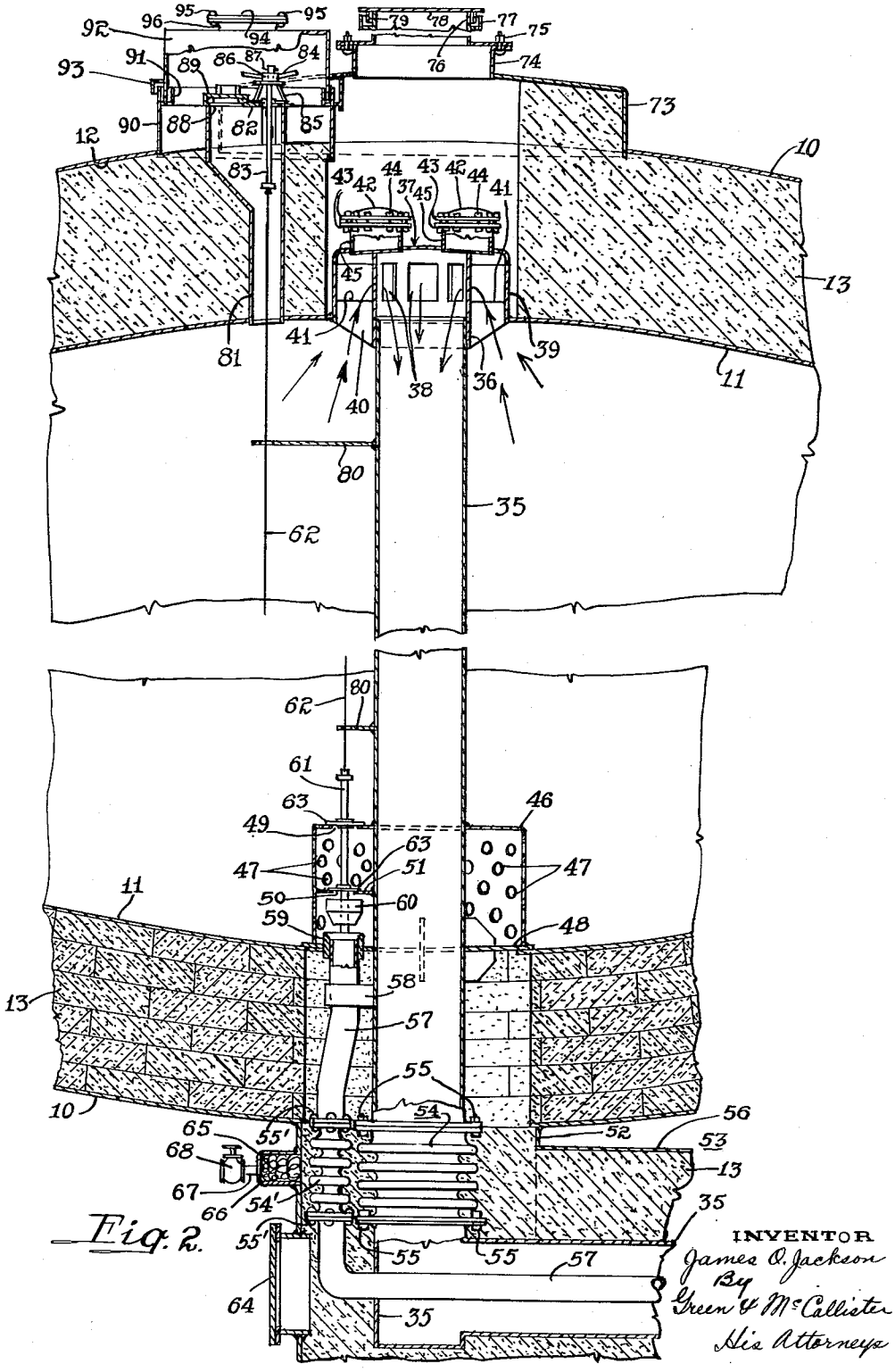


Fig. 2.

INVENTOR
James O. Jackson
By
Green & McCallister
His Attorneys

Oct. 16, 1945. J. O. JACKSON 2,386,958

SPHERICAL TYPE INSULATED CONTAINERS FOR LIQUEFIED GASES

Filed Jan. 8, 1942 7 Sheets-Sheet 3

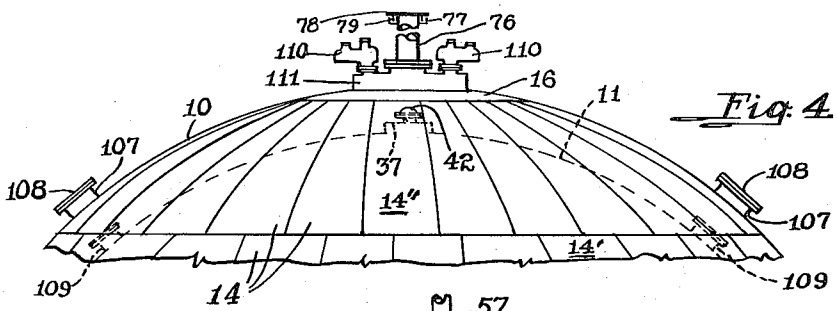


Fig. 4.

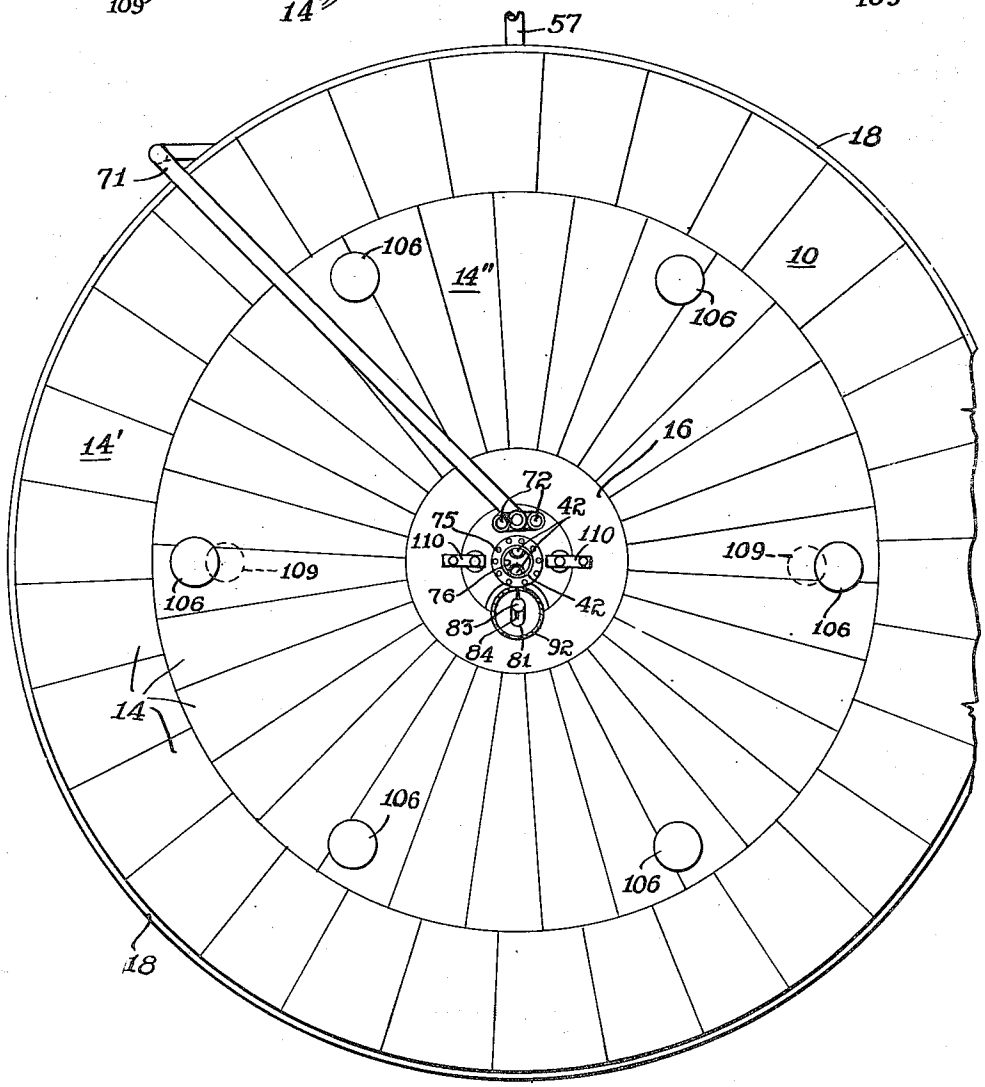


Fig. 3

INVENTOR
James O. Jackson
By Green & McCallister
His Attorneys

Oct. 16, 1945. J. O. JACKSON 2,386,958

SPHERICAL TYPE INSULATED CONTAINERS FOR LIQUEFIED GASES

Filed Jan. 8, 1942 7 Sheets-Sheet. 4

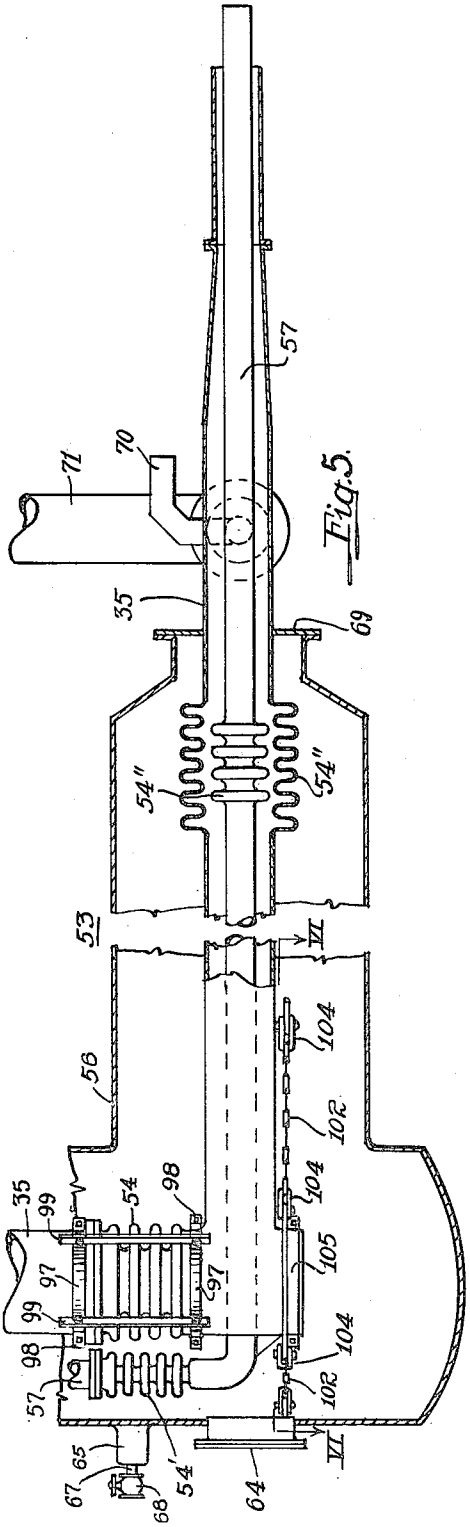


Fig. 5.

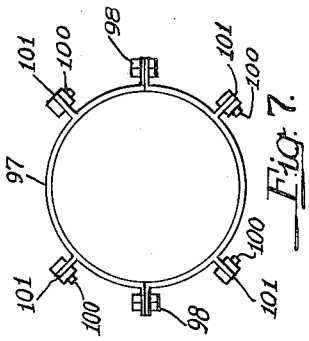


Fig. 7.

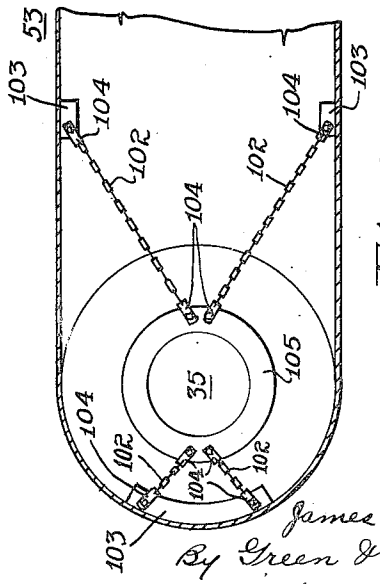


Fig. 6.

INVENTOR
James O. Jackson
By Green & McCallister
His Attorneys

Oct. 16, 1945. J. O. JACKSON 2,386,958

SPHERICAL TYPE INSULATED CONTAINERS FOR LIQUEFIED GASES

Filed Jan. 8, 1942 7 Sheets-Sheet 5

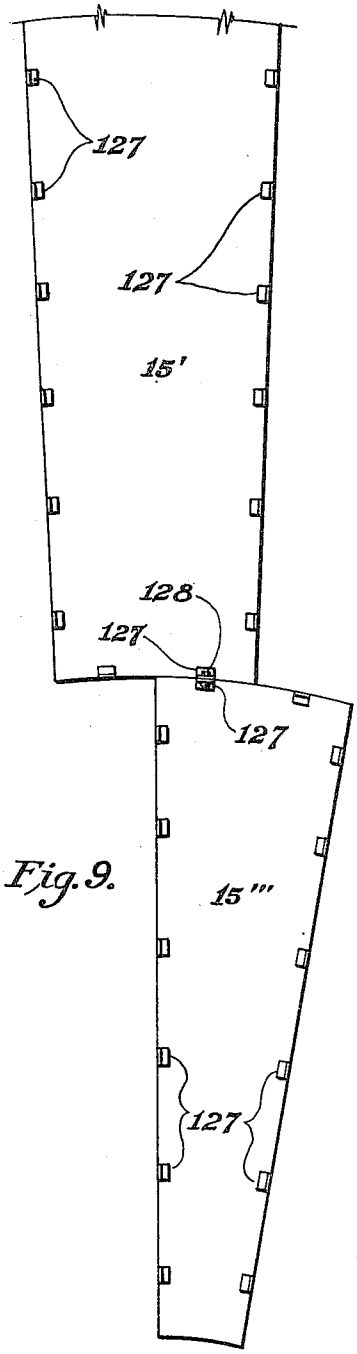


Fig. 9.

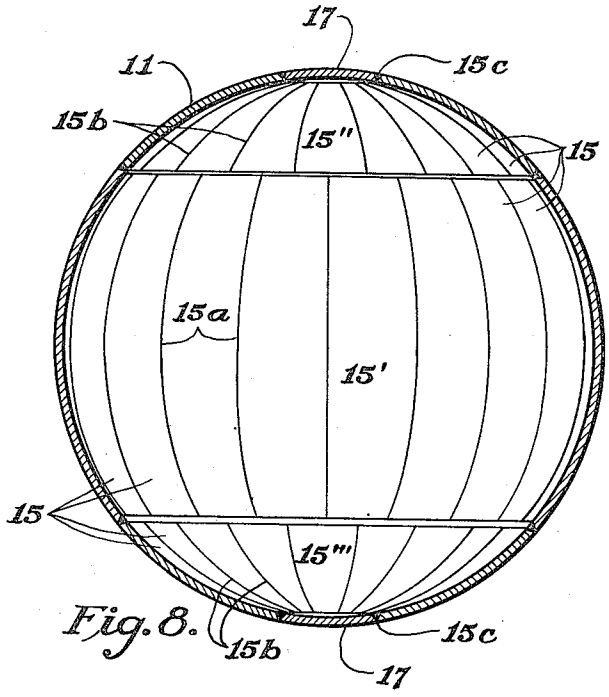


Fig. 8.

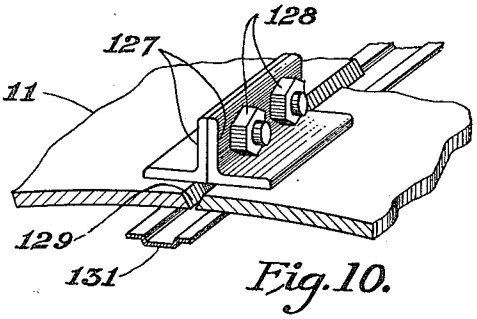


Fig. 10.

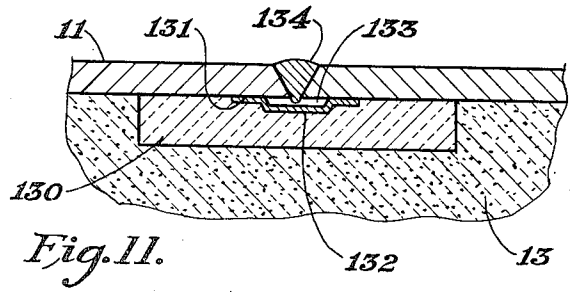


Fig. 11.

James O. Jackson INVENTOR

BY Green & McCallister

His ATTORNEYS

Oct. 16, 1945. J. O. JACKSON 2,386,958

SPHERICAL TYPE INSULATED CONTAINERS FOR LIQUEFIED GASES

Filed Jan. 8, 1942 7 Sheets-Sheet 6

Fig. 13.

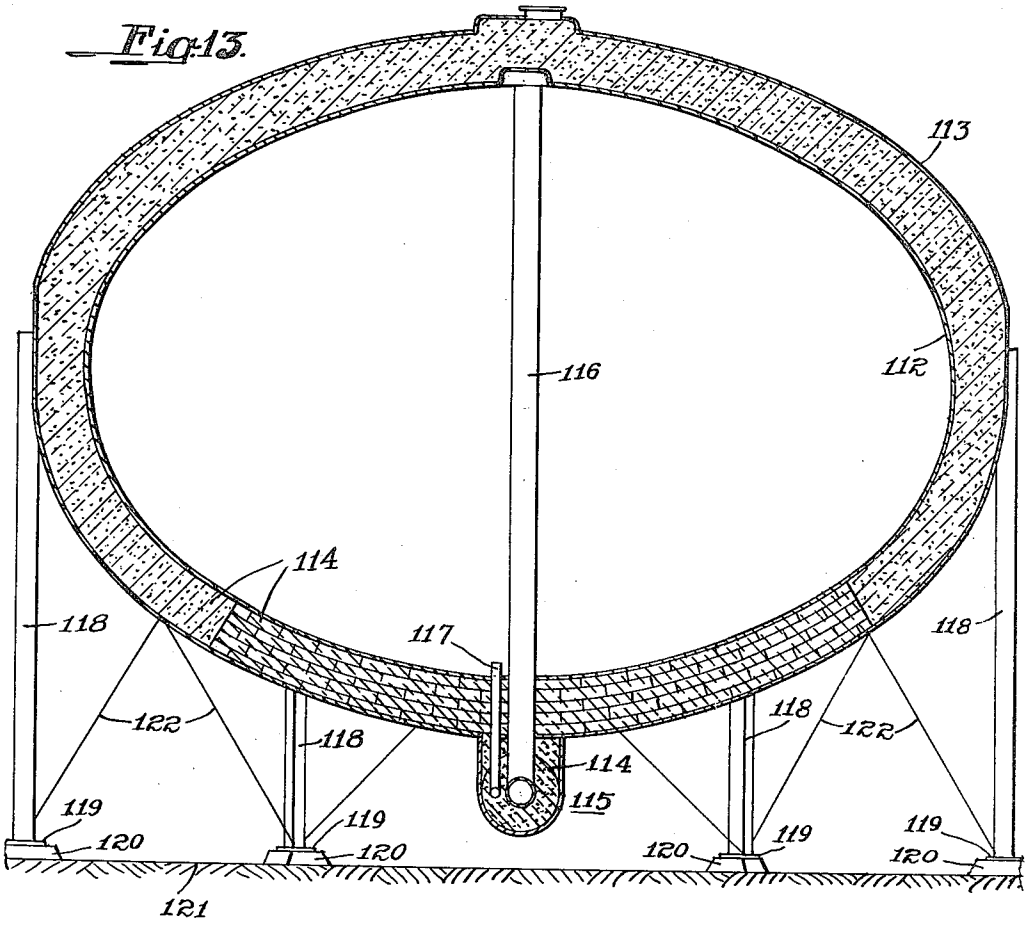
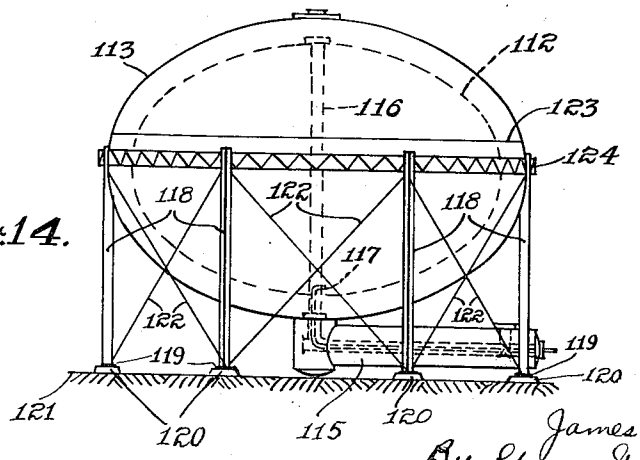


Fig. 14.

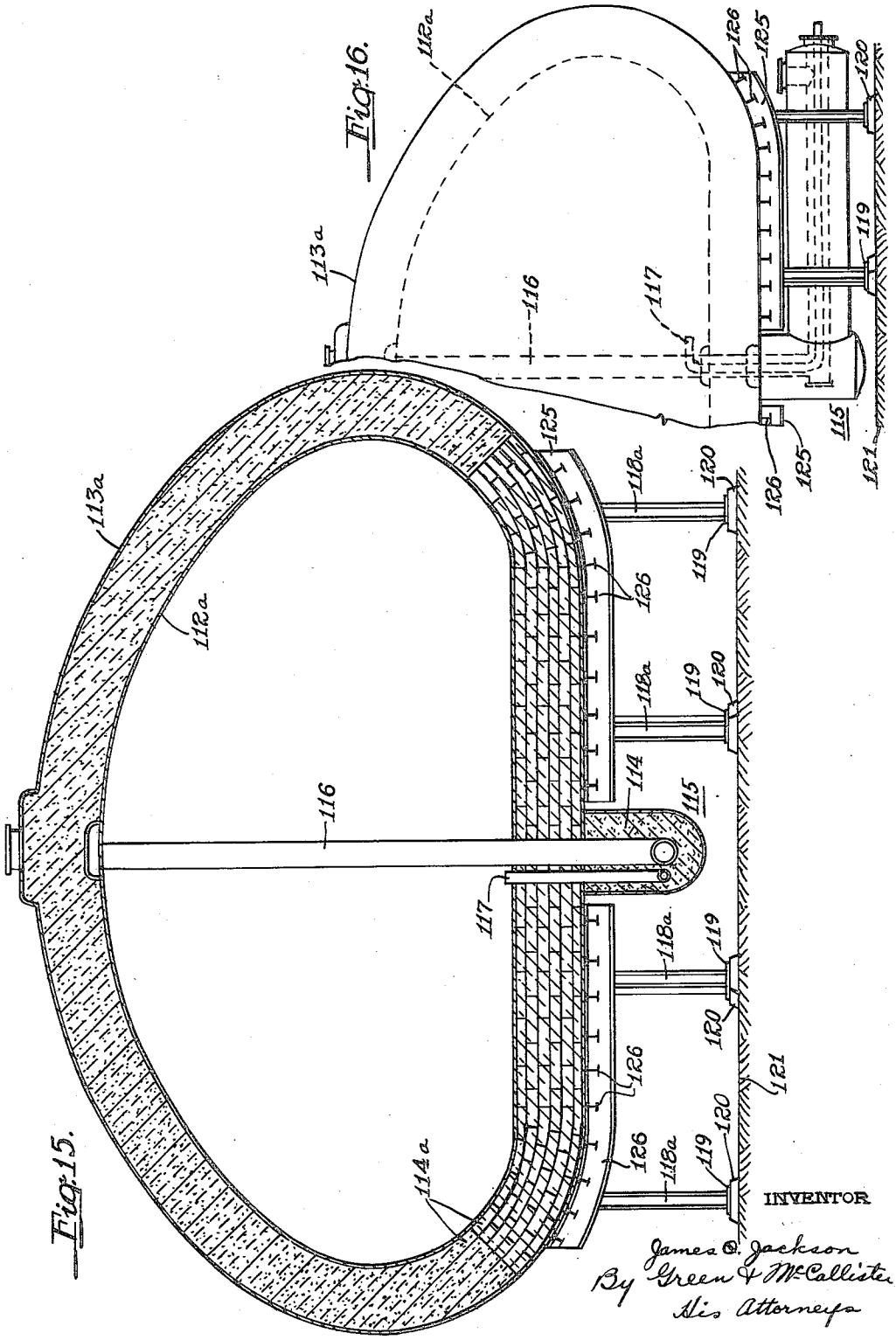


INVENTOR
James O. Jackson
By Green & McCallister
His Attorneys

Oct. 16, 1945. J. O. JACKSON 2,386,958

SPHERICAL TYPE INSULATED CONTAINERS FOR LIQUEFIED GASES

Filed Jan. 8, 1942 7 Sheets-Sheet 7



INVENTOR

James O. Jackson

By Green & McCallister

His Attorneys

Patented Oct. 16, 1945

2,386,958

UNITED STATES PATENT OFFICE

2,386,958

SPHERICAL TYPE INSULATED CONTAINER FOR LIQUEFIED GASES

James O. Jackson, Crafton, Pa., assignor to Pittsburgh-Des Moines Company, a corporation of Pennsylvania

Application January 8, 1942, Serial No. 426,012

21 Claims. (Cl. 62—1)

This invention relates to insulated containers of relatively great size capable of storing extremely cold liquids such, for instance, as liquefied natural gas.

An object of this invention is to produce an insulated container capable of safely and economically storing for long periods a relatively great quantity of liquefied gas such as liquefied natural gas.

Liquefied natural gas at atmospheric pressure has a temperature far below 0° F. (actually about —258° F.) and is subject to some evaporation and another object of this invention is to provide means for safely and economically taking care of the gas resulting from evaporation of liquefied natural gas stored in an insulated container of relatively great size.

A further object of this invention is to produce means for safely and economically introducing and withdrawing liquefied natural gas from insulated containers of relatively great size.

A further object is to produce improved mechanism by means of which low temperature liquefied gas can be charged into and removed from a relatively large insulated storage tank without damage to such tank or such mechanism.

A further object is to produce improved mechanism for controlling the flow of liquefied gas into and from an insulated storage tank of relatively great size, without permitting conduction to such tank of an appreciable amount of heat.

A still further object is to produce improved mechanism for controlling and limiting to a safe value, pressures generated by the evaporation of liquefied gas within an insulated storage tank of relatively great size.

In the accompanying drawings wherein I have illustrated successful embodiments of the present invention:

Fig. 1 is an elevational view, partly in section, of a preferred form of insulated spherical container responding to my present invention;

Fig. 2 is an enlarged vertical fragmentary section through the axial portion of the container of Fig. 1;

Fig. 3 is a plan view, with certain parts omitted and broken away, of the container of Figs. 1 and 2;

Fig. 4 is a vertical elevational view of the upper portion of the container of Figs. 1 to 3, inclusive, taken at right angles to Fig. 1;

Fig. 5 is an enlarged sectional view, partly in elevation, through the boot shown in Fig. 1 and illustrates certain additional devices not shown in Figs. 1 and 2, the insulation surrounding the gas vent pipe not being shown in this figure;

Fig. 6 is a horizontal sectional view illustrating the manner in which the lower end of the vapor pipe is supported within the boot and is taken along the line VI—VI of Fig. 5;

Fig. 7 is an enlarged plan view of parts of Fig. 5 illustrating the means for maintaining and supporting the expansion joint in the lower end of the vapor pipe;

Fig. 8 is a fragmentary view of the interior of the inner shell of the container of Fig. 1 and illustrates the manner of constructing the same;

Fig. 9 is an enlarged view of two of the sphere plates of Fig. 8 and illustrating the manner in which such plates are maintained in relative position during erection until permanently secured together;

Fig. 10 is a fragmentary perspective view illustrating two sphere plates in the upper half of the inner shell of the container and shows the clips for temporarily holding such plates together and the groove between the plates for reception of the weld metal;

Fig. 11 is a fragmentary sectional view taken through a typical weld seam in the lower portion of the inner shell;

Fig. 12 illustrates in fragmentary perspective certain structural details of the container of Fig. 1;

Fig. 13 is a medial sectional view, partly diagrammatic, of a modified form of container which is ellipsoidal in shape;

Fig. 14 is an elevational view on a reduced scale of the ellipsoidal container of Fig. 13;

Fig. 15 is a view similar to Fig. 13 of a further modified form of tank having a spheroidal shape; and

Fig. 16 is a partial elevational view of the container of Fig. 15.

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

Insulated containers of the character here involved are intended primarily to constitute means for supplementing the supply of natural gas or other gaseous fuels or materials to a distributing system which, for example, furnishes gas to domestic and industrial users. To be of value, such containers must have a large capacity and the liquefied gas must be available whenever required. For example, in the wintertime or during cold weather the demand for fuel gas ordinarily increases very markedly and often to a point beyond the ability of the pipe line to supply such gas; under such circumstances my present tanks

or containers fill all requirements. While there is always some vaporization or regasification of the liquefied gas stored within the tank or container, my new containers are so constructed as to keep losses to a minimum and have such a capacity that, if unused, a tank full of liquefied gas would not be exhausted by evaporation or vaporization for approximately two years. The gaseous equivalent of the liquefied gas is approximately 600 times the volume of liquid. It is to be understood that one or a plurality of the present containers may be employed depending upon conditions, and that where more than one are employed they may be suitably interconnected by communicating piping.

Spherical containers such as those here involved are characterized by having a maximum strength and volumetric capacity for a minimum size and weight and by a minimum external surface for a given volume. I, therefore, prefer a container which has a spherical shape but I have found that some departures can be made from a true sphere while still retaining the principles of my invention and that I may, for example, employ containers which are spheroids, ellipsoids or other variants of true spheres. In each case the container is supported above the earth's surface and this is advantageous not only because the atmosphere is permitted to circulate entirely around the container to equalize the temperature thereof but also to keep the ground below and adjacent the containers from freezing. Were it attempted to rest the containers on the ground in the manner employed in connection with present day oil tanks, the low temperatures due to the liquefied gases contained therein would cause freezing of the earth and a consequent heaving thereof. This would result in distorting or buckling the adjacent portions of the container and the introduction of undesired stresses. Such conditions are highly undesirable and would in some cases entirely destroy the utility of the container. It will, furthermore, be understood that the construction of large elevated insulated containers gave rise to numerous problems which had to be overcome. That such are successfully solved by the present invention is evidenced by the fact that containers embodying this invention are being successfully employed commercially.

The spherical container of Fig. 1 et seq. has an outer metallic shell 10 and an inner metallic shell 11 which is smaller than and generally concentric with the outer shell so as to provide therebetween a spherical chamber 12, which is completely filled with an insulating material 13 capable of constituting an effective barrier against the infiltration of heat from the outside atmosphere to the interior of inner shell 11. As shown in Figs. 1 and 2 in particular, the major portion of the chamber between the inner and outer shells is filled with granular insulating material, in this instance cork. In the lower portion of this chamber between the bottom portions of the shells the insulating material is preferably in the form of cork blocks or other shapes since such insulation must also serve the purpose of supporting the inner shell. I have found that molded cork blocks are entirely satisfactory where comparatively large or concentrated loads are involved since molded cork blocks are of low heat conducting value and have the ability to withstand the imposed compressive loadings at temperatures below −100° F. without progressive yielding, creep or settling.

It will further be observed from Fig. 1 in particular that the heat insulating material between the shells may differ in thickness from bottom to top. The insulation is of the molded block type from the bottom up to a point which is not above the mid-point of the container and I have determined that for structural and functional reasons the block type insulation should extend upwardly for about 45° from the bottom, i. e., this type of insulation is used in about the bottom fourth of the container. Above the block type insulation the insulation is of the granular type. While all the insulation is relatively compressible, the block type of insulation which is less compressible than the granular type is necessary for load-supporting purposes and it will be noted that the inner shell rests directly upon such block type insulation. The granular insulating material between the top portions of the shells is considerably thicker than the block type insulation between the bottom portions of the shells, as shown. In Fig. 1, the ratio is approximately 5:3. Thus, for block type insulation 3 feet in thickness between the shell bottoms, the granular type insulation between the shell tops is 5 feet, but other ratios may be employed depending upon the desired temperature gradient between the atmosphere and the contents of the container, the cost of the insulation and other recognized factors. In this connection, the granular type of insulation is ordinarily much less expensive than the block type, but the former is not capable of sustaining considerable loads as is the block type. Again, the upper portion of the container is that subjected to the sun's rays and the thicker insulation is thus desirable there. Equal thicknesses of granular and block type insulating material have approximately equal thermal efficiency.

It will further be appreciated that when the block type insulation compresses due to the weight of the inner shell and its contents, the axial pipe (35) moves downwardly, sometimes as much as 6 inches. Thus, the expansion joints hereinafter described as well as the sliding fit at the upper end of such pipe become necessary and important adjuncts of the container not only on account of movements due to compression of the insulation but also to take care of expected contraction and expansion due to temperature changes.

Shells 10 and 11 are each composed of a plurality of metal plates 14 and 15, respectively, so shaped and welded together as to form the spherical shells aforesaid. As will hereinafter more fully appear, outer shell 10 may be composed of ordinary carbon steel but inner shell 11 is composed of a special material which does not become unduly embrittled at the low temperatures to which such shell is subjected during use. The outer shell is completed by metal saucers 16 and the inner shell by similar saucers 17, suitably welded in place.

Referring to Fig. 8, for example, which is a view of the interior of the inner shell 11, it will be observed that this shell is made up of three series of plates, viz., a set of central plates 15' and two sets of polar or end plates 15'' and 15'''. The central plates are relatively long and constructed in the general manner of barrel staves. They are welded to one another along their longitudinal edges, as can be noted by the seams 15a. Plates 15' are curved both longitudinally and transversely and, of course, the curvatures are imparted in such manner and extent as to provide a central sphere portion of the requisite size when the plates are assembled. The end plates

15'' and 15''' are likewise curved both longitudinally and transversely and are so shaped as to substantially complete the polar regions of the sphere. They are welded together along the weld lines 15b. Metal saucers 17 are welded in place in the locations shown, 15c being the circular welds. It will be understood that all the welded seams in the inner shell are so formed as to be fluid-tight since the inner shell constitutes the receptacle for the liquefied gases or other liquids existing at low temperatures.

Since many metals and alloys become embrittled at low temperatures, and thus lose ductility and their ability to withstand strains, it is necessary to employ special metals and alloys which do not become unduly embrittled even at temperatures as low as about —260° F. It has been found that a metal or alloy which has, at the low temperature involved, an impact value (Charpy) of less than 10 ft. lbs. is unsatisfactory for use under the conditions encountered. Ordinary mild steels or low carbon steels as well as many other common or well-known metals and alloys, when tested at low temperatures, have an impact value as low as 2–3 ft. lbs., which represents practically complete loss of ductility and renders them valueless for low temperature service. I have found that the austenitic steels are highly resistant to embrittlement at low temperature, and even at temperatures in the neighborhood of —260° F. have an impact value well over 10 ft. lbs. and thus are capable of use for the inner shell in my new container. Among the austenitic steels suitable for low temperature use I include 18–8, which is an alloy composed of approximately 18% chromium, approximately 8% nickel, carbon up to about .20% with the balance substantially all iron except for the usual contaminants such as sulphur, phosphorus and the like in common amounts. The austenitic steels are, however, relatively expensive and, therefore, are not economical for large containers. I prefer to employ nickel steel with a nickel content of about 3½% as such is an eminently satisfactory material. It is composed of low carbon steel to which has been added approximately the amount of nickel designated, but in this connection I wish to point out that nickel may be employed up to approximately 10% and that even rather small percentages of nickel in fractional amounts below 1% constitute a substantial improvement over straight low carbon steel. Such variations are deemed to be a part hereof and it is also within the scope of my invention to employ metals which do not become embrittled at the low temperatures involved, such as copper and aluminum. In general, I wish to point out that the inner shell 11 of my new container may be composed of any metal or alloy which has an impact value of at least 10 ft. lbs. at the particular temperatures involved in any given installation.

The outer shell 10, as will be best observed from Figs. 3 and 4, is constructed similarly to the inner shell 11 and is composed of a series of central carbon steel plates 14' and polar or end plates 14'' and 14''', the plates being shaped, assembled and welded in a manner which will be understood from the figures in question and from Fig. 8. The outer shell is not subjected to the influence of a low temperature and, therefore, need not be made of a special material like that of the inner shell although it must be fluid tight. It will be appreciated that the outer shell is in constant contact with the atmosphere which circulates completely around the same and, therefore, equalizes the temperature thereof. While the inner surface of the outer shell is in contact with the insulating material, the outer shell is at no time reduced to a temperature low enough to cause it to fail. Thus, I preferably fabricate the outer shell from standard carbon steel sheets or plates which are, as understood, suitably configured so as to produce, when assembled, a shell of the desired size and diameter.

Referring further to Fig. 1, it will be observed that the outer shell 10 is provided with a circular stiffening ring 18 which is horizontally disposed and welded thereto somewhat above its equatorial section. Between the stiffening ring 18 and the top portion of the shell I provide the stiffeners 19 which, it will be noted, are arranged in the manner of meridians of longitude on the earth's surface and thus converge toward the top of the shell. The number, size and spacing of stiffeners 19 may be varied in accordance with the particular installation and especially in accordance with the size of the container. By referring to Fig. 12 it will further be appreciated that the circular horizontal stiffening ring 18 is T-shaped in section, that the horizontal web 18' thereof has its inner edge attached (welded) to the outer shell 10 and that the flange 18'' is disposed vertically.

Fig. 12 also discloses that each of the stiffeners 19 is T-shaped in section and that the lower end of the web 19' thereof is secured to the web 18' of stiffening ring 18 by means of angle plates 20 which are bolted or riveted together and to the stiffener ring web as at 21, or these parts may be secured in any other suitable manner as by welding, if preferred. The flange 19'' of each such rib 19 has its lowermost edge resting upon the upper edge of the flange 18'' of the stiffening ring 18. The relation of such parts to the plates 14' and 14'' of the outer container 10 is likewise delineated and a connection is made between the underside of the web 18' to the adjacent plate 14' by means of angle plates 22 suitably bolted, riveted, welded or otherwise suitably secured thereto as at 23.

The outer shell 10 is, as shown, supported an appreciable distance above the surface of the earth, which in Fig. 1 is designated by the ground line 24. Columns 25 are provided and are spaced around the container in a circular row, being welded or otherwise suitably secured to the outer shell at the areas of contact. The particular size, shape and spacing of such columns depends to some extent upon the size of the container and the weight of the liquid contents thereof. The lower ends of these columns 25 are provided with base plates 26 which rest upon or are embedded in the concrete foundations 27 which are of substantial size and strength and the lower portions of which are properly enlarged and embedded in the earth. It will be understood that the weight of the container and its contents is transferred to the foundations through columns 25. It is preferable but not essential that the columns 25 be guyed for purposes of added stability and in Fig. 1 I have illustrated the use of guy rods 28, the ends of which are securely connected to plates 29, and turnbuckles 30 are provided for the usual purpose of varying or adjusting the tension on said rods.

As will also appear from Fig. 1, a circular horizontal balcony 31 is provided, access to which may be had by any suitable means (not shown) such as a ladder or circular stairway. This balcony is

composed of a lower circular girder 32 and an upper circular girder 33, and between the two are disposed the angular connecting members or bars 34. It is to be understood that a suitable flooring generally composed of metal gratings extends inwardly from the girder 32 and may be suitably attached to shell 10 and that the girder 33 constitutes a guard and hand rail. The particular details of the balcony are not per se a part of the present invention. Circular girders 18 and 32 function as the upper and lower flanges of a horizontal circular girder disposed at the level of the points of connection between outer shell 10 and columns 25. Thus, the girder 32 is subjected to load and concentrates that load in the columns.

My new container is provided with operating mechanism the general arrangement of which is shown in Fig. 1 but the details of which will be more clearly apparent from Figs. 2 and 5. Roof member 37 is provided with one or more rupture discs 42, the function and operation of which will be explained hereinafter. These ruptured discs are of frangible material and are normally maintained in unbroken condition between suitable clamping rings or the like 43, bolted together at 44, and mounted on the short vertical tubes 45.

Near its lower end, pipe 35 passes downwardly through an opening in the top of a cylindrical housing 46. This housing has perforations 47 in its side wall and is suitably secured to an annular bottom member 48, as by welding. Bottom member 48 is secured to the inner shell 11 above an opening which is provided for that purpose. The top of housing 46 has a central opening for accommodating pipe 35 to which it is welded. The housing top is also provided with an opening 49 which is aligned with an opening 50 in a horizontal plate-like member 51 welded to housing 46 and to pipe 35. Pipe 35 passes through both the inner and the outer shells of the container, through the space therebetween and into a cylindrical member 52 which forms one end of a boot-like metal casing or housing 53, to be described. The upper and lower portions of pipe 35 are integrally connected together by an expansion joint or section 54. This expansion section is a short corrugated piece of pipe having a bellows-like structure and action and the ends thereof are flanged for connection to the upper and lower portions of pipe 35 by means of bolts 55. At its lower end, pipe 35 makes a 90° turn to horizontal and extends through the horizontal portion 56 of boot-like metal casing or housing 53.

Adjacent pipe 35 I provide a pipe 57 which serves both as an inlet and outlet pipe for the liquid contents of the container. This pipe is suitably maintained in appropriate position by a bracket member 58 extending from and secured to pipe 35 and a cylindrical collar 59, the wall of which is beveled at its upper end to provide a tapering opening and seat for the reception of a plug valve 60 which is correspondingly tapered. The plug valve is secured on the lower end of a guide rod 61, to the upper end of which is secured the lower end of a cable or the like 62. Guide rod 61 passes through guide discs 63 which are secured in the position shown in Fig. 2 by means of welding, brazing or the like, and they ensure that the plug valve in its downward travel will always seat accurately in the upper end of the outlet and inlet pipe 57. The position illustrated in Fig. 2 shows the plug valve in its upper or open position.

Pipe 57 is also provided with an expansion joint or section 54' similar to that in the pipe 35. Below the expansion section, pipe 57 turns through 90° and passes through the end wall of pipe 35, thereafter traveling concentrically within the horizontal portion of pipe 35, as shown. Pipes 35 and 57 are provided with similar expansion joints or sections 54'' just before they emerge from the horizontal portion of boot 53. The portions of the boot-like casing or housing surrounding these pipes and expansion sections are considerably larger than the pipes themselves, thus providing spaces which are filled with insulating material 13. Pipe 57, when the tank is being filled, contains liquefied gas at a temperature of about —244° F. and at a pressure of about 15 pounds per square inch gauge. When this liquefied gas enters the tank, its pressure is reduced at the surface to about five pounds per square inch gauge and its temperature is reduced to about —254° F. A portion of the liquefied gas within the tank evaporates, lowering the temperature of the remainder and the flash or evaporated gas has the same temperature, namely —254° F. This flash gas is conducted out of the tank through vent pipe 35. The flash or vent gas passing from the tank through vent pipe 35 surrounds the horizontal portion of pipe 57 which conducts the liquefied gas into and from the tank. The temperature of this flash or vent gas at this point is somewhat warmer than —254° F. and ranges around —225° F. because of absorption of heat from the insulation within the casing or housing 53.

Heat entering boot-like casing or housing 53 travels slowly through the insulation surrounding vent pipe 35 and is absorbed by the vent gas in pipe 35, thus raising the temperature of such gas. Only a very small amount of such heat is conducted to pipe 57 because of the small temperature difference between pipes 57 and 35 with the result that most of the heat which is conducted into the boot-like casing 53 from the outside is absorbed by the vent gas leaving the tank and is thus prevented from being absorbed by the liquefied gas entering the tank. The fact that that portion of vent gas conduit 35 which extends outwardly beyond the tank or container is arranged in heat shielding relation to the outwardly extending portion of liquefied gas pipe 57 improves the thermal efficiency of the tank and makes it unnecessary to reliquefy such portion of the liquefied gas that would have been evaporated if it were not for such arrangement.

The vertical wall portion of boot 53 is provided with an access opening normally closed by a cover 64. The boot is also provided with a metal chamber 65 welded or otherwise secured thereto and communicating with the interior of the boot. Chamber 65 is filled with a filtering material 66 such as steel wool, mineral wool or the like, and is preferably packed in such manner that the density of the filtering medium increases in a radially outward direction. This may be accomplished by packing the filtering material tightly in the chamber adjacent the outer end thereof and then successively more loosely packing in the filtering material in the direction of the boot. It is understood that the boot is provided with an aperture at the point where the chamber 65 is attached. The outer end of the chamber is provided with an aperture in which a copper tube or the like 67 is secured. The outer end of this tube is provided with a needle valve or the like 68, which is connected to any suitable device or means for creating a vacuum. In such manner

the boot and the insulation can be relieved of air and moisture and reduced to a low internal pressure which enhances the insulating effect. This then becomes the resultant insulating effect produced both by evacuation and the use of insulating material. Since during evacuation there is some tendency for insulating granules to move toward the needle valve, the use of filtering material as described prevents obstruction of the valve and loss of insulating material and, if I desire, I may reduce the tendency of the granular insulating material to move toward the needle valve by employing cork blocks, strips or sheets (not shown) over the opening in the boot where the chamber 65 is attached, and such cork pieces may be similar to those between the lower portions of the container shells.

As will be best noted from Fig. 5, pipe 35 begins to taper somewhat beyond the outer end 69 of the horizontal portion of boot 53, and pipe 57 serving as the inlet and outlet for liquefied gas passes through end 69 and extends therebeyond. Outlet pipe 57 is, however, provided just beyond the boot with a branch offtake pipe 70, suitably valved, and which may lead to or be connected to any suitable mechanism, such as a regassifier, since the primary function of the withdrawn liquefied gas is to supplement a gas distributing system. Vent gas conduit 35 beyond the outer end of boot-like casing 53 is provided with a branch conduit 71 which is of substantially the same cross sectional area as the vent gas conduit and which extends upwardly to a position above the top of the container as disclosed in Fig. 1. At its top, this branch conduit is provided with one or more valve devices designed to open at a predetermined or excessive pressure. This branch conduit serves as an emergency device for venting gas from conduit 35 in the event of such rapid generation of gas in the container that a material increase in internal pressure ensues.

Outer shell 10 of the container is provided with a cylindrical polar cap piece 73 having a depending flange which is secured to the edge wall of an opening in the top of the shell. This cap piece is provided with a cylindrical collar portion 74 terminating in a horizontal annular flange which is bolted at 75 or otherwise suitably secured to the lower horizontal flange of a short vertical section of pipe 76, the upper portion of which has secured thereto an annular tray-like member 77. This sub-assembly is completed by a closure disc 78 resting on the top of the pipe section 76 and having a depending flange 79 projecting into the tray-like member 77. Oil or some other suitable sealing medium is contained in the tray-like member 77 so as to cut off communication under normal conditions with the atmosphere above the container. The parts just described are above the rupture discs 42 and are placed into communication with the interior of inner shell 11 when the rupture discs become broken due to the existence of excess pressure within the said inner shell.

Cable member 62, above referred to, passes up through one or more guides 80, projecting radially from and welded to pipe 35. The cable member 62 passes through the inner shell within a hollow box-like member 81 which extends between the shells, as shown in Fig. 2. Member 81 has an upper closure member 82 which has an opening through which a rod 83, attached to the upper end of cable 62, extends. The upper end of rod 83 is provided with a manually operable device 84 maintained in position by a tripod-like support 85. Rod 83 has a threaded portion which engages a nut-like member 86. Above nut-like member 86 rod 83 is drilled to receive a transversely extending cotter pin or the like 87 which prevents downward movement of rod 83 beyond a predetermined point and also prevents accidental disassembly. By suitably rotating device 84 which is provided with spokes or handles, valve 60 through the movement of rod 83, cable 62, rod 61 can be raised, and movement of device 84 in the opposite direction closes the valve. In other words, rod 83 can be raised or lowered vertically through the nut-like member by appropriate manipulation of device 84.

The top closure 82 of member 81 is also provided with an access opening 88 and a cover 89. In order to seal off yet give access to the parts just described, a cylindrical collar 90 is positioned therearound in spaced relationship. The upper end of cylindrical collar 90 is provided with a sealing tray 91. A flanged covering member 92 rests in the sealing tray and has an outwardly and downwardly extending annular flange 93 which, with the sealing liquid in tray 91 completes the seal. The top of collar 90 is provided with a removable disc-like closure member 94 which is normally bolted in place as at 95, as shown, to the flanged upper end of a short tubular piece 96 rising from and communicating with cover member 92.

Since the boot 53 is of considerable weight and length, it is desirable to so support pipe 35 that it can not be harmfully affected by movement of the boot. I therefore provide means for supporting pipe 35 adjacent expansion section 54 and therefore adjacent the supported end of the boot. As will be understood from Figs. 5 and 7, this includes means for limiting the downward expanding movement of expansion joint 54. This means comprises a pair of vertically spaced two-part clamping rings 97 bolted together at 98 and a plurality of vertically arranged angularly spaced bars 99 which are bolted at 100 or otherwise suitably secured to lugs 101 extending outwardly from said clamping rings 97.

I also provide, as shown in Figs. 5 and 6, means for limiting lateral movements of pipe 35 with relation to expansion joint or section 54. This means includes a plurality of chains or other flexible connecting members 102, the outer ends of which are connected to plates 103, by means of yokes 104, which are secured to the outer portion of the boot wall and the inner ends of which are connected by means of yokes 104 to an annular supporting ring 105 which surrounds the lowermost end of the vertical portion of pipe 35. I prefer to use chains for these supports because of the low heat conductivity inherent in a chain. The purpose of these supports is to restrain collar 105 from movement in a horizontal direction, thus relieving expansion joint 54. These supports also prevent damage to expansion joint 54'' by horizontal movement laterally of the boot. These supports permit slight vertical movement of collar 105 which occurs when the container is cooled down or warmed up due to expansion of the metal between such collar and the inner shell 11 by which pipe 35, through housing 46, is supported.

The outer shell 10 is provided with a plurality of manholes 106 to give access to the interior thereof and to provide means for introducing insulating material into the space between the shells. The precise number, size and spacing of

such manholes depend upon the size and nature of the particular container. At such points the outer shell is provided with apertures in which short pipes 107 are inserted and suitably secured as by welding. Such pipes are usually flanged at their outer ends and are normally closed by a manhole cover or closure 108. The inner shell 11 is provided with only two such manholes 109 and, as particularly shown in Figs. 3 and 4, these are preferably located at diametrically opposite points and in such relationship to a corresponding pair of manholes in the outer shell as to enable access to be gained to the interior of the inner shell through such manholes in the outer shell. As will also be apparent from Figs. 3 and 4, breather valves 110 are provided for the usual purpose in a polar fitting 111 secured to the top of the outer shell.

As explained above, my present invention is not limited to the use of a spherical container and in Figs. 13 and 14 I have illustrated an ellipsoidal container. This comprises an inner ellipsoidal shell 112 and an outer ellipsoidal shell 113 substantially uniformly spaced from the inner shell. Between the shells insulating material 114 is provided which constitutes an effective barrier against the infiltration of heat. This insulation is partly in granulated form and partly in the form of blocks, strips or sheets of cork or other suitable insulating medium. The latter are employed throughout the areas subjected to the most concentrated loading. As shown in Fig. 13, these areas are between the bottom portions of the two shells. For simplicity and to prevent undue repetition, the ellipsoidal container of Figs. 13 and 14 is shown somewhat diagrammatically. Insofar as the provision of the boot 115 is concerned, this is to be understood as being identical with or essentially the same as the boot 53 above described. A central vertical axial pipe 116 is provided which extends through the inner container and into the boot, and a liquid outlet pipe 117 is provided in a manner which will be understood from what has preceded. The outer shell is supported by a plurality of spaced vertical columns 118 terminating at their lower ends in base plates 119 which are associated, as before, with the foundations 120 embedded in the earth up to a point such as that indicated by the ground line 121. Braces or stress equalizers in the form of guy rods 122 or the like are provided in a manner similar to those shown in Fig. 1. The outer shell may likewise also be provided with a circular girder 123 above its equatorial portion, and a balcony 124 completes the unit. These parts are described above in connection with Fig. 1.

As further shown in Figs. 15 and 16, the container may be in the form of a spheroid or a modified sphere in which the lowermost portion is straightened or flattened so that the container has the form which a drop of liquid mercury normally assumes on a flat clean surface. The correspondence of parts as compared with Figs. 13 and 14 will be clear from the numerals employed. In this form I have found it desirable to support the bottom of the outer shell by a system of grillage beams between the tops of the columns 118*a* and the container bottom. These may be in the form of sets of metal beams 125 and 126 arranged at right angles to one another. The grillage equalizes the stresses on the container bottom and transmits the load to the columns and thence to the foundations and into the ground.

The welding procedure utilized in connection with the fabrication of the inner shells of these containers will be more fully understood by referring to my copending applications Serial No. 425,756, filed January 6, 1942, now Patent 2,337,049 and Serial No. 427,069 filed January 16, 1942. From these it will be appreciated that difficulties are encountered in so producing these welded structures that they will have the necessary strength and ductility at low temperatures. Ordinary steels and conventional welds become embrittled at low temperatures, thereby suffering serious loss in ductility. It is required by the A. S. M. E. Code for Unfired Pressure Vessels that steel for low temperature vessels shall have a Charpy impact value of at least ten ft. lbs. at the temperature at which it is to be used. By making the inner shell of each of my new containers out of a nickel steel containing about 3½% (3–4%) of nickel and by employing the procedure and weld metal, set forth in my aforesaid copending applications, I have made it possible to produce welded structures which even at temperatures as low as —260° F. have a Charpy impact value of from 18–20 ft. lbs at —260° F.

As illustrated in Figs. 9, 10 and 11, typical welding operations in connection with the fabrication of the inner shell 11 are carried out by associating a pair of plates such as those designated at 15′ and 15‴ in the relationship shown in Fig. 9 and temporarily securing the same together mechanically by means of clips, one of which, for the upper part of such shell is illustrated in Fig. 10. Each such clip is composed of two metal angle members 127, the flanges of which are secured to the shell plates and the webs of which are secured together as by bolts 128. It will be noted that the contiguous edges of the shell plates are beveled so as to provide a V-shaped groove 129, the wider end of which is adjacent the clips. Weld metal is deposited in such groove and forms a particularly effective union between the plates. After properly preparing the plates for welding as by cleaning the same they are preheated prior to welding. I have found that by preheating the plates to a temperature of from about 170–350° F., i. e., a temperature materially above the prevailing ambient temperature, an effective weld is consistently secured. The weld metal becomes alloyed with the plates forming a permanent integral structure.

As shown in Fig. 11, the lower plates of the inner shell may be welded in place, even though the cork blocks are combustible. In carrying out welding under such conditions, I first place a non-combustible member such as a refractory or metallic plate 130 in such insulation and flush with the surface thereof. I then secure to the marginal portions of contiguous shell plates, as by spot welding, a metal backing-up strip 131, the center of which is depressed as at 132 to form a shallow channel 133 between it and the adjacent surfaces of such shell plates. The V-shaped groove between the plates is then filled with weld metal 134, part of which enters the said shallow channel and forms an exceedingly effective union and interlock having good impact value at low temperature which exceeds that of the plates so united.

The space between the inner and outer shells above the cork blocks is not filled with granular cork until the welding on both shells has been completed. For this reason, no metal plate 130 is necessary in making the welds located above the upper line of the cork blocks.

Below the mid horizontal section of the inner shell the welding is preferably carried on from the inside of the shell and above such section, the welding is preferably carried on from the outside. The weld grooves therefore for the lower half of the inner shell will be on the inside of such shell, while for the upper half the grooves will be on the outside.

It is to be understood that the particular shapes illustrated and described are submitted by way of example and are not to be deemed as limitative or restrictive. Within the purview of the present invention I may employ a container which is either spherical or a modified sphere such as the ellipsoidal or spheroidal forms described above. The expression "spherical type container" is intended to cover all forms of container forming a part of the present invention, and where employed herein is generic in its significance. It is to be understood further that my new containers may be made of any required size and of any suitable materials and that while the containers are especially designed for storing relatively large quantities of liquefied gases or other liquids at relatively low temperatures, theoretically my new containers could also be employed in connection with the storage of hot liquids or liquids at elevated temperatures. The scope of the invention is rather that defined by the appended claims.

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

1. An insulated container for storing liquefied gas, comprising inner and outer spaced apart metallic shells insulated one from the other, means communicating with the inner shell adjacent its bottom for conveying liquefied gas into and from said shell, a casing having fluid tight connection to the outer shell, extending an appreciable distance from such connection and surrounding and spaced from said liquefied gas conveying means, a vent gas conduit communicating with the interior of the inner shell adjacent its top and having a portion thereof extending through said casing in heat shielding relation to said liquefied gas conveying means, said conduit being of sufficient cross sectional area to provide a free vent for vapors forming within the inner shell above the liquefied gas contained therein, and means for insulating said casing from said conduit and said liquefied gas conveying means.

2. An insulated contained for storing liquefied gas, comprising inner and outer spaced apart metallic shells insulated one from the other, means communicating with the inner shell adjacent its bottom for conveying liquefied gas into and from said shell, a casing having fluid tight connection to the outer shell, extending an appreciable distance from such connection and surrounding and spaced from said liquefied gas conveying means, a vent gas conduit communicating with the interior of the inner shell adjacent its top and having a portion thereof extending through said casing in heat shielding relation to said liquefied gas conveying means, said conduit being of sufficient cross sectional area to provide a free vent for vapors forming within the inner shell above the liquefied gas contained therein, valve means within the inner shell for controlling said liquefied gas conveying means, and means operable from the exterior of the container for opening and closing said valve means.

3. An insulated container for storing liquefied gas, comprising inner and outer spaced apart metallic shells with insulating material therebetween, a metallic boot-like casing having fluid tight connection to the lower part of the outer shell and extending an appreciable distance from such connection, a pipe serving as a liquefied gas inlet and outlet, having an orifice within the inner shell adjacent its bottom and extending from such orifice into and through said casing, a vent gas conduit extending from near the top of the inner shell through an opening in the outer shell and through said casing in heat shielding relation to said pipe, insulation between said casing and said conduit, means operable from the exterior of the container for opening and closing said orifice, and means within said casing for flexibly supporting said conduit.

4. An insulated container for storing liquefied gas, comprising inner and outer spaced apart metallic shells with heat insulating material therebetween, a pipe serving as a liquefied gas inlet and outlet pipe, a vent gas conduit within the inner shell extending above the liquefied gas level, secured within an opening in the bottom of such shell and substantially paralleling said pipe where the latter passes through said insulating material, means in said conduit and pipe for compensating for movement thereof due to temperature changes, and means providing a support for the upper portion of said conduit and which includes a sliding joint.

5. An insulated container for storing liquefied gas, comprising inner and outer spaced apart metallic shells, insulation between such shells, a liquefied gas pipe having an orifice within and near the bottom of the inner shell and extending outwardly beyond the container, a vent gas discharge conduit having its inlet adjacent the top of the inner shell and extending downwardly through the bottoms of the inner and outer shells with a portion thereof arranged in heat shielding relation to said liquefied gas pipe.

6. A container for storing liquefied gas, comprising inner and outer spaced apart metallic shells, heat insulating material between said shells, a liquefied gas pipe having an orifice within and near the bottom of the inner shell, a vent gas discharge conduit having its inlet adjacent the top of the inner shell and extending downwardly through the bottoms of the inner and outer shells and then laterally beneath the container with part thereof arranged in heat shielding relation to said liquefied gas pipe and a casing having fluid tight connection with the lower portion of said outer shell and extending an appreciable distance from such connection and surrounding said vent gas conduit and said pipe.

7. A container for storing liquefied gas, comprising inner and outer spaced apart metallic shells, heat insulating material within the space between said shells, a liquefied gas pipe having an orifice within and near the bottom of the inner shell, a vent gas discharge conduit having an inlet near the top of the inner shell, extending downwardly through the bottoms of the inner and outer shells and having part thereof arranged in heat shielding relation to said pipe, a valve controlling the flow of liquefied gas through said orifice, and means operable from the exterior of the container for controlling said valve.

8. An insulated container for storing liquefied gas, comprising inner and outer spaced apart

metallic shells insulated one from the other, a liquefied gas conduit having a valve controlled orifice within and near the bottom of the inner shell and extending outwardly beyond the container, a vent gas discharge conduit having its inlet near the top of the inner shell and extending downwardly and outwardly through the inner and outer shells and beyond the container and having a portion thereof arranged in heat shielding relation to said liquefied gas conduit, and a liquefied gas outlet pipe connected to said liquefied gas conduit.

9. A container for storing liquefied gas, comprising inner and outer spaced apart metallic shells, heat insulating material within the space between said shells, a vent gas discharge conduit having its inlet near the top of the inner shell and extending downwardly through the bottoms of the inner and outer shells, and a cylindrical member attached to the upper portion of the inner shell and surrounding the upper end of said conduit, the upper end of said conduit having a sliding fit with said cylindrical member.

10. A reservoir for storing liquefied natural gas, comprising inner and outer metallic shells, heat insulating material within the space between such shells, a vent gas discharge conduit having its inlet near the top of the inner shell and extending downwardly and outwardly through and beyond such shells, and a branch conduit connecting with said gas conduit outside of the reservoir and extending above the same; said branch conduit being provided with a check valve constructed to permit escape of gas when excessive evaporation occurs within the inner shell.

11. A structure according to claim 1 in which the inner and outer shells are substantially spherical, the casing is secured to the outer shell at its lower polar region and the vent gas conduit extends vertically above said polar region.

12. An insulated container for storing liquefied gas, comprising inner and outer spaced apart metallic shells, insulating material arranged in the space between said shells; the inner shell being fabricated from sections of steel alloy plate containing from about 2% to about 10% nickel; said plate sections being joined together by weld metal containing from about 15% to about 30% chromium and from about 10% to about 25% nickel; the inner shell having attached to one of its surfaces and straddling the joints between its adjacent plate sections, metallic strap-like members formed to provide pockets for said weld metal, and protective members of non-combustible material located between the insulating material and the strap-like members attached to the lower portion of such shell; such protective members being held in place by such insulating material.

13. A structure according to claim 2 in which the means for opening and closing said valve means is insulated from the inner shell.

14. A structure according to claim 1, in which the inner and outer shells are substantially spherical.

15. A structure according to claim 1, in which the inner and outer shells are in the form of ellipsoids.

16. A structure according to claim 1, in which the inner and outer shells are in the form of ellipsoids with flattened bottoms.

17. A structure according to claim 1, in which the vent gas discharge conduit extends vertically within the inner shell and terminates near the top thereof.

18. A structure according to claim 1, in which the vent gas conduit extends vertically within the inner shell and includes a sliding joint to provide for expansion and contraction of such inner shell.

19. A structure according to claim 1, in which the inner and outer shells are substantially spherical and the vent gas conduit extends vertically within the inner shell above the lower polar region of such shell and terminates near the top of such shell.

20. A structure according to claim 1 in which the casing surrounding the outwardly extending portions of the conduit and pipe has its outer end closed and hermetically sealed to the vent gas conduit.

21. A structure according to claim 1, in which the outwardly extending portions of the vent gas conduit and the liquefied gas conveying means are provided with means for compensating for changes in their lengths due to temperature changes.

JAMES O. JACKSON.