June 11, 1963 J. G. MACORMACK ETAL 3,093,260

INSULATED REFRIGERATION TANK STRUCTURES

Filed April 8, 1960 4 Sheets-Sheet 1

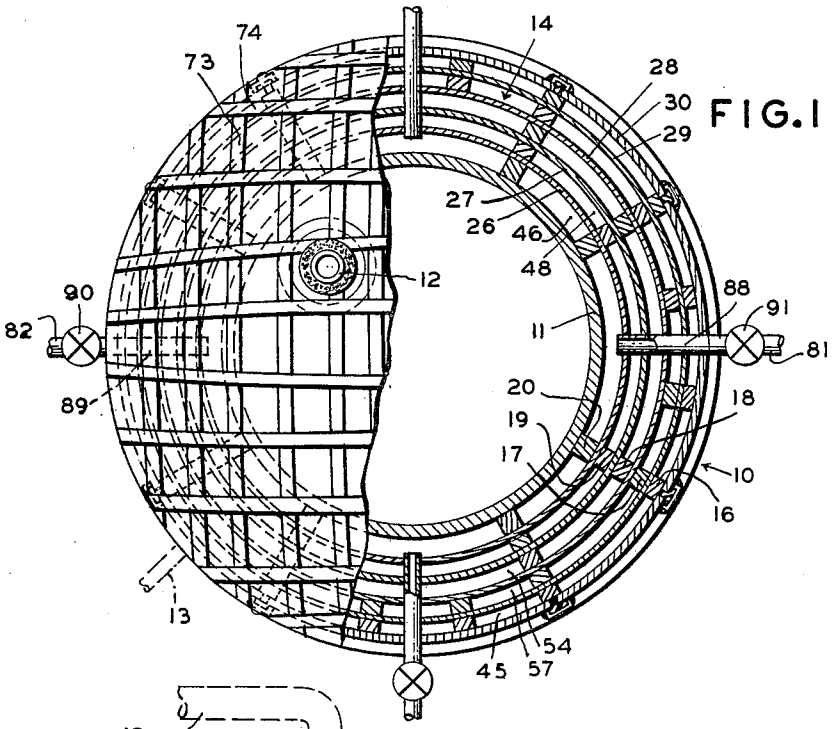


FIG. 1

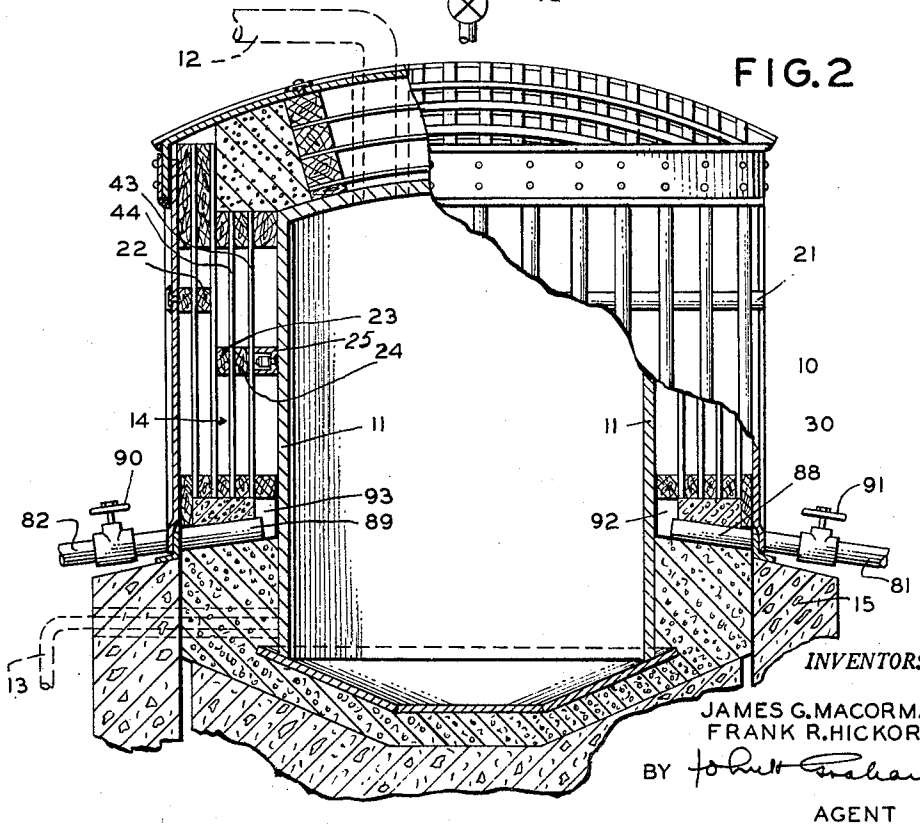


FIG. 2

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INSULATED REFRIGERATION TANK STRUCTURES

Filed April 8, 1960 4 Sheets-Sheet 2

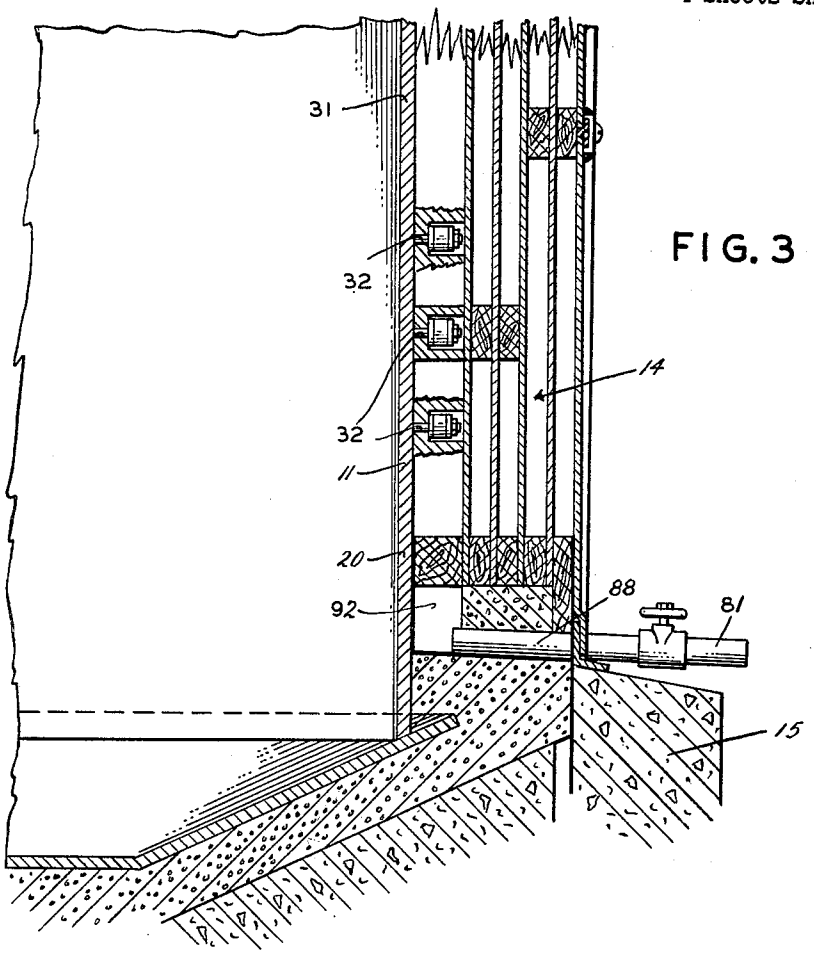


FIG. 3

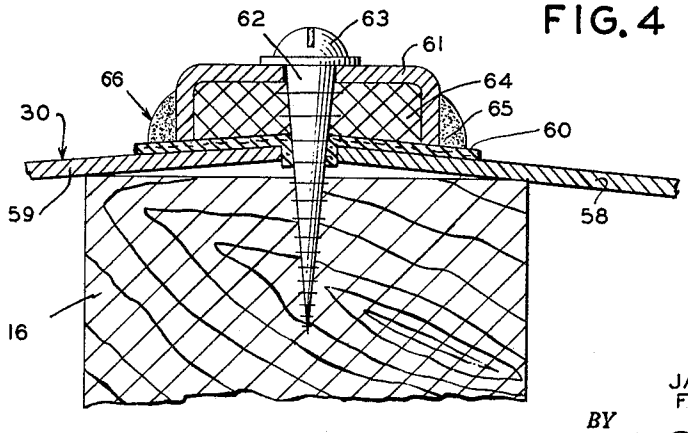


FIG. 4

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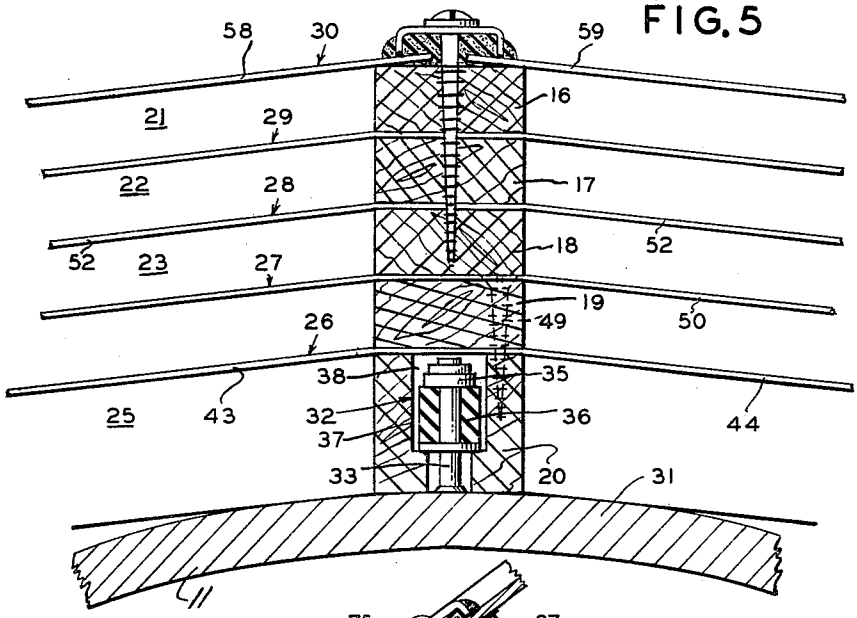
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INSULATED REFRIGERATION TANK STRUCTURES

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FIG. 5



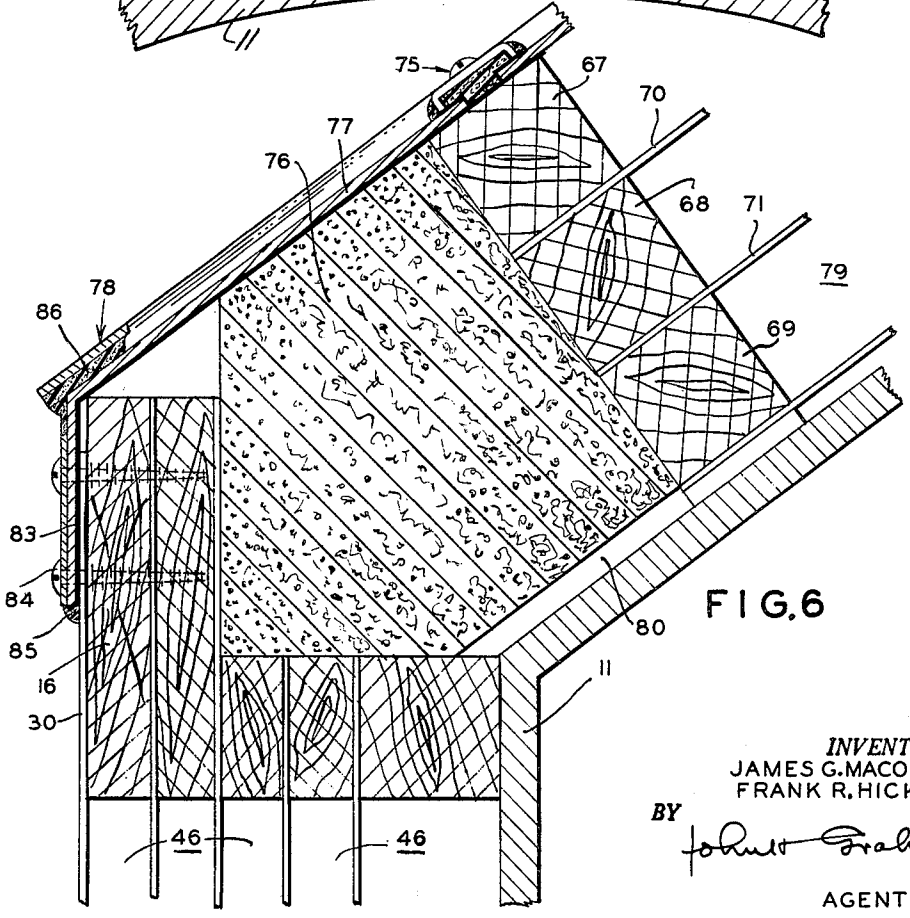


FIG. 6

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INSULATED REFRIGERATION TANK STRUCTURES

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FIG. 7

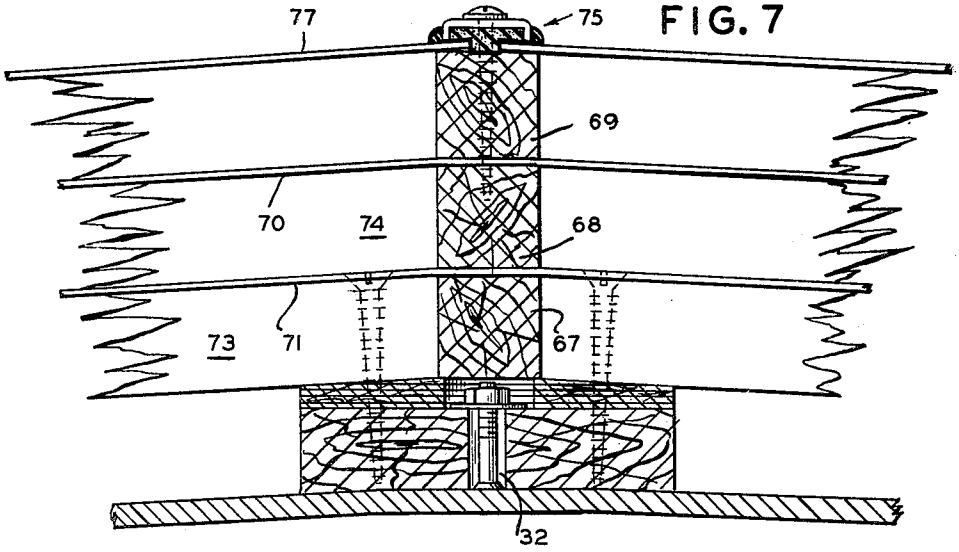


FIG. 8

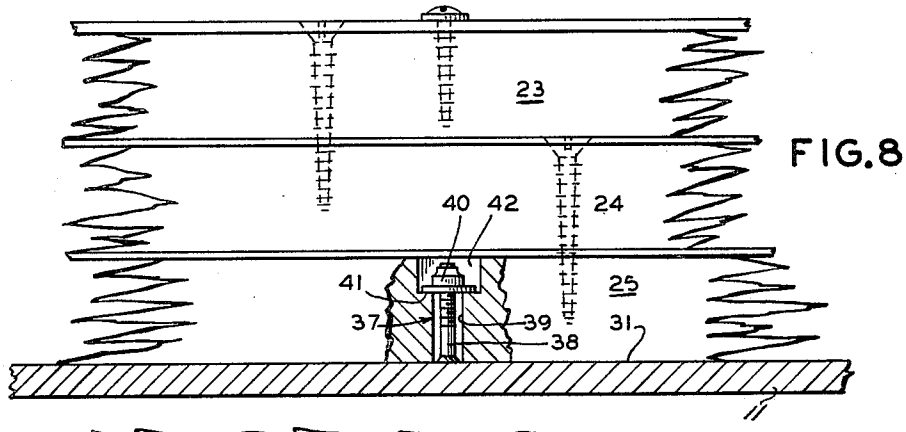
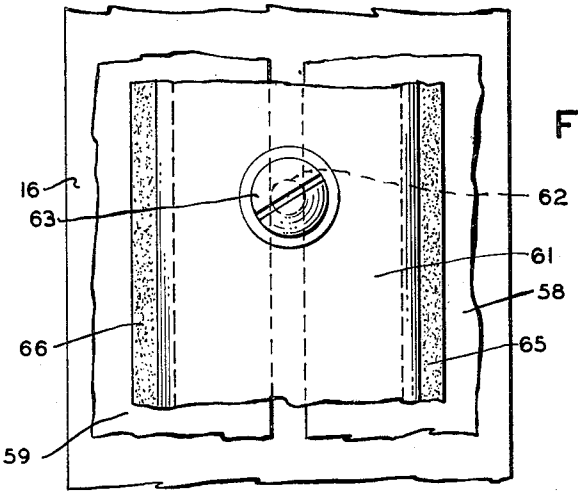


FIG. 9



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United States Patent Office 3,093,260 Patented June 11, 1963

3,093,260 INSULATED REFRIGERATION TANK STRUCTURES

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Filed Apr. 8, 1960, Ser. No. 20,909
2 Claims. (Cl. 220—14)

This invention relates to tanks and like containers for holding various materials at low temperatures and is particularly concerned with large tanks which are utilized for storage of normally gaseous materials at temperatures and pressures so that these are in liquid condition. It has been the practice to store liquefied gases of this nature in large tanks, various means being provided for insulating the tank proper with respect to the environment in which it is placed.

One of the problems which is faced in the installation of such tanks is the insulating of the tank with respect to its environment such as to achieve a good efficiency of operation, since it is necessary to have a very efficient insulating structure if the liquefied materials within the tank are to be maintained at their correct temperature level without danger of vaporizing and/or without the need of constantly adding more refrigerant thereto. Thus, the efficiency factor of the insulating structure is a very important point with respect to the efficiency as a whole of the storing of the liquefied gases in such tanks.

This is particularly the case when the tank and its insulating structure is installed outdoors in variable-climate areas whereby same is subjected to a wide change in ambient temperatures over the seasons. It is also particularly a problem, when the contents of the tanks are to be periodically changed so that the conditions within the tank as to temperature and/or pressure or periodically different, irrespective of the ambient conditions to which the structure as a whole is subjected.

As an example of this latter problem, it is pointed out that the normal boiling point of ammonia is in the order of —30° F., whereas the normal boiling point of liquefied petroleum gases (LPG) is in the order of +30° F. These are two of the common liquefied gases which are stored in tanks of this nature, and thus it will be recognized that a tank utilized alternatively for ammonia and LPG will have a range of internal temperature of —30° F. to +30° F. which must be taken care of and compensated for in the insulating structure surrounding the tank. Furthermore, in an area in the eastern part of the United States of America, for example, it is quite usual to have the ambient temperature from say 95° F. in the summer to say 10° F. in the winter, and thus there is a large external temperature difference in the environment of the tank to consider with respect to the insulating function of the structure external of the tank which is adapted for insulating the body thereof.

Heretofore, it has been proposed for tanks which are to be installed in open areas, namely, not installed in buildings or other closed places, to surround the tank with an outside shell or container and, between the shell and the tank, solid insulating materials are packed which are calculated to be of sufficient thickness and of such insulating property to take care of the situations identified above. This system may be quite efficient at the start, but there art two major problems which have to be considered for continued use of the insulated tank. The first of these is the expansion or contraction of the tank itself which will take place for instance, when the tank is initially emptied of its refrigerated contents and then refilled. Secondly, there is the problem of water condensation which water is deposited within the insulation itself and is usually held by the interstices of solid

insulation materials, thus rendering the insulation less efficient as time goes on. It is virtually impossible to avoid some water condensation of this nature in open installations which are subjected to environmental variations in ambient temperatures even if the tank is kept always at an even internal refrigeration temperature. The temperature of the metal walls of the tank may be less than the surrounding temperature of the insulating body, and thus water will be deposited on the outside of the metal tank walls containing the refrigerant in the form of snow or ice thus lessening the efficiency of the system. Furthermore, this deposit of snow may be melted from time to time and then be deposited as water in the insulation itself. Also, this water in the insulation may freeze and cause by-passes for heat transfer externally through the insulation, which is both inefficient and deleterious. Therefore, in the case of insulation structures for such tanks where general solid packing type of insulation is utilized, after use for a period of time the insulation becomes lessened in efficiency and in due course will be completely inefficient and the insulation will have to be replaced which is both expensive and a time-consuming effort.

To sum up, therefore, there are problems with respect to this type of insulated refrigeration tank body with respect to (*a*) the expansion or contraction of the tank walls proper and (*b*) the water condensation which must take place. It is with these problems that the present invention is chiefly concerned.

The refrigeration tank with which the invention is concerned is conventional and may comprise a metal shell of cylindrical form with a dome-shaped top and a cone-shaped bottom, all being duly welded and sealed to stand the pressures and the temperatures of the liquefied gases which are to be the contents thereof. In accordance with the present invention surrounding this tank there will be an outer shell and it should be recognized that whenever the tank is colder than the body of air in the area between the tank and the shell and whatever the type of insulation between the tank and the shell, there is bound to be some water condensation. If this water is not removed, it must deposit in such places as to reduce the efficiency of the insulation with the obvious result of making it necessary to increase the amount of refrigeration control placed upon the contents of the tank. The loss of efficiency of any form of insulation between the tank and the shell which will result from this water condensation will be proportional to the amount of water which is condensed as it accumulates, and of course as it accumulates over periods of time, this situation will get increasingly worse unless means are provided for removal of the water of condensation. While it may seem obvious to remove this water of condensation, this is not possible with the type of solid packed insulated structure which is usually provided for such tanks and, as previously mentioned, the water of condensation will either coat the tank, as ice, or will be trapped as liquid water and held in the interstices in the solid packed or bulk insulation utilized, with the obvious deleterious effect.

It is accordingly an object of the present invention to provide a tank structure for use for the storage of normally gaseous materials in liquid form particularly those requiring extreme conditions of cold and/or pressure, where the two major problems of expansion of the tank, and condensation of water outside of the tank, are solved.

It is a further object of the invention to provide an improved tank structure for storage of liquefied gases at low temperatures where the adverse effect of condensation of water external of the tank containing the liquefied gases are minimized and negated. Another object of the invention is to provide a strong permanent installation including

the insulation structure which is more economical to operate and more efficient in action.

The tank structure provided in accordance with the present invention is especially useful where the temperatures of the contents of the tank proper vary materially due, for example, to the use of different materials for storage therein under different temperature and pressure conditions at different times, so that different problems of water condensation are encountered from time to time and where the ambient temperatures with respect to the whole structure i.e. the tank and its insulating shell, vary greatly.

Accordingly, the invention generally provides an inner tank of conventional form for holding the liquefied gas or like material under suitable low temperature and/or low pressure, said tank being insulated by an outer surrounding shell which is made of assembled metal sheets such as aluminum sheets, which are sealed at the butting or overlapping edges with a vapor barrier seal leaving free air spaces between the external wall of the tank and the outer shell, means being provided communicating with the free spaces formed between the tank and the shell to withdraw the condensate water, as desired. Means are also provided for the removal of frost or snow deposited on the outer surface of the tank. Thus, by practicing the present invention there is provided means to tap off or drain the water of condensation formed in the area or areas between the exterior tank wall and the shell, this shell being of the form known as a vapor barrier type of insulating structure, using free air spaces between metallic walls. Also, means may be provided, if desired, to send a hot blast of suitable gas into the air spaces above-mentioned between tank and shell, to render any frozen water either deposited on the walls of the tank itself or upon the metal sheets making up the insulating shell in liquid form, which will permit the draining off of the liquid water therefrom.

As previously mentioned, in using tank structures of this type, it may be desired to store different materials under the required conditions of temperature and pressure at different times in order to make possible the utilization of the tanks throughout the year to the greatest degree of efficiency. The various materials to be stored, which are gases duly treated to cause them to become liquid, may have extreme differences of temperature and pressure conditions. The following Table I gives the physical properties of certain common gases which are stored in this type of tank to show this extreme range of such materials, it being realized that many other gases of this general nature can be liquefied and stored under suitable conditions of temperature and pressure which are not in this list.

TABLE I

Name	Formula	Molecular Weight	Normal Boilig Pt., Temp., ° F.	Critical Point	
				Temp., ° F.	Pressure, p.s.i.a.
Air		28.97	−317.9		
Ammonia	NH_3	17.03	−28.1	270.32	1,639
Butane	C_4H_{10}	59.2	28.0	308.00	525
Chlorine	Cl_2	70.91	−29.0	293.00	1,118
Ethane	C_2H_6	30.07	−127.6	90.09	708
Ethylene	C_2H_4	28.05	−154.8	49.8	742
Methane	CH_4	16.04	−258.6	−116.50	673
Nitrogen	N_2	28.02	−320.5	−232.78	492
Oxygen	O_2	32.00	−297.3	−181.84	730
Propane	C_3H_8	44.09	−43.7	206.24	617
Propylene	C_3H_6	42.08	−53.3	197.4	667

In Table I by critical temperature is meant the highest temperature at which a gas can be liquefied irrespective of pressure. If the temperature of the gas is below its critical temperature, increasing the pressure will eventually cause the gas to liquefy, but above the critical temperature a gas can be compressed indefinitely without the appearance of a liquid state. By critical pressure is meant the specific vapor pressure of the fluid that exists at the critical temperature. The normal boiling point given is that of the normal boiling point of the gas. From the above table, it will readily be seen that the conditions within a tank for use with such materials may be quite extreme, depending upon the material utilized, since the ranges of the boiling point and the critical temperatures and pressures are extremely wide for the various gases referred to, and all of these may readily be stored in the manner defined herein.

The accompanying drawings illustrate one form of the tank structure according to the present invention which is exemplary of the manner of achieving the objects and advantages of the invention. In the drawings:

FIGURE 1 is a plan view of the tank structure in accordance with the present invention, with parts broken away, in section;

FIGURE 2 is an elevation of the tank structure of FIGURE 1, with parts broken away, in section;

FIGURE 3 is an enlarged detail of the side walls of the tank structure, in accordance with FIGURE 2, in cross-section;

FIGURE 4 is a detail, enlarged and in plan view, of the method of moisture vapor-barrier sealing of the outer wall of the shell of FIGURE 2;

FIGURE 5 is an enlarged detail of the manner of fastening the shell walls surrounding the tank to form the tank structure of FIGS. 1 and 2, with the means for permitting expansion of the tank relative to the shell clearly shown;

FIGURE 6 is an enlarged detail of the manner of fastening a roof and wall structures together to form the tank structure of FIGS. 1 and 2;

FIGURE 7 is an enlarged detail of the manner of supporting the roof structure to the tank structure;

FIGURE 8 is a detail of another floating expansion joint as alternative to FIG. 5; and

FIGURE 9 is an enlarged detail of the vapor-sealing means of FIG. 4, in elevation.

Referring now specifically to FIGURES 1 and 2 of the drawings, the general arrangement of the tank structure as a whole according to the present invention is shown at **10**. The interior tank **11** will contain the liquefied gas to be stored under suitable temperature and pressure in conventional manner, and the structure of the inner tank **11** is completely conventional, this being for instance a metal tank of cylindrical body, conical or domed head and dished base duly welded to resist the necessary pressures to be applied. Conventionally, there will be conduits communicating with the interior of the tank **11** such as those shown at **12** from above and **13** from above and **13** from below, these being for filling and emptying the tank, the arrangement of the conduits **12** and **13** being shown dotted since these are completely conventional and not part of the present invention.

Arranged externally surrounding the inner tank **11** is the insulating unit or structure generally shown at **14** in accordance with the present invention. As shown in FIGS. 1 and 2, the insulating structure **14** is comprised of a plurality of concentric spaced apart walls which define air spaces therebetween to be more specifically described hereinafter. The whole tank structure **10** is suitably supported upon a concrete base **15** and is self-supporting, as shown particularly in FIG. 2 of the drawings.

In order to better illustrate and describe the particular structure of the walls reference is made to FIGS. 3, 5 and 6, in conjunction with FIGS. 1 and 2.

As shown specifically in the right hand part of FIGS. 1 and 2, there is provided a skeleton structure for supporting the various insulating walls of the insulating unit **14**, which comprises a plurality of upright wooden batons or supports **16** which are arranged at spaced intervals circumferentially of the tank. A further group of upright wooden supports **17** are provided interior of the supports **16**, namely on a circumferential path which has a lesser diameter than that of the uprights **16**

and within this structure there are provided three more circumferentially arranged arrays of upright wooden supports **18**, **19** and **20**, the said circumferentially arranged uprights being on lesser diameters progressively inwardly with the series of uprights **20** being arranged as the innermost supports, and actually, as will be clearly seen from FIG. 1, this last array of upright supports **20** are in direct contact with the external wall of the tank **11** which contains the liquefied materials to be stored. Thus, as shown in FIGS. 1 and 2 there is provided, in accordance with this invention, a series of circumferentially arranged and concentric rings of upright posts or supports identified as numerals **16** to **20**, each of the said series being laterally spaced from the other a predetermined amount as dictated by the actual width of the sheets of metal which will be thereto applied, as hereinafter defined. The view in FIG. 5 shows the arrangement of the upright wooden supports **16** to **20** in detail, identifying this spacing and arrangement.

In order to provide mechanical strength to the structure and at the same time provide some horizontal attachment points, there is also provided a plurality of horizontal supports or crossbeams shown in FIG. 2 at **21**. These crossbeams may extend around the whole of the periphery of the circumferential array of uprights or may only extend a partial way therearound in order to give a staggered arrangement. Specifically, shown for example in FIG. 2, there is an array of horizontal crossbeams **21** and **22** which extend between the upright wooden supports **16** and **17** and **18**, together with a further array of three horizontal crossbeams **23**, **24** and **25** which are arranged between the crossbeams **18**, **19** and **20** at a lower position with respect to the height of the structure as shown in FIG. 2, thereby staggering the horizontal supports or crossbeams relative to each other.

There is therefore provided in accordance with the invention, a self-supporting wooden structure external of the inner tank **11** which comprises a framework of a plurality of concentric rings or arrays of upright posts which have around them in a horizontal direction a plurality of horizontal supports or crossbeams which may be continuous or may be in a staggered formation, as specifically shown. The wooden framework thus provided for the insulating structure **14** will be suitably anchored at the ground by any conventional means which does not require specific illustration. In accordance with the invention there is provided, supported upon each of the various concentric array of upright supports to form a skin or shell, a plurality of thin metallic plates, which are preferably aluminum, and which are stretched around the structure to provide as shown in FIG. 1 particularly a plurality of shells of metal in a radially spaced concentric ring formation relative to the inner tank **14**. These shells are shown generally in FIG. 1 at **26** to **30**, **26** being the inner shell, **30** being the outer shell. It will also be noted that the outer shell **30**, at least (see FIGURE 5) is of heavier weight material, namely thicker than the inner shells, as is desirable in accordance with one feature of the present invention in order to give mechanical strength and/or greater insulating effect at the outer face of the structure by the outer shell **30**.

In order to best indicate the manner of operation in accordance with the present invention, there will now be given a description of how the actual insulating structure **14**, is built utilizing the apparatus defined hereinbefore.

The innermost upright wooden supports **20** are suitably placed around the outer wall of the inner tank **11** as specifically shown in FIGS. 1, 2, 3 and 5, the spacing thereof being selected in accordance with the needs of supporting the skin **26** which will be placed therearound. The degree of spacing of the upright supports **20** around the inner tank is not material to the practicing of the invention. Since the tank wall **11** may expand and contract, as previously discussed, it is desirable that the upright **20** be associated with the wall of the tank **11** in such manner that expansion and contraction will be absorbed and will have no basic effect upon the skin or shell **26** which is to be arranged upon the uprights **20**. Since the wooden battens making up the frame of the shell have a definite give or yield and are somewhat resilient, in some cases, this can be relied on to give the desired floating of the tank. Preferably, however, positive floating attachment is provided. To this end, attachment is therefore made between the support **20** and the actual outer wall of the tank **11** identified as **31** by means of an expansion bolt **32**. To this end, there is attached to the wall **31** an upright extending pin **33** which has thereon a cap **35**, with a resilient compression pad **36** therebetween. Within the body of the upright **20** there is provided a bore **37** in which is inserted a ferrule **38** and it will be seen that the cap **35** slides within the ferrule **38** and butts thereagainst compressing or releasing pad **36**. Thus, longitudinal movements of the pin **34** will carry the cap **35** relative to the ferrule **38** and any such movement, which will be downwardly in FIG. 5, will compress the resilient pad or packing **36** and movement therefore will be absorbed. In other words, if movement of the wall **31** takes place by contraction or expansion for any reason, then such movements will not be imparted in any way to the upright **20** but will be absorbed by the expansion bolt assembly **32**.

There will be provided a plurality of the expansion bolts **32** for the uprights **20** whereby the uprights **20** in their concentric array will be in no way influenced by the movements of the wall **31** caused by the extremes of temperature within the tank **11** which may be expected in this type of structure and the uprights **20** will float relative to tank **11**. Having arranged the array of uprights **20** around the periphery of the tank **11** and floatingly attached these thereto utilizing the expansion bolts **32** of FIG. 5, there is then placed around the uprights a first arrangement of horizontal crossbeams **25**, as shown in FIG. 2 for example. It will of course be realized that the horizontal crossbeams **25** do not necessarily comprise one continuous string but rather are small segments or portions of crossbeam which are fitted between the uprights **20**, to provide a continuous surface at the exterior of the uprights **20** upon which there is to be placed the shell **26**. In FIG. 5 the arrangement of the three horizontal intermediate crossbeams **23**, **24** and **25** is shown, it being borne in mind that the crossbeam **25** will be in contact with the face of the tank **11**, namely in contact with the wall **31**, and thus some means should be provided whereby movement of crossbeam **25** due to contraction and expansion of the said wall **31** should be avoided. In FIG. 8 there is shown another form of expansion bolt which can be utilized in order to make sure that the beam **25** does not follow any movements of the wall **31**, but floats relative thereto, this comprising an expansion bolt **37** which has a pin **38** attached to the wall **31** of the tank, which pin moves through a ferrule **39** arranged in the crossbeam **25**, there being provided a cap **40** on the end of the pin **38**, with a washer **41** which can move freely within the bore **42** provided in the beam **25**. Thus, movements of the pin **38** caused by movements of the wall **31** will be permitted relative to the crossbeam **25** and the cap **40** can be adjusted to allow both expansion and contraction while still providing adequate anchorage of the beam **25** against the wall **31**. It should also be obvious that the beam **25** will be suitably anchored to two parallel upright members **20** where it contacts same, this being the usual wood-to-wood contact, such as by means of nails or wood screws.

Having arranged the crossbeams **25** in association with the uprights **20**, it is now possible to apply the first shell or skin **26** of metallic insulating material. To this end there is applied to the skeleton framework of the uprights **20** and the crossbeams **25** a plurality of sheets of thin aluminum which are placed, in this particular case, in a vertical array and are suitably attached to the wooden

framework thus presented formed of uprights 20 and crossbeams 25. The butting ends of the various upright placed sheets, which sheets can run from the top to the bottom of the actual tank, are shown in FIG. 5 particularly, where sheet 43 abuts with sheet 44 at a point midway approximately of the upright 20. In FIG. 2 the upright sheet is identified as 43 as an indication of where this will lie relative to the inner tank 11. The sheets 43 and 44 are suitably attached to the upright 20 which is the main support therefor, as by stapling, screws or nails and no attempt is made to render the joint vapor-tight. In other words, the sheets are run vertically from the top to the bottom of the tank structure and are suitably attached as by staples to the framework of wooden supports with the edges of the various sheets 43 and 44 abutting. A plurality of sheets will thus be spaced around the circumference of the tank and these will be attached to the various uprights 20 and crossbeams 25, namely, on the framework provided. Where they cross over the horizontal crossbeams 25, again they will be suitably attached with no attempt to in any way vapor seal these joints. When this has been accomplished the inner tank 11 will now be surrounded by a complete cover in the form of a concentric spaced-away aluminum shell 26 made up of various sheets such as 43 and 44. It should be realized that the shell 26 is made up of a large plurality of sheets and the number of sheets utilized depends entirely upon the manageable width of the vertical sheets used, the spacing of the uprights 20 and like design factors, which are not part of the present invention.

After the application of this first shell 26, further upright batons or supports are now placed over those already utilized, namely the uprights 20, and thus a plurality of upright wooden supports 19 are placed around the circumference of the tank and these are attached to the uprights 20 as by wood screws 49 (FIG. 5) to form a second framework of wooden supports. By providing the first shell 26 spaced from and circumferentially surrounding the wall 31 of the tank 11, there is arranged an air space 46 in the form of an annular chamber (FIG. 1). This air space acts as an insulating barrier together with the shell 26 as will hereinafter be more fully described. Since no attempt has been made to vapor seal the joint of the various sheets making up the shell 26, there will be free interchange of water vapor through the joints at the wooden supports 20 and 25, and thus in effect the annular space 46 is not vapor sealed to all intents and purposes. In order to form a second annular chamber of the same nature, the various upright supports 19 are placed circumferentially around the tank, being located above the uprights 20 as shown in FIG. 5, and again in like manner to the described form with respect to uprights 20 a shell 27 defining an air space or chamber 48 is provided (FIG. 1). Since the problem of expansion and contraction of the wall 31 will not affect the uprights 19, there is no need for expansion joints therebetween. It will of course be realized that the crossbeams 24 are associated with uprights 19 and the second shell 27 is formed of vertical sheets as before, and the sheets identified as 50 and 51 are applied to the framework of wooden supports 24 and 19 to form the air space 48, these sheets 50 and 51 abutting and being duly stapled or the like to the upright supports 19 and to the crossbeams 24.

The structure of the insulating chambers forming the insulating structure 14 may be formed completely of the vertical sheets such as those defined as 43 and 44, 50 and 51 of FIG. 5 as hereinbefore stated, but, in one mode of practice of the invention, the next two shells of metal to be formed are wrapped around in a horizontal manner. To this end, upright supports 18 are placed in association with the supports 19 already attached and are attached, as heretofore defined. Crossbeams 23 are associated with the uprights 18, as hereinbefore defined. The crossbeams 23 are associated with the uprights 18, so that there is provided again a framework of wooden supports. Now, the single aluminum sheet 52 is wrapped around in a horizontal manner over the assembled framework and is again stapled, or attached in like manner as desired, to the various wooden supports; a further sheet is placed therebeneath in a horizontal manner; and this again is attached, the two sheets either abutting or overlapping, as desired. Thus, there will be provided a third horizontally formed shell 28 which will define a third air space or chamber 54.

In the specific embodiment of the invention there is provided two more shells of insulating metallic structure, and, as shown in FIG. 5, the next shell 29 is also horizontally wrapped around the unit being supported on the batons 17 which will be suitably attached to the supports 18 and the horizontal crossbeams 22 will be supported thereover, whereby there will be provided a third shell 28 and a fourth air space 57 (FIG. 1).

It is obvious that one can select any number of shells and air spaces which are needed for the particular insulating structure 14, to take care of the conditions within the tank 11 and the ambient conditions external of the structure 14, and accordingly each shell will be built up to specification using vertical supports equivalent to 16 to 20, horizontal supports equivalent to 21 to 25, either vertical or horizontal wrapping of metal sheets equivalent to those forming the respective shells 26, 27, 28 and 29, thereby providing a plurality of air spaces 46, 48, 54 and 57 within reflective insulating sheets of metal (FIG. 2).

The outer shell, which is now to be provided, is preferably of heavier metallic material and is attached in a totally different way to its respective framework of wooden supports and therefore, irrespective of the number of inner shells which have been provided, the outer shell will now be described specifically in the manner in which it is constructed, to accomplish the purpose of this invention.

In similar manner to that heretofore described, the uprights 16 are placed around the circumference of the tank structure in a concentric array (FIG. 5) and are suitably attached as hereinafter disclosed to the other members 17. The crossbeams 21 are then put in place and thus there is provided a wooden framework support for the outer skin, shell or enclosure of the structure 14 which insulates the tank. The outer shell 30 (FIG. 1) comprises a vertically arranged plurality of heavier metal material of the reflective insulating type, such as aluminum. Since this is the outer wall of the insulating structure 14, the weight of metal selected will have need for mechanical strength in mind. The abutting edges of the vertical strips of aluminum are aligned with respect to the upright support 16 and in accordance with the invention are suitably capped and sealed by means of an insulating water-impervious vapor-barrier type of seal whereby the outer skin or enclosure 30 is substantially impervious to the ingress or egress of air, water-vapor or water.

Reference is now made to FIGS. 4, 5 and 9 to identify the exact form of vapor barrier sealing means utilized for the outer shell 30 in accordance with the present invention. The supports 16 have the two metal sheets 58 and 59 which are to form the outer enclosure shell 30 and air space 45. It will be noted that these do not exactly abut but are spaced apart by a predetermined small amount. The amount of spacing can be selected for the purpose hereinafter described. In order to completely vapor-seal the joint of the two sheets 58 and 59, there is first applied thereover an adhesive insulating tape. This is preferably a ductile metal tape, such as a plastic and aluminum foil laminate tape, which has an adhesive base. Tape 60 is applied adhesively along the length of the

joint of the sheets 58 and 59 to close the joint and seal same. This therefore provides the first sealing of the two sheets 58 and 59 by means of a suitable pressure-sensitive tape which is pressed in position and adhesively bonded to the sheets. Over this sensitive tape there is applied a channel-shaped metallic sealing strip 61 which is suitably bored at spaced intervals along its length, as at 62, to receive wood screws 63 for the purpose of fastening the channel-shaped mould strip 61 in fixed position relative to the wooden upright 16, as shown in FIG. 4, and in pressure-contact with tape 60. The pressure applied by this screw 63 will cause the leaves of the channel 61 to press into and make contact with the sealing tape 60 and thus insure a better contact and sealing at this point. Thus, there is a control of pressure which can be applied to the seal, by virtue of the screw 63.

Prior to the tightening down of the channel strip 61, the open area is preferably filled with a suitable caulking compound 64 (FIG. 4). This compound may be of the type which does not harden permanently and thus act as a somewhat resilient barrier, thus making contact with the area in which it lies at all times. Furthermore, when the pressure to the channel 61 is applied by means of the screws 63, the caulking compound 64 will be distributed firmly and spread over the whole area within the channel and will fill up all interstices to form a complete seal. A bead of the same or a different caulking compound may be placed externally of the channel 61 where this makes contact with the tape 60, as shown at 64 and 66, this forming a bead of caulking compound which will run throughout the length of the wall of the tower or tank and will waterproof same. The procedure taken is in order to make the sealing of the two metallic sheets 58 and 59 complete and as impervious to water vapor as is possible throughout the length thereof. There is thus provided an outside shell 30 which is substantially completely vapor sealed from the atmosphere as is desired in order that there may be no transfer of the external atmosphere and the internal atmosphere. No transfer of air or water vapor from the enclosure 14 externally to the atmosphere or vice versa can take place, whereby the reflective insulation type enclosure 14 will be substantially impervious to ingress and egress of water, vapor, air or water.

It is necessary in order that the insulating structure be complete that there be provided a suitable means for enclosing the top of the tank with like insulating properties and with complete communication between the insulating areas above the tank and the walls of the insulating structure 14 hereinbefore described.

In accordance with the invention, therefore, there is provided a dome-shaped structure above the top of the tank which is constructed in a similar manner to the manner in which the walls have been constructed to form the enclosure 14, i.e. as a plurality of insulating metallic shells defining air spaces therebetween with a final sealing of the outside enclosure or shell 30. Reference is made to FIG. 6 which illustrates the attachment of the roof structure to the wall structure in accordance with the present invention. As will be seen in FIGS. 6 and 7, there is provided a plurality of spaced apart wooden frame members 67, 68 and 69 which are adapted to support metallic sheets to form shells identified as 70, 71 and 77. Since the specific arrangement of the supporting of the roof shells 70, 71 and 77 is equivalent to that disclosed for the structure 14, it is not considered necessary to identify the exact manner of constructing same. As shown in FIGS. 6 and 7, the roof is floatingly mounted as at 72 with similar expansion bolts to those shown in FIG. 5 at 32. Reference is made to FIG. 1 on the left hand side where there are provided various wooden cross members, two of which are shown at 73 and 74, forming a framework. Over this framework there is applied the shell 70 and the shell 71, the two inner shells being simply stapled to their frameworks and the outer shell 77 being sealed in place as previously defined as is shown in FIG. 6 at 75, this being a similar seal to that of FIG. 4. Thus, the roof will join the walls with only the area 76 being free of any form of insulation. The outer shell 77 of the roof which is moisture vapor-barrier sealed by the sealing means 75, will meet the moisture vapor-barrier sealed outer shell 30 at an area shown as 78 on FIG. 6. The roof shell 77 will be lapped over the shell 30 by means of the flange 83 which is attached to the supports 16 by screws 84. A suitable layer 85 of insulating compound is arranged between the overlap of flange 83 and the outer face of shell 30. A bead 85 of caulking compound is run around the overlap area of flange 83 and shell 30. Finally, the gutter formed by this joint will be flashed with caulking compound as at 86. Thus, the roof structure will be adequately sealed with respect to the outer shell 30 where this is attached. It will be realized that there is very little leakage path in this jointure area except for the area 76 previously referred to which is a hollow space created by the framework. In order to take care of insulating area 76 this is filled with any suitable insulating solid composition which is packed in place between the various wooden batten structures, as shown.

In accordance with the present invention it is necessary to provide a clear passageway between the area defined as space 79, which is the first air space of the roof structure, i.e. that nearest tank 11, and the air space defined as space 46 being the inner air space next to the tank 11. To this end, there are provided various channels identified as 80 through the solid insulation. These channels may be direct conduits of aluminum such as semi-circular gutters or they may simply be suitable scorings and indentations in the insulation, it being only necessary to make sure that the inner air space 79 of the roof structure openly communicates directly with the inner air space 46 of the wall structure. Thus, the air spaces next to the tank 11 and its proof is open and free.

To summarize, reference is made to FIGS. 1 and 2 where it will be seen that there has been provided a completely insulated tank 11 which is surrounded by a plurality of shells of reflective insulation, the outer shell of which is completely sealed against water vapor or air passage or water passage between the inside and the outside, or vice versa. Tank 11, both wall and roof, is completely thus insulated. This structure is clearly shown in FIG. 2 and it will be realized that reflective insulation with air spaces therebetween forms one of the best insulating structures possible, whatever the temperature of the contents of the storage tank 11 may be and whatever the external or ambient temperature may be. However, in such structures it is inevitable that due to the changes of the ambient temperature and due to the impossibility of complete sealing of air and water vapor, some condensation of water vapor will take place. This may take place in the form of ice or snow on the wall 31 of the tank 11 externally thereof and within the air space 46 and roof space 72. Therefore, if the moisture thus produced or present in this air space and in the other air spaces of the insulating structure 14 is not removed, it will tend to reduce the insulating properties of the structure 14 and may also cause ultimate harm and damage to the various walls and the like. In other words, it is desirable that the water present in the various air spaces and specifically in the air space 46 and 79 be removed, and since some such water must exist, means are provided in accordance with the invention for periodically removing same.

Since the tank 11 may store various materials and since as hereinbefore defined the temperature differentials within the tank may be extreme, for instance the storage of anhydrous ammonia at —30° F. and the storage of butane at 30° F. as exemplified, there will be a definite problem, if no means are provided to remove this water of condensation.

It should be realized that there is complete communi-

cation between all the various air spaces formed in the walls of the body structure **14** and the roof structure and thus any withdrawal from the inner and most important spaces, space **46** in the walls and space **79** in the roof, will take care of the condensation and any water vapor present which could cause such damage and lack of efficiency. Since also there is a complete communication between the air space **79** of the roof structure and the air space **46** of the wall structure by virtue of conduits **80**, and also since none of the inner walls are vapor-tight, removal from the air space **46** of the moisture whether in liquid or vapor form will take care of the whole of the inside area insulating structure **14** and comprising both wall structure and roof.

To this end there is provided at **81** and **82** (FIGS. 1 and 2), two drainage pipes which comprise conduits **88** and **89** which directly communicate with the interior space **46** of the structure **14**. The drainage devices **81** and **82** are provided with conventional valves **90** and **91** whereby they can be opened or closed at will, and it will be noted that preferably conduits **88** and **89** slope downwardly and outwardly to allow gravity withdrawal, if desired. Thus, it will be obvious that at any time desired the valves **90** and **91** may be opened and any water may be drained out of the structure **14** which has accumulated. Due to the angle of approach of the drainage devices **81** and **82**, this can be by gravity and due to the particular arrangement and communication of the various air spaces, gravity flow toward the drainage devices **81** and **82** will be accomplished. As will be seen in FIG. 2, there is provided a small slump at the end of the conduits **83** and **84**, the slumps being identified as **92** and **93**. Thus, there is a place for accumulation of water in the liquid phase. There may be several of the drainage devices identified as **81** and **82** arranged around the periphery of the tank structure at the lower points thereof as shown, the placement and number being selected to suit design specifications.

If desired, the particular drainage devices **81** and **82** may be utilized for the alternative purpose of blowing warm or dry air or other gas into the air space to pick up the moisture. To this end therefore one of the devices, for example **81**, may be set to blow in hot gases such as air throughout the air spaces of the complete structure **14** comprising walls and roof whereas the other device **82** may be set with suitable suction thereon to draw out the blown-in hot gases. This enables a quick scouring of the complete inner structure **14** in a very short time and removal therefrom of not only liquid water and vaporous water but also removal of any ice or snow which may have formed on any of the metallic parts within the structure or on the tank wall **31** itself.

Thus, there is provided in accordance with this invention means to insulate a tank such as the storage tank **11** by self-supporting and upstanding walls of reflected insulation, such as aluminum, arranged as a plurality of concentric shells around the tank in number necessary to create a complete insulating barrier, the outer shell being sealed from the atmosphere with as complete a vapor barrier as is possible. Since, however, no vapor barrier is perfect, there is also provided means to remove any water of condensation in either liquid or vaporous form from the air spaces within the said insulating structure and, if desired, to send through the air spaces a stream of drying gas or heat or both to scour the metallic walls and/or remove any water vapor present in the interior of the insulating structure. By this means therefore the highest degree of insulation is obtained, with the removal of any water of condensation in either vaporous or liquid form from the tank walls itself from spaces in the insulating structure and from the shells of reflective insulation material forming the insulating structure.

Various modifications are obvious including the aforesaid use of plurality of nozzles situated at any desired point for utilization for either withdrawing water or for adding heat or drying gases to the air spaces. Furthermore, as has been previously defined, the particular structure and arrangement of the aluminum or like metal walls can be vertical or horizontal and in the case of the roof can lie in any plane as is needed in order to obtain the desired insulating properties.

Where reference has been made to the removal of water generally, it is obvious that this may be in any physical state, as ice, vapor or liquid or a mixture thereof. Also, when reference is made to the use of gases for removal of such water, it is obvious that dry gases or hot gases may be used, or both, or even a powdered desiccant may be employed. Furthermore, while use of the conduits or nozzles entering into the inner air space may be employed for water removal or scouring with hot, dry gas, for example, it is obvious that a flood of hot liquid could be passed therethrough to clean the tank face.

While it is preferable to utilize caulking compound as an extra sealing means with respect to the vapor seal externally of the outer wall or enclosure of both walls and the roof, such sealing compound may be dispensed with since the sealing tape and the metallic channel may be sufficient to cause the necessary vapor barrier to be established. Alternatively instead of utilizing a caulking compound, the interior of the channel may be filled instead with a soft resilient tape which can be forced into contact with the surface of the metallic tape and cause extra sealing, namely a liner may be utilized within the channel instead of the use of a caulking compound.

Various modifications of the invention hereinbefore described may be made while, for example, a generally cylindrical tank with concentric insulating walls thereabout has been described, it is obvious that the tank and/or the structure can be of other shapes, particularly an ellipse. Even a square tank and/or a square insulating structure can be formed in the manner hereinbefore described without departing from the spirit of the invention. The references made herein to walls of reflective metal insulation are inclusive, in most cases, of the equivalent roof wall, so that the side walls mounted on the frameworks of battens and the roof walls mounted on the scaffolds of battens are, in effect, continuous walls, being attached to each other, and having the airspaces formed thereby, each in communication directly, if desired.

With the use of the insulating structure heretofore defined, there may also be used various solid forms of insulation at strategic points, in that use thereof will in no way affect the efficiency of the particular structure, and furthermore when utilizing the device to add either hot gases or dry gases to the air spaces, this will tend to remove from such solid insulation materials any water which is held thereby and thus keep the whole of the interior of the insulating structure dry and at peak efficiency.

While reference has been made to the use of expansion bolts to permit expansion and contraction of the tank walls relative the frame and thus forming a floating connection, it is possible to dispense with said attachments and rely on the natural resiliency of the wood framework to allow compensation for such physical movements of the tank.

What is claimed is:

1. An insulating tank structure for holding a liquefied gas at low temperatures having the combination of a tank having walls and a roof, for containing said gas, with a structure arranged thereabout for insulating said tank from the atmosphere comprising a first non-vapor sealed thin aluminum metal side wall supported on a first framework which spaces said side wall away from the tank wall by a preselected amount to form a first side airspace, expansion bolts anchoring said first framework to said tank walls in a floating manner, a first non-

vapor sealed roof formed of a thin aluminum metal wall supported on a roof scaffold which spaces said first roof wall away from the tank roof by a preselected amount, to form a first roof airspace, expansion bolts anchoring said first roof wall to said tank roof in floating manner, said first side airspace and said first roof airspace being channelled for communication with each other, a second thin aluminum metal non-vapor sealed side wall and a second thin aluminum metal non-vapor sealed roof wall each supported on a side framework and roof scaffold which spaces the second side and roof walls away from the first side and roof walls by a preselected amount, to form second side and roof airspaces in communication with each other, a third thin aluminum metal side wall supported on a third framework which spaces the third side wall away from the second side wall by a preselected amount to form a third side airspace, a third thin aluminum metal roof wall supported on a third roof scaffold which spaces said third roof wall away from said second roof wall by a preselected amount, to form a third roof airspace, said third wall airspaces communicating with each other, vapor sealing means on the outer face of the third metal side wall and on the third metal roof wall, comprising a pressure sealed tape over all joints forming said walls and a pressure cap embracing said tape and forcing it into contact with the wall faces, a plurality of conduits extending through said side walls communicating with said first side and roof airspace and projecting into the atmosphere external of said structure and control valves on said conduits normally sealing said conduits from the atmosphere to permit venting of said first airspace by opening said valves.

2. An insulating tank structure for holding a liquefied gas at low temperatures having the combination of a tank having walls and a roof, for containing said gas, with a structure arranged thereabout for insulating said tank from the atmosphere comprising a first non-vapor sealed thin aluminum metal side wall supported on a first framework which spaces said side wall away from the tank wall by a preselected amount to form a first side airspace, compression bolts anchoring said first framework to said tank walls in a floating manner, a first non-vapor sealed roof thin aluminum metal wall supported on a roof scaffold which spaces said first roof wall away from the tank roof by a preselected amount, to form a first roof airspace, compression bolts anchoring said first roof wall to said tank roof in a floating manner, said first side airspace and said first roof airspace being channelled for communication with each other, at least a second thin aluminum metal non-vapor sealed side wall and at least a second thin aluminum metal non-vapor sealed roof wall each supported on a side framework and roof scaffold which spaces the second side and roof walls away from the first side and roof walls by a preselected amount, to form second side and roof airspaces in communication with each other a third thin aluminum metal side wall supported on a third framework which spaces the third side wall away from the second side wall by a preselected amount to form a third side airspace, a third thin aluminum metal roof wall supported on a third roof scaffold which spaces said third roof wall away from said second roof wall by a preselected amount, to form a third roof airspace, said third wall airspaces communicating with each other, said walls all being made up of thin sheets of aluminum with their edges abutting and vapor sealing means for said walls comprising a pressure sealing adhesive tape applied along the abutting edges of said sheets, a continuous channel with its protruding edges in contact with the faces of said sheets and fastened to said framework and overlying said adhesive tape, caulking compound within the areas created by said channel when in position, a final bead of caulking compound at the contact edges of said channel, a pressure cap embracing said adhesive tape and forcing it into contact with the wall faces, a plurality of conduits extending through said side walls communicating with said first side and roof airspace and projecting into the atmosphere external of said structure and normally closed control valves on each of said conduits, to permit venting of said first airspace by opening said valves.

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