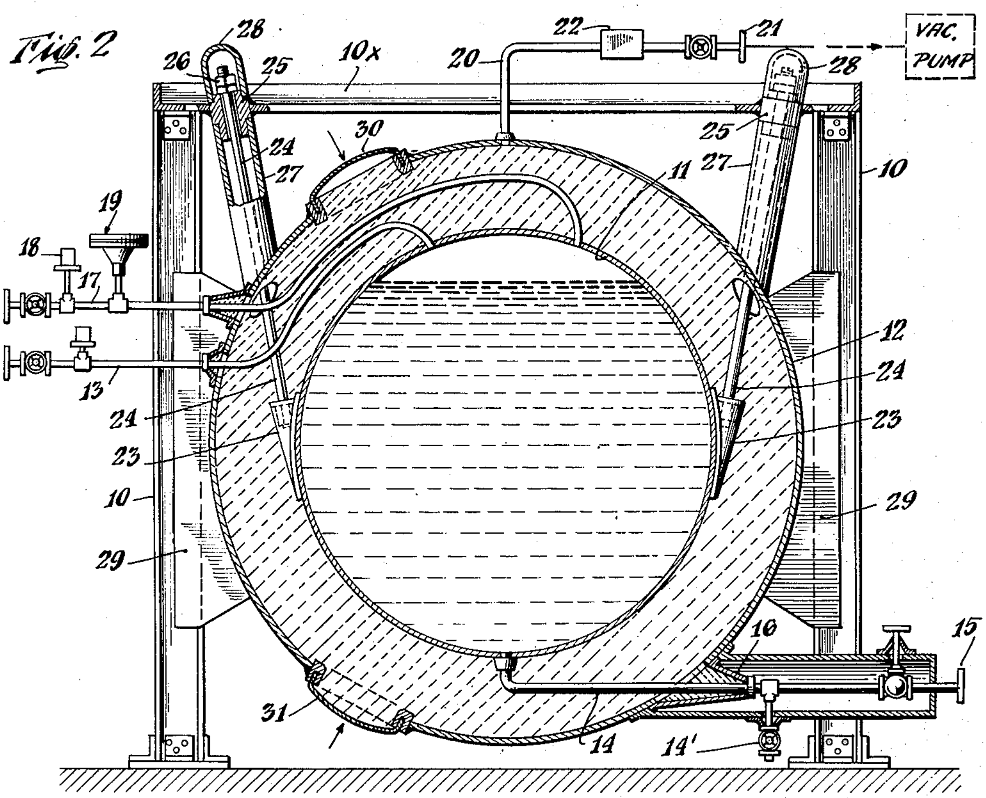
March 12, 1946. L. I. DANA 2,396,459

INSULATED CONTAINER FOR LIQUEFIED GASES AND THE LIKE

Original Filed Dec. 7, 1939 2 Sheets-Sheet 1

Fig. 2



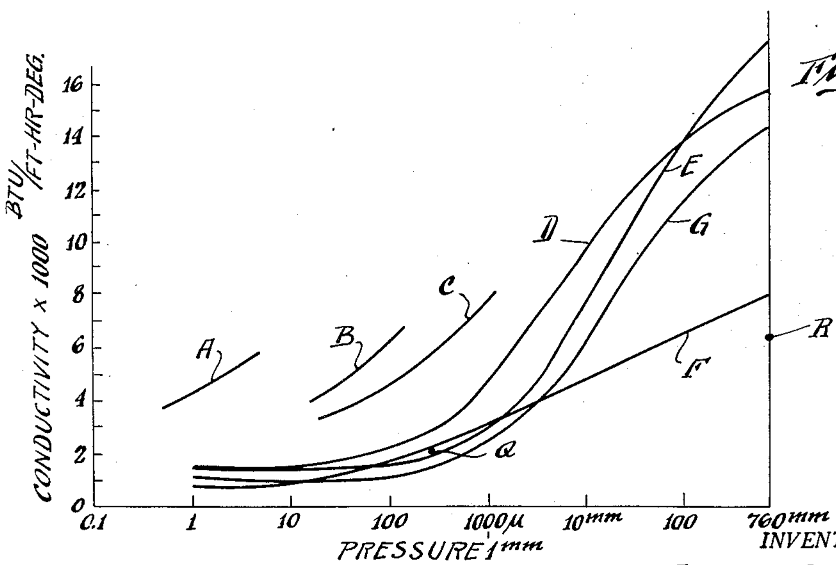


Fig. 1

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Fig. 3

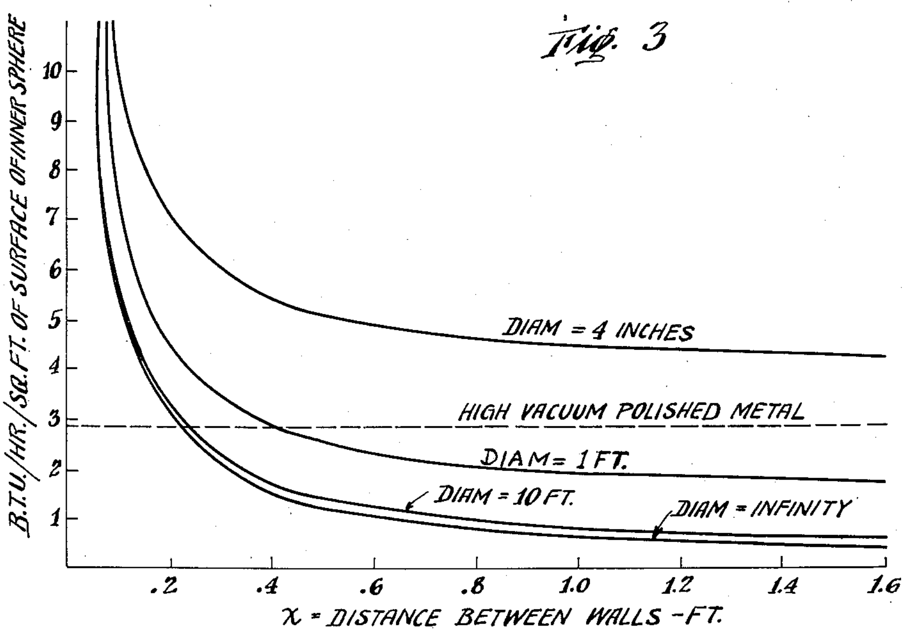
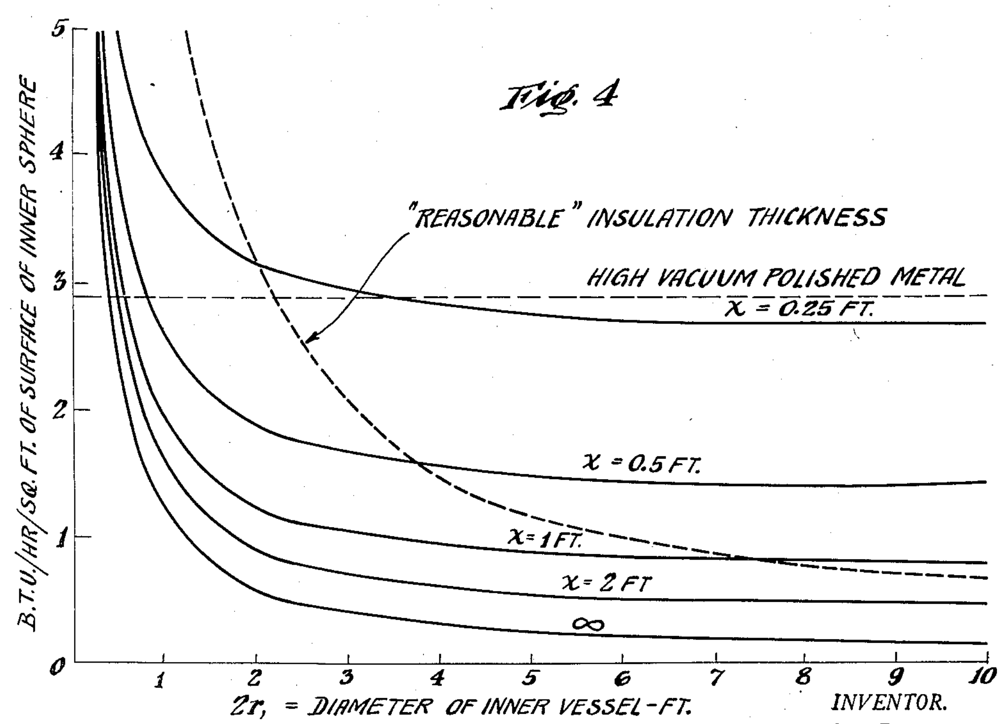


Fig. 4



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UNITED STATES PATENT OFFICE

2,396,459

INSULATED CONTAINER FOR LIQUEFIED GASES AND THE LIKE

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Original application December 7, 1939, Serial No. 307,945. Divided and this application August 28, 1943, Serial No. 500,308

3 Claims. (Cl. 62—1)

This invention relates to insulated containers for liquefied gases and the like, and particularly to double-walled insulated containers adapted for storing and/or transporting liquefied gases that have boiling points at atmospheric pressure at or below 233° K., such as liquid oxygen, and which have the space between their walls evacuated and maintained under a relatively low absolute pressure; the temperature of 233° K. being that at which the vapor pressure of water is just below 100 microns of mercury.

The present application is a continuation of my former application Serial No. 307,945, filed December 7, 1939.

The invention has for its object generally the provision of containers of the character indicated in which the separation of the walls defining the evacuated insulating space is made relatively wide and filled with a powdered insulating material and evacuated to a unique degree which gives a highly efficient insulating effect in a relatively economical manner.

More particularly, the invention relates to double-walled containers which are adapted for commercial or industrial transport and/or storage service and are provided with heat insulation by making the space between the walls have a relatively low heat transfer rate and which is maintained highly efficient by the introduction of a suitable comminuted filling, such as a substantially dry powdered insulating material, and evacuated by ordinary commercial vacuum pumps so as to reduce the heat conductivity to a selected low value.

Still another object is to provide an improved container that reduces the heat transfer rate to a relatively permanent low value and thereby increases the thermal efficiency, such container being designed to hold its contents with the reduced heat transfer rate in a manner such that liquefied gases may be stored therein for relatively long periods without substantial loss.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts, which will be exemplified in the construction hereinafter set forth and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

Fig. 1 is a chart showing heat transfer characteristics of an insulating space of a double-walled container when filled with comminuted insulating material in accordance with the invention;

Fig. 2 is a view, partly in elevation and partly in vertical section, showing details in the construction of a double-walled container for liquid oxygen having a powder filled evacuated insulating space in accordance with the invention; and

Figs. 3 and 4 are further explanatory charts.

It has heretofore been suggested to insulate containers for liquid oxygen and the like against the entry of heat by means of a powder filled evacuated space by J. Aberdeen and T. H. Laby in their communication published in the Proceedings of the Royal Society (London), vol. A-113, pp. 459–477, in the year 1926. In their communication, these authors state that the thermal conductivity of the space between two walls is substantially a linear function of the logarithm of the pressure of the gas enveloping the powder filling in the insulating space.

Aberdeen and Laby point out that the transfer of heat across an evacuated space between the inner and outer walls which form the container, when at different temperatures, takes place by convection, conduction, and radiation. Where a highly evacuated insulating space alone is employed for insulating double-walled containers or receptacles, the transfer of heat is chiefly by radiation. To reduce the transfer of heat by radiation, in double-walled vessels, it was customary to make the inner surfaces of the two walls highly reflecting. This has been accomplished either by suitable coatings or by polishing, the latter being generally adopted where the walls are of metal. For large commercial metal walled vessels intended for storing or transporting a liquefied gas, such as liquid oxygen, polishing is a relatively expensive item in manufacture. Also the provision and maintenance of an extremely high order of vacuum is inconvenient in ordinary commercial practice.

In ordinary double-walled containers having the space between the walls evacuated sufficiently to provide a relatively high vacuum therein, the chief source of heat transfer is by radiation. Such radiation transfer may be minimized by the use of interposed reflecting surfaces, but no further reduction in heat transfer rate can be obtained by any commercially obtainable increase in the degree of vacuum to be employed. The limiting value of the heat transfer rate is, therefore, proportional to the liquid container surface.

In a powder insulation, particularly when under a vacuum as taught in the U. S. Patent to Stanley, No. 1,071,817, heat transfer by radiation is relatively small, due to the presence of small reflecting surfaces or laminae; heat transfer hence takes place by conduction and convection, although the latter is usually of relatively low value if the insulation be finely divided. If gas be present at atmospheric pressure, heat transfer takes place very largely by conduction through the gas itself with only a small amount due to conduction through the powder particles directly. Since this heat transfer is almost entirely by conduction, it forms the basis of the usual heat insulating practice in which advantage is taken of increased thicknesses of insulation where possible or economical.

In an evacuated powder filled insulating space, conduction through the gas is reduced to a point where it also becomes negligible. Under these circumstances, a condition is approached in which the heat transfer is limited solely to conduction through the solid particles of the powder itself. But the conduction through the powder is very low because of the circumstance that there are only very minute areas of contact between an enormous number of particles in the powder. The thermal conductivity of the material of which the powder is composed is of relatively little importance. The above limiting condition is provided in the practice of the invention. The laws of thermal conductivity are so applied that advantage is ta[illegible] thickness in insulation where feasible.

That this is so may be readily seen from the following, assuming we have two walls between which heat is transferred by radiation that are black body radiators, and whose absolute temperatures are taken as T_1 and T_2 respectively, of which the latter is taken to be the higher. Then the heat lost by radiation is proportional to $T_2^4-T_1^4$. The effect of introducing a thin lamina between the container walls whose surfaces have the same emissive power as the surfaces it separates is to reduce the heat transferred by radiation to one-half. For convenience of reference, the calculation is given here, where the temperature of the lamina is denoted by T_x. Then, since the rates at which it absorbs and emits radiation are equal, we have

$$T_2^4-T_x^4=T_x^4-T_1^4 \qquad (1)$$

It may be shown that the total radiation passing from the hot to the cold wall is reduced in proportion to the ratio,

$$\frac{T_2^4-T_x^4}{T_2^4-T_1^4} \qquad (2)$$

Solving the Equation 1 for T_x^4 and introducing the value obtained into 2, we obtain a value of one-half for the radiation ratio. It is evident that if two laminae are introduced between the two walls, the radiation is reduced to ¼; if three are introduced, the radiation is cut to ⅛. It is apparent that the introduction of comminuted material, such as a powdered or fibrous insulating substance, between the walls is equivalent to introducing a large number of laminae of the character indicated, and such large number operates substantially to reduce the amount of heat transferred by radiation to a negligible quantity.

Operation of a container built in accordance with my invention showed a heat leak which was unexpectedly low in comparison with other types of insulated containers. The analysis contained herein explains, I believe, the reasons for such results. I find that validity of the statement of the law of thermal conductivity for a powder filled insulating space, made by Aberdeen and Laby in their article above referred to, is insufficient for modern practice. In the practical case, size and shape of the insulating space as well as the thermal conductivity must be considered. The well known equation for the thermal conduction between two concentric spheres is:

$$Q=\frac{4\pi k_a r_1 r_2 (T_1-T_2)}{r_2-r_1} \qquad (3)$$

when Q is the rate at which heat is transferred across the insulating space between two curved walls whose radii are respectively r_1 for the inner wall, and r_2 for the outer wall; the quantities T_1 and T_2 denoting respectively the absolute temperatures of the inner and outer walls. k_a denotes the average thermal conductivity of the space in suitable units, for example, in B. t. u./-foot-hour-degree F. If the rate of transfer through a unit area of the inner wall be obtained in the above formula, then the formula may be further developed and a more simple expression written. To this end, if q is used to denote such unit area rate, ΔT put for T_1-T_2, and x for the distance r_2-r_1 which separates the two spherical walls, the following equation may be derived from Equation 3:

$$q=k_a\Delta T\left(\frac{1}{x}+\frac{1}{r_1}\right)$$

From this it is evident that the radius of the inner wall and the distance therefrom to the outer wall operate independently to affect the rate of heat transfer per unit area. It is seen from Equation 4 that a low rate of heat transfer cannot be had for a small vessel by merely increasing the thickness of the insulating space.

This characteristic of the insulating space and the theory of heat transfer discussed above may be further explained through the medium of sets of graphs of Equation 4, drawn respectively for the variables x and r_1. Such graphs are depicted in the drawings in Figs. 3 and 4. The value of k_a used in computing the data for these curves is obtained from curve E of Fig. 1 at a pressure of 100 microns. The significance of this value is discussed later.

These graphs also show a straight horizontal dotted line which is designated as "high vacuum polished metal." The ordinate of this line represents the heat transfer per unit area of the inner container for the usual double-walled metal flasks having polished surfaces and a very high vacuum, but not filled with insulation. Heat transfer in such flasks is almost entirely by radiation, and as this is unaffected by the gap between the metal surfaces, the resultant heat transfer rate is represented by a straight horizontal line.

On examining these graphs, it is apparent that small vessels (of the order of 1 ft. diameter or less) are quite properly made with polished metal and without powder for liquid oxygen service. Since small vessels are made for ease in handling, the smaller, lighter non-powder vessels will have considerable advantage due to smaller outside dimensions, less weight, and in general lower heat leak. When it is noted that a six inch (2 liter) flask of equal efficiency would have to be surrounded by a layer of insulation 19 inches thick so that the insulation would occupy about 17 times the volume of the liquid, it is quite apparent that powder insulation is out of the question for such a size liquid container.

A two foot sphere (120 liter) with four inches of powder in vacuum insulation would have the same thermal efficiency as a polished metal high vacuum container. The powder insulation would double the space volume required for the container and add somewhat to its weight. This appears to be about the border-line case. For vessels smaller than this, the non-powder type would evidently be more desirable.

For vessels over 2 ft. in diameter a reasonable amount of powder insulation will give better performance than a non-powder type insulation. A reasonable amount of powder insulation is taken to mean a volume of insulation of about or equal to that of the liquid container. For containers of the relatively large sizes, for example, for one whose diameter is 10 ft., a reasonable amount of powder will give about one-fifth the heat leak which would be obtained by the use of a vacuum space devoid of powder. While the above discussion is, of course, limited to spherical vessels, it obviously can be extended along similar lines to apply equally well to cylindrical vessels.

Thus it is seen that large double-walled containers are efficiently insulated by the combination of vacuum and powder and that this efficiency alone is sufficient reason for using this type of insulation. Likewise it is seen that small double-walled containers or flasks, which have polished metal walls enclosing an evacuated space for insulation, still have a useful role as portable containers for liquefied gases such as liquid oxygen.

In the practice of the present invention, the rate of heat transfer across the insulating space of relatively large containers for liquefied gases of the character indicated, is made to have a relatively low value by the introduction of a substantally dry heat insulating material in comminuted form into the insulating space and then pulling a vacuum in the space to an extent which reduces the rate of heat transference across the insulating space to a relatively low value which approaches relatively closely the lowest obtainable. Polishing of the metal walls of containers of the present invention hence may obviously be dispensed with.

The material introduced into the insulating space is to be packed therein uniformly and care should be taken to avoid pockets, in order that the resultant rate of heat transfer may be substantially uniform throughout the powder filled insulating space. The comminuted filling material to be introduced into the insulating space should be in a substantially dry state and contain no substantial amount of absorbed water or other vapor that may distill off under the influence of the vacuum in the insulating space. To this end, advantage is taken of the fact that the outer wall of the inner vessel when filled with liquid oxygen, or the like, is at a temperature below 233° K., which temperature readily condenses any small amount of vapor, such as water vapor, that may have been absorbed from the environment and would distill off under the influence of the vacuum when in service. The insulating filling thus introduced being in direct communication with the outer wall of the inner vessel permits the low temperature of this wall to contribute materially to the maintenance of the vacuum.

The filling material for the insulating space between the inner and outer vessels of containers of the present invention is selected from a class comprising substances which are normally substantially dry and possess low thermal conductivities, such class being preferably further limited for liquid oxygen service to those substances or materials which have the property of being chemically inert to liquid oxygen. The class of filling materials possessing these characteristics and at present known to be suitable for the practice of the invention comprises: asbestos fiber, powdered magnesium carbonate, a magnesia cement consisting of a major portion of magnesium carbonate and a minor portion of asbestos fiber, a diatomaceous silica such as that sold under the trade name "Sil-O-Cel," a flocculent and blown silica such as that sold under the trade name "Silica Aerogel," a fiberized fused silica and limestone such as that sold under the trade name "Banroc," a glass wool, and combinations of two or more of the same. In general, therefore, the filling material should comprise a solid which is finely divided and may be bonded as in the case of the magnesia cement noted above, or unbonded in the form of a loose powder or minute fibers. The filling would be characterized throughout by minute interconnected pores or voids and have a low apparent density. The term "solid" as employed herein is intended to mean the class of substances distinguished from gases or liquids.

The empirical relation, disclosed by Aberdeen and Laby, I have also ascertained, holds for vessels to which it may be properly applied only within certain limits and that beyond these limits such linear relation is departed from. At the lower limit the slope of the logarithm is found to decrease suddenly to a relatively low value, i. e., the conductivity characteristic for such slope has a knee and for still lower vacua changes very slowly or becomes almost constant for all lesser values of the absolute pressure. The degree of vacuum here employed is taken in the neighborhood of the knee and thus has a unique value which provides the desired thermal resistance reducing the passage of heat across the insulating space to the very low value referred to above.

Thus, when a vacuum is pulled on an insulating space having a comminuted or powdered filling, as here proposed, in a container for a liquefied gas, such as liquid oxygen, arranged for industrial service, the heat transfer characteristic, while initially having relatively large values and operating mainly by conduction through the gas, rapidly decreases in value with increasing vacuum until the knee values of the pressure are reached. For such values the rate of heat transfer changes; for lower values the heat transfer being only by conduction through the powder. The thermal resistance for the latter mode of heat transference is seen to increase with the distance between two walls across which heat is to pass. Hence, the thermal resistance of the insulation for powder filled evacuated double-walled vessels of sufficiently low curvature may be given any desired value, i. e., it may be increased to such value by increasing the spacing between the walls of the inner and outer vessels. A relatively wide insulating space is thus advantageous.

The unique degree of vacuum to be employed may be determined from a graph of the characteristic which relates the rate of heat transfer across the powder filled insulating space to the degree of vacuum. Such a graph is a curve which shows the conductivity and has, in general, a relatively steep portion sloping backward to the knee which gives the low critical value of the pressure, below which the conductivity is relatively constant. A desired value of the absolute pressure in the neighborhood of the knee may be picked from a curve plotted to depict the characteristic.

Referring now to Fig. 1, several curves are drawn showing conductivity characteristics for various fillings. The abscissae of the curves are on a logarithmic scale graduated first in microns and then in millimeters of mercury. These, of course, show pressures and may be read directly as such, while the ordinates show the related thermal conductivities; the insulating space for which they are drawn being filled with insulating material in accordance with the invention. Curve A is the characteristic for a glass wool, curve B for a fused silica and lime, while curves C and D represent the characteristics resulting from two different mixtures of magnesia cement. Curve E represents that of diatomaceous silica, while F represents that of a flocculent silica material. All these curves are inclined downwardly and backwardly toward the origin and have a sharp break or knee, where the curve levels off. This is seen to occur in the region where the absolute pressure is of a value substantially between 100 and 1000 microns of mercury for the materials whose characteristics are depicted by curves D, E, and F. A relatively high absolute sub-atmospheric pressure is, of course, desired for commercial reasons provided the conductivity is sufficiently low. From these curves it is seen that values of the absolute pressure higher than 1000 microns are commercially feasible with other materials of the class and may be used in the practice of the invention. On the left of their knees, these curves are seen to have values which are relatively low and not greatly different. Hence this order of vacuum may be regarded as the unique value desired for the practice of the invention. Such vacuum, however, is readily pulled by commercial vacuum pumps, and is readily adapted for use in commercial or industrial service.

For the purpose of further comparison, an additional point is depicted on the chart in Fig. 1, at Q. Point Q shows an isolated value of the transfer rate due almost entirely to conduction when the evacuated space has a filling of an ordinary form of a commercial insulating silica.

The invention may also be used where the initial atmosphere enveloping the comminuted filling is a gas other than air which has a relatively low thermal conductivity, for example, argon, carbon dioxide, and the like. Such gaseous atmosphere has, as a rule, lower thermal conductivities than air, and this characteristic is in part imparted to the comminuted filling when evacuated to the degree desired. The properties of argon are depicted in this connection in Fig. 1, by way of further example. Here curve G shows the transfer rate of the diatomaceous silica sold under the trade name "Sil-O-Cel 505-H" against absolute pressure and it is seen to be relatively lower than curve E, which latter represents the same material having an initial atmospheric envelope of air. Point R shows a similar gain at atmospheric pressure for an insulating silica initially enveloped in argon as compared with air shown by curve F.

Referring to Fig. 2 of the drawings, an exemplary container of the invention is shown where 10 denotes generally an external frame composed of uprights, or leg members, and connecting cross-members 10x, from which a wall 11 of an inner vessel of the container is suspended, such vessel being adapted to hold a liquefied gas that is to be placed or stored in the container either with or without the aid of a lining or basket (not shown). Outside of the vessel 11 and disposed in substantially rigid spaced relation with respect thereto is a second or outer vessel 12 which is also supported from the frame 10, the manner of support being described below. The space intervening between the vessels thus provided is a closed space provided for insulating purposes and has a constant volume. These vessels are preferably made of metal; for example, the outer vessel may be made of steel while the inner is made of a bronze, which is chosen for its resistance to shock at relatively low temperatures. These vessels may be spherical or of other convenient shape that is resistant to stresses. However, the wall of the outer vessel is advantageously strengthened by exterior webs or internal rings. The intervening or insulating space has no communication with the outside except that provided for the pulling of the vacuum, as hereinafter more fully explained.

A valve controlled connection 13 for filling purposes is provided leading from a suitable point without the outer vessel to a point within the inner vessel. Similarly, a valve controlled withdrawal connection 14 is provided leading from a point near the bottom of the vessel 11 to a suitable external point and has a suitable coupling means 15 by which it may be connected to a suitable discharge receiving device or system (not shown). Each pipe connection here employed is provided, at the point where it passes through the wall of the vessel 12, with sealing means of a character which transmits relatively little heat to the connection. Such means are shown, by way of example, in detail on the connection 14 where there is depicted a conical wall 16 that is preferably of a material of relatively low thermal conductivity and is shaped to interpose a relatively large amount of thermal resistance to the passage of heat from the vessel 12 to the connection 14; the cone being welded or otherwise integrally attached both to the wall of vessel 12 and to the connection 14. Such connection is preferably so shaped and disposed that expansion, contraction, and other stresses are accommodated without liability of incurring a break in the hermetic seal. There may be also connected, in association with the connection 14 or otherwise, one or more trycocks, such as shown at 14'. Other standard accessories, such as a liquid-level gauge, etc., may be additionally connected to the inner vessel.

As illustrations of such additional accessories, inner vessel 11 is shown provided with a conventional blowdown or evaporation connection 17 which is valve controlled and when closed is adapted to afford relief for any excess of pressure that may accumulate, through a safety valve 18 and also through a bursting diaphragm device 19 which provides a quick opening in the event of any sudden rise in pressure in the vessel 11.

In order that the space between the walls of the vessels 11 and 12 may be evacuated after assembly, and while in service, a valved connection 20 is attached to the outer vessel 12 and communicates with the inside space. The outer end of connection 20 has a coupling 21 for attachment to a suitable vacuum pulling means, indicated diagrammatically in the drawing as a pump. A commercial mechanical vacuum pump is a suitable means of this character indicated. In the connection 20 there is preferably introduced a vacuum space relief device 22 which has a diaphragm adapted to burst should any undesired pressure actually accumulate in the space between the walls of the vessels 11 and 12.

While substantially any supporting means adapted to hold vessels 11 and 12 in substantially rigid spaced relation may be employed, that preferred for large-sized commercial vessels employs virtually independent support for each of the vessels from frame 10 so that the outer vessel will not have stresses impressed in addition to that applied by the atmosphere on account of evacuation. A suitable arrangement of this character for thus supporting the vessels is disclosed in the application of O. A. Hansen, Serial No. 290,969, filed August 19, 1939, which issued September 23, 1941 as Patent No. 2,256,673, and is shown here by way of example. To this end, the inner vessel 11 is shown provided with means comprising a plurality of brackets or lugs 23 made fast to the outer surface of vessel 11, preferably by brazing or welding, which have attached thereto suspending rods or cables 24, each extending generally upwardly and outwardly and secured in suitable means, such as a collar 25, made fast to frame 10 at a suitable point, for example, to the cross-bar 10x. The rods 24 are preferably of relatively low thermal conductivity and may be constructed of a material having such property as well as a high tensile strength, for example, of stainless steel. Each such rod 24 is passed through the collar and is threaded at its upper end for engagement with one or more nuts 26 which are screwed on the end of the rod. The collar is preferably secured to the frame by welding or brazing and has a reduced lower end for the reception of a sleeve 27 which houses the rod 24, the sleeve being brazed or welded at its lower end onto the wall of vessel 12 and may be similarly attached to the collar itself.

In order that this structure may be hermetically sealed against the passage of gas into or out of the space between vessels 11 and 12, a housing or cap 28 is disposed over the nuts 26 and brazed, welded or soft soldered onto the collar 25; the joint between collar and cap being shown as made by reducing the top of the collar sufficiently to fit snugly into the cap, a fillet of metal to close the joint being added by brazing, welding, or soldering.

To afford a rigid support for the vessel 11 in the above-described manner, at least three rods or cables are required; the use of but three is generally sufficient for spherical vessels. Four or more cables, however, may be employed, especially where the frame 10 is square or rectangular in plan. Still more, for example, six or eight, may be employed when the nested vessels have the form of elongated vessels with spherical ends, or have the shape of oblate ellipsoids.

To support the outer vessel in place, other supporting means are provided between the frame 10 and the outer wall of vessel 12, such means being structurally independent of the support for vessel 11. The supporting means so provided may have any convenient form; for example, one or more web members 29, interposed as shown, each having one edge bolted or welded to an upright member of frame 10 and an opposite edge in contact with or made fast to the outer wall of vessel 12.

The insulating space is filled with powdered material here employed while the space between vessels 11 and 12 is open to the atmosphere, care being taken in the filling to avoid uneven packing of the insulating material and the formation of pockets. In order to afford access to the space between vessels 11 and 12 for filling or other purposes, one or more openings are provided in the wall of vessel 12 which preferably have grooves or flanges to which manhole covers may be sealed in a gas-tight manner by soldering or brazing when it is desired to close the space after filling. Two such covers are shown for the vessel 12 in the drawings, one at 30 for the top and one at 31 for the bottom.

In operation, the container is filled by connecting the connection 13 to a source of supply of the liquefied gas which is to be stored in vessel 11. The flow of the liquefied gas into the container may be controlled by manipulating the valve in connection 13. In order to permit the liquid thus introduced to displace any gaseous filling that may be in the inner vessel, the evaporation connection 17 is opened to the atmosphere or connected to a gasometer in the event that it is desired to conserve the gas thus displaced. Liquid may be withdrawn from the container in the usual manner by opening the withdrawal connection 14. In the interim it may be desired to maintain the vessel 11 closed to the atmosphere. This, of course, is accomplished by closing the valve in the evaporation connection 17.

The insulating space between the walls of the vessels 11 and 12 may be evacuated initially before the container is filled with liquid or during the filling and storage periods. The vacuum pump may either be disconnected after evacuation or connected permanently in order to maintain the vacuum in the space between the walls of the inner and outer vessels at the desired value and offset any leakage. The vacuum desired to be maintained is, of course, of an order of about 0.1 mm. of mercury, which brings the conductivity into the "low region" of the heat transfer characteristic. Such an arrangement is suitable for double-walled containers intended for commercial and industrial purposes.

The low resulting rates of heat transfer for the insulating space thus provided for the container makes it feasible to close the evaporation connection 17 for long periods of time without generating undue pressures within the inner vessel which would open the safety valve or otherwise require the evaporation connection to remain permanently open. The evacuated insulating space thus provided in the container in accordance with the invention increases the efficiency of the container and reduces the losses due to evaporation to relatively low values.

The container of the present invention is not only capable of operating at high efficiencies for long periods of time but also meets all the safety requirements for devices of this character and avoids substantially all possibility of damage arising from possible sudden rises in pressure in either the inner or the outer vessel.

Where the container of the present invention is intended for transport service, the frame for supporting the vessel is, of course, made to be portable, such constructions being well known in the art.

Since certain changes may be made in the above construction and different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

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

1. A large container for a body of liquefied gas having a boiling point at atmospheric pressure below 100° K. and comprising in combination an inner tank for holding such body of liquefied gas, the inner diameter of said tank being not less than 2 feet, a relatively larger outer gas-tight shell extending about said inner tank providing therewith an intervening evacuatable insulation space having a minimum thickness not less than one quarter of a foot and a maximum thickness such that the volume of the insulation space does not exceed the volume of said tank by more than 50 per cent, said insulation space containing a low apparent density filling of finely divided solid material and being evacuated to a combined gas and vapor pressure therein above 1 micron but below 10 millimeters of mercury absolute, the walls of said tank and shell being sufficiently rigid to sustain the respective differential fluid pressures acting thereon, means for supporting said inner tank in spaced relation to said shell independently of said filling, said supporting means for said inner tank extending through said space, a liquid conduit communicating with the bottom of said inner tank, and a gas conduit communicating with the upper part of said inner tank, both said conduits extending through said space to the exterior of said shell, said supporting means and conduits being constructed to provide substantial resistance to heat conduction, the thickness of said space and the pressure therein being correlated within the specified ranges and with the character of the filling to restrict the heat inflow through the insulation into said tank to less than 5 B. t. u. per hour per sq. ft. of surface of the inner tank under a temperature differential of 200° C. (360° F.).

2. A large container for liquefied gas having a boiling point at atmospheric pressure below 100° K. and comprising in combination an inner tank holding a body of such liquefied gas, the inner diameter of said tank being not less than 2 feet, a relatively larger gas-tight shell completely encompassing said inner tank and providing therewith an intervening evacuatable insulation space having a minimum thickness not less than one quarter of a foot and a maximum thickness such that the volume of the insulation space does not exceed the volume of said tank by more than 50 per cent, said insulation space containing a filling of finely divided non-combustible solid material and being evacuated to a combined gas and vapor pressure therein above 1 micron but below 10 millimeters of mercury absolute, the walls of said tank and shell being sufficiently rigid to sustain the respective differential fluid pressures acting thereon, means for supporting said tank in spaced relation to said shell independently of said filling, said supporting means for said tank extending through said space, a liquid conduit communicating with the bottom of said tank, and a gas conduit communicating with the upper part of said tank, both said conduits extending through said space to the exterior of said shell, said supporting means and conduits being constructed to provide substantial resistance to heat conduction, said inner tank serving to confine said body of cold liquid and to freeze on its outer surface water vapor from said space and filling material, the thickness of said space and the pressure therein being correlated within the respective specified ranges and with the character of the filling to restrict the heat inflow through the insulation into said tank to less than 4 B. t. u. per hour per sq. ft. of surface of inner tank under a temperature differential of 200° C. (360° F.).

3. The combination, with a large container, of a body of liquefied gas having a boiling point temperature at atmospheric pressure equal to or lower than that of liquid oxygen, said container comprising an inner tank holding said liquid, the inner diameter of said tank being not less than 2 feet, a relatively larger outer gas-tight shell concentrically arranged about and completely encompassing said inner tank and providing therewith an intervening evacuatable insulation space having a minimum thickness not less than one quarter of a foot and a maximum thickness such that the volume of the insulation space does not exceed the volume of said tank by more than 50 per cent, supporting means for said inner tank extending through said space, a liquid conduit communicating with the bottom of said inner tank and a separate gas conduit communicating with the upper part of said inner tank, both said conduits extending through said space to the exterior of said outer shell, said supporting means and conduits being constructed to provide substantial resistance to heat conduction, said insulation space containing a filling of finely divided solid material and being evacuated to a combined gas and vapor pressure therein above 1 micron but below 4 millimeters of mercury absolute, said inner tank serving to confine said body of cold liquid and to freeze on its outer surface water vapor from said space and filling material, the thickness of said space and the pressure therein being correlated within the respective specified ranges and with the character of the filling to restrict the heat inflow through the insulation into said inner tank to less than 3 B. t. u per hour per sq. ft. of surface of inner tank under a temperature differential of 200° C. (360° F.).

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