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METHOD AND DEVICE FOR THERMALLY INSULATING A VESSEL

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FIG. 1

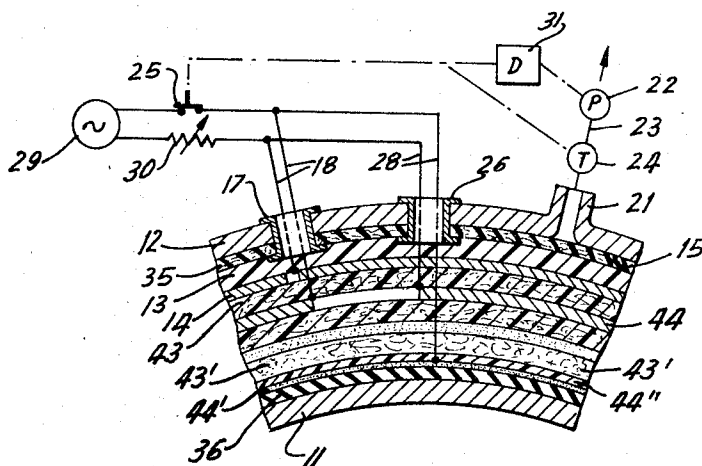
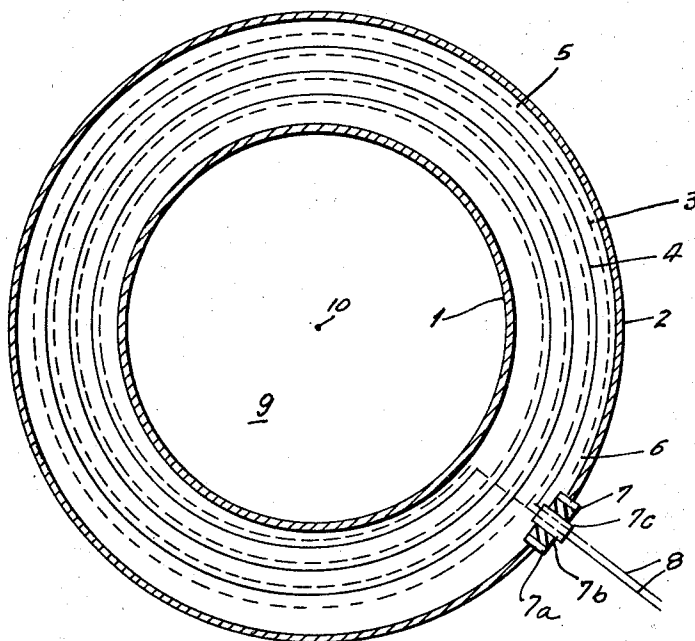


FIG. 2

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**METHOD AND DEVICE FOR THERMALLY  
INSULATING A VESSEL****Albert Hofmann, Grunwald, Germany, assignor to Linde  
Aktiengesellschaft, a corporation of Germany****Filed Mar. 19, 1968, Ser. No. 714,305****Claims priority, application Germany, Mar. 31, 1967,****L 56,146****Int. Cl. B65d 7/22****U.S. Cl. 220—10****8 Claims****ABSTRACT OF THE DISCLOSURE**

Method of preparing an insulated vessel, especially for a low-temperature fluid such as a liquefied gas, wherein the insulation in the hermetically sealed space between the inner and outer walls of the vessel consists in part of a resistance-heating metallic film and a pair of conductors pass through the outer wall of the vessel and are connected across the metallic layer for resistance heating of the interior of the insulating space to drive out gases and moisture prior to evacuation and final sealing.

My present invention relates to a method of preparing double-wall insulating vessels for the receipt of low-temperature substances, e.g. liquefied gases and to a device for carrying out this method.

It is common practice in the cryogenic field to provide double-wall vessels for the receipt of liquefied gases (e.g. liquid oxygen, air, nitrogen, etc.) in which an insulating space is provided between the walls of the vessel. This space can be evacuated and may be filled with an insulating mass. In U.S. Pats. 3,009,600 and 3,018,016, there are described improvements in the insulation of such spaces in which, in addition to a mass of insulating material (e.g. glass or other mineral fibers with or without binders) heat-reflective layers or films are provided to act as radiation barriers separating the conductive barriers (i.e. the thermally nonconductive masses) from one another. In the first-mentioned patent, a plurality of such barriers is provided in the radial direction (with respect to the axis of the vessel) by one or more spirally coiled layers of reflecting mass or a multiplicity of concentric layers which are spaced by fibrous separating material. The laminate thus may comprise alternating layers of fiberglass mats and aluminum foil whereby the glass-fiber layers constitute conduction and convection barriers and the metallic layers form radiation barriers. In Pat. No. 3,018,016, it is pointed out that the radiation barriers can include aluminum layers vapor-deposited upon a synthetic-resin foil. The aluminum-coated elements are crimped or crumbled to reduce heat transfer by conduction.

It has also been recognized, in connection with the preparation of such vessels to receive low-temperature liquids and the like, that the presence of residual gases in the insulating space can severely restrict the insulating qualities of the double-wall structure. It has been found, in fact, that adsorbed or mechanically trapped gases and moisture (water vapor) may remain within the insulating space even after evacuation and gradually are released from entrapment to reduce the vacuum and increase the heat loss by conduction and convection. Thus, it has been proposed, prior to evacuation, to subject such vessels to heating in ovens and other units having volumetric capacities sufficient to accommodate the vessels which, as will be apparent, may be of relatively large size.

I have now found that these techniques are insufficient at best since they do not expunge all of the gases and trapped moisture which can be released by heating. It appears that the insulating layers within the space between the vessel walls act to impede heat transfer within

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the insulating space during the heating operation, much as they restrict heat loss through the walls when used to contain the liquefied gases. As a consequence, the spaces within the insulating mass at which the gases and moisture are trapped are not raised to a temperature sufficient to render the heating effective in driving out most of the gases and moisture. Accordingly, once the vessel is sealed and even after a heat treatment of this nature, a conventional vessel manifests increased pressure within the insulating space and decreased insulating capabilities. I have found, therefore, that a significant problem arises even though most of the gases are expunged, by the inability of conventional heating methods to drive out the residual substances mentioned earlier.

A further disadvantage of the conventional techniques resides in the need for large-capacity furnaces, a requirement which, in turn, has limited the size of the vessels which can be produced. Furthermore, the oven-heating processes require considerable time since the heat must penetrate through insulating layers which are designed to preclude such heat flow.

It is the principal object of the present invention to provide an improved method of and device for preparing double-wall vessels, especially for low-temperature storage of liquids and the like which involves less production time and expense, which improves the insulating qualities of the vessel, and which affords a simple and convenient approach to the preparation of vessels of substantially any size.

I have found that this object and others which will be apparent hereinafter, may be attained and the heating of the interior space of a double-wall insulating vessel improved to the point that adsorbed and entrapped gases, which may be unaffected by oven-heating, can be expunged from the space by generating the heat within the insulating chamber directly instead of transferring the heat to this chamber from the exterior. According to a specific feature of this invention, the insulating material within the space between the walls of the vessel constitutes a resistance-heating element through which an electric current is passed to produce the heat necessary to expunge gases from this insulating space. This system has the advantage that, whereas external heating requires heat flow through a chamber in which the barrier to such heat flow increases with increasing evacuation, evacuation can be carried out by the present system without any effect upon the heating action since the heat is applied directly to the exposed surfaces of the insulating material from which the absorption gases must be driven and the suction facilitates such desorption of the gases. As a result, both the heating and evacuation steps can be substantially accelerated. Furthermore, it is possible to achieve much higher vacuums in the insulating space and to reach such vacuums in much shorter times than has been possible heretofore.

According to a more specific feature of this invention, the packing within the insulating space comprises a metallic reflecting barrier or layer, e.g. as described in the abovementioned patents and other art of the same class, the metallic reflecting layer serving as the resistance-heating element. Thus, the device of the present invention comprises a double-wall vessel between the walls of which an insulating mass is disposed in an evacuable insulating space, the insulating material being at least in part formed with metallic reflecting layers across which an electric current is applied by a pair of conductors extending through the external wall of the vessel. The metallic layer, e.g. an independent foil, a foil laminated to an insulating support or a combination thereof, may extend about the entire circumference of the inner wall or chamber in which the low-boiling-point liquid is disposed or only partly around this chamber.

Advantageously, the metal layer forming the resistance-heating element is spirally wound about the axis of the vessel or is formed in concentric layers with electrically nonconductive insulating layers spacing the metallic layers apart and bridging completely the space between the successive turns of the foil or metallic layer. Thus, the outer surfaces of the insulating layers directly contact the successive turns and are heated thereby to drive adsorbed and mechanically trapped gases rapidly from these insulating layers. The required quantity of heat can be precisely dimensioned to the needs of the system, whereas earlier systems were not able to dimension the thermal energy in this manner, by determining the current flow through the layer and choosing the length thereof which is to be effective. In other words, it is not necessary that the entire length of the metallic layer be effective as a heating element nor that only a single length be used. A number of stretches of the metal layer of limited length may be connected electrically in parallel and may be spaced along the radiation barriers. A single turn or a plurality of turns of the reflective barrier may be used or a plurality of spaced-apart segments may be employed substantially uniformly distributed over a full 360°. Moreover, the evacuation is carried out concurrently with resistance heating and it has been found that it is not essential that the evacuation be terminated prior to termination of the heating. During the heating operation, the thermally insulating layers are degassed and the desorbed gases must be removed as long as the insulation remains hot. Accordingly, I prefer to terminate the heating slightly before the suction pump is shut down so that the latter become inoperative only when the thermal insulation cools below the desorption temperature.

The electrically nonconductive thermally insulating material may be asbestos, heat-resistant synthetic resins (e.g. phenol-formaldehyde resins), fiberglass paper or the like. The use of fiberglass paper has the important advantage that it is gas-permeable and, when used as a heat barrier, can be easily evacuated. Moreover, the fiberglass paper is heat-resistant and noncombustible and withstands higher temperatures than, for example, synthetic resins. Since it permits higher heating temperatures, it also allows more rapid evacuation. The metallic layer preferably is a metal with low absorptivity and high reflectivity for heat, preferably aluminum. Vapor-deposited aluminum or synthetic resin foils may form a laminate in which the synthetic resin is the thermal barrier and the vapor-deposited aluminum film serves both as resistance-heating element and radiation shield.

While reference has been made above to the use of the term "vessel" in describing the principles of the present invention, it should be noted that it is intended to include by this expression not only insulating storage containers but also ducts through which low-temperature liquids are conducted and all other structures using double-wall insulation (e.g. insulated electric-cable sheets for superconductive cables).

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description and specific example, reference being made to the accompanying drawing, in which:

FIG. 1 is a cross-sectional view in a radial plane diagrammatically illustrating the problems of the present invention; and

FIG. 2 is a fragmentary cross-sectional view drawn to an enlarged scale illustrating other features thereof.

In FIG. 1, I show a double-wall container, which may have the configuration of the containers shown in the afore-mentioned U.S. patents but merely represents substantially any double-wall insulated chamber as has been noted above. This vessel comprises a cylindrical inner wall 1 defining a low-temperature chamber 9 receiving a low-boiling-point liquid, e.g. a liquefied gas such as air, oxygen or nitrogen. The cylindrical inner wall 1 is

concentric with the outer cylindrical wall 2 which, like the inner wall 1, is composed of metal and is spaced from the inner wall to define an annular insulating space or chamber 5. Within this chamber, I provide an insulating packing consisting of alternating layers (in the radial direction) of a glass-fiber mat 3 and an aluminum foil 4 spirally wound about the axis 10 of the vessel. The mat 3 lies inwardly and outwardly of the foil 4 so as to electrically insulate it from the walls 1 and 2. Between the outer wall 2 and the outer turn of the insulating material, I prefer to leave an annular space 6 which functions as a manifold communicating between the vacuum fitting (not shown) and the pores and interstices of the insulating packing. This gap facilitates evacuation of the chamber 5.

The outer wall 2 is provided with a vacuum-tight hermetic seal 7 consisting of a cylindrical sleeve 7a, an insulating bushing 7b and a feed-through insulator 7c through which a pair of electrical conductors 8 are led into the chamber 5 and are connected to the poles of an electric current source not shown. The conductors 8 are electrically connected to the spirally coiled aluminum foil 4 such that substantially the entire foil functions as a resistant-heating element and conductor of electricity.

#### EXAMPLE

A vessel having the configuration of that of Pat. No. 3,009,600 is provided with a foil and fiberglass-mat packing as illustrated in FIG. 1. The foil has a length  $L$  of 100 m., a width  $B$  of 100 mm. and a thickness  $D$  of 0.010 mm. and a specific resistivity  $\rho = 2.76 \times 10^{-5} \Omega \text{mm}$ . From the relationship

$$R = \frac{\rho \cdot L}{B \cdot D}$$

it will be apparent that the total resistance of the foil is 2.76 ohms. Using a voltage  $V = 24$  volts, the power relationship  $W = V^2/R$  shows that the power  $W$  is about 210 watts, equivalent to about 180 kcal./hr. The packing within the space 5 has a total mass  $m = 50$  kg. and a specific heat  $c = 0.20$  kcal./kg.° C. When this mass is to be heated from a temperature  $t_1$  of 20° C. to a temperature  $t_2$  of 300° C., it is apparent from the relationship

$$z = \frac{m \cdot c \cdot (t_2 - t_1)}{w}$$

that the heating time  $z$  is about 15.5 hours. This heating time can be reduced by a factor of 2 or more by providing a corresponding number of foils or increasing the voltage applied thereacross.

In FIG. 2, I show another system embodying this invention. In this embodiment, the outer wall 12 of the evacuated insulating space or interior chamber 15 is formed with a fitting 21 connecting the insulating space or interior chamber 15 with a suction pump 22 via a conduit 23 containing a temperature sensor 24. This sensor controls a switch 25 in series with the leads 18 and 28 and an electric source 29. A variable resistor 30 is provided in this circuit to regulate the voltage applied across the length of heating elements. The thermostat 24 also operates, via a time delay device 31, the cutoff for pump 22. Thus, heating is continued until a predetermined temperature (e.g. the 300° C. mentioned earlier) is attained and pumping continues during this period. When the temperature is reached, however, sensor 24 opens switch 25 to cut off further heating while pumping continues for a delay period sufficient to allow the insulating mass to cool below the degassification temperature. Note that the pump 22 is operated after switch 25 by the delay period of the delay network 31 and is not connected in series with the latter as is clearly indicated by the dot-dash line in FIG. 2.

The wall 12 is shown to be provided with a plurality of feed-through insulators 17 and 26 spaced along the wall and associated each with a respective set of leads 18, 28 and a corresponding length of heating elements.

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In this embodiment, an insulating layer 35 is provided along the inside of wall 12 while a corresponding insulating layer 36 is formed along the outer surface of the inner wall 11 of the vessel to prevent electrical shorting of the heating circuits. A first heating element is formed by two complete turns of a spirally wound laminate consisting of a relatively thick synthetic-resin bonded mat of glass or mineral (e.g. asbestos) fiber as shown at 13, the metal foil 14 being bonded to the layer 13 with the resin. At 43 and 44, I show part of the second heating element energized by the leads 28, in which the foil 44 is vapor-deposited upon a resin-bonded mat 43 of glass or asbestos fibers. Another portion of this heating element is vapor-deposited film 44' carried by a synthetic-resin foil 44'' which, in turn, is spaced from the next outer turn by a fiberglass or asbestos mat 43'.

I claim:

1. A method of thermally insulating a chamber enclosed at least in part by a double-wall rigid structure defining an insulating space, comprising the steps of filling said space with a packing consisting at least in part of thermally insulating material and at least in part of electrically conductive material, evacuating gas from said space, heating said space to expunge gases therefrom by passing a resistance-heating electric current through the electrically conductive material to generate heat within said packing, evacuating said expunged gases from said space, and hermetically sealing said evacuated space.

2. A double-wall vacuum structure for thermally insulating a chamber, comprising metal rigid wall means including a pair of spaced-apart walls defining between them a thermally insulating vacuum space, a packing within said space comprising at least one layer nonelectrically conductive and low thermal conductivity and at least one metallic radiation-barrier layer throughout said space electrically insulated from said walls, conductor means connected to said metallic layer for passing an electric current therethrough to resistively heat said space, and a source of electric current connectible to said conductor means.

3. The double-wall structure as defined in claim 2 wherein said layers are wound spirally in said space and said

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conductor means is connected across the entire length of said metallic layer.

4. The double-wall structure defined in claim 2 wherein said conductor means comprises respective sets of conductors connected across limited lengths of said metallic layer.

5. The double-wall structure defined in claim 2, further comprising a temperature-responsive switch means connected in circuit with said conductor means and said source.

6. The double-wall structure defined in claim 2 wherein said layer of low thermal conductivity is composed of a material selected from the group which consists of asbestos fibers, glass fibers and synthetic resin.

7. The double-wall structure defined in claim 2 wherein said metallic layer is composed of aluminum.

8. The double-wall structure defined in claim 7 wherein said aluminum is vapor-deposited on one side of a synthetic-resin foil.

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