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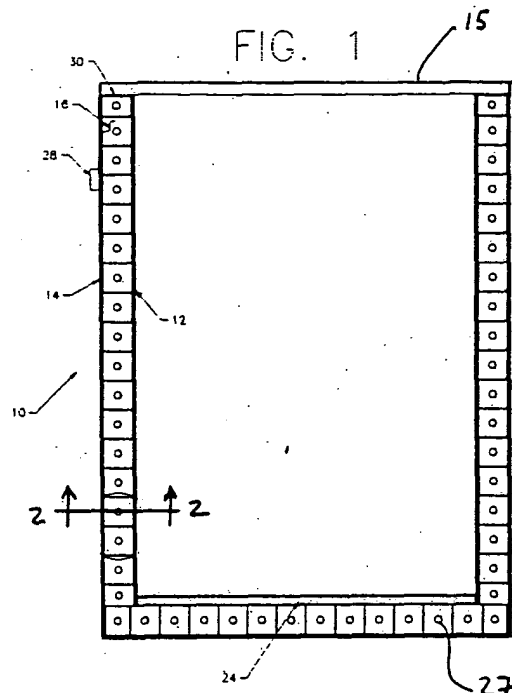
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(54) **Improved cryogenic freezer**

(57) A rectangular double walled cryogenic freezer (10,110) has a vacuum space (16,116) filled with alternating layers of flexible insulating material (20,120) and a reflective material (18,118). A support structure (22,122) is also positioned in the vacuum space

(16,116). The support structure (22,122) is open-celled and provides structural support for the freezer walls to prevent wall deformation when a vacuum is drawn. The support structure (22,122) may be open-cell rigid foam (122) or a support grid (22) sandwiched between two layers of rigid insulation material (26a,26b).



Description

BACKGROUND OF THE INVENTION

[0001] This invention relates to cryogenic freezers, and, more particularly, to a vacuum insulated cryogenic freezer that provides increased storage capacity and improved insulation performance.

[0002] Cryogenic freezers have a wide variety of industrial applications, including but not limited to, storing biological materials such as blood, bone marrow, and micro-organic cultures. These biological materials must be maintained at low temperatures in order to be stored for an extended period without deteriorating.

[0003] Cryogenic freezers typically are double walled, vacuum insulated containers partially filled with a cryogenic liquid such as liquid nitrogen for establishing an extremely cold storage environment. Liquid nitrogen has a low boiling point of 77.4 K (-320.4° F). Since cryogenic liquids have a low boiling point and, thus, a low heat of vaporization, heat inflow from the ambient can cause significant losses of cryogen due to the evaporation.

[0004] In order to minimize the amount of cryogen lost due to evaporation, the cryogenic freezer requires thermal and radiant barriers such as insulation and a high vacuum between the container walls. The vacuum space can also be filled with multiple layers of insulation to reduce heat transfer.

[0005] An example of multi-layered insulation is a low conductive sheet material comprised of fibers for reducing heat transfer by conduction. Also, the insulation can comprise radiation layers that are combined with the fiber layers. The radiation layer reduces the transmission of radiant heat in the freezer see, for example, U.S. Patent No. 5,542,255 to Preston et al. and U.S. Patent No. 5,404,918 to Gustafson.

[0006] The insulation and vacuum chambers of prior cryogenic freezers address the heat transfer problems due to the low boiling point of the cryogen. But, the characteristics of the insulation materials pose limitations to the physical design of the cryogenic freezers.

[0007] Containers have been designed with the vacuum space capable of maintaining a low pressure of 0.1 microns when the container is holding a cryogen. Such containers, however, typically feature a round, oval, or cylindrical shape. Such shapes provide the structural strength required by the walls of the container when such a high vacuum is drawn. If these cryogenic freezers were rectangular, the walls would collapse or deform when the vacuum is drawn due to insufficient structural support. Typically, the insulation materials disposed in the vacuum space of flat panel freezers fail to provide enough structural support for the container walls. Thus, the shape of the container is limited to cylindrical shapes.

[0008] Accordingly, it is desirable to provide a cryogenic freezer with optimum storage capacity such as a

cube or rectangular enclosure which enables the walls of the freezer to maintain their shape when a high vacuum is drawn.

[0009] A rectangular cryogenic freezer that addresses the above issues is disclosed in U.S. Patent No. 6,230,500 to Mao et al. The Mao et al. '500 patent discloses a rectangular freezer with a vacuum space that is filled with alternating layers of reflective material and three dimensional geometric grid support structure material. The reflective material is comprised of pieces of reflective foil surrounding an insulating material, such as SUPERGEL foam, manufactured by the Cabot Corporation of Boston, Massachusetts. While effective, a disadvantage of the freezer of the Mao et al. '500 patent is the added costs and manufacturing complexity of using multiple support structure layers. In addition, the three dimensional geometric grid material and reflective material of the Mao et al. '500 are expensive to construct.

[0010] Accordingly, it is an object of the present invention to provide a cryogenic freezer that offers maximum storage capability at a low cost with flat interior and exterior walls.

[0011] It is another object of the present invention to provide a cryogenic freezer with reduced thermal conductivity and radiant energy transfer.

[0012] It is another object of the present invention to provide a cryogenic freezer that is economical to construct.

SUMMARY OF THE INVENTION

[0013] The present invention is a cryogenic freezer for storing materials at temperatures deviating greatly from ambient. The freezer includes inner and outer containers, each having four walls and a bottom. The inner container is positioned within the outer container and the tops of their walls are sealed so that a vacuum space is defined therebetween. A plurality of alternating layers of reflective material and a flexible insulating material are positioned in the vacuum space adjacent the walls of the inner container. A support structure is positioned in the sealed vacuum space with one side positioned adjacent to the plurality of alternating layers and the other side adjacent to the walls of the outer container. The support structure substantially reduces deflection of the walls when air is evacuated from the vacuum space.

[0014] The support structure may be a support grid sandwiched between two layers of rigid insulating material. The support grid includes a first set of parallel strip members oriented perpendicular to a second set of parallel strip members so that a plurality of cells are formed. Openings are provided in the parallel strip members so that the cells are open. Alternatively, the support structure may be an open-cell foam material. The vacuum space also includes a molecular sieve for absorbing gases therein. A sealable vacuum port is formed in the outer container and is in communication with the vacu-

um space so that a vacuum may be pulled on the vacuum space.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

FIG. 1 is a side elevation view showing a section of a first embodiment of the cryogenic freezer of the present invention;

FIG. 2 is an enlarged sectional view taken along line 2-2 of FIG. 2 showing the support grid and the reflective material that are inserted between the inner and outer container;

FIG. 3 is a perspective view of the support grid of the cryogenic freezer of FIGS. 1 and 2;

FIG. 4 is a top view of the support grid of FIG. 3;

FIG. 5 is a side elevation view showing a section of a second embodiment of the cryogenic freezer of the present invention;

FIG. 6 is an enlarged sectional view taken along line 6-6 of FIG. 5 showing the support foam and the reflective material that are inserted between the inner and outer container.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] With reference to FIG. 1, a first embodiment of the cryogenic freezer of the present invention is indicated generally at 10. The cryogenic freezer 10 features an inner container 12, an outer container 14, and a vacuum space 16 therebetween. The inner container 12 and outer container 14 are preferably constructed from stainless steel. Typical freezer dimensions are 27" x 27" x 35" (L x W x H).

[0017] The freezer 10 is cubic or box-shaped and the inner container 12 and the outer container 14 each have four square or rectangular side walls and a square or rectangular bottom. A top 15 is pivotally connected to the top edge of the freezer. The rectangular freezer takes up the same amount of floor space as cylindrical shaped cryogenic freezers commonly known in the art. The larger volume of the rectangular design, however, provides additional storage space in the freezer.

[0018] As illustrated in FIG. 2, the vacuum space 16 contains alternating layers of a reflective material 18 and a flexible insulating material 20 adjacent to inner container 12. A support structure in the form of a support grid 22 sandwiched between two layers of rigid insulation material 26a and 26b is positioned between the outer container 14 and the alternating reflective and flexible insulating material layers.

[0019] As illustrated in FIG. 1, the vacuum space includes a molecular sieve 24. The molecular sieve 24 can be, but is not limited to, a carbon or ceramic based material. The molecular sieve 24 is preferably laid on the outside bottom surface of the inner container 12 during assembly. The molecular sieve 24 addresses the problem of out-gassing and chemically absorbs gas remaining after a vacuum is drawn.

[0020] Alternatively, getters, commonly known in the art, can be placed at the bottom of the freezer in the vacuum space. The getters also address the problem of out-gassing. The getters chemically absorb the gas remaining after a vacuum is drawn.

[0021] Turning to FIG. 2, the reflective material 18 is preferably comprised of sheets of reflective foil. An example of a suitable flexible insulating material 20 is insulation paper such as CRYOTHERM 243 insulating paper from the Lydall Corporation of Manchester, Connecticut. At least one layer of the flexible insulating material 20 is placed on either side of the reflective foil 18. The air between the reflective and flexible insulating material layers is evacuated as the vacuum space 16 is evacuated. The reflective foil reduces the radiant energy that is transmitted through the vacuum space 16 between the inner container 12 and the outer container 14. The flexible insulating material 20 provides a thermal barrier between each layer of reflective foil.

[0022] FIG. 3 illustrates, in general at 22, a perspective view of the support grid. The support grid 22 features a first set of parallel strip members 23 that are oriented in perpendicular fashion to a second set of parallel strip members 24. As a result, as illustrated in FIG. 4, a number of cells 25 are formed. As illustrated in FIGS. 1, 2 and 3, the portions of the strip members 23 and 24 defining the walls of each cell 25 are provided with openings 27. As a result, the support grid 22 features an open-cell configuration to allow air to be evacuated out of the vacuum space 16 to form the vacuum. The open-cell grid structure also enables the molecular sieve 24 to absorb residual moisture and gas in the vacuum space to insure long vacuum life.

[0023] The support grid preferably is constructed from a composite, plastic, or ceramic material. The support grid 22 material should be selected to limit the thermal conductivity and control out-gassing in the vacuum space. A list of appropriate materials for the support grid 22 includes, but is not limited to, T304 stainless steel, polyurethane, Ryton R4, Vectra LCP, Vectra E130, Noryl GFN-3-801, Ultem 2300, Valox 420, Profax PP701N, polypropylene and Nylon 66.

[0024] The support grid 22 provides physical support to the walls of the inner and outer containers 12 and 14 of the cryogenic freezer so that when a vacuum is drawn in vacuum space 16, they do not collapse. The support grid 22 can withstand the maximum pressure at full vacuum because of its grid structure. The support grid 22 uniformly distributes the load on the walls of the inner and outer containers 12 and 14. Thus, the thickness of

the walls of the inner and outer containers 12 and 14, respectively, can be reduced.

[0025] The low heat transfer coefficient of the support grid 22 minimizes the heat conducted from the outer container 14 to the inner container 12. The support grid 22 also reduces heat conductivity by maximizing the open space and minimizing direct contact between the support grid 22 and the layers of rigid insulation material 26a and 26b (FIG. 2).

[0026] As stated above and illustrated in FIG. 2, the support grid 22 is sandwiched between two layers of rigid insulation material 26a and 26b. The rigid insulation material preferably is G-11 fiberglass sheeting. The rigid insulation material provides additional thermal insulation between the support grid 22 and the outer container 14 as well as between the support grid and the alternating layers of reflective material 18 and flexible insulation material 20. In addition, rigid insulation material 26a prevents the edges of support grid 22 from tearing the reflective and flexible insulation materials 18 and 20.

[0027] The cryogenic freezer 10 is assembled by placing the molecular sieve 24 on the outside bottom surface of the inner container 12. Alternating layers of the reflective material 18 and flexible insulation 20 are layered in the vacuum space such that the first and last layer placed are flexible insulation 20. The number of layers is preferably thirty or less. This is followed by the rigid insulation material 26a, then the support grid 22 and then the rigid insulation material 26b which abuts the inside surface of the outer container 14. After the inner container 12 is positioned within the outer container 14, the annular opening between the two at the top of the freezer is closed with a ring-shaped top plate, illustrated at 30 in FIG. 1. The top plate 30 is welded to the top edges of the inner container 12 and the outer container 14 to seal the space between them, that is, vacuum space 16.

[0028] A vacuum is drawn in space 16 to increase the insulation value of the freezer. The cryogenic freezer 10 includes a port 28 (FIG. 1) in the outer container 14 for that purpose. The port 28 may be located at the rim of the top or on the bottom of the freezer. A vacuum pump is connected to the port 28 to evacuate the air in the vacuum space 16. Thereafter the port is sealed.

[0029] A second embodiment of the cryogenic freezer of the present invention is indicated in general at 110 in FIG. 5. As with the embodiment of FIGS. 1-4, the freezer includes an inner container 112 and an outer container 114 with a vacuum space 116 therebetween. The inner and outer containers each include four rectangular or square side walls and a square or rectangular bottom so that the freezer is cubic or box-shaped. In addition, as with the embodiment of FIGS. 1-4, a molecular sieve 124 or a getter is positioned within the vacuum space 116 to absorb gas therein. A top 115 is pivotally connected to the top edge of the freezer.

[0030] As illustrated in FIG. 6, the vacuum space 116 is filled with a foam support structure 122 and, as with

the embodiment of FIGS. 1-4, alternating layers of reflective material 118 and flexible insulation 120. The reflective material 118 and flexible insulation 120 may be constructed of the same materials recited above with reference to reflective material 18 and flexible insulation 20 in FIG. 2.

[0031] The foam support structure 122 replaces the support grid and rigid insulation layers (22, 26a and 26b, respectively, in FIG. 2) of the embodiment of FIGS. 1-4. The rigid open cell foam support 122 may be, but is not limited to, plastic, metallic or ceramic open cell foam. The foam material should be selected to limit the thermal conductivity and control out-gassing in the vacuum space. For example, the support foam material may be, but is not limited to, stainless steel, polyurethane or polystyrene.

[0032] The support foam provides physical support to the walls inner and outer containers 112 and 114 so that when a vacuum is drawn on vacuum space 116, they do not collapse. The support foam 122 can withstand the maximum pressure at full vacuum because of its cellular structure. The support foam 122 uniformly distributes the load on the walls of the inner and outer containers 112 and 114. As a result, the thickness of the walls may be reduced.

[0033] The support foam 122 is configured with an open-cell structure to allow air to be evacuated out of the vacuum space 116 to form the vacuum. The open-cell foam structure enables the molecular sieve 124 to absorb residual moisture and gas in the vacuum space 116 to ensure long vacuum life for the freezer. As with the embodiment of FIGS. 1-4, the low heat transfer coefficient of the support foam 122 minimizes the heat conducted from the outer container 114 to the inner container 112. The support foam 122 also reduces heat conductivity by maximizing the open space.

[0034] The cryogenic freezer 110 is assembled by placing the molecular sieve 124 on the outside surface of the bottom of the inner container 112. Alternating layers of the reflective material 118 and the flexible insulation 120 are then placed in the vacuum space 116 such that the first layer placed against the inner wall 112 is flexible insulation material. Preferably up to 30 layers are formed with the last sheet being a sheet of flexible insulation material. The support foam 122 is next positioned so as to rest between the layers and the walls of outer container 114 when the freezer is assembled. Once the inner container 112 is properly positioned within the outer container 114, the resulting open annular top is closed, and the vacuum space 116 sealed, by a ring-shaped top plate 130 that is welded to the top edges of the walls of inner container 112 and outer container 114 (FIG. 5).

[0035] As with the embodiment of FIGS. 1-4, a vacuum is drawn in space 16 to increase the insulation value of the freezer. The cryogenic freezer 110 includes a sealable port 128 (FIG. 5) in the outer container 114 that connects to a vacuum pump for that purpose.

[0036] While the preferred embodiments of the invention have been shown and described, it will be apparent to those skilled in the art that changes and modifications may be made therein without departing from the spirit of the invention, the scope of which is defined by the appended claims.

Claims

1. A cryogenic freezer for storing materials at temperatures deviating greatly from ambient comprising:

- a) an inner container, said inner container comprising four walls and a bottom;
- b) an outer container enclosing the inner container and defining a vacuum space therebetween, said outer container comprising four walls and a bottom, said inner container being connected to the outer container at the top of said walls to seal said vacuum space;
- c) a plurality alternating layers of reflective material and flexible insulating material; and
- d) a support structure positioned in the sealed vacuum space with one side positioned adjacent to the plurality of alternating layers, said support structure substantially reducing deflection of the walls when air is evacuated from the vacuum space.

2. The cryogenic freezer of claim 1 wherein said support structure is a support grid.

3. The cryogenic freezer of claim 2 wherein the support grid includes a first set of parallel strip members oriented perpendicular to a second set of parallel strip members so that a plurality of cells are formed.

4. The cryogenic freezer of claim 3 wherein openings are provided in said parallel strip members so that the cells are open.

5. The cryogenic freezer of claim 4 where the support grid is sandwiched between layers of rigid insulation material.

6. The cryogenic freezer of claim 2 wherein the support grid is sandwiched between layers of rigid insulation material.

7. The cryogenic freezer of claim 6 wherein the rigid insulation material is fiberglass sheeting.

8. The cryogenic freezer of claim 1 where in the support structure is open-cell foam.

9. The cryogenic freezer of claim 1 wherein the vacuum space also includes a molecular sieve for ab-

sorbing gases therein.

10. The cryogenic freezer of claim 1 wherein the flexible insulation material is insulation paper.

11. The cryogenic freezer of claim 1 wherein the reflective material is reflective foil.

12. The cryogenic freezer of claim 1 further comprising a sealable vacuum port formed in the outer container.

13. The cryogenic freezer of claim 1 wherein the plurality of alternating layers are adjacent to the inner container and the support structure is adjacent to the outer container.

14. A method for assembling a doubled walled vacuum insulated cryogenic freezer for storing materials at temperatures deviating greatly from ambient comprising the steps of:

a) providing an inner container with four walls and a bottom;

b) positioning a plurality of alternating layers of reflective material and flexible insulating material adjacent to the inner container;

c) positioning a support structure adjacent to the plurality of alternating layers for preventing deflection of the walls and bottom surface when a vacuum is drawn;

d) positioning the inner container in an outer container, the outer container having four walls and a bottom, to define a vacuum space therebetween;

e) connecting the inner container to the outer container at the top walls to seal the vacuum space; and

f) evacuating air from the vacuum space.

15. The method of claim 14 further comprising the step of sandwiching the support structure between two layers of rigid insulation material.

16. The method of claim 15 wherein the rigid insulation material is fiberglass sheets.

17. The method of claim 14 wherein the flexible insulation material is insulation paper.

18. The method of claim 14 wherein the reflective material is reflective foil.

19. The method of claim 14 wherein the support structure is a support grid.

20. The method of claim 14 wherein the support structure is open-cell foam.

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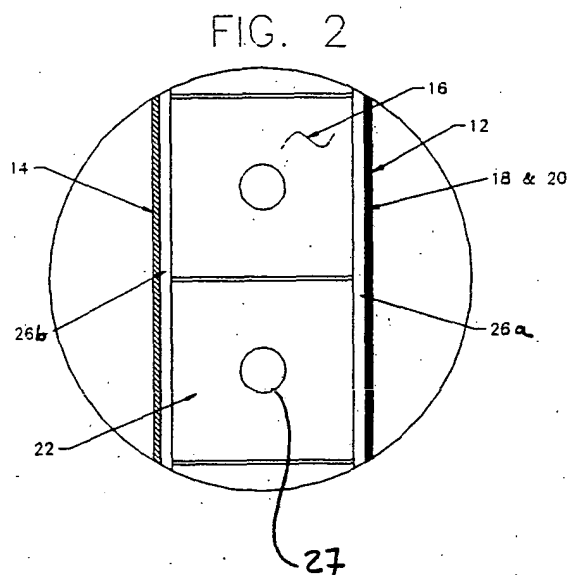
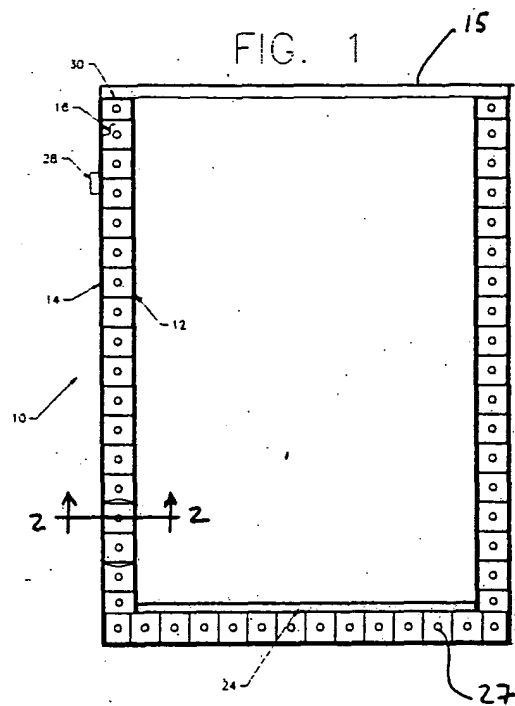


FIG. 3

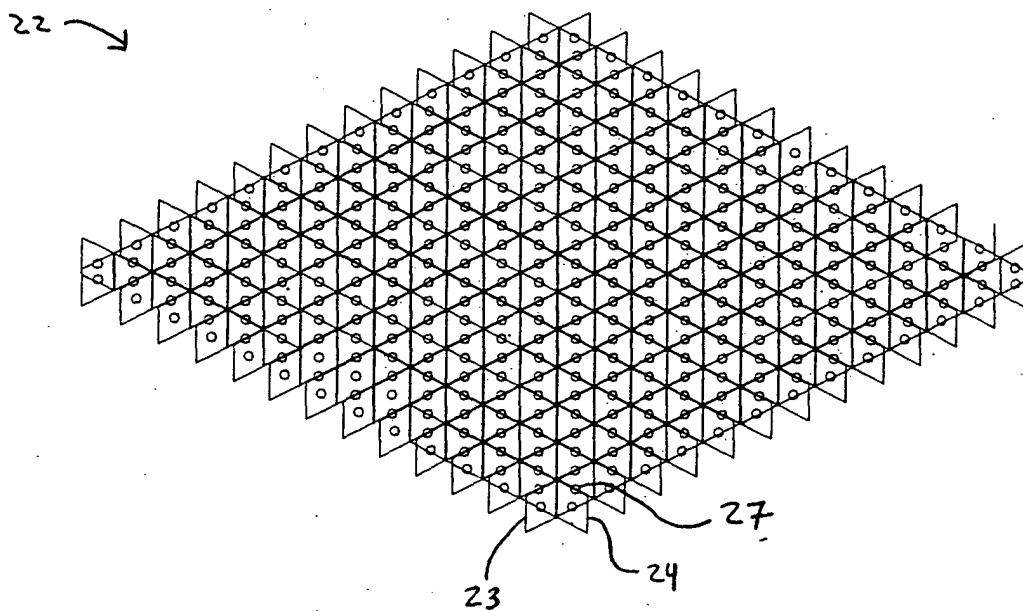


FIG. 4

