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MODULAR DEWAR VESSEL FOR CRYOGENIC USE

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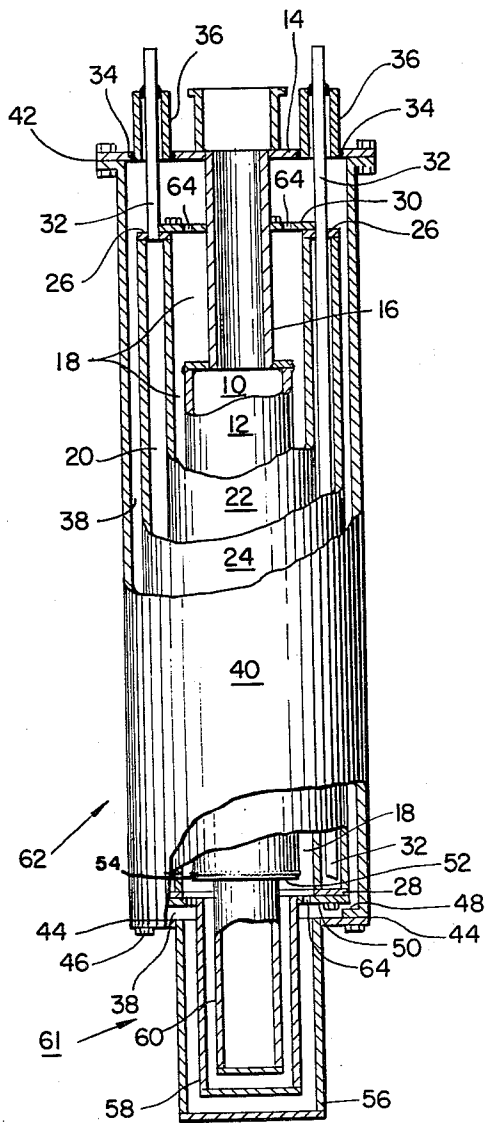


FIG. 1

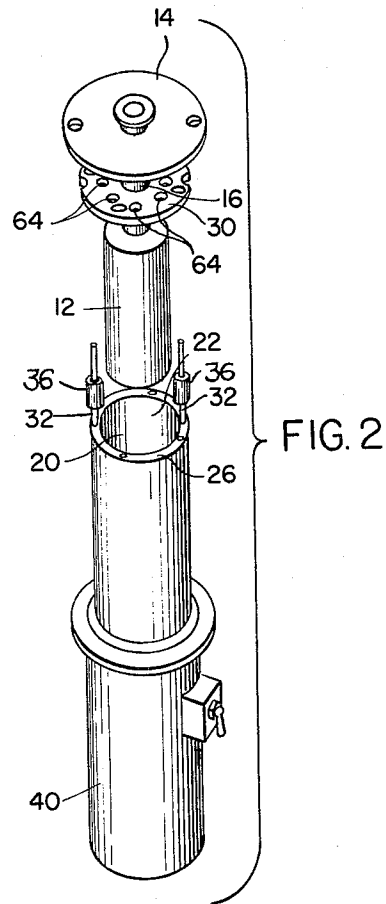


FIG. 2

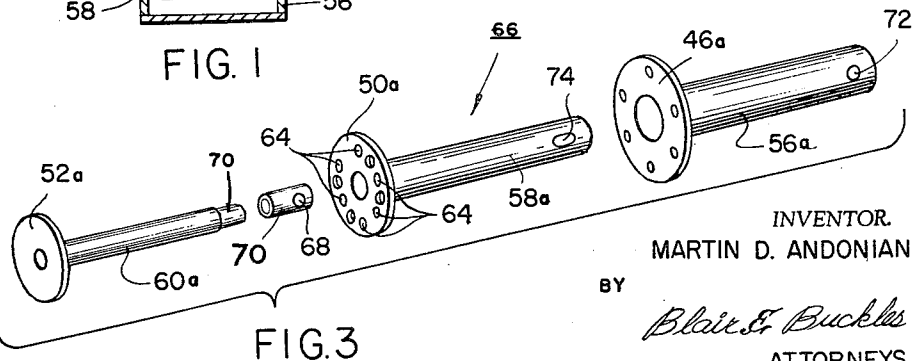


FIG. 3

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MODULAR DEWAR VESSEL FOR CRYOGENIC USE
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This invention concerns a vacuum-insulated vessel for low temperature use. More particularly, it relates to a modular design for a vacuum-insulated multi-walled container for use with cryogenic fluids such as liquid helium, hydrogen, nitrogen, etc. The modular design provides for ready disassembly of a double-Dewar container for low cost manufacture, ease of repair or modification.

The advantages and utility to scientists of using liquefied gases such as helium, etc., to study the behavior of various substances at very low temperatures have long been established. The most convenient method for achieving very low temperatures is to utilize the latent heat of vaporization of materials having very low boiling points. Commercial availability of liquefied gases such as nitrogen, hydrogen, and helium has opened new avenues for scientific exploration.

As might be expected, the use of cryogenic liquids to achieve low temperatures has created new needs for apparatus to economically contain these fluids while providing access to the low temperature environment associated with them. Many designs for insulated vessels have appeared and are in current use. The majority of these designs are for special purpose applications, and have a common fault that once assembled, they are extremely difficult to disassemble for repair or modification. Certain special properties of liquid helium, specifically the property of essentially zero viscosity at temperatures below 2.19° K., cause normal leak testing procedures to be inadequate. The thermal properties and high cost of liquid helium preclude testing prior to complete assembly. Thus, a leak occurring only when superfluid helium is present cannot be detected, located, and repaired without first assembling the vessel in its final form, and with prior constructions the disassembly for repair can require much time and expense.

Moreover, the rapid rate of technological progress has resulted in very rapid obsolescence of experimental equipment. The results of one experiment usually generate the need for other experiments requiring facilities which may be different from the original. Even a minor dimensional change, for example, in the size of a sample, may render useless an expensive cryogenic facility. For example, a double-Dewar arrangement used to house a sample for certain experiments may be wholly unsuitable for other samples or other experiments, although only slight differences in size or shape are involved. Substantial savings in time and money could be achieved by modifying the vessel if it could be readily disassembled and reassembled.

Accordingly, it is the primary objective of this invention to provide an improved double-Dewar vessel having a modular design which facilitates modification to accommodate a wide variety of low temperature operations by means of interchangeable appendages and structures.

It is a further object of this invention to achieve this modular design while at the same time retaining thermal efficiency in the interest of operating economy.

It is a further object of this invention to provide a vessel of the above type capable of economical fabrication and a high degree of operator safety.

Other objects will be in part obvious, and in part pointed out in detail hereinafter.

This invention accordingly comprises the features of construction, combinations of elements and arrangement of parts which will be exemplified in the constructions

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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 cross sectional view showing details of construction of a cryogenic vessel, embodying the invention, comprising a modular Dewar body and a typical tail section;

FIG. 2 is an exploded perspective view of the modular Dewar body of FIG. 1, showing the manner in which it is readily disassembled and reassembled; and

FIG. 3 is an exploded perspective view of another tail section which may be used with the Dewar body of FIGS. 1 and 2.

For clarity, in the following discussion assume that the inner shell of the Dewar is filled with liquid helium and the thermal radiation shield is filled with liquid nitrogen, although this invention could be used with other cryogenic liquids.

With reference to the drawings, a Dewar vessel constructed in accordance with the present invention is shown in FIG. 1. As illustrated therein, it comprises an inner helium chamber 10 bounded by an inner cylindrical housing 12. The housing 12 is supported from a top plate 14 by means of a thin-walled tube 16, which communicates with the exterior of the vessel for filling and, in some circumstances, insertion of elements to be cooled.

Surrounding the housing 12 and separated from it by a vacuum insulation space 18 is an annular nitrogen chamber 20, bounded by a nitrogen shield comprising concentric casings 22 and 24 and sealed by top and bottom annular disks 26 and 28. The nitrogen shield is supported by a thermal grounding flange 30 and removably attached thereto by bolts (not shown) which secure the disk 26 to the flange. The flange 30 is attached to the thin-walled tube 16 by means of a fused metal joint, e.g., by soldering, brazing or welding. It performs a dual function of mechanical support and of cooling the inner tube 16 to a temperature approaching that of the liquid refrigerant in the annular chamber 20. The chamber 20 communicates with the exterior of the vessel through one or more tubes 32, used for filling and venting purposes. The tubes 32 are surrounded by outer tubes 36, and the tubes 36 in turn are surrounded by packing where they penetrate the top plate 14, to provide a vacuum-tight joint. For this purpose, I prefer to use elastomer O ring gaskets 34 in sliding joints, which provide also for motion to accommodate differential contraction resulting from temperature changes in the tubes 32 or the tube 16.

As best seen in FIG. 2, this arrangement also facilitates removal of the annular chamber 20 by unbolting the thermal grounding flange 30 and withdrawing the chamber downward with respect to the top plate 14.

With further reference to FIG. 1, the outer tubes 36 are disposed about, and slightly spaced from, the tubes 32. They are welded, only at their top ends, above the plate 14, to the tubes 32. As noted below, there is a vacuum in the space below the tubes 36 and thus, also in the spaces between the tubes 32 and 36. This vacuum, combined with the relatively high thermal impedances of the tubes 32 and 36, serves to thermally isolate the tubes 32 from the O ring gaskets 34, which are in tight contact with the tubes 36. Thus, the gaskets 34 are essentially at room temperature, even when liquid nitrogen is poured into the chamber 20 through one of the tubes 32.

The sliding joint design shown is only an example of how to accomplish disassembly of the annular chamber 20 from the top plate 14. Another approach would be to

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use bellows seals in the tubes 32, sleeves 36, tube 16, or grounding flange 30 to allow for differential contraction and disassembly.

Surrounding the housing 24 of the annular chamber 20 and separated from it by a second vacuum insulation space 38 is an outer shell 40, which serves to support the entire structure and to maintain a vacuum tight envelope around the insulation space 38.

The outer shell 40 is attached to the top plate 14 by means of a bolted flanged joint 42 and is closed at the bottom by a similar bolted flanged joint generally indicated at 44. More specifically, a flange plate 46 is bolted to an interior flange 48 affixed to the shell 40.

A flange plate 50 is bolted to the annular disk 28 at the bottom of the chamber 20 to complete the intermediate temperature thermal envelope around the inner chamber 10.

The inner chamber 10 is closed at the bottom by means of a removable plate 52 held in place by a fused metal joint 54 of a low melting point alloy, although a bolted flanged joint may also be used when desired.

The plates 46, 50 and 52 may be provided with apertures and connected to tubular extensions indicated at 56, 58 and 60 to facilitate experiments which require insertion into confining auxiliary apparatus such as an electromagnet gap.

Since the tail section 61, comprising plates 46, 50 and 52 and their extensions, may be readily removed from the Dewar body, generally indicated at 62, a wide variety of extensions or appendages may be interchangeably employed to accommodate varying experimental requirements with the same Dewar body.

The bolted flanged joint 42 between the outer shell 40 and the top plate 14 facilitates the removal of the inner chamber 10 (housing 12) and the annular chamber 20 (casings 22 and 24) as a unit, thereby exposing the chamber 20 structure for repair or modification. The bolted joint between the thermal grounding flange 30 and the chamber 20 structure, together with the sliding feature of the joints between the tubes 32 and 36 and the top plate 14 permits disassembly of the housing 12 from the annular chamber 20. FIG. 2 is an exploded view showing the manner in which disassembly is accomplished. Disassembly in this manner provides ready access to all joints in the entire structure for repair or modification.

Preferably, the surfaces bounding the vacuum insulating spaces 18 and 38 are specially treated to reduce their emissivity at the long wave-length infra-red radiation associated with low temperatures. This treatment consists of gold plating all stainless steel surfaces in contact with the vacuum space. The gold plating serves an additional purpose in the bolted joints between the thermal plates 30 and 50 and the nitrogen cooled annular disks 26 and 28, in that it provides soft ductile mating surfaces to achieve efficient thermal contact, which is otherwise difficult to achieve under high vacuum conditions. The bolts connecting the plates 30 and 50 to the disks 26 and 28 should not extend through the disks, in order not to disturb the vacuum tight isolation between the chamber 20 and the spaces 18 and 38.

It is well known to those schooled in the art that the vapor pressures of the commonly occurring vapors and gases at the temperature of liquid helium are extremely low. Only helium and hydrogen have vapor pressures measurable by conventional vacuum gauges. Gases and vapors with the notable exception of helium, are rapidly condensed on a helium cooled surface and are effectively removed from the volume surrounding such surfaces. In the design shown, the vacuum insulating spaces 18 and 38 are in communication by means of ports 64 in plates 30 and 50, so that both are effectively pumped by condensation of gases and vapors on the outer surface of the inner housing 12, which is the coldest surface in the insulating spaces (e.g., at or close to the temperature of liquid helium). The resulting extremely high vacuum in

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the spaces 18 and 38 eliminates thermal energy transport by the mechanism of gaseous conduction, contributing substantially to high thermal efficiency. On the other hand, in certain cases, it may be desirable to isolate the vacuum spaces 18 and 38 from each other, in which case it is preferable to provide a valve between them which is opened when the Dewar vessel is under long-term operation.

The utilization of the vacuum pumping effect of a very cold surface permits the use of the elastomer gaskets 34 and also similar gaskets used to seal the flanged joints 42 and 44. Without this effect, the diffusion of gases through and the evolution of gases and vapors from the elastomer gaskets would result in an increase in pressure in the vacuum insulation spaces and thermal efficiency would be impaired. By using the pumping effect, the need for charcoal or other adsorbents in the vacuum spaces is completely eliminated.

In this connection, it is noted that with the above construction, all the elastomer gaskets, i.e., in the joints 42 and 44, as well as the gaskets 34, are essentially at room temperature, and therefore, they operate efficiently with their full resiliency.

The vacuum pumping effect of cold surfaces cooled by liquids other than helium is effective on many vapors, but cannot, of course, remove gases having appreciable vapor pressure at the temperature of the liquid refrigerant.

FIG. 3 shows a tail section 66 which may be substituted for the tail section 61 of FIG. 1. The section 66 includes flanges 46a, 50a and 52a, similar to their counterparts 46, 50 and 52. Also included are tubular extensions 56a, 58a and 60a, which are somewhat different from the corresponding parts in FIG. 1.

More specifically, to provide visual or X-ray access to a sample 68 held in a sample holder 70, a vacuum tight window 72 of quartz or the like is provided in the section 56a. A corresponding aperture 74 extends through the wall of the extension 58a of the nitrogen shield. At the lower end of the extension 60a is a solid projection 76, to which the sample holder 70 is attached. Thus, the sample 68 is maintained at a very low temperature without being immersed in the helium.

It can thus be seen that I have provided a novel and improved device for utilization of the cooling effects of liquefied gases. A unique degree of convenience and flexibility is provided, while maintaining a high order of thermal efficiency. The Dewar vessel can be readily disassembled for repair or modification, and the design permits substitution or interchange of a wide variety of appendages or tail sections to facilitate the execution of many different experiments with a single Dewar body. The disassembly feature is enhanced by use of intercommunicating vacuum insulating spaces to permit the vacuum pumping effect of a very cold surface to remove any gases or vapors evolved by diffusion or effusion from elastomer seals used in the demountable joints. A variety of constructional features have been provided for purpose of increased convenience and efficiency.

It will be apparent to those skilled in the art that many and varied changes and modifications could be made in the modular Dewar herein described and shown in the accompanying drawings. For example, metal O rings can be used to minimize leakage through gasketed joints. Further, bellows seals can replace sliding O ring seals to prevent damage by differential contraction.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the scope of the invention, 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.

It is also to be understood that the following claims are intended to cover all of the generic and specific

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features of the invention which, as a matter of language, might be said to fall therebetween.

I claim:

1. A multi-walled vacuum insulated vessel comprising
 - (a) an outer vacuum shell,
 - (b) an intermediate low temperature thermal radiation shield having inner and outer walls forming a chamber between them,
 - (c) an inner container,
 - (d) a first plate extending across and removably secured to a first end of said shell,
 - (e) a conduit extending from said inner container outwardly through said first plate,
 - (f) first sealing means sealing the interior of said inner container from the space around said inner container and within said outer shell,
 - (g) second sealing means sealing said chamber from said space,
 - (h) a supporting structure for supporting said shield from said first plate, and
 - (i) means removably securing said shield to said supporting structure.
2. The combination defined in claim 1 including
 - (a) a tube extending from the interior of said shield through said first plate, and
 - (b) means forming a hermetic seal between said tube and said first plate and permitting movement of said tube through said first plate.
3. The combination defined in claim 2 including means securing said conduit to said first plate.
4. The combination defined in claim 2 including means forming a passageway between said hermetic seal and the exterior surface of said inner container.
5. The combination defined in claim 1 including a tail section comprising a second plate extending across, removably secured to, and sealing a second end of said shell.
6. The combination defined in claim 5
 - (a) in which said inner and outer walls are tubular, and
 - (b) said chamber has a first end facing said first plate and a second end facing said second plate, said first and second ends being defined by said second sealing means,
 - (c) said tail section including
 - (1) a third plate extending across and in close thermal contact with said second sealing means and spaced from said second plate, and
 - (2) a fourth plate removably attached to said inner container and sealing an aperture therein opening toward said third plate.
7. A multi-walled vacuum vessel comprising
 - (a) an inner container having a first end and a second end,
 - (b) a thermal radiation shield
 - (1) surrounding and spaced from said inner container, and
 - (2) comprising first and second tubular walls, said second wall surrounding and spaced from said first wall to form a chamber between them,
 - (c) a tubular outer shell surrounding and spaced from said second wall,
 - (d) a first plate extending across a first end of said shell and removably secured thereto,
 - (e) a conduit
 - (1) communicating with the interior of said inner container and extending through said first plate from a first end thereof facing said first plate, and
 - (2) sealed to said first plate where it passes there-through,
 - (f) first sealing means sealing said first end of said inner container,
 - (g) a second plate extending across the second end of said shell and removably secured thereto,

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- (h) said first and second walls having
 - (1) first ends defining a first end of said chamber and facing said first plate, and
 - (2) second ends defining a second end of said chamber and facing said second plate,
- (i) first and second sealing means sealing said first and second ends of said chamber,
- (j) a third plate extending across said second end of at least said first tubular wall and removably secured thereto,
- (k) a fourth plate extending across an aperture in said inner container opening toward said third plate and removably secured to said inner container to seal said aperture,
- (l) a fifth plate
 - (1) extending across said first end of said first tubular wall and removably secured thereto,
 - (2) surrounding and affixed to said conduit between said inner container and said first plate,
 - (3) in close thermal contact with said chamber and said conduit.
8. The combination defined in claim 7 including
 - (a) a tube communicating with the interior of said chamber and extending through said first plate,
 - (b) means forming a seal between said tube and first plate permitting said tube to slide through said first plate.
9. The combination defined in claim 8 in which said sealing means includes
 - (a) a second tube
 - (1) surrounding and transversely spaced from said tube,
 - (2) extending through said first plate, and
 - (3) sealed to said first tube outside said vessel, and
 - (b) an elastomeric gasket between and contacting said second tube and said first plate.
10. The combination defined in claim 9 including means forming passageways between the outer surface of said inner container, and
 - (a) the joints between said first and second plates and said shell, and
 - (b) said gasket.
11. The combination defined in claim 7 including means forming passageways between the outer surface of said inner container and the joints between said first and second plates and shell.
12. The combination defined in claim 7 in which said second, third and fourth plates include first, second and third tubular extensions, respectively,
 - (a) said extensions being spaced apart from each other,
 - (b) said extensions extending away from said first plate,
 - (c) said first extension surrounding said second extension, and
 - (d) said second extension surrounding said third extension.
13. The combination defined in claim 12 including
 - (a) means for securing an object within said second extension and in close thermal contact with said third extension,
 - (b) means forming an aperture in said second extension,
 - (c) a window in said first extension,
 - (d) said window and said aperture being disposed in a line extending through said object.
14. The combination defined in claim 2 including means communicating between
 - (a) the space between said outer shell and said radiation shield and
 - (b) the space between said shield and said inner container.

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ROBERT A. O'LEARY, *Primary Examiner*.