

[54] **CRYOSTAT HAVING HEAT EXCHANGING MEANS IN A VENT TUBE**

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[51] Int. Cl. F25b 19/00

[58] Field of Search 62/45, 514; 324/.5

[56] **References Cited**

UNITED STATES PATENTS

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Primary Examiner—Meyer Perlin

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[57] **ABSTRACT**

A cryostat is disclosed which includes a liquid helium chamber for cooling an object such as a superconducting solenoid to cryogenic temperatures. A vent tube is connected in gas communication with the liquid helium chamber and extends outwardly therefrom for venting vaporized helium. An elongated plug partially closes off the vent tube and defines an annular gas passageway in the space between the plug and the inside wall of the vent through which the evolved gaseous helium is vented for cooling the inside wall of the vent tube. The plug includes a liquid nitrogen chamber and thermal insulation is interposed in the plug between the liquid nitrogen and liquid helium chambers to provide a thermal barrier therebetween. The use of liquid nitrogen in the plug improves the thermal isolation of the liquid helium chamber from the surrounds and reduces the liquid helium consumption.

8 Claims, 3 Drawing Figures

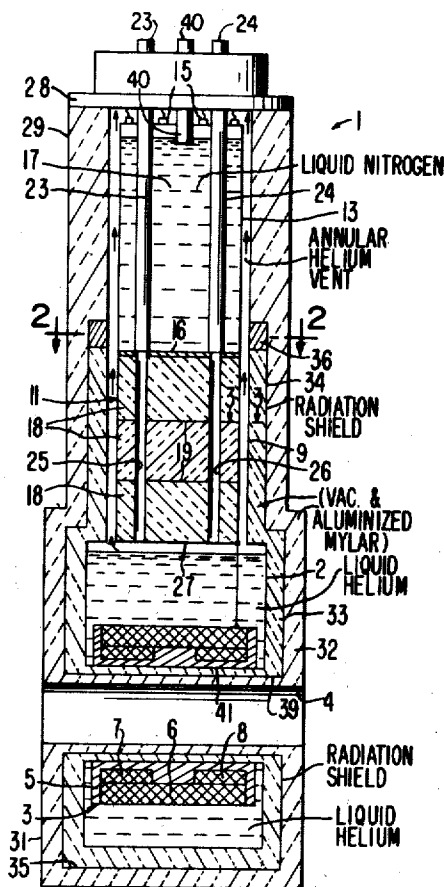


FIG. 1

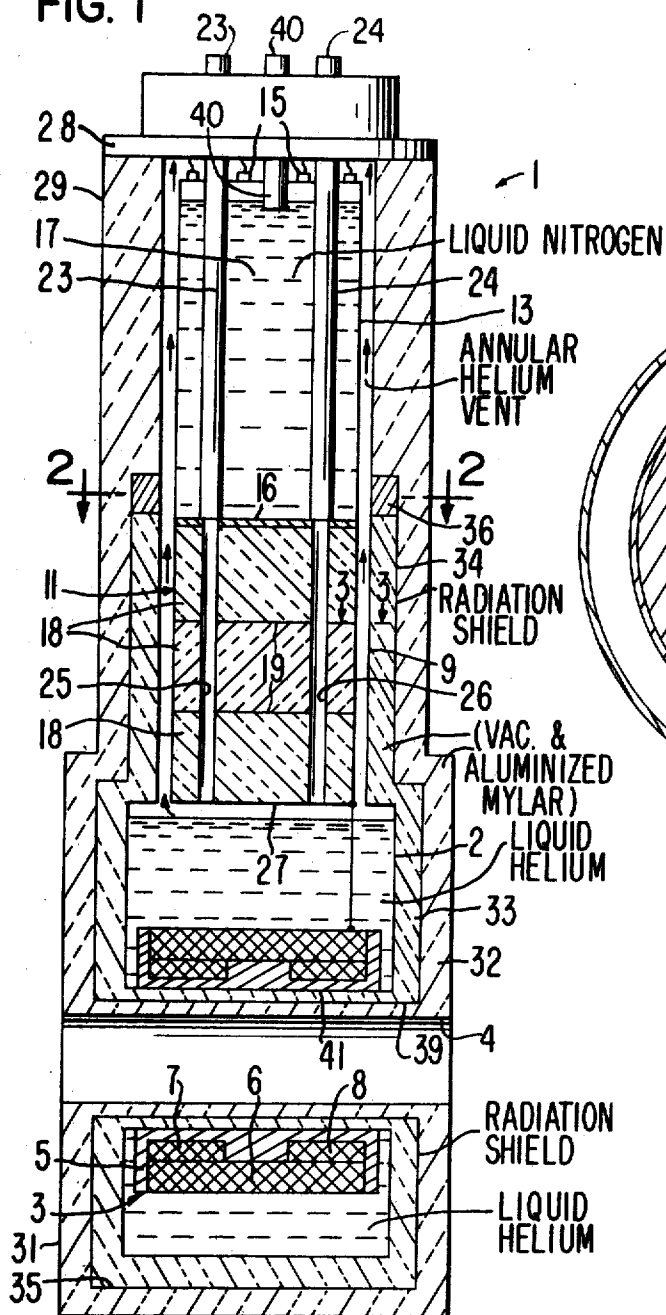
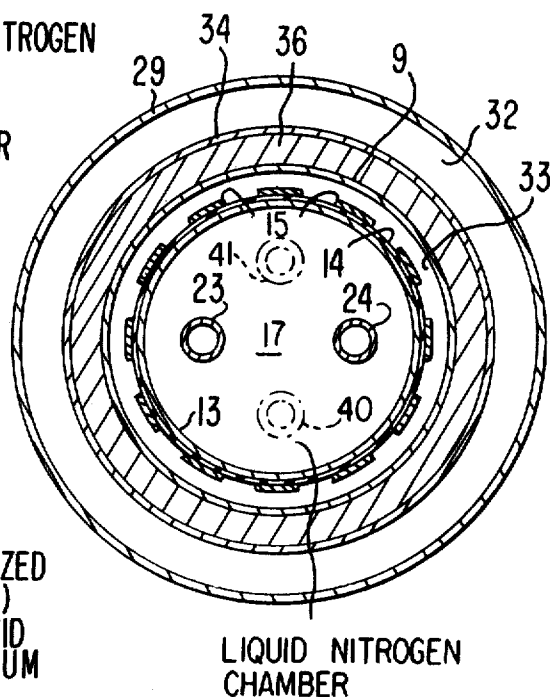
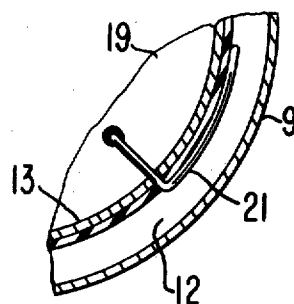


FIG. 2



LIQUID NITROGEN CHAMBER

FIG. 3



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CRYOSTAT HAVING HEAT EXCHANGING MEANS IN A VENT TUBE

DESCRIPTION OF THE PRIOR ART

Heretofore, liquid helium cryostats have been built wherein a liquid helium chamber was vented by means of a vent tube, such vent tube being partially closed by a plug. The plug carried an array of ribbon-shaped electrical leads around the outside periphery thereof in heat exchanging relation with the annular vented helium passageway defined by the space between the plug and the inside wall of the vent tube. This heat exchanger cooled the leads and other heat paths into the liquid helium chamber, thereby greatly reducing the liquid helium consumption. A liquid nitrogen chamber surrounded the liquid helium chamber and was separated from the liquid helium chamber by an evacuated space and was separated from a surrounding outside envelope by a second evacuated space. The walls of the surrounding liquid nitrogen chamber served as a radiation shield for the liquid helium chamber. The problem with this arrangement is that by placing the liquid nitrogen chamber around the outside of the liquid helium chamber, the diameter of the cryostat becomes relatively large and the weight of the cryostat is correspondingly relatively high, as of on the order of 150 pounds, for a 50 KG superconducting magnet cryostat. Such a cryostat is disclosed and claimed in U.S. Pat. No. 3,412,320, issued Nov. 19, 1968 and assigned to the same assignee as the present invention.

SUMMARY OF THE PRESENT INVENTION

The principle object of the present invention is the provision of an improved cryostat having heat exchanging means in a vent tube.

One feature of the present invention is the provision, in a cryostat having a first cryogenic chamber vented to the atmosphere via a vent tube and including a plug partially closing off the vent tube to define a gas passageway in the space between the plug in the inside wall of the vent tube, of a second cryogenic chamber disposed in the plug with thermal insulation provided in the plug between the first and second cryogenic chambers, whereby improved thermal isolation is obtained for the first cryogenic chamber to reduce consumption of the cryogenic liquid employed in the first chamber.

Another feature of the present invention is the same as the preceding feature wherein a pair of concentric evacuated chambers are disposed surrounding the first cryogenic chamber for thermally insulating the first chamber from the surrounds and such evacuated chambers having a common partitioning wall therebetween forming a radiation shield, such shield being connected in heat exchanging relation to the vent tube for cooling the radiation shield.

Another feature of the present invention is the same as any one or more of the preceding features wherein the plug includes at least one thermally conductive plate disposed intermediate the length of the insulation in the plug to provide an isothermal plane in the plug and such plate being connected in heat exchanging relation with the gas passageway around the plug for cooling the plate in use.

Other features and advantages of the present invention will become apparent upon a perusal of the following specifications taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal schematic sectional view, in line diagram form, of a cryostat incorporating features of the present invention,

FIG. 2 is an enlarged sectional view of a portion of the structure of FIG. 1 taken a long line 2—2 in the direction of the arrows, and

FIG. 3 is an enlarged sectional detail view of a portion of the structure of FIG. 1 taken along line 3—3 in the direction of the arrows.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown a cryostat 1 incorporating features of the present invention. The cryostat 1 includes a liquid helium chamber 2 of generally rectangular cross section and formed by sheet metal, such as 0.090 inch thick stainless steel having typical transverse inside dimensions of approximately 4 inches in one direction and 5 inches in the other and having a length of 15 inches. The liquid helium chamber 2 is filled with liquid helium and contains therewithin an object, such as a superconductive solenoid 3, to be cooled to liquid helium temperature. In the particular embodiment of the cryostat 1 which is depicted herein, the solenoid 3 mounted in the horizontal position and includes a horizontally directed central access passageway 4, which may be operated at liquid helium temperature, liquid nitrogen temperature, or at room temperature, in a manner more fully described below. Sample materials to be subjected to the intense magnetic field of the solenoid 3 are placed within the access passage 4. In a typical example, the access passage 4 has an inside diameter of approximately one inch and the solenoid 3 is capable of providing a 50 KG magnetic field within a three-quarter inch spherical volume centrally of the access passage 4 with a homogeneity greater than 1 percent.

The solenoid 3 includes a conductive bobbin 5, as of copper on which is wound a main solenoid winding 6 of superconductive wire and the bobbin 5 is notched at opposite ends to receive auxiliary corrective coils 7 and 8, respectively, for correcting the homogeneity of the magnetic field.

A cylindrical vent tube 9 having an inside transverse diameter of approximately 3.5 inches and which is made of 0.035 inch thick stainless steel is connected at one end in gas communication with the liquid helium chamber 2. In a typical example, the vent tube 9 is approximately 14 inches long and is partially closed off by an elongated cylindrical plug structure 11 having an outside diameter of slightly less than the inside diameter of the vent tube 9 to define an annular gas passageway 12 in the space between the periphery of the plug 11 and the inside wall of the vent tube 9. The plug 11 includes a hollow cylindrical tubular body member 13, as of 0.035 inch thick stainless steel sheet. An epoxy resin glass cloth cylinder 14, having brass conductive leads 15 fixed to the outside thereof, is fixed around the outside of the tubular member 13. In a typical example, the epoxy glass cloth is 0.020 inches and the brass leads 15 are 0.002 inches thick and have a generally ribbon configuration, as shown in FIG. 2. The ribbon conductors extend lengthwise of the plug structure 11 for making electrical contact to circuit elements disposed within the liquid helium chamber 2.

A partitioning plate 16 as of 0.125 inch thick stainless steel is sealed across the inside of the tube 13 to form a liquid nitrogen chamber 17 in the region of space above the plate 16. Liquid nitrogen chamber 17 is filled with liquid nitrogen in use through either fill and exhaust conduit 40 or 41. Interposed in the plug structure 11 between the liquid helium chamber 2 and liquid nitrogen chamber 17 is a thermally insulative structure 18 as of polyurethane foam to provide a thermal barrier between the liquid nitrogen in chamber 17 and the liquid helium chamber 2. The insulative structure 18 fills the interior of the plug structure 11 in the region below the plate 16. Interposed in the insulative structure is a pair of thermally conductive plates 19, as of copper sheet material. The plates 19 are axially spaced apart approximately 2 inches and extending transversely of the plug structure 11 to define a pair of axially spaced isothermal planes across the plug 11. As shown in FIG. 3, the plates 19 each include a thermally conductive wire 21, as of copper, which is affixed at one end to the plate 19 and which includes an extension protruding into the annular liquid helium vent passageway 12, such that the plate 19 is placed in heat exchanging relation with the vented helium for cooling of the plates 19 in use. The wire 21 may be placed in a region where there are no electrical leads 15 or, as an alternative, a

sheet of insulating material may be disposed between the wire 21 and the conducting leads 15.

A pair of stainless steel tubes 23, 24, as of 0.5 inch O.D. and 0.020 inch wall thickness, pass axially through the liquid nitrogen chamber 17 and are sealed as by heliarc weld to the lip of a pair of openings in the bottom plate 16 of the liquid nitrogen chamber 17 such that one of the tubes defines a passageway for receiving the liquid helium fill tube, not shown, while the other tube permits overflow of excess liquid helium from the helium chamber 2. Tubes 23, 24 are axial registration with a pair of bores 25 and 26, respectively, passing through the insulative structure 18, isothermal plates 19, and the lower wall 27 of the plug 11 to permit communication with the liquid helium chamber 2. The lower wall 27 of the plug 11 is an insulative plate 27, as of linen base phenolic, which has a pair of apertures in alignment with the bores 25 and 26, respectively.

The upper end of the vent tube 9 is sealed, as by heliarc welding, to a transverse flange 28, as of stainless steel. An outer tubular envelope of the cryostat 1 is formed by tubular structure 29 having an upper cylindrical portion sealed, as by heliarc welding, to the flange 28 and joined to a lower rectangular portion 31. The lower envelope portion 31 surrounds the liquid helium chamber 2 and vent tube 9 and is partitioned into a pair of concentric evacuated regions 32 and 33, respectively, by means of a common partitioning wall 34, as of 0.030 inch thick copper, which forms a radiation shield between the liquid helium chamber 2 and the outer envelope 29. Shield 34 includes an upper cylindrical portion and a lower rectangular portion 35. The upper end of the partitioning wall 34 is thermally conductively connected to the vent tube 9 via the intermediary of a thermally conductive ring 36, as of copper, which is soldered to the outside of the vent tube 9 and to the inside of the partitioning wall 34. The thermally conductive ring 36 is disposed in a position which is axially coextensive with a lower portion of the liquid nitrogen chamber 17 such that the ring 36 is operated at a temperature close to liquid nitrogen temperature, namely, 77 K. Since the radiation shield 34 is made of a thermally conductive material, it serves as an isothermal member, whereby the radiation shield 34 operates at liquid nitrogen temperature. The vented helium serves to provide a thermally conductive path through the annular gas passageway 12 between the liquid nitrogen in reservoir 17 and the ring 36. The temperature drop across the annular passageway 12 is of the order of a degree Kelvin.

The partitioning wall 34 is apertured along a longitudinal seam to permit gas communication between the inner and outer evacuated regions 32 and 33. The evacuated regions 32 and 33 are also filled with aluminized mylar with approximately 20 thicknesses of the aluminized mylar being disposed between adjacent walls to minimize transfer of thermal energy between the inside liquid helium chamber 2 and the outside envelope 29, by radiation, conduction, or convection. In a typical example, the outside envelope 29 is made of stainless steel, having a wall thickness of 0.125 inches and having an outside diameter, in the lower rectangular region of the envelope, of 5 inches in one direction and 6 inches in the other transverse direction. The overall length of the rectangular section of the outer envelope is approximately 15 inches.

A plurality of horizontally directed concentric tubular members 4, 39, and 41 are joined to the outer envelope 29, radiation shield 34, and helium chamber 2 to permit access to the center of the superconducting solenoid 3. In an alternative embodiment, not shown, removable quartz windows are sealed into the outer envelope 29 in alignment with the center of the solenoid 3 and tubular member 4 is deleted to permit the interior of the solenoid 3 to be operated at liquid nitrogen temperature. In still a further alternative embodiment, inner tube 39 is eliminated, thereby exposing the center of the solenoid 3 to tube 41 which is operated at liquid helium temperature such that the region of the magnetic field between the quartz windows, not shown, is operated at liquid helium temperature.

The advantage of the cryostat, of the present invention, which includes the liquid nitrogen chamber 17 and the plug structure 11 is that the loss of liquid helium is substantially the same as that for a similar unit weighing approximately three times the weight of the structure of the present invention. More specifically, the prior art cryostat of the type disclosed in the aforecited U.S. Pat. No. 3,412,320 had a helium consumption rate of approximately 175 cc per hour and weighed 150 pounds, whereas the cryostat of the present invention weighs approximately 45 pounds and has a liquid helium consumption rate of approximately 180 cc per hour.

Since many changes could be made in the above construction and many apparently widely different embodiments of this 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.

What is claimed is:

1. In a cryostat, a first cryogenic chamber means for containing a first cryogenic liquid for cooling an object disposed in heat exchanging relation with said chamber to cryogenic temperatures, said first cryogenic chamber including means for filling with said first cryogenic liquid and for removing evaporated gas of said first cryogenic liquid, vent tube means connected in gas communication with said first cryogenic chamber and extending outwardly therefrom for venting vaporized cryogenic liquid from said first cryogenic chamber, plug means partially closing off said vent tube means and defining a gas passageway in the space between said plug means and the inside wall of said vent tube and through which the evolved gaseous cryogenic liquid is vented from said chamber for cooling the inside wall of said vent tube, THE IMPROVEMENT COMPRISING, second cryogenic chamber means for containing a second cryogenic liquid, said second cryogenic chamber including means for filling with said second cryogenic liquid and for removing evaporated gas of said second cryogenic liquid, said second cryogenic chamber being disposed in said plug means, and thermal insulative means interposed in said plug between said first and said second cryogenic chambers for providing a thermal barrier therebetween.

2. The apparatus of claim 1 including a plurality of ribbon shaped electrically conductive leads disposed about the periphery of said plug means in heat exchanging relation with the vented evolved cryogenic gas for cooling said leads.

3. The apparatus of claim 1 including a pair of concentric evacuated chambers surrounding said first cryogenic chamber for thermally insulating said first cryogenic chamber from the surrounds, said pair of evacuated chambers having a common partitioning wall therebetween, and said common partitioning wall being made of a thermally conductive material to form a radiation shield and being connected in heat exchanging relation to said vent tube for cooling said radiation shield.

4. The apparatus of claim 3 wherein said common partitioning wall is made of copper, and said thermally conductive connection from said vent tube to said partitioning wall includes an arcuate member interposed between said vent tube and said partitioning wall to form the thermally conductive connection therebetween.

5. The apparatus of claim 4 wherein said arcuate thermally conductive member is axially coextensive with at least a portion of said second cryogenic chamber.

6. The apparatus of claim 1 including at least one thermally conductive plate disposed intermediate the length of said thermally insulative means in said plug, said thermally conductive plate being mounted with the plane of the plate generally transverse to the longitudinal axis of said plug and vent tube to provide an isothermal plane in said plug, and means providing a thermally conductive path from said plate to said annular gas passageway such that said plate is cooled by the vented cryogenic gas.

7. The apparatus of claim 6 wherein said thermally conductive path interconnecting said gas passageway and said plate

includes a thermally conductive wire connected to said plate and extending into said gas passageway.

8. The apparatus of claim 6 including a plurality of said thermally conductive plates spaced at intervals along the axis of said plug, and including thermal insulative means interposed between adjacent ones of said plates.

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