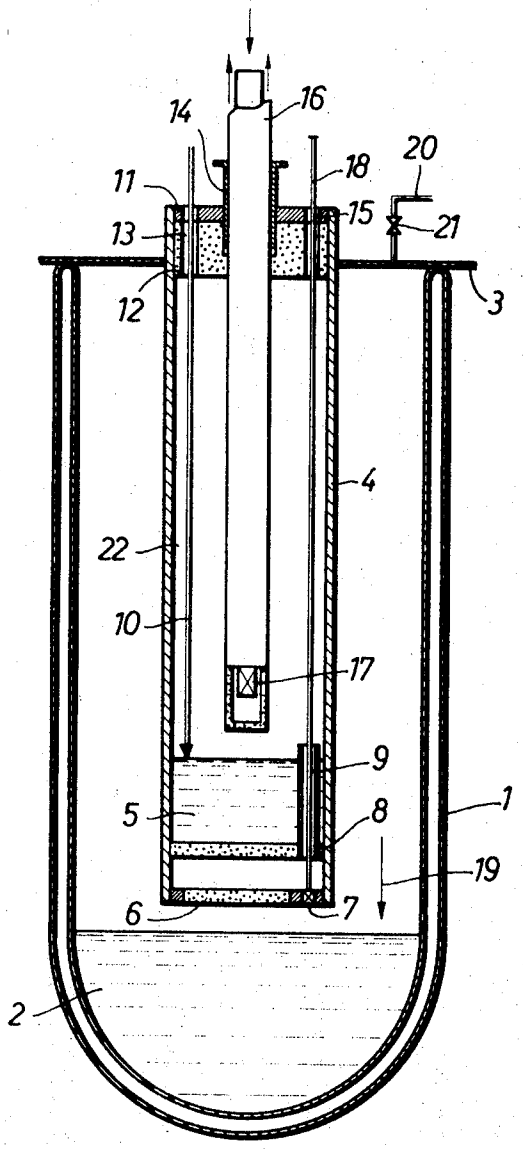
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CRYOSTAT DEVICE

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CRYOSTAT DEVICE

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ABSTRACT OF THE DISCLOSURE

In a cryostat having a helium replenishing bath separated from a helium working bath by a first filter element made of a material which is at least partially impermeable to gaseous helium and helium I, as well as to any helium II having a temperature higher than that of the working bath, a second filter element of such material supported in the replenishing bath container spaced from and above the first filter element. The second filter element forms the normal floor of the replenishing bath. A space between the first and second filter elements is in communication with the replenishing bath container portion above the replenishing bath, whereby there is substantially no pressure difference across the second filter element so that the possibility of pressure-caused breakthrough of the replenishing helium into the working bath is eliminated.

CROSS-REFERENCE TO RELATED PATENT

The present invention relates to an improvement of the invention set forth in U.S. Pat. No. 3,442,091, issued May 6, 1969, to Gustav Klipping, Albrecht Elsner, and Gerd Hildebrandt for "Delivery of Coolant to Cryostats."

BACKGROUND OF THE INVENTION

U.S. Pat. No. 3,442,091 concerns a device for continually cooling in a liquid bath, especially at temperatures below 2.17° K., using a He II bath. Temperature regulation is obtained by controlling the pressure in the vapor chamber above the helium bath. Replenishment is controlled as a function of the level of the helium bath. The outlet of a vacuum-jacket syphon opens into a replenishment chamber which is under reduced pressure. Helium is fed intermittently into the replenishment chamber through the vacuum-jacket syphon. The replenishment chamber is separated from the chamber containing the helium bath by a filter element which is at least partially impermeable to gaseous helium, helium I, as well as to helium II of higher temperature than the temperature of the helium II bath.

An apparatus according to U.S. Pat. No. 3,442,091 makes it possible to replenish a helium working bath held at temperatures below the λ-point by reduced pressure, while maintaining the working bath temperature constant. Such working baths are used for cooling objects. Such apparatus makes it possible to continually cool objects at temperatures below 2.17° K.

To replenish the working bath, liquid helium, boiling at atmospheric pressure (4.2° K.), is brought from a storage vessel through a syphon cooled by exhaust gas. The syphon carries on its end an expansion valve surrounded by a sintered body or the equivalent. This helium passes through the expansion valve into a replenishment chamber held under reduced pressure and expands and cools. The filter is practically impermeable for this replenishing bath so long as the temperature of the replenishing bath

is higher than the temperature of the working bath below the filter.

SUMMARY OF THE INVENTION

It has been discovered that if the pressure difference across filter of U.S. Pat. No. 3,442,091 exceeds a certain maximum value dependent on the pressure below the filter, then liquid helium begins to flow from the replenishing bath, through the filter, into the working bath, even though the temperature of the replenishment bath is above that of the working bath. The pressure below the filter of course, corresponds to the particular working temperature of the working bath. At a temperature of the working bath of 1.5° K., which corresponds to a pressure below the filter of 5 millibars, such liquid breakthrough occurs at a pressure difference of 650 millibars. As another example, at a working bath temperature of 2.1° K., which corresponds to a pressure below the filter of 47 millibars, liquid breakthrough occurs at 50 millibars.

As is evident from the two examples of the last paragraph, liquid breakthrough begins at increasingly higher pressure differences as the temperature of the working bath decreases. While in general this breakthrough does not lead to a change of the temperature in the working bath, it can have a disturbing effect on the steady state operation of the apparatus, since the pump attached to the space above the working bath is subjected to an undesirably high loading.

An object of the present invention, therefore, is to prevent liquid breakthrough at higher pressure differences across the filter.

This as well as other objects which will become apparent in the discussion that follows are achieved by the feature that the replenishment chamber of U.S. Pat. No. 3,442,091 is provided with at least one filter additional to that shown in that patent. This additional filter is spaced above the first filter element and the space between the first filter element and this second filter element is in communication with the portion of the replenishment chamber above the second filter element.

With the double filter of the present invention, the phenomenon of liquid breakthrough is prevented with certainty, since the pressure difference across the upper filter element (whose job it is to support the replenishment bath) is always zero. The gravitational pressure of the liquid helium, which is yet acting on the upper filter, is negligibly small: $\rho gh=3$ mb. for a height of the liquid of 200 mm. On the other hand, liquid flow through the double filter upon reaching or going below the working temperature of the working bath still proceeds as in the U.S. Pat. No. 3,442,091, since the blocking effect of both filters is lost at the same time. The liquid flows through the upper filter into the space between the filters and from there through the lower filter into the working bath below.

BRIEF DESCRIPTION OF THE DRAWING

The sole figure of the drawing is a cross-sectional view of the cryostat of the invention, the plane of the cross section containing the cylindrical axis of the cryostat.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Since the present invention is an improvement of that disclosed in U.S. Pat. No. 3,442,091, only so much of the old structure as will suffice to show the connection of the present invention is illustrated in the single figure of the drawing. The details of the remainder of the old structure are available in the above-mentioned patent and incorporated herein by reference.

Referring now specifically to the figure, inner container 1 of the cryostat of the present invention holds a helium II working bath 2. The radiation protection, which surrounds the inner container, and which is cooled with liquid nitrogen, has been omitted from the drawing, since its illustration is not required by one skilled in the art for a proper understanding of the invention.

The inner container 1 is provided with a cover 3 which carries a cylindrical partition 4 which forms the replenishment chamber of the present apparatus. This partition holds the helium replenishing bath 5 and is closed at its lower end by a fine-pored filter element 6. The filter element 6 can be bypassed by a valve 7 located in the floor of the partition 4 adjacent the filter element 6. Above the filter element 6 and within partition 4 is provided a second filter element 8 having the same fine pores of the first filter element 6. The filter element 8 is provided with a hole and the outer diameter of one end of an overflow tube 9 is sealed in this hole so that the space between the two filter elements 6 and 8 is in communication with the portion 22 of the replenishing chamber lying above the helium replenishing bath 5. Overflow tube 9 extends upwardly into portion 22.

The maximum level of the helium replenishing bath 5 is controlled by a level sensor 10. The partition 4 is closed at its upper end by lid 11 having a heat insulating layer 12. Bores 13, 14 and 15 pass through the lid 11 to provide entrance for the level sensor 10, a vacuum-jacket syphon 16 and its expansion valve 17, and a valve rod 18 for actuating the valve 7. As shown in detail in the drawings of U.S. Pat. No. 3,442,091, the vacuum-jacket syphon 16 with its expansion valve 17 has a radiation protection jacket cooled by exhaust gas from the helium replenishing bath 5. That is, through this syphon not only liquid helium is flowing into the replenishment chamber which is here schematically indicated by the arrow pointing downwards at the top of the figure but also the cold gas evaporated from the helium replenishing bath 5 is pumped out through a tube connected to the radiation shield inside the jacket, which here is indicated by the direction of the two arrows pointing upwards at the top of the figure.

The level of the working bath 2 is controlled by schematically illustrated level sensor 19. The gas evaporating from the working bath 2 is removed via exhaust gas line 20 and control valve 21.

During operation, the cryostat of the figure is first cooled with its valve 7 open, and filled with liquid helium. During this time, the coupling of level sensor 10 to valve 17 is deactivated and liquid helium overflows from bath 5 into the overflow tube 9. Then the valve 7 is closed and the pressure above the working bath 2 is brought down to the pressure corresponding to the desired working bath temperature below 2.17° K (λ-point). In this way steady state operation is reached.

When the level of the working bath falls below the level sensor 19 because of evaporation, the expansion valve 17 at the end of the syphon 16 is opened with the help of a signal from sensor 19. Consequently, liquid helium begins to flow from a storage vessel downwards through the liquid carrying pipe in syphon 16. This flow is indicated by the uppermost arrow in the figure. This helium has an initial temperature of 4.2° K. (boiling temperature of helium at one atmosphere pressure). Upon passing through expansion valve 17, it expands due to the lower pressure present in portion 22 of the replenishing chamber and consequently its temperature falls below 4.2° K. This helium collects above the upper filter element 8 to form helium replenishing bath 5. When the replenishing bath 5 reaches level sensor 10, expansion valve 17 closes. Upon the closing of expansion valve 17, the pressure in the portion 22 of the replenishing chamber is reduced by means of a pump connected to the exhaust gas line inside the vacuum jacket of syphon 16. This pressure is reduced until the temperature of the replenishing bath 5 reaches or falls below the preset temperature of the working bath 2. When this temperature is reached, the filter 8 becomes permeable to the liquid replenishing helium and the replenishing bath 5 begins to run down into the space between the filters 6 and 8. As soon as a few millimeters of liquid helium have collected on top of the lower filter 6, the filter 6 becomes permeable and the replenishing bath 5 runs then through both filters 6 and 8 down into the working bath 2 and fills it up.

Regarding the flow of liquid helium from the replenishing bath 5 into the working bath 2 at temperature or pressure equality on both sides of the filter 6 and at negative pressure differences (P_{above} is less than P_{below}), the behavior obtained is the same as that obtained using a single filter: the replenishment bath 5 flows downwards unhindered upon reaching the proper temperature. For positive pressure differences across filter 6 (P_{above} is greater than P_{below}), as indicated above, undesired liquid breakthrough can occur when a single filter is used. However, as an advantage of the present invention, the double filter 6 and 8 remains completely shut until the proper temperature is reached in the replenishing bath 5, since no pressure difference exists across the filter element 8 supporting the replenishing bath 5. Consequently, the danger of disturbance in the working bath below the filter by an undesired liquid breakthrough because of a positive pressure difference is completely eliminated. The operation of the apparatus of U.S. Pat. No. 3,442,091, consequently becomes more dependable.

It will be understood that the above description of the present invention is susceptible to various modifications, changes, and adaptations and that the same are intended to be comprehended within the meaning and range of equivalents of the appended claims.

We claim:

1. In apparatus for the continuous low-temperature cooling of objects in a helium II working bath;

which apparatus includes a working bath chamber for containing the working bath, means for maintaining a reduced pressure in the working bath chamber for regulating the temperature of the working bath, a vacuum-jacketed syphon means for periodically replenishing the working bath from a helium storage vessel, a replenishing chamber disposed at least partially in said working chamber above the working bath and arranged for receiving the liquid helium delivered by the syphon means, said replenishing chamber including a first filter element forming at least a portion of the lower extermity of said replenishing chamber and separating the interior of said replenishing chamber from the working bath, said first filter element being of a material which is at least partially impermeable to gaseous helium and helium I, as well as to any helium II having a temperature higher than that of the working bath, and means for maintaining a reduced pressure in said replenishing chamber;

wherein the improvement comprises: a second filter element arranged in said replenishing chamber above said first filter element and spaced therefrom, said second filter element being of a material which is at least partially impermeable to gaseous helium and helium I, as well as to any helium II having a temperature higher than that of the working bath; and

a communication means for placing the space between said first and second filter elements in communication with the portion of said replenishing chamber above said second filter element.

2. An apparatus as claimed in claim 1, wherein said communication means is an overflow tube sealed in a hole through said second filter element and extending into the portion of said replenishing chamber above said second filter element.

3. An apparatus as claimed in claim 2, further comprising a valve means in said first filter element for bypassing said first filter element and a rod means extending through said overflow tube for the selective opening and closing of said valve means.

4. An apparatus as claimed in claim 2, further comprising means for sensing a maximum level of liquid helium in the portion of said replenishing chamber above said second filter element, said overflow tube extending to a level above said maximum level.

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3,442,091 5/1969 Klipping et al. ---------- 62—55

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