

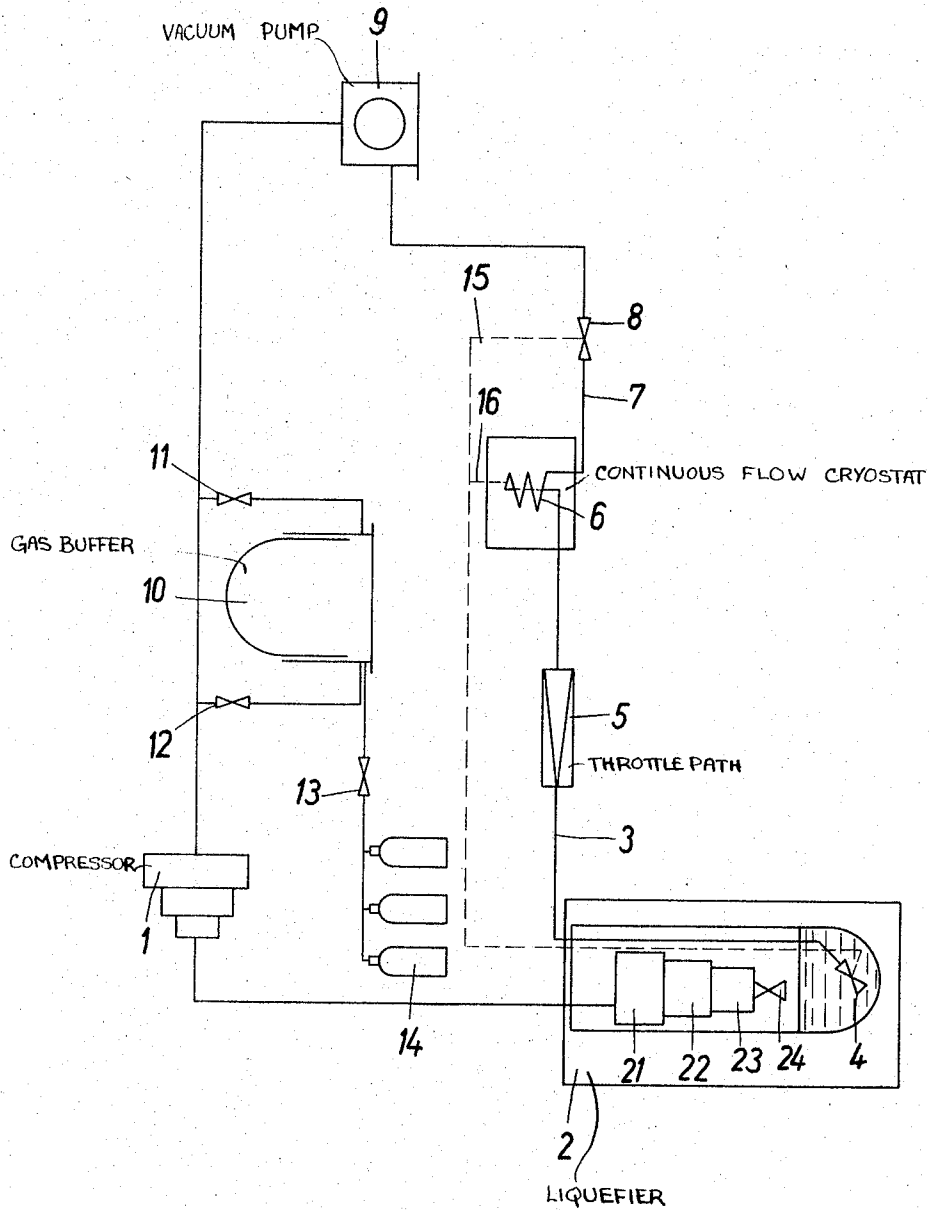
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COOLING DEVICE FOR HELIUM

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COOLING DEVICE FOR HELIUM

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The present invention relates generally to the refrigeration art and, more particularly, to a helium refrigerator wherein the liquid helium from the sump of a helium liquefying device is fed to an externally located consumption device and the gas pumped out of the latter is recycled through the liquefying device.

In the cryogenic art, a refrigerator is understood to mean a continuously operating refrigerating plant for producing low temperatures in the range of 2.5 to 30° K. Such a plant has as a particular characteristic thereof that the liquid vapor mixture (e.g., hydrogen or helium) collecting downstream from the expansion valve is fed in its entirety to the consumer or cryostat, and that the cold gas obtained in the consumer is refed, in accordance with its temperature, into the low pressure portion of one of the lower counter-current heat exchangers in the liquefying device.

The advantage of this cryogenic system resides in the higher refrigerating power of the plant produced with the same mechanical power as employed for a liquefying device. The consumer utilizes not only the evaporation energy of the liquid refrigerating medium, but also the enthalpy of the cold gas resulting from the temperature difference when entering and exiting from the consumer. The further refrigeration power in the gas is almost completely utilized in the liquefying device by means of the cold gas recycling process.

At higher operating temperatures, correspondingly higher amounts of refrigeration energy may be supplied to the consumer or, in other words, the refrigeration energy available for the consumer becomes smaller when approaching the boiling point of the refrigerating medium. Correspondingly, refrigerators are employed most advantageously in cases where large amounts of refrigeration energy are required and where continuous operation is indispensable. However, there are also provided refrigerators for small amounts of refrigeration energy at higher temperature, for example, 1 w. at 20° K., for the cooling of amplifier elements.

With operating temperatures above the boiling point of the refrigerating medium, the consumer is generally located outside of the liquefying device. With operating temperatures below the boiling point, however, a fluid bath at the desired temperature is usually produced within the liquefying device, i.e., the sample to be cooled is inserted into the liquefying device.

A disadvantage of known refrigerators is that they have little flexibility with respect to the operating conditions, e.g., temperature and refrigeration energy.

At operating temperatures above the boiling point of the refrigerating medium, the inlet wherein the cold gas is refed into the liquefying device is selected in such a manner that the temperature in the liquefying device at this inlet corresponds to the temperature of the returning gas. Certain variations may be obtained by providing several inlets in the liquefying device which can be used selectively. However, the construction of the counter-current heat exchangers must be adapted to accommodate the quantity of cold gas produced in the consumer. This means that a refrigerator in each case must be adapted for the particular operating conditions.

At operating temperatures below the boiling point of

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the refrigerating medium, the conditions are even more unfavorable. Here, the temperature of the fluid bath present in the sump of the liquefying device wherein the sample is inserted is lowered below the boiling point by decreasing the pressure above the liquid. In order to cool the fluid bath to 2.5° K., for example, the pressure above the boiling liquid must be decreased from 760 mm. Hg to 77 mm. Hg. This is accomplished by removing the gas which is produced by pumping it, by means of an externally located vacuum pump connected to the low pressure gas exit of the liquefying device, through the counter-current heat exchangers. Thus, the pressure in the entire low pressure portion of the liquefying device is lowered to a pressure corresponding to the desired temperature or to a still lower pressure determined by the flow resistance. In order to achieve a sufficiently small flow resistance of the counter-current heat exchangers and a sufficient heat exchange in these counter-current heat exchangers, the heat exchangers must be specially constructed for the desired operating conditions. Thus, a refrigerator of conventional design possesses very little flexibility with regard to operating temperature and refrigerating power at operating temperatures below the boiling point of the refrigerating medium.

An object of this invention is the provision of a refrigerator arrangement having great flexibility with regard to operating temperature and refrigerating power.

Another object of this invention is the provision of thermostatically operating valves for regulating the flow to and from the consumer whereby a desired temperature is maintained within the consumer.

A further object is to provide a high efficiency refrigerator system for temperatures below 4.2° K. wherein the need for auxiliary refrigerant in the consumer is eliminated.

In order to overcome the disadvantages of the prior refrigerator systems encountered in producing low temperatures, this invention provides a thermostatically operated valve in the liquid refrigerant supply line for regulating the flow of the liquid refrigerant from the liquefying device to the consumer, which is a continuous flow cryostat, in accordance with the temperature at a selected point within the continuous flow cryostat. The thermostatically operated valve is preferably located at the inlet of the supply line in the sump of the liquefying device. A vacuum pump for removing the gas from the continuous flow cryostat is connected to the continuous flow cryostat via another thermostatically operated valve which is also controlled in accordance with the temperature at a selected point within the continuous flow cryostat. The vacuum pump is connected to a compressor through a gas buffer which equalizes the volume of gas flowing to the compressor, the compressor in turn feeding the liquefying device and providing a cyclic operation. This invention also provides for the supply line from the liquefying device to the continuous flow cryostat to function as a throttle path whereby the supply line operates to maintain an excess pressure in the low pressure portion of the liquefying device, as is necessary for the normal liquefier operation, and to maintain in the evaporator a pressure below one atmosphere, corresponding to the desired temperature below 4.2° K., the pressure drop taking place in the supply line for the liquid refrigerant.

Additional objects and advantages of the present invention will become apparent upon consideration of the following description when taken in conjunction with the accompanying drawing in which a schematic view of a system constructed in accordance with the present invention is illustrated.

With more particular reference to the drawing the helium refrigerator system comprises a helium liquefier 2

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supplied with high pressure gas by a compressor 1. The liquefier comprises in addition to an engine (not shown), several counter-current heat exchangers 21, 22, 23, as well as a Joule-Thomson expansion valve 24. The system further comprises a feed line for the liquid refrigerant 3 having a liquid control valve 4 and a throttle path 5 connecting the liquefier 2 to a continuous flow cryostat 6. The continuous flow cryostat 6 and the throttle path 5 may be of the type shown in co-pending U.S. application Serial No. 396,556, filed September 16, 1964, now Patent No. 3,279,214 for Pump. The continuous flow cryostat 6 is provided with an exhaust gas line 7 which is connected via a gas regulating valve 8 to a vacuum pump 9, a gas buffer 10 and to the compressor 1. The gas buffer 10 may be selectively inserted into the system via valves 11 and 12 to equalize the volume of exhaust gas supplied to the compressor. A gas supply 14 shown as bottled gas is connected to the gas buffer 10 through a valve 13. The regulating valves 4 and 8 are connected, via lines 15 and 16, with one or more temperature sensing elements provided at a selected point within cryostat 6, whereby the liquid regulating valve 4 controls the supply of liquid to the continuous flow cryostat 6 and the gas regulating valve 8 controls the pressure or temperature, respectively, in the cryostat.

In operation, the refrigerator is first cooled down by feeding gaseous helium from the gas supply 14 via the gas buffer 10 and the compressor 1 into the liquefying device wherein the helium is liquefied. When the sump of the liquefier 2 is filled with liquid helium, the liquid control valve 4 is opened with the vacuum pump 9 operating and liquid helium is conducted via the throttle path 5 into the continuous flow cryostat 6 where it evaporates under normal pressure or under reduced pressure, thereby effecting the desired cooling to the desired temperature.

After the desired temperature has been reached, the operation of the thermostatically controlled valves 4 and 8 commences in dependence upon the temperature of the continuous flow cryostat 6, whereby the temperature of the cryostat is kept constant. The adjustment to any other desired temperatures may be effected during operation by adjusting the control valves 4 and 8. The refrigerant whose refrigerating content can be completely utilized in the continuous flow cryostat 6 is then recycled, in gaseous form, from the vacuum pump 9 to the suction side of the compressor 1.

During the operation of the plant, the preferred operating pressure for maintaining equilibrium of the plant is a pressure of approximately 1.2 atmospheres in the low pressure portion of the liquefier 2, and at operating temperatures below 4.2° K., there is simultaneously provided a pressure below 1.0 atmosphere in the continuous flow cryostat 6 which corresponds to the desired temperature.

Thus, it is noted that in the refrigerator system of this invention, the liquid helium is conducted from the sump of the liquefying device, by means of a vacuum pump, into a continuous flow cryostat where it evaporates and effects the desired cooling. The constant temperature in the continuous flow cryostat is regulated by regulating the feed of liquid by means of a control valve in the supply line for the liquid refrigerant, which valve is thermostatically controlled in dependence upon the temperature in the cryostat and by controlling the pressure in the cryostat via a control valve in the exhaust line which is likewise controlled in dependence upon the temperature in the cryostat, in a thermostatic manner. The gaseous helium conveyed by the vacuum pump is conducted, selectively via the gas buffer, to the compressor which supplies the helium liquefying device with the required high pressure gas.

The advantage of such a refrigerator arrangement resides particularly in its great flexibility, with respect to the temperature to be produced, as well as with respect to the refrigerating energy available for the consumer. In accordance with the invention, it is possible to employ temperatures in the continuous flow cryostat which are

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below as well as above 4.2° K. and to vary the temperature during operation without the danger of the liquefying device and the entire system losing equilibrium. The stored liquid in the sump of the liquefying device represents a reserve in refrigeration energy, i.e., the refrigerating power taken therefrom can also vary within wide limits, or can be subjected to variations during operation. When setting temperatures below 4.2° K., only the continuous flow cryostat is maintained under decreased pressure, while the low pressure portion of the liquefying device is, as usual, under a slight excess pressure. Thus, conventional helium liquefying devices can be employed for operating the proposed refrigerator device without special constructional alterations which is particularly advantageous. A further advantage of the device is that considerably higher refrigeration energy is available for the consumer, because the entire refrigeration content of the cold helium gas can be utilized in the continuous flow cryostat, i.e., up to room temperature. Therefore, an auxiliary refrigerant such as liquid nitrogen, which is normally indispensable in the refrigerator operation to cool the radiation shield of the consumer may be eliminated. The radiation shield of the continuous flow cryostat is cooled with cold exhaust gas.

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

What is claimed is:

1. A cryogenic gas refrigerator system using a refrigerant, comprising, in combination:

a compressor;

liquefier means connected to said compressor for liquefying a refrigerant;

a continuous flow cryostat connected to said liquefier means for producing controllable low temperatures by evaporation of the liquid refrigerant;

first thermostatically controlled valve means for regulating the flow of the liquefied refrigerant between said liquefier means and said continuous flow cryostat in response to the temperature at a point within said cryostat;

a vacuum pump connected between said continuous flow cryostat and said compressor for pumping the gas from said cryostat to said compressor; and second thermostatically controlled valve means for regulating the flow of the gas between said continuous flow cryostat and said vacuum pump in response to the temperature at a point within said cryostat.

2. A system as defined in claim 1 comprising means for supplying a refrigerant in gaseous form to said compressor.

3. A system as defined in claim 2 further comprising: a first fluid conveying means connected between said liquefier and said continuous flow cryostat;

a second fluid conveying means connected between said cryostat and said pump; and

a third fluid conveying means connected between said pump and said compressor, including a gas buffer volume in a by-pass line.

4. A system as defined in claim 3 wherein said means for supplying refrigerant in gaseous form is connected to said third fluid conveying means via said gas buffer volume for supplying an equalized volume of gas to said compressor.

5. A system as defined in claim 3 wherein said liquefier means is provided with a sump wherein the liquefied refrigerant is stored;

said first fluid conveying means having an inlet located in said sump; and

said first thermostatically controlled valve means being connected to said first fluid conveying means at said inlet.

6. A system as defined in claim 3 wherein said first fluid conveying means provides a throttle path for said liquefied refrigerant for producing a reduction in pres-

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sure between said liquefier means and said continuous flow cryostat.

7. A system as defined in claim 6 wherein equilibrium is maintained in said system at a desired temperature below 4.2° K., by providing:

a first pressure slightly in excess of one atmosphere in the low pressure portion of said liquefier means; and a second pressure below one atmosphere in said continuous flow cryostat, said second pressure corresponding to the desired temperature; whereby said first fluid conveying means provides the reduction in pressure between said liquefier means and said cryostat.

8. A cryogenic helium refrigerator system for temperatures below 4.2° K., comprising:

a compressor;
means for supplying helium in gaseous form to said compressor;

liquefier means connected to said compressor for liquefying said helium, said liquefier means having a low pressure portion wherein a pressure slightly in excess of one atmosphere is maintained and a sump for storing the liquid helium;

a continuous flow cryostat for producing controllable low temperatures by evaporation of said liquid helium said cryostat having temperature sensing means therein, and in said cryostat a pressure below one atmosphere being maintained;

first fluid conveying means having an inlet in said sump connected between said liquefier means and said continuous flow cryostat, said first fluid conveying means providing a throttle path wherein a reduction in pressure is produced between said liquefier means and said cryostat;

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first thermostatically controlled valve means provided at the inlet of said first fluid conveying means for regulating the flow of said liquid helium through said first fluid conveying means in response to said temperature sensing means;

a vacuum pump for removing the helium gas originating in said continuous flow cryostat from said cryostat and supplying said gas to said compressor;

second fluid conveying means connected between said cryostat and said vacuum pump;

second thermostatically controlled valve means provided within said second fluid conveying means for regulating the flow of said gas through said second fluid conveying means in response to said temperature sensing means; and

third fluid conveying means connected between said vacuum pump and said compressor, comprising a gas buffer volume in a by-pass line for equalizing the volume of gas supplied to said compressor if necessary, said third fluid conveying means having connected thereto, via said gas buffer volume, said means for supplying helium in gaseous form to said compressor.

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