

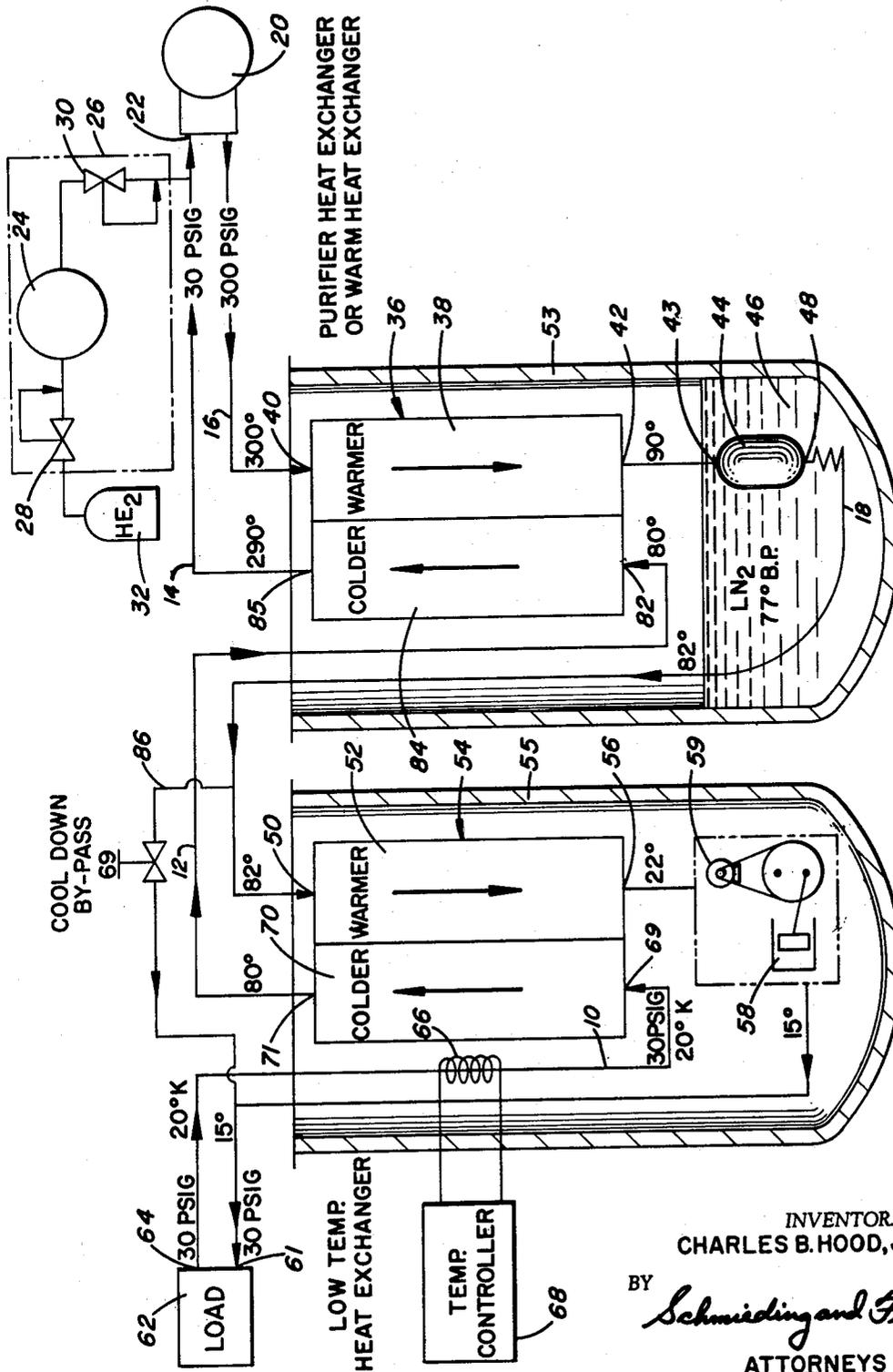
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DENSE GAS HELIUM REFRIGERATOR

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DENSE GAS HELIUM REFRIGERATOR

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This invention relates to dense gas helium refrigerators.

In general, the helium refrigerator of the present invention is uniquely compact for its output due to a novel arrangement of warm and cold heat exchanges, the outlet flow from the warm heat exchanger being passed through a gas purifier disposed in a bath of liquid nitrogen before being delivered to the inlet to the low temperature heat exchanger and thence to the load. This arrangement provides a relatively small temperature differential in the order of approximately 2 degrees Kelvin at the cold end of the low temperature heat exchanger which is a relatively small temperature differential as compared to a difference of approximately 10 degrees Kelvin between the paths at the low temperature end of the warm heat exchanger.

The difference between the 10 degree temperature difference at the cold ends of the paths of the warm heat exchanger and the 2 degree temperature difference at the cold ends of the paths of the cold heat exchanger is absorbed by the previously mentioned evaporating liquid nitrogen bath surrounding the gas purifier through which is passed the flow between the two exchangers. This results in a relatively small temperature differential for any given physical dimensions of the heat exchanger means.

As another advantage of the present invention compactness of size results from feeding the warm end of the warm heat exchanger with a compressor provided with a suction pressure regulating apparatus that eliminates the need for large supply gas holders.

As another advantage of the present invention the refrigerator is provided with a rapid cool-down apparatus which greatly reduces the time required to cool-down the refrigerator itself and the load. This is accomplished in two hours as compared with many hours or days, the latter being the required time without the rapid cool-down feature.

As another advantage the refrigerator of the present invention includes an automatic temperature controller which operates at cryogenic temperatures and which accurately regulates the temperature of the refrigerant leaving the load and entering the cold heat exchanger.

As still another advantage of the present invention the refrigerator includes an adsorption type gas purifier located in the flow between the warm and cold heat exchangers which serves to remove gaseous impurities such as oxygen, nitrogen, and carbon dioxide which would otherwise freeze-out in colder portions of the refrigeration cycle.

It is, therefore, an object of the present invention to provide a dense gas helium refrigerator that is highly efficient yet extremely compact for its capacity.

It is another object of the present invention to provide a refrigerator of the type described that utilizes a novel suction pressure regulator apparatus at the intake side of the compressor whereby large gas holders are eliminated.

It is another object of the present invention to provide a refrigerator of the type described that includes a rapid cool-down apparatus whereby the load in the refrigerator itself can be brought down to operating temperatures in a minimum of time.

It is another object of the present invention to provide a refrigerator of the type described that includes an auto-

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matic temperature controller that permits the setting of various desired temperatures for the return flow of refrigerant whereby the small critical temperature difference at the cold ends of the paths of the low temperature heat exchanger can be precisely maintained at various desired temperature values.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein a preferred form of embodiment of the invention is clearly shown.

In the drawings:

The figure of the drawing is a diagrammatic view of a dense gas helium refrigerator constructed in accordance with the present invention.

Referring in detail to the drawings, the figure illustrates a cryogenic refrigerator that includes a compressor 20 having an inlet 22 connected to a tank 24 of a suction pressure regulating apparatus indicated generally at 26. The pressure regulating system 26 includes a valve 28 for maintaining a constant pressure, for example, 50 p.s.i. in tank 24, and valve 30 for maintaining a constant pressure, for example, 30 p.s.i. at the inlet of the compressor.

A gaseous helium supply means is diagrammatically illustrated at 32 and serves to supply the helium gas refrigerant to tank 24 via valve 28.

The outlet of compressor 20 is connected by a conduit 14 to a warm heat exchanger indicated generally at 36 and the flow therein enters a warmer path 38 at an inlet 40 and is released from an outlet 42 to the inlet 43 of an adsorption type gas purifier 44 that contains an adsorptive substance such as silica gel, charcoal, or the like.

The purpose of purifier 44 is to freeze-out gaseous impurities such as oxygen, nitrogen, or carbon dioxide which would otherwise freeze-out in colder portions of the cycle.

It should be pointed out that purifier 44 is immersed in an evaporating bath 46 of liquid nitrogen having a boiling point temperature of 77 degrees Kelvin.

The outlet 48 of purifier 44 is connected by a conduit 18 to an inlet 50 of a warmer path 52 of a cold heat exchanger indicated generally at 54 and the outlet 56 of this heat exchanger delivers the refrigerant to the inlet of an engine 58.

It should be pointed out that the warm heat exchanger and low temperature heat exchanger are each disposed in a respective dewar 53 and 55.

The expansion engine works against an external load applied by a synchronous motor, or other suitable means, located outside the dewar and diagrammatically illustrated at 59.

The outlet of the engine is in turn connected to the inlet of a load 62.

After the gaseous refrigerant passes through the load it leaves the outlet 64 via a conduit 10 and thence passes through a heating element 66 of a flow temperature controller 68. Controllers of this type include a sensing means that automatically varies a variable voltage transformer to increase or decrease the heating effect applied to the gaseous flow via heating element 66 as may be required to maintain a constant temperature, for example 20 degrees Kelvin, at an inlet 69 of a cooler path 70 through cold heat exchanger 54.

After the flow leaves outlet 71 of colder path 70 of cold exchanger 54 via conduit 12 it enters an inlet 82 of a colder path 84 of warm heat exchanger 36 and upon leaving outlet 85 of warm heat exchanger 36 it is returned via a conduit 14 to the inlet of compressor 20.

For purposes of rapid cool-down a bypass conduit 86 is connected between the outlet of purifier 44 and the inlet 61 of the load and a shut-off valve 69 is provided for controlling the cool-down operation.

In operation, gaseous helium from a pressurized supply 32 passes through suction pressure regulating apparatus 26 wherein pressure regulating valve 28 maintains tank 24 at 50 p.s.i. and pressure control valve 30 maintains a line pressure of 30 p.s.i. at the inlet 22 of compressor 20. 5

The refrigerant leaves the compressor at 300 p.s.i. and 300 degrees Kelvin and is cooled-down to 90 degrees Kelvin in warmer paths 38 of warm heat exchanger 36.

In passing through purifier 44 the previously mentioned impurities are frozen-out and the gas leaves the evaporating bath 46 of liquid nitrogen at approximately 82 degrees Kelvin. 10

In flowing through the warmer path of the low temperature heat exchanger the temperature drops to 22 degrees Kelvin and then to 15 degrees Kelvin in passing through expansion engine 58. 15

In passing through the load 62 the refrigerant absorbs 5 degrees and is raised to 20 degrees Kelvin or to other temperature values slightly above or below 20 degrees Kelvin. Before the flow is returned to the cooler path 70 of the cold heat exchanger it is precisely controlled by temperature controller 68 so that it enters the cooler path at 20 degrees Kelvin to provide an exact temperature difference at the cold end of the low temperature exchanger. 20

It should be pointed out that the temperature difference at the cold end of the low temperature heat exchanger is critical since in taking heat out of the load 62 temperature difference is relatively small; i.e., 5 degrees Kelvin. It should, therefore, be understood that if even one degree is lost in the temperature difference at the cold end of the low temperature heat exchanger; say, a temperature rise from two degrees to 3 degrees Kelvin, then there is a resulting loss of 20 percent in the total output efficiency of the refrigerator. 25

The gas from the cold end of the low temperature heat exchanger is warmed in the return flow through the warm heat exchanger and thence delivered back to the suction side of the compressor to complete the cycle. 35

For purposes of rapid cool-down, at the outset of operation, valve 69 is opened whereby cold helium gas from the outlet of purifier 44 is released directly into load 62 via line 86. When the load cools the cold gas goes back to the low temperature heat exchanger thereby cooling low temperature heat exchanger 54 and also expansion engine 58, said expansion engine being in heat exchange relationship with the low temperature heat exchanger. 40

While the form of embodiment of the present invention as herein disclosed constitutes a preferred form, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow. 45

I claim:

1. A cryogenic refrigerator comprising, in combination, a compressor including an inlet and outlet; cryogenic gas refrigerant supply means; suction pressure regulation means connected between the compressor inlet and said gas supply means; a warm heat exchanger comprising a warmer path including an inlet and an outlet and a colder path including an inlet and an outlet; a cold heat exchanger comprising a warmer path including an inlet and an outlet and a colder path including an inlet and an outlet; a gas purifier connected between the outlet of the warmer path of said warm heat exchanger and the 55

inlet of the warmer path of the cold heat exchanger, said purifier being disposed in a liquid cryogenic gas; an expansion engine including an inlet connected to the outlet of the warmer path of the cold heat exchanger and an outlet leading to the load to be refrigerated; a first conduit leading from said load to be refrigerated to the inlet of the colder path of the cold heat exchanger; a second conduit means connecting said outlet of the colder path of said cold heat exchanger to the inlet of the colder path of said warm heat exchanger; a third conduit connecting the outlet of the colder path of the warm heat exchanger with the inlet of the compressor; and a fourth conduit connecting the outlet of the compressor with the inlet of the warmer heat exchanger. 60

2. The cryogenic refrigerator defined in claim 1 that includes a gas flow temperature controller for the flow of gaseous refrigerant in said first conduit.

3. The cryogenic refrigerator defined in claim 1 that includes a rapid cool-down by-pass conduit leading from the outlet of said gas purifier to said load; and valve means in said by-pass conduit.

4. In a cryogenic refrigerator the combination of a warm heat exchanger including a warmer path and a colder path; a cold heat exchanger including a warmer path in series with said warmer path of said warm heat exchanger and a colder path in series with said colder path of said warm heat exchanger; means containing an evaporating bath of liquified cryogenic gas; and a gas purifier in said bath and including an inlet connected to the outlet of the warmer path of said warm heat exchanger and an outlet connected to the inlet of the warmer path of said cold heat exchanger, the temperature difference between the two paths of the cold heat exchanger being less than the temperature difference between the two paths of the hot heat exchanger; a compressor having an outlet connected to said warmer path of said warm heat exchanger; expansion means including an inlet connected to said warmer path of said cold heat exchanger and an outlet connected to said load to be refrigerated; and conduit means connecting said load to be refrigerated with said colder path of said cold heat exchanger. 65

5. The cryogenic refrigerator defined in claim 4 that includes a suction pressure regulation means for the inlet of said compressor.

6. The cryogenic refrigerator defined in claim 4 that includes with the inlet of the colder path of said cold heat exchanger; a gas flow temperature controller for the flow of gaseous refrigerant in said conduit.

7. The cryogenic refrigerator defined in claim 4 that includes a rapid cool-down by-pass conduit leading from the outlet of said gas purifier to said load; and valve means in said by-pass conduit. 70

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