

[54] **HELIUM REFRIGERATOR**

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[51] Int. Cl.² **F17C 13/02**

[58] Field of Search **62/49, 125, 129, 130; 73/295**

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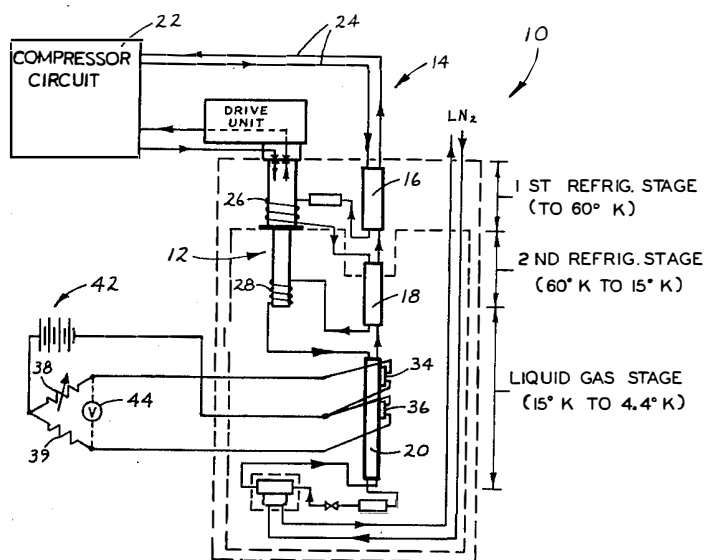
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[57] **ABSTRACT**

An improved helium refrigerator of the type which includes a plurality of counter-flow heat exchangers and has a maximum reserve cooling capacity when the final or low-temperature heat exchanger is substantially filled with liquid helium, and a minimum reserve cooling capacity when the low-temperature heat exchanger is substantially filled with gas. An electrical bridge circuit including a pair of temperature-responsive resistors is mounted on the low-temperature heat exchanger for providing a continuous indication of the reserve cooling capacity of the refrigerator.

2 Claims, 4 Drawing Figures



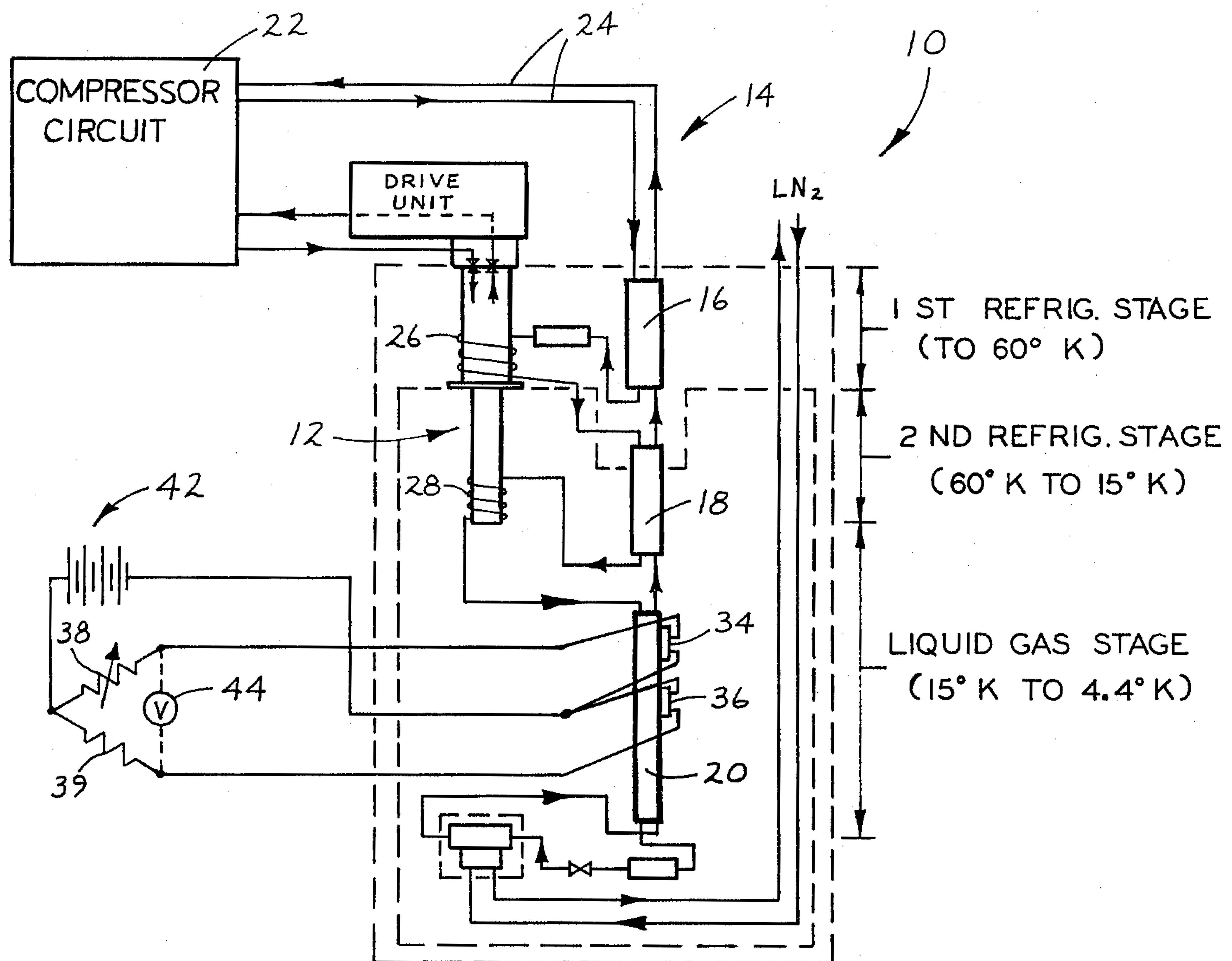


Fig. 1

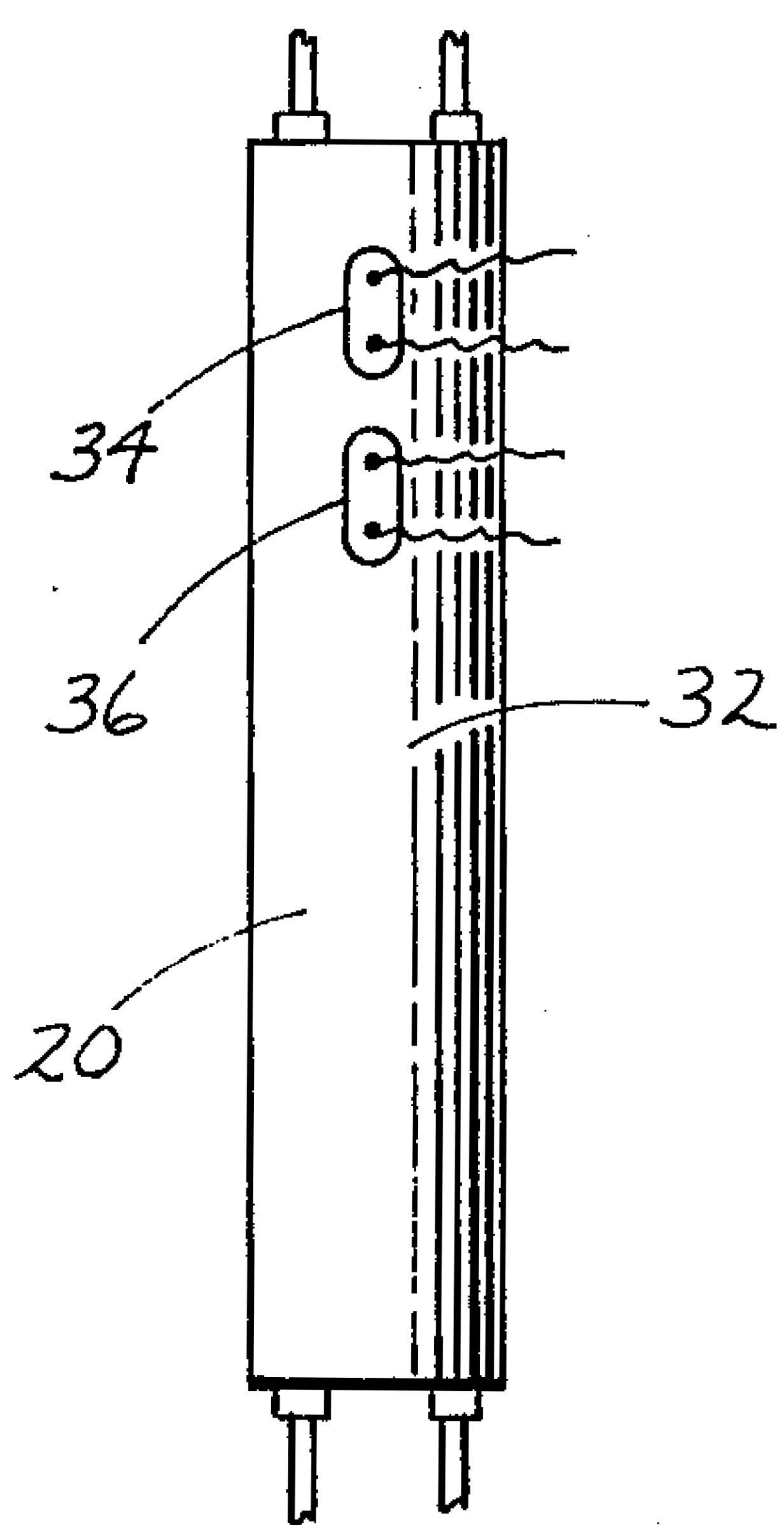


Fig. 2

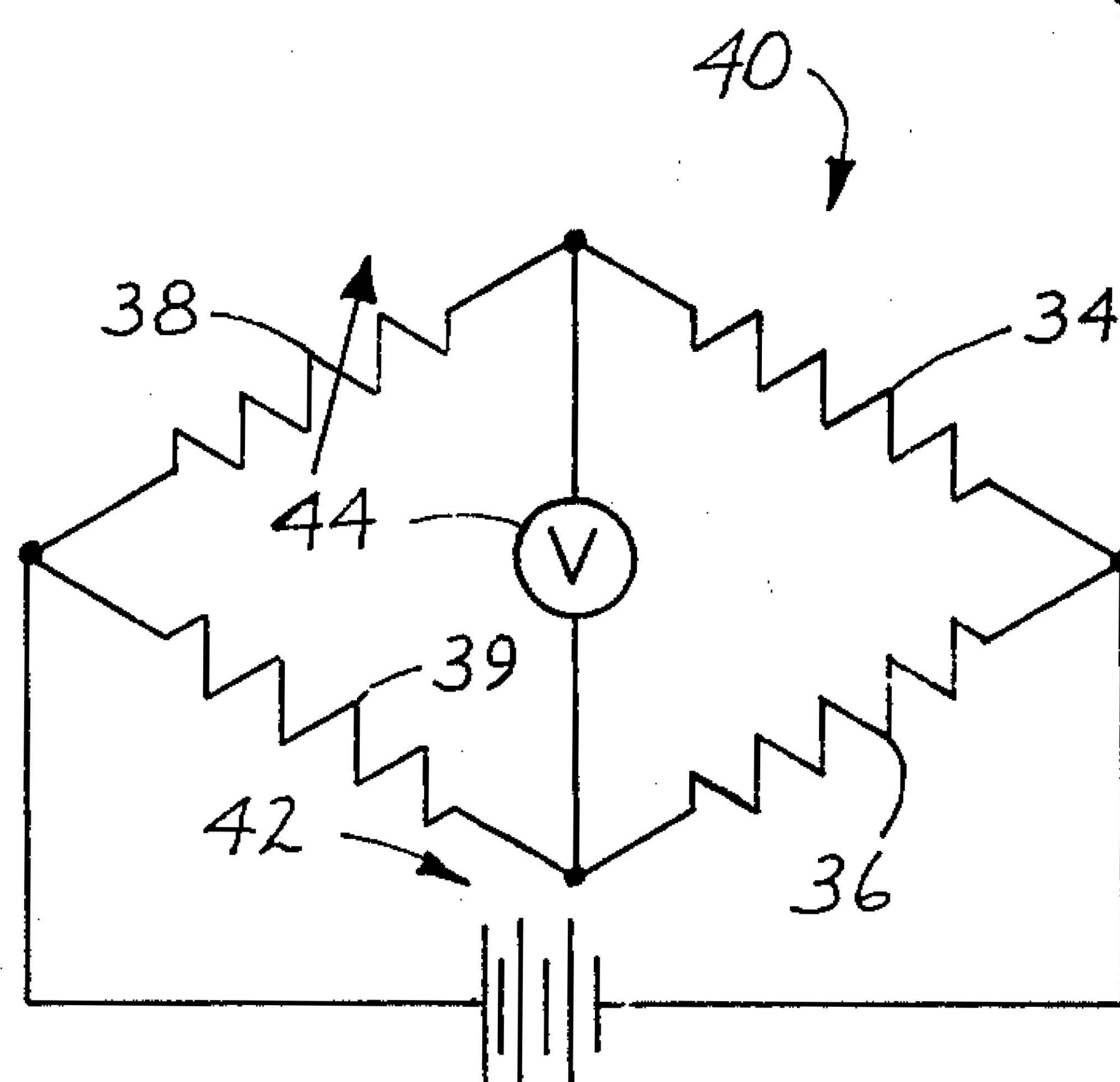


Fig. 3

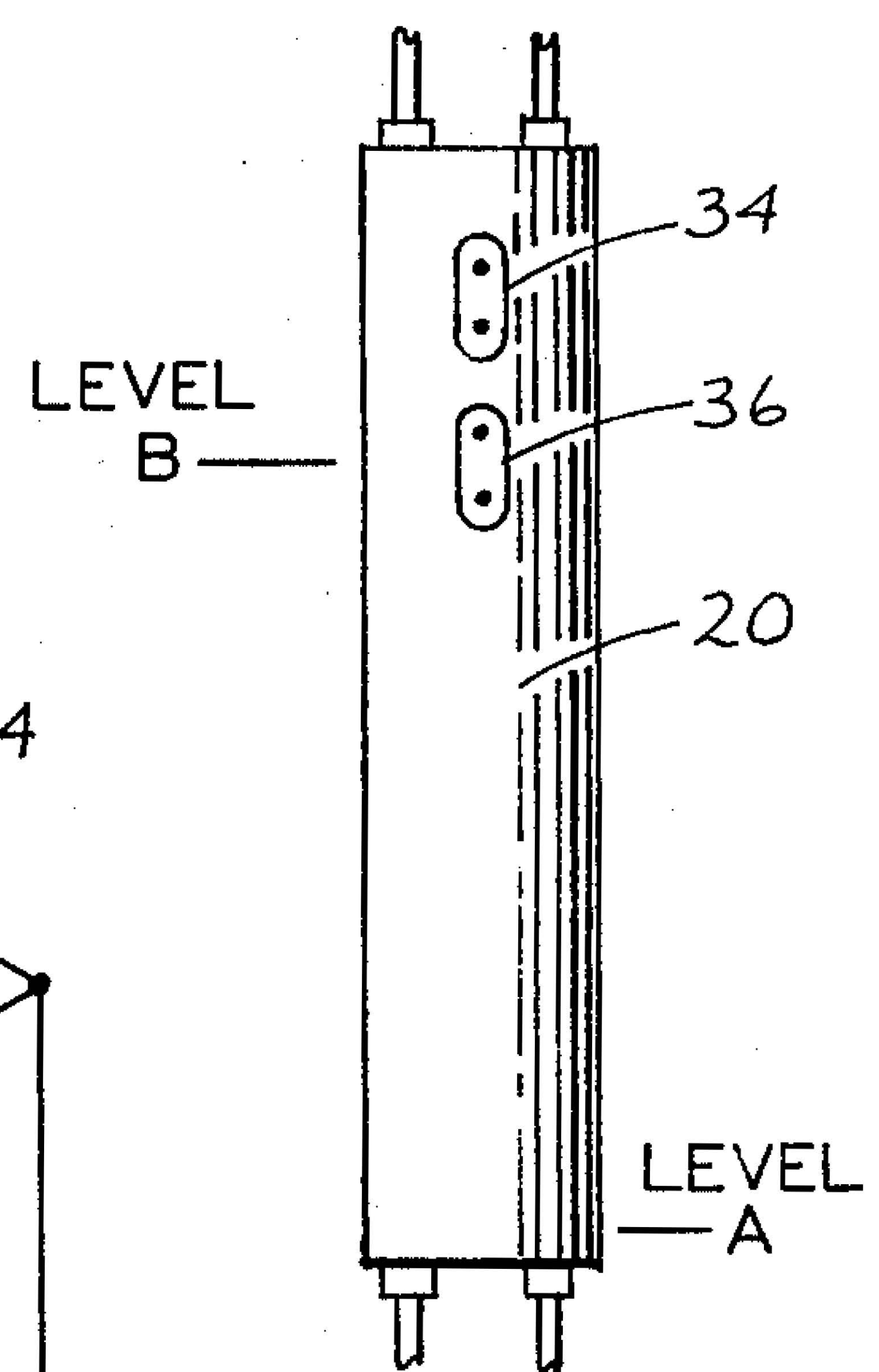


Fig. 4

HELIUM REFRIGERATOR

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention generally relates to cryogenic systems and more particularly to an improved helium refrigerator of the type including a series of counter-flow heat exchangers and having a temperature-sensing bridge circuit thermally coupled with the low-temperature counter-flow heat exchanger for detecting changes in the quantity of liquid helium present therewithin for continuously providing intelligence indicative of the reserve cooling capacity of the refrigerator.

2. Description of the Prior Art

Maser systems employed in tracking stations utilized in the tracking of bodies beyond the earth's atmosphere frequently include cryogenic devices capable of cooling maser systems to approximately 4.4° K. Often, a helium refrigerator is employed for this purpose. Helium refrigerators employed in the cooling of masers found in tracking stations normally are of a type characterized by multi-stage, counter-flow heat exchangers and are known to have reserve cooling capacities directly proportional to the level of the liquid helium found in the low-temperature heat exchanger of the final stage.

The reserve cooling capacity of helium refrigerators heretofore has been determined through techniques which require that known quantities of electrical energy be applied to the refrigerators, through heating elements mounted on the low-temperature heat exchangers thereof for periods sufficient to boil away the liquid helium reserves. Of course, such operations can be performed only during those periods when the tracking stations are quiescent. As a consequence, a great deal of difficulty is encountered in acquiring, in real-time, intelligence indicative of the reserve cooling capacity for an on-line or operational refrigerator.

It is therefore the general purpose of the instant invention to provide means for continuously providing intelligence indicative of the reserve cooling capacity of an on-line helium refrigerator.

OBJECTS AND SUMMARY OF THE INVENTION

Is an object of the instant invention to provide an improved helium refrigerator.

It is another object to provide in a helium refrigerator means for continuously providing a signal indicative of the cooling capacity of the refrigerator.

It is another object to provide in a helium refrigerator an electrical circuit connected with the low-temperature heat exchanger for providing intelligence indicative of changes of temperature in the heat exchanger, whereby the reserve cooling capacity of the refrigerator readily can be determined during periods when the refrigerator is in an operational mode.

These and other objects and advantages are achieved through the use of a temperature sensing bridge circuit thermally coupled with the low-temperature heat exchanger of selected helium refrigerators for continuously providing an electrical signal indicative of the

change in temperatures within the heat exchanger, as will become more readily apparent by reference to the following description and claims in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view illustrating a helium refrigerator including temperature sensing means for providing a continuous indication of the reserve cooling capacity of the refrigerator.

FIG. 2 is an elevational view of a low-temperature heat exchanger employed in the refrigerator shown in FIG. 1, illustrating a pair of electrical resistors thermally coupled with the heat exchanger.

FIG. 3 is a schematic view illustrating a bridge circuit within which the resistors shown in FIG. 2 are connected for providing intelligence indicative of temperature changes within the heat exchanger.

FIG. 4 is an elevational view illustrating alternate positions of levels of liquid helium with a heat exchanger during periods of operation.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings wherein like reference characters designate like or corresponding parts throughout the several views there is shown in FIG. 1 a helium refrigerator, generally designated 10, which embodies the principles of the instant invention.

The helium refrigerator 10, as shown, is of a type frequently employed in cooling a two-stage coaxial expansion engine, generally designated 12, provided within a maser system not shown. Since the maser system forms no part of the instant invention a detailed description thereof is omitted in the interest of brevity. However, it is to be understood that the helium refrigerator has utility separate and apart from the cooling of masers. As shown, the helium refrigerator 10 includes a Joule-Thomson circuit, generally designated 14. The circuit 14 includes a first stage counter-flow heat exchanger 16, a second stage counter-flow heat exchanger 18, and a final, low-temperature counter-flow heat exchanger 20. These heat exchangers are of a known design and form no specific part of the instant invention.

The heat exchanger 16 is connected with a compressor circuit 22 through suitable tubing 24. The heat exchanger 16 reduces the temperature of the refrigerant helium delivered thereto and conducted therethrough from ambient temperatures to 60° K. (Kelvin). The thus cooled gas is then passed through a coil, designated 26, circumscribing a first stage of the engine 12 where a cooling function is performed. The gas is then delivered to the second stage heat exchanger 18 wherein the temperature of the gas is reduced from 60° K. to 15° K. and thereafter delivered through a coil 28 circumscribing the second stage of the engine 12 where a further cooling function is performed. From the coil 28, the gas is delivered to the low-temperature heat exchanger 20 at which the temperature of the gas is reduced from 15° K. to 4.4° K.

While the structure of heat exchangers is well known and a detailed description of the heat exchangers 16, 18 and 20 is omitted in the interest of brevity, it is to be understood that these heat exchangers include a pair of adjacent tubes which serve to conduct refrigerant in

opposite directions therethrough. The heat exchangers are encased in a thermally conductive jacket 32.

As is well understood by those familiar with multi-stage helium refrigerators, the maximum reserve cooling capacity for a given refrigerator exists when the low-temperature heat exchanger is substantially filled with helium in its liquid stage. Conversely, the reserve cooling capacity for the refrigerator is minimized once the liquid has been boiled out of the low-temperature heat exchanger.

It has been discovered that it is possible to monitor, both continuously and accurately, the reserve cooling capacity of a refrigerator, even during those periods in which the refrigerator is on-line. This is achieved simply by mounting a pair of temperature sensitive resistors, designated 34 and 36, on the jacket 32 of the low-temperature heat exchanger 20 and connecting the resistors 34 and 36 in a first pair of arms of a temperature sensing bridge circuit, generally designated 40, FIG. 3. Within the other pair of arms of the bridge circuit 40 there is connected a resistor 38, having a variable resistance, to be employed in balancing the circuit 40 for purposes which will hereinafter be more fully explained, and a resistor 39, having a fixed resistance for purpose well understood by those familiar with the design and operation of bridge circuits.

The resistors 34 and 36 have a coefficient of thermal resistance such that as the resistance thereof varies in a manner which is inversely proportional to changes in temperature occurring within the heat exchanger 20. As a practical matter, the resistors 34 and 36 are $\frac{1}{2}$ watt, 50 ohm. carbon resistors which are commercially available and have a logarithmic temperature coefficient of resistance, such that small changes in temperature can readily be detected.

As illustrated in the drawings, the resistors 34 and 36 are mounted near the high temperature end of the heat exchanger 20, in close spatial relationship. Thus, the greatest temperature differential which can be detected by the bridge circuit 40 exists when the liquid helium within the heat exchanger rises to a level, designated Level B, FIG. 4, directly opposite the lowermost resistor 36, so that this resistor is caused to be cooled to its lowest possible temperature. Similarly, the minimum temperature differential which can be detected exists when the level of the liquid helium drops to its lowest possible level, designated Level A, within the heat exchanger 20 so that the temperatures of the resistors 34 and 36 are substantially the same. Hence, it is possible to continuously monitor the reserve cooling capacity of the refrigerator simply by detecting differences in the voltage drops occurring across the resistors 34 and 36 of the temperature sensing circuit 40. In practice, the resistance of resistor 38 is varied to achieve a balancing of the bridge circuit 40, prior to a placing of the refrigerator 10 on-line.

As a practical matter, a suitable D.C. power source, generally designated 42, is connected across the bridge circuit and serves to establish flow of electrical current therethrough in a manner well understood by those familiar with such circuits. Additionally, a volt meter 44, preferably a five-place digital volt meter, is connected across the bridge and employed for detecting differences in the voltage drops as they occur across the resistors 34 and 36, also in a manner well understood by those familiar with bridge circuits. The detected differences in the voltage drops are converted to electrical

signals, by any suitable means, not shown, and transmitted through a suitable transmission circuit, also not shown, to a monitoring station remotely related to the refrigerator 10.

OPERATION

It is believed that in view of the foregoing description, the operation of the device will readily be understood and it will be briefly reviewed at this point.

Calibration of the bridge circuit is performed preparatory to placing the refrigerator 10 on-line. To achieve this result, the liquid helium within the low-temperature heat exchanger 20 is substantially boiled off so that the level of the liquid is at a level corresponding to the level indicated Level A in FIG. 4. When the level of the liquid is at Level A, the temperature of the resistors 34 and 36 is substantially the same, due to their remote relationship with the level of the liquid helium. The variable resistor 38 is now adjusted so that the voltage dropped across the resistors 34 and 36 is equalized so that the reading taken at the volt meter 44 indicates a balanced condition for the bridge and a corresponding zero reserve cooling capacity for the refrigerator 10.

The refrigerator 10 is then placed on-line and caused to cool sufficiently for causing an accumulation of liquid helium to occur in the low-temperature heat exchanger 20. As an accumulation of liquid helium occurs, the level of the liquid helium rises toward the lowermost resistor 36 causing the electrical resistance of that resistor to increase. As the liquid approaches a level opposite the resistor 36, designated Level B, FIG. 4, the temperature of the resistor is dropped to approximately 4.4° K., while the temperature of the resistor 34 remains at substantially 15° K. due to the warming effect of the gases being introduced into the heat exchanger 20 as it passes from the coil 28. At this instant, the detected differences in the voltage drop occurring across the resistances of the resistors 34 and 36 is maximized indicating that the liquid helium reserve is maximized. Consequently, the maximized differences in voltage drops detected by the volt meter 44 serves to indicate that a maximum reserve cooling capacity for the refrigerator now exists. The reading taken at the volt meter 44 preferably is converted to electrical intelligence and transmitted through suitable electrical circuits to remote monitoring stations, whereby a real-time monitoring of the reserve cooling capacity of the refrigerator 10 is facilitated.

In view of the foregoing, it should readily be apparent that the refrigerator 10 which embodies the principles of the instant invention provides a practical solution to the perplexing problem of facilitating a continuous monitoring of the reserve cooling capacity of a given cryogenic refrigerator, while the refrigerator remains operational, all without introducing significant thermal energy into the system.

Although the invention has been shown and described in what is conceived to be the most practical and preferred embodiment, it is recognized that departures may be made therefrom within the scope of the invention, which is not to be limited to the illustrative details disclosed.

What is claimed is:

1. In combination with a helium refrigerator of the type including a low-temperature counter-flow heat exchanger, adapted to be substantially filled with helium

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in a gaseous state as well as in a liquid state, encased in a relatively thin external jacket formed of thermally conductive material and having a maximum reserve cooling capacity when the heat exchanger is substantially filled with liquid helium and a minimum reserve cooling capacity when the heat exchanger is substantially filled with helium in a gaseous state, means for providing a continuous indication of the reserve cooling capacity of said refrigerator, including:

- A. a pair of mutually spaced electrical resistors mounted in spaced relation on the external surface of said jacket, near the uppermost end thereof, each being characterized by a logarithmic coefficient of resistance inversely proportional to temperature; and

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B. circuit means for continuously providing intelligence indicative of temperature induced changes in the differential in the electrical conductivity of said pair of resistors including, means connecting said pair of resistors in electrical parallelism within a common electrical bridge circuit, means for simultaneously applying a common voltage across said resistors, and means including a voltmeter connected between said resistors for comparing temperature induced changes in voltage drops across the resistors of said pair.

2. The improvement of claim 1 wherein each of said electrical resistance means comprises a carbon resistor characterized by a maximum resistance at 4.4° K.

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