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Peterson

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[54] **PROPORTIONATE FLOW CRYOSTAT**

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[52] **U.S. Cl.** **62/56,** 62/514

[51] **Int. Cl.** **F25b 19/00**

[58] **Field of Search** 62/514, 56

[56] **References Cited**

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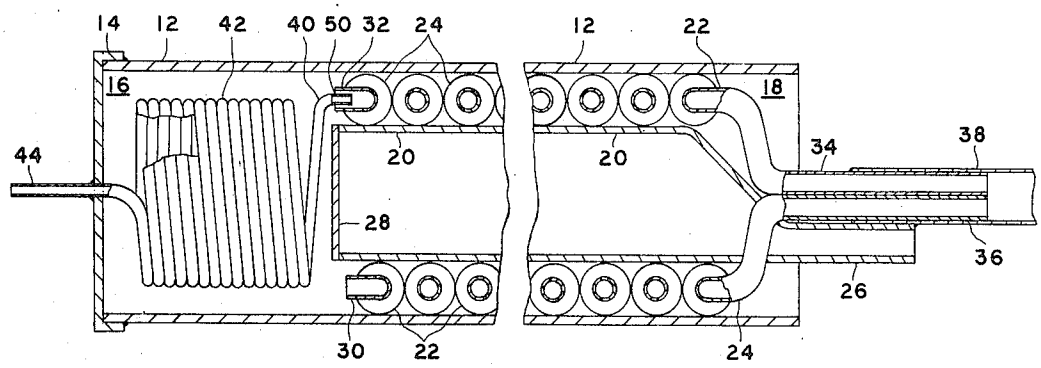
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[57] **ABSTRACT**

Disclosed is a proportionate flow cryostat for remotely cooling an associated object without being physically connected thereto. The invention herein described was made in the course of or under a contract, or subcontract thereunder, with the Department of the Navy.

10 Claims, 2 Drawing Figures



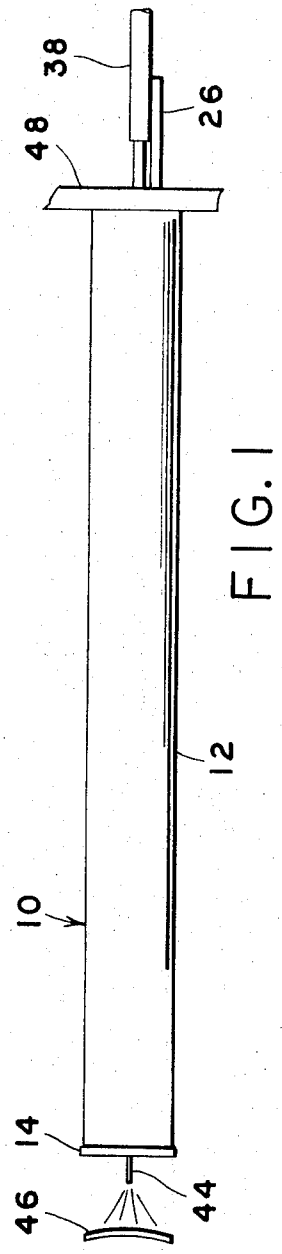

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FIG. 1

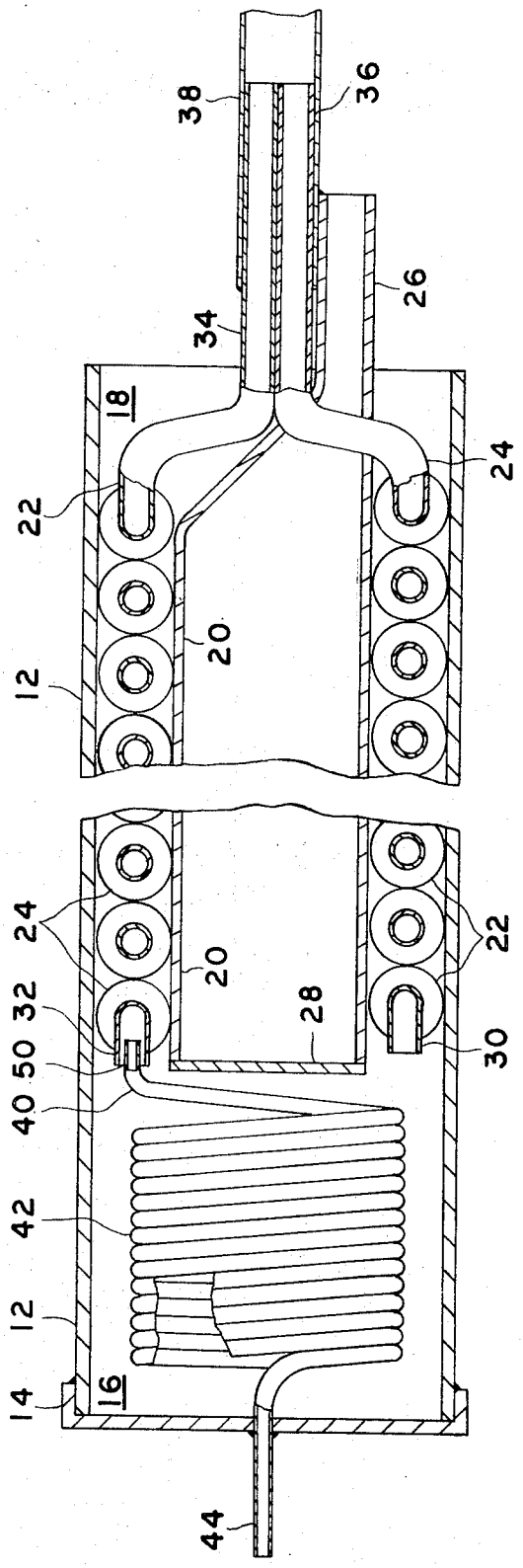

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FIG. 2

PROPORTIONATE FLOW CRYOSTAT

BACKGROUND OF THE INVENTION

Joule-Thomson effect cooling devices, commonly referred to as cryostats, are well known in the art and are generally employed to produce the extremely low temperatures required to maintain radiation sensing devices at cryogenic temperature levels. Examples of conventional Joule-Thomson effect cryostats are provided in U.S. Pat. Nos. 2,991,633, 3,095,711, 3,353,371, 3,415,078 and 3,431,750.

While a great diversity of cryostats have been developed, it has generally been required that the object or component to be cooled be in intimate contact with the cryostat. This contact can in many instances restrict the proper operation of the object to be cooled. For example, the flexible connections between a conventional cryostat and an infrared detector mounted upon a two axis gimballed platform will invariably hinder the free movement of the gimballed platform due to the connections' finite resistance to bending and flexing.

In addition, conventional cryostats, in order to achieve rapid initial cool-down, require excessively large coolant flows and/or sophisticated coolant valving and control mechanisms Further, the backpressure developed in conventional cryostats, that is the pressure within the cold end of the cryostat housing, tends to reduce the efficiency of the cryostat and its maximum cryogenic temperature.

SUMMARY OF THE INVENTION

The invention is directed to a cryostat in which the flow is proportioned between a component cooling stage and a regenerative stage or stages. The component cooling stage in which a coolant is expanded to ambient pressure, directs a proportioned amount of coolant, in the form of a spray, against the component to be cooled.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic plan view of the proportioned flow cryostat of the present invention.

FIG. 2 is an enlarged sectional view of the cryostat of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As illustrated in FIGS. 1 and 2, the proportioned flow cryostat 10 includes a hollow, generally cylindrical, cryostat housing 12 closed at one end by a generally cupshaped end cap 14. The housing and end cap 14, made of a material such as stainless steel, combine to form a tubular chamber having a closed end 16 and an open end 18.

Co-axially disposed with the housing 12 is a generally cylindrical mandrel 20 around which are alternately wound, finned tube, regenerative heat exchangers 22 and 24. The mandrel 20 has a necked down projection 26 at the open end 18 of the housing 12. The closed end 28 of the mandrel 20 terminates a short distance from the closed end 16 of the housing 12 such that an opening remains between the closed end 28 of the mandrel 20 and the end cap 14 of the housing 12.

Both the heat exchangers 22 and 24 terminate near the closed end 28 of the mandrel 20 at outlets 30 and 32 respectively. Heat exchanger inlets 34 and 36 for heat exchangers 22 and 24 project outward from the

open end 18 of the housing 12 near the axis thereof. A coolant inlet 38 is disposed around heat exchanger inlets 34 and 36 to deliver coolant thereto from a high pressure coolant source (not shown). Gases having a positive Joule-Thomson coefficient, such as nitrogen, hydrogen, helium, oxygen, argon, krypton, and xenon, under pressures up to 8,000 psi, are examples of suitable coolants.

As clearly shown in FIG. 2, the outlet 30 of regenerative heat exchanger 22 discharges coolant into the closed end 16 of the housing. The outlet 32 of regenerative heat exchanger 24 discharges a portion of its coolant flow into the inlet 40 of a component cooling nozzle 42 which extends into the outlet 32. The component cooling nozzle 42 comprises a plain tube, helical coil having an outlet 44 which extends through the end cap 14 of the housing 12. The coolant from the component coolant nozzle outlet 44 is directed against the component to be cooled such as the detector 46. A mounting flange 48 may be provided at the open end of the housing 12 to facilitate positioning and mounting of the cryostat 10 with respect to the detector 46.

In operation, gas, such as nitrogen, is supplied at high pressure to the coolant inlet 38 for distribution to the regenerative heat exchanger inlets 34 and 36. The high pressure nitrogen gas is expanded through these heat exchangers 22 and 24 which effects initial cooling thereof. The initially cooled nitrogen from the heat exchanger outlet 30 and that portion of the nitrogen from the outlet 32 which does not enter the component cooling nozzle inlet 40 passes over the component cooling nozzle 42 and then regeneratively cools the heat exchangers 22 and 24 as the nitrogen flows between the mandrel 20 and housing 12 and finally exits through the open end 18 of the housing 12. That portion of the nitrogen from the outlet 32 which enters the nozzle inlet 40 is further expanded and cooled in the component cooling nozzle 42 both from the expansion thereof and from the effects of the regenerative coolant passing thereover. The nitrogen exits from the outlet 44 in the form of a partially liquified nitrogen spray at a temperature as low as −196° C.

The component cooling nozzle inlet 40 is inserted, but not otherwise fastened, into the regenerative heat exchanger outlet 32. An annular space 50 is formed between the outside diameter of the inlet 40 and the inside diameter of the outlet 32. The resistance to flow through a channel such as this is proportional to the length and cross sectional area of the channel, thus, since the depth of insertion of the inlet 40 into the outlet 32 and the diameter of 32 and 40 can easily be varied, the proportion of flow of coolant between the annular nozzle 50 and the inlet 40 can easily be controlled in this manner or by varying the overall length of tubing in the component coolant nozzle 42. By either method any desired amount of coolant can be proportioned to the component to be cooled. There is buildup of backpressure at the closed end 16 of the housing 12. This backpressure in conventional cryostats causes the temperature of the expanded coolant to be higher than if it were expanded to room ambient pressure since the liquid temperature of a gas is proportional to its pressure. Conventionally, the component to be cooled is mounted directly to the end cap 14 of a cryostat. Thus, it experiences the temperature consistent with the backpressure at the closed end 16. This backpressure effect is eliminated in the present invention by further

expanding the coolant from the component cooling nozzle outlet **44** to ambient pressure and thus this enables the coldest possible temperature to be achieved at the coolant nozzle outlet **44**.

While two regenerative heat exchanger stages have been illustrated, only one stage, namely stage **24**, is required for the cryostat to function. The second stage **22** does, however, significantly improve efficiency and increase cooling capacity. It should be noted that a single gas supply is utilized to feed the dual wound heat exchangers. No moving parts or active valves are required to route and/or proportion flow between the cooling and regenerative stages.

The cryostat of the present invention is particularly adapted for use to remotely cool a component such as an infrared detector which must be able to move relative to the cryostat. An infrared detector mounted upon a two axis gimballed platform can easily be cooled by an aft positioned cryostat suitably mounted to a stationary structure without any physical connection to the detector. The spray from the detector will provide the cooling yet leave the detector free to move in any direction permitted by its own gimballing system.

Other applications of the cryostat include possible utilization in medicine and particularly cryosurgery. The cryostat can provide liquid nitrogen within seconds using only a high pressure supply of nitrogen that has an essentially infinite shelf life. This liquid nitrogen, for example, can be directed at a wart to saturate it and thus remove it in a clean, efficient, and inexpensive manner. Liquified gases can also be used in more complex surgery such as tonsilectomies, etc. The cryostat eliminates the need for the storage of liquid nitrogen in vacuum insulated flasks which have a relatively short storage life. It also eliminates the insulated supply lines and special cryogenic valves associated therewith. The cryostat of the present invention generates the liquid at the location where it is to be utilized and thus makes its utilization much more practical. It is also especially adaptable to miniaturization.

While specific embodiments of the invention have been illustrated and described, it is to be understood that these embodiments are provided by way of example only and that the invention is not to be construed as being limited thereto, but only by the proper scope of the following claims.

What I claim is:

1. A cryostat comprising:

a cryostat housing having a closed end and an open end;

a mandrel coaxially disposed within said cryostat housing;

at least one regenerative heat exchanger wound around said mandrel within said cryostat housing to receive and partially expand a high pressure coolant, said at least one regenerative heat exchanger having an outlet to discharge partially cooled and expanded coolant at the closed end of said cryostat housing; and

a component cooling nozzle disposed within the closed end of said cryostat housing and operably associated with one of said at least one regenerative heat exchanger to receive a proportioned amount of partially cooled and expanded coolant therefrom and to further expand and cool the coolant, the remainder of the partially cooled and expanded coolant from the one regenerative heat exchanger outlet and all of the coolant from any other regenerative heat exchanger outlets being discharged into the closed end of the cryostat housing to cool the component cooling nozzle and the at least one regenerative heat exchanger before passing out of the open end of said cryostat housing, said component cooling nozzle having an outlet extending out of said cryostat housing to direct a flow of cooled coolant against a component to be cooled.

2. A cryostat comprising:

a cryostat housing having a closed end and an open end;

a mandrel coaxially disposed within said cryostat housing, said mandrel and said cryostat defining an annular space therebetween and a chamber at the closed end of said housing;

first and second regenerative heat exchangers alternately wound around said mandrel and disposed in the annular space between said mandrel and said housing, said first and second regenerative heat exchangers disposed to receive and partially expand a high pressure coolant and discharge the partially expanded coolant at the chamber at the closed end of said housing; and

a component cooling nozzle disposed within the chamber at the closed end of said housing to receive and further expand a proportioned flow of partially expanded coolant from said first heat exchanger and to discharge said coolant exterior of said housing, the remainder of the partially expanded coolant from said first heat exchanger and the entire flow of said second heat exchanger discharged into the chamber at the closed end of said housing to regeneratively cool the component cooling nozzle and the first and second heat exchangers before passing out the open end of said cryostat housing.

3. The cryostat of claim **2** wherein said cryostat housing and said mandrel are both generally cylindrical.

4. The cryostat of claim **3** wherein said first and second regenerative heat exchangers are both finned tube, coiled heat exchangers.

5. The cryostat of claim **4** wherein said component cooling nozzle is a plain coiled tube.

6. The cryostat of claim **2** and in addition a source of high pressure coolant operably associated with said first and second regenerative heat exchangers to provide coolant thereto.

7. The cryostat of claim **6** wherein said high pressure coolant is selected from the group of nitrogen, hydrogen, helium, oxygen, argon, krypton, and xenon.

8. The cryostat of claim **6** wherein said high pressure coolant is nitrogen under a pressure of up to 8,000 psi.

9. A method of generating a flow of partially liquified coolant comprising the steps of:

partially expanding a high pressure coolant in a first heat exchanger;

further expanding a portion of the partially expanded coolant from the first heat exchanger in a second heat exchanger to produce a partially liquified coolant flow; and

regeneratively cooling the first and second heat exchangers with that portion of the partially expanded coolant from the first heat exchanger

which is not further expanded in the second heat exchanger.

10. A method of cooling a high pressure coolant comprising the steps of:

partially expanding the high pressure coolant in a first heat exchanger;

proportioning the partially expanded coolant from the first heat exchanger into a first portion and a second portion;

further expanding the first portion of the partially expanded coolant in a second heat exchanger into a partially liquified coolant flow; and

regeneratively cooling the first and second heat exchangers with the second portion of the partially expanded coolant.

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