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COOLING APPARATUS

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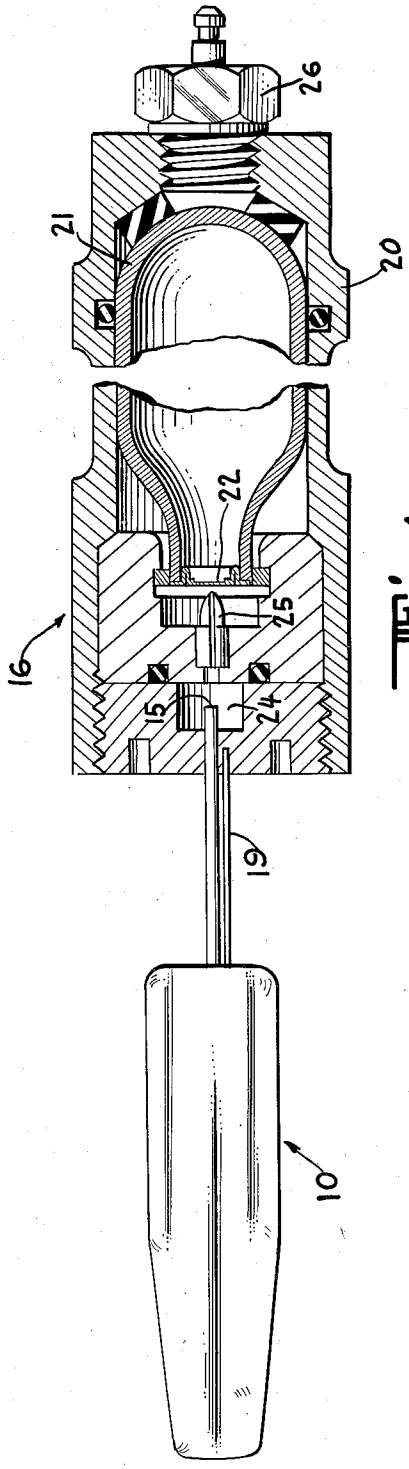


Fig. 1

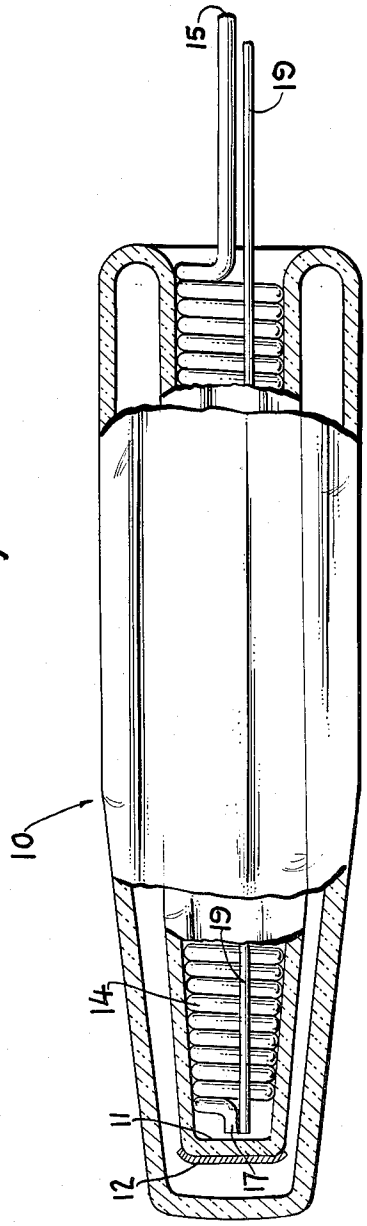


Fig. 2

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COOLING APPARATUS

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The present invention relates to refrigeration, and, more particularly, to apparatus for maintaining an element at a much lower temperature than the ambient temperature.

It has been found that certain electrical components such as photocells, particularly infrared cells, can be operated more efficiently at a temperature of about —100° F. or lower, because at such temperatures the sensitivity of the cell is increased and the noise to signal ratio of the cell is greatly decreased.

It has thus been proposed to maintain such cells at a low temperature by expanding a compressed gaseous medium such as air or nitrogen in the vicinity of the light sensitive element of the cell whereby the medium is refrigerated due to the Joule-Thomson effect in conjunction with counterflow heat exchange. More specifically, such apparatus included a coil of tubing through which the compressed gas was directed and the expanded cool medium was caused to counter-flow in heat exchange relation to precool the compressed gas.

For aircraft installations or otherwise, where space and weight are important factors, the use of air or nitrogen was not practical because either a relatively heavy compressed gas storage receptacle or a gas compressor system was required as the source of the medium. Also, the compressed gaseous medium must be completely dry to prevent the formation of water ice which might block the flow of the medium, wherefore further apparatus had to be added to dry the gaseous medium.

In order to reduce the weight of the apparatus, it was suggested to use liquefied carbon dioxide because of its greater storage density and its greater cooling capacity on a mass basis than air or nitrogen. When this was tried, one of two difficulties had to be contended with.

If the carbon dioxide is supplied at an economical rate just sufficient to maintain the element at a temperature of about —100° F., only a small supply of carbon dioxide is required but the bore of the tubing utilized must be of such a small dimension that the carbon dioxide, in expanding at the outlet opening of the tubing and returning to precool the carbon dioxide in the coil, causes carbon dioxide snow or ice to form inside the tubing just upstream of the opening and to block the tubing whereby flow ceases. Thus, after the cell element had been cooled, it began to warm up again before the solid carbon dioxide in the tubing thawed to restart the flow of liquid carbon dioxide. The result was that the cell element warmed up intermittently and functioned erratically, thereby defeating the purpose of the cooling apparatus.

On the other hand, if the bore of the tubing is of a larger dimension which is not subject to freeze-ups, the flow rate becomes of a magnitude whereby a large supply of carbon dioxide stored in a relatively heavy receptacle must be available to maintain the cell element cool over a substantial period of time. This is objectionable because of the weight and space factor involved.

If the precooling step were omitted to avoid freeze-ups, the cooling efficiency of the carbon dioxide would be lowered to such an extent that a somewhat greater mass of carbon dioxide would be required to accomplish its intended purpose.

Accordingly, an object of the present invention is to

provide apparatus for cooling elements to a much lower temperature than the ambient temperature which overcomes the foregoing difficulties and objections.

Another object is to provide such apparatus which maintains the element at a substantially constant temperature.

Another object is to provide apparatus for controlling the flow of an expandable fluid material capable of being solidified.

A further object is to accomplish the foregoing in a simple, practical and economical manner and with a relatively small mass of expandable fluid material and with lightweight apparatus.

Other and further objects of the invention will be obvious upon an understanding of the illustrative embodiment about to be described, or will be indicated in the appended claims, and various advantages not referred to herein will occur to one skilled in the art upon employment of the invention in practice.

In accordance with the present invention, the foregoing objects are accomplished by discharging an expandable fluid material such as high pressure carbon dioxide, which preferably has been precooled, into a zone adjacent an element to be cooled to expand the carbon dioxide and form sufficient carbon dioxide snow at the point of discharge of the carbon dioxide into the zone to cause the discharge of carbon dioxide to cease, and supplying heat to the carbon dioxide snow to sublime the same and to re-establish discharge of the carbon dioxide.

A preferred embodiment of the invention has been chosen for purposes of illustration and description, and is shown in the accompanying drawing, forming a part of the specification, wherein:

FIG. 1 is a view illustrating the cell in elevation and the source of carbon dioxide in section with a portion broken away.

FIG. 2 is an enlarged elevational view, partly in section, illustrating the cell equipped with cooling apparatus in accordance with the present invention.

Referring to the drawing in detail, there is shown, by way of example, an infrared cell which includes a tubular double-wall evacuated glass envelope such as a Dewar tube **10** having an inner end wall **11**, and a light sensitive element **12** within the envelope adjacent the inner side of the end wall. Other structural details of the cell are not shown and the manner in which the cell functions need not be described because such information is not necessary to understand the manner in which the element is to be cooled by the apparatus about to be described.

The cooling apparatus includes heat exchange flow conducting means such as a helical coil **14** formed of capillary tubing or other tubing suitably dimensioned which is mounted in the well of the envelope. The coil has an inlet **15** at its outer end which is connected to a source **16** of high pressure expandable fluid material such as liquefied carbon dioxide, and has an outlet **17** at its inner end for directing the carbon dioxide adjacent the end wall **11** where the element **12** is located.

When cold high pressure liquefied and/or gaseous carbon dioxide or the like is expanded at the outlet **17**, a Joule-Thomson effect is obtained to provide a mixture of carbon dioxide snow and cold gaseous carbon dioxide. The carbon dioxide snow has an extremely low temperature relative to the ambient temperature and is capable of cooling the element **12** to about —109° F. The cold gaseous carbon dioxide of the mixture and that formed when carbon dioxide sublimes, exits to the atmosphere in regenerative counter-flow heat exchange relationship with the incoming carbon dioxide passing through the

coil **14** to precool the latter before discharge through the outlet **17**. Such precooling has the advantage that the mixture which is formed as it leaves the outlet has a high snow to gas ratio, whereby an adequate supply of snow is provided for maintaining the element at a temperature of about —109° F. For example, if the carbon dioxide, prior to expansion, is precooled to about —109° F., about 72% of the carbon dioxide by weight is converted into snow.

However, such precooling also causes the carbon dioxide to be solidified at or just upstream of the outlet **17** after the aforementioned low temperature condition has been established in the zone or chamber where the outlet is located, thereby blocking the passageway of the coil and stopping the flow of carbon dioxide. This in itself is not objectionable so long as there is an adequate amount of snow in the chamber to maintain element **12** at the desired low temperature.

Thus, in accordance with the present invention, an adequate supply of snow is assured by first converting a large percentage of carbon dioxide to snow and then thawing the solid carbon dioxide snow at the outlet **17** or in the coil **14** to re-establish flow through the coil. This is accomplished by supplying heat to the coil adjacent the outlet, for example, by a heat conductive element **19**, such as a copper wire having its inner end bonded to the outlet end of the coil in heat conducting relationship therewith and having its outer end extending outwardly of the well of the envelope and secured in heat conducting relationship to a heat source such as the structure **16** providing the carbon dioxide source.

The source **16** comprises a metallic casing **20**, a cartridge **21** having a closure **22** for confining carbon dioxide therein and being slidably mounted in the casing, an outlet chamber **24** with which the outer end **15** of the coil tubing communicates, and a discharge head including a conventional tubular or slotted pin **25** for establishing communication between the interior of the cartridge **21** and the outlet chamber **24**, whereby carbon dioxide is supplied from the cartridge to the coil.

Puncturing of the closure **22** may be effected by moving the cartridge towards the pin. This can be accomplished in a convenient manner, which lends itself to remote control, by providing an assembly **26** including an electrically ignitable charge of propellant adapted to drive the cartridge **21**, like a piston, towards the pin **25** with sufficient force to cause the pin to pierce the closure **22**.

As a specific example of practicing the present invention, apparatus was constructed having the dimensions about to be set forth.

The coil **14** consists of 54 inches of stainless steel hypodermic tubing having an outer diameter of .015 inch, an inner diameter of .003 inch and a wall thickness of .006 inch. The coil has a length of about 2 inches and an outer diameter of .188 inch.

The copper wire has a length of about 3 inches and a diameter of about .025 inch and is thermally bonded by soldering to the tubing at the orifice and to the end wall of the cartridge casing **20**.

The cartridge contains about .3 ounce of medical carbon dioxide having a pressure of about 850 p.s.i.a. at 70° F.

The coil and the wire were inserted into the well of an infrared photocell envelope and the photocell was connected in a detecting network in a conventional manner. The entire apparatus shown, with the cartridge filled, weighs only about eleven ounces and can be placed in a space having a length of about seven inches and a diameter of about one inch.

In operation, with the cartridge casing at an ambient temperature of about 72° F., the cartridge closure was punctured to release the carbon dioxide, and the carbon dioxide was discharged from the outlet **17** and expanded into the space at the closed end of the well. After about one minute of discharge, the temperature of the element **12** was reduced to about —109° F. This temperature was maintained within an immeasurably small tolerance for one hour, eleven minutes and ten seconds, the contents of the cartridge being almost completely discharged at the end of that period.

During such discharge, the flow of carbon dioxide through the outlet ceased after sufficient snow was present near the element **12** to maintain the latter at about —109° F., and flow was re-established before any measurable rise in temperature of the element took place. Under such conditions of alternate freezing and thawing, the average flow rate of the carbon dioxide is about .004 ounce a minute.

The duration of effective cooling achieved by the above described apparatus is by far in excess of the minimum requirements of the applications for which this apparatus is intended.

The heat load conducted through the copper wire added only about 10% to the heat load of the photocell element, and provided automatic temperature stabilization for the photocell since it acts as an analogue to the photocell. That is, as the heat load on the photocell increases, the heat conducted through the copper wire increases correspondingly to cause the frozen carbon dioxide to thaw more frequently, thereby delivering the required additional refrigeration to the photocell.

While the present invention has been described in connection with cooling elements, it wil be understood that the freezing and thawing cycle can be utilized for other advantageous purposes, for example, to control the flow of another material.

By the term "expandable fluid material," as used herein and in the appended claims, is meant any fluid material which has a positive Joule-Thomson cooling effect and is capable of solidification at a given temperature and at a pressure either above or below atmospheric pressure. Examples of such materials are carbon dioxide, nitrous oxide, argon, nitrogen and refrigerants of the halogenated hydrocarbon type.

From the foregoing description, it will be seen that the present invention provides an extremely simple, efficient and reliable manner of cooling elements to a much lower temperature than the ambient temperature by means of light weight apparatus occupying a minimum of space.

As various changes may be made in the form, construction and arrangement of the parts herein, without departing from the spirit and scope of the invention and without sacrificing any of its advantages, it is to be understood that all matter herein is to be interpreted as illustrative and not in any limiting sense.

I claim:

1. In apparatus for maintaining an element at a much lower temperature than the ambient temperature, the combination of an element to be cooled, means providing a chamber having a wall adjacent said element, flow conducting means including capillary tubing having an inlet at one end adapted for connection to a source of high pressure expandable fluid material and having an outlet nozzle at its other end for directing the fluid material into said chamber in the vicinity of said wall and causing the same to expand and be at least partially converted to its solid phase and thereby cool said element, passageway means extending from said chamber to the atmosphere for causing expanded cold gaseous fluid material to flow in regenerative heat exchange relation with the incoming fluid material in said flow conducting tubing, and a heat conducting wire having one end at the zone in said chamber in heat conducting connection with said flow conducting means adjacent to where the fluid material is converted to its solid phase and having its other end disposed externally of said chamber whereby heat thereto is supplied thereto and is conducted to the solid phase material at said outlet nozzle.

2. Apparatus according to claim 1, including a mass

having a much higher temperature than said cooled element and being in heat conducting connection with the end of said wire disposed outwardly of said chamber.

3. In apparatus for maintaining an element at extremely low temperature relative to the ambient temperature, the combination of an element to be cooled, means providing a chamber having a wall adjacent said element, a cylindrical coil of capillary tubing having an inlet at one end adapted for connection to a source of high pressure expandable fluid material and having an outlet nozzle at its other end for directing the fluid material into said chamber adjacent said wall and causing the same to expand and be at least partially converted to its solid phase at said outlet and thereby cool said element, said coil having passageway means therein for causing expanded cold gaseous fluid material to flow in regenerative heat exchange relation with the incoming fluid material in said tubing, and a heat conducting wire extending through said passageway having one end bonded to said coil in heat conducting relation adjacent said

outlet nozzle and having its other end disposed outwardly of said coil whereby heat is supplied thereto and is conducted to the solid phase material at said outlet nozzle.

4. Apparatus according to claim 3, including a mass having a much higher temperature than said cooled element and being in heat conducting connection with the end of said wire disposed outwardly of said chamber.

References Cited in the file of this patent

UNITED STATES PATENTS

1,497,278	Josephson	June 10, 1924
1,515,119	Josephson	Nov. 11, 1924
1,516,437	Humpoletz	Nov. 18, 1924
1,525,095	Josephson	Feb. 3, 1925
1,556,734	Taylor	Oct. 13, 1925
1,625,712	Cremieu	Apr. 19, 1927
1,847,321	Wetmore	Mar. 1, 1932
1,876,915	Gordon	Sept. 13, 1932
2,261,808	Morris	Nov. 4, 1941
2,307,013	Batzle	Jan. 5, 1943