# United States Patent [19]

**Rein**

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[54] **UNDERWATER HEAT SINK**


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[52] **U.S. Cl.** .............................. **62/48,** 62/50, 62/52, 128/142.2, 128/203

[51] **Int. Cl.** .............................................. **F17c 11/00**

[58] **Field of Search** ...................... 62/48, 50, 51, 52; 128/142.2, 203


[56] **References Cited**

UNITED STATES PATENTS


| | | | |
|---|---|---|---|
| 2,322,617 | 6/1943 | Dayhuff | 62/48 |
| 3,366,107 | 1/1968 | Frantom | 128/142.2 |
| 3,386,458 | 6/1968 | Wasserman et al. | 128/142.2 X |
| 3,570,481 | 3/1971 | Woodberry, Jr. | 128/142.2 |
| 3,807,396 | 4/1975 | Fischel | 128/142 |



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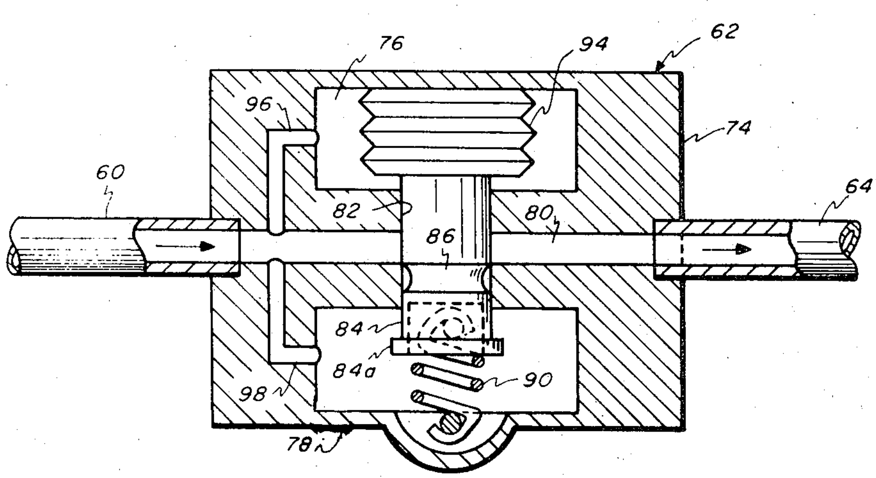
[57] **ABSTRACT**


A cryogenic heat sink is described in association with underwater breathing apparatus of the cryogenic oxygen supply type. The heat sink is characterized by utilization of oxygen absorbent material to generate a low pressure on a body of liquid oxygen, the low pressure being regulated by a pressure responsive valve, so that the liquid oxygen vaporizes to seek an equilibrium condition between vapor and liquid states at a single predetermined constant temperature.


**4 Claims, 2 Drawing Figures**



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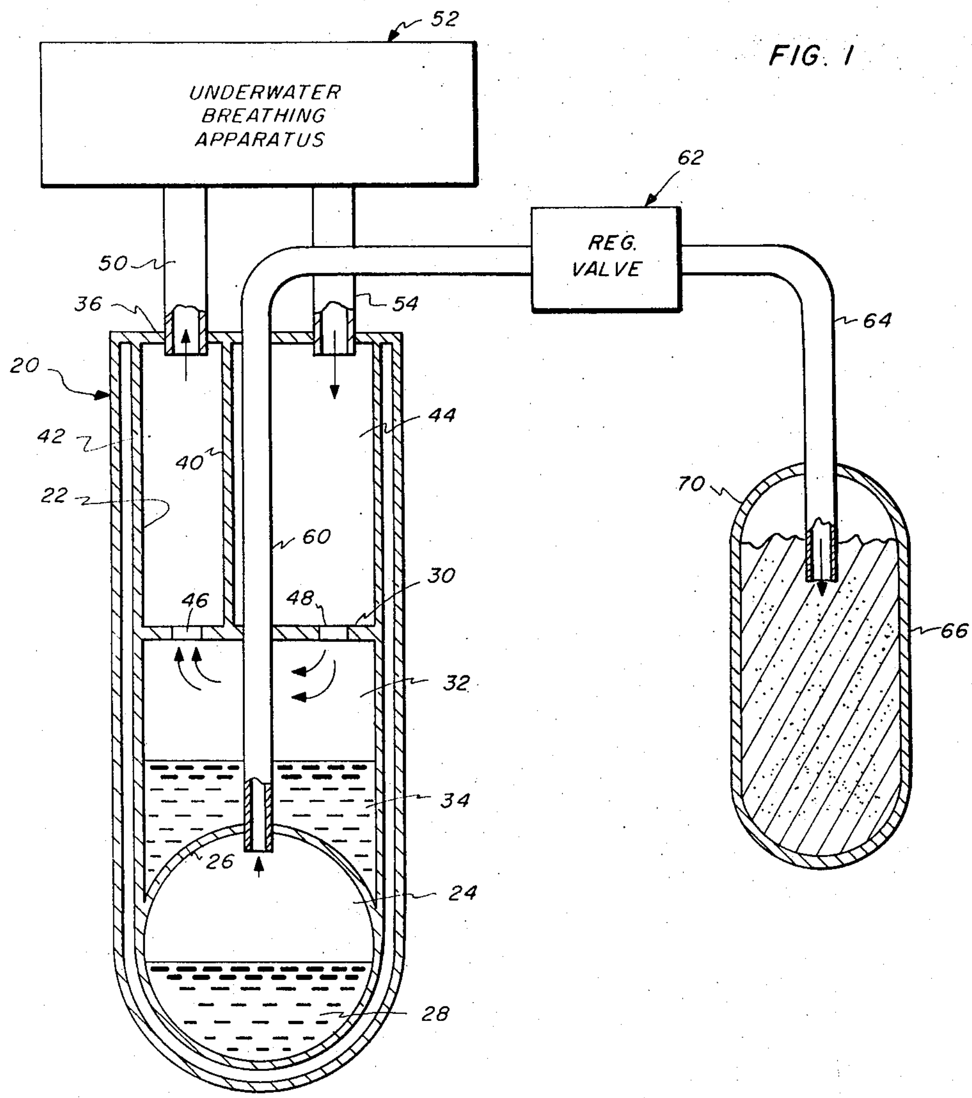


FIG. 1

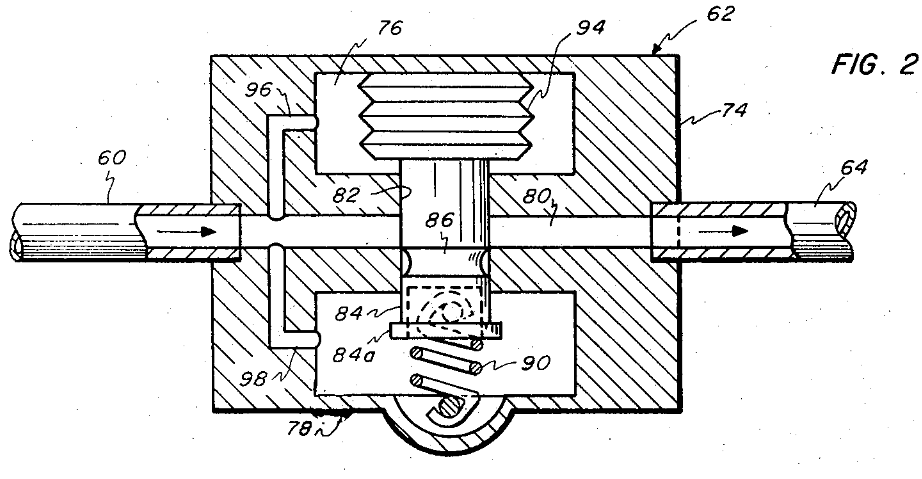


FIG. 2

# UNDERWATER HEAT SINK

## STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for Governmental purposes without the payment of any royalties thereon or therefor.

## FIELD OF THE INVENTION

This invention relates generally to underwater breathing apparatus of the type known as "cryogenic," in that the breathing gas is derived, in whole or part, from liquified gas, e.g., liquid air or liquid oxygen carried at very low temperatures in a reservoir. More particularly, the invention is directed to an underwater, cryogenic heat sink, in combination with such breathing apparatus, for maintaining a substantially constant low temperature circuit in the liquified reservoir, whereby a number of operational advantages can be achieved.

## DISCUSSION OF THE PRIOR ART

Among the virtues that are common to cryogenic diver's breathing apparatus, or life support systems, is the ability to carry a large quantity of oxygen, air, or other oxygen/gas mixture in liquid form at relatively low pressures, thereby avoiding the need for heavy, potentially dangerous, high pressure flasks carrying compressed gases. Typically, the known cryogenic diving apparatus carries a supply of liquid oxygen, air, or other mixture, in an insulated flask, or Dewar, and utilizes boil off therefrom for a breathing gas supply at a pressure only slightly different from the ambient water pressure at the particular depth at which the diver is working. A substantially constant predetermined pressure with respect to ambient pressure has been maintained in such systems by venting the excess boil off, through suitable pressure responsive valves, to the ambient water medium. Examples of these systems are found in U.S. Pat. No. 3,366,107 to R. L. Frantom, U.S. Pat. No. 3,570,481 to J. W. Woodberry, and U.S. Pat. No. 3,572,048 to R. H. Murphy. Because the water pressure and temperature conditions can vary considerably from point to point during a dive, and since the diver's oxygen consumption rate varies considerably with work and depth, the prior art systems have been calculated to permit boil-off from the liquified gas supply at the maximum rate possibly needed under the most severe circumstances, with no provision for controlling the rate of boil-off.

The result has been wasteful of the liquified gas supply, thereby shortening the duration of dive, and has prevented the achievement of a fully closed, bubble-free system. Obviously, conservation of the liquid breathing gas supply is logistically desirable, while a bubble-free system is advantageous for covert military operations, as well as to be free of the noise and reduced visibility often created by escaping bubbles.

Moreover, it is well understood that the partial pressure of oxygen that is required in a breathing gas mixture to properly sustain a diver must stay relatively constant as depths increase. The problem of regulating this partial pressure of the oxygen in a cryogenic system, as well as the previously mentioned disadvantages, can be eased considerably by maintaining the liquid oxygen reservoir at a predetermined temperature, e.g., −213°F, by extracting heat therefrom as necessary to accomplish this. Heretofore, no known apparatus has been available that could be easily carried by a diver as part of a self-contained breathing apparatus, would operate to maintain a selected low temperature in a liquid oxygen reservoir thereof irrespective of ambient pressure changes, and would do so without itself generating bubbles and requiring power consuming equipment such as pumps.



## SUMMARY OF THE INVENTION

The present invention aims to overcome the mentioned disadvantages or shortcomings of the prior art, as well as others, through the provision of a cryogenic heat sink that serves to maintain the temperature of a liquid oxygen or other liquified medium in a reservoir, at a predetermined temperature irrespective of ambient pressure changes.

With the foregoing in mind it is an important object of the invention to provide a cryogenic heat sink that is operable, in an underwater environment, in conjunction with a cryogenic breathing apparatus.

Another object is the provision of a cryogenic heat sink that is characterized as a closed system in that it utilizes evaporation from a body of liquified gas to extract heat from the matter to be cooled or temperature regulated, and an accumulator or adsorbing means for maintaining a predetermined reference pressure in the heat sink system.

Still another object is the provision, in an improved cryogenic breathing apparatus for underwater use, of a heat sink of the foregoing character that comprises a pressure responsive valve means between the body of liquified gas and a relatively low pressure zone in which the adsorbent material is disposed, and valve means being responsive only to the absolute pressure of the vapor over the liquified gas and operative to pass vapor to the low pressure zone whenever the absolute pressure of the vapor exceeds the pressure of equilibrium for a selected temperature to be maintained in the body of liquified gas and its vapor.

Other objects and many of the attendant advantages will be readily appreciated as the subject invention becomes better understood by reference to the following detailed description, when considered in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic illustration of cryogenic underwater heat sink apparatus embodying the invention; and

FIG. 2 is an enlarged sectional view of a regulating valve forming part of the apparatus of FIG. 1.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

A cryogenic heat sink embodying the invention is illustrated in the drawings in association with an underwater cryogenic breathing system of the type wherein gaseous oxygen for enriching the diver's breathing gas mixture is derived by evaporation from a supply of liquid oxygen.

Referring to FIG. 1, a container or tank **20** having thermally insulated walls **22**, conveniently in the nature of a Dewar flask, has a chamber **24** defined in the lower portion thereof by a heat conducting or exchanging wall **26**. Chamber **24** contains a quantity of liquified gas, liquid oxygen **28** in the present example, the purpose of which will be made apparent as this specification proceeds. Immediately above heat exchanging wall **26**, and below a wall **30**, is a chamber **32** in tank **20** that serves as a reservoir for containment of a quantity of liquified gas, liquid oxygen **34** in the present example.

Above wall **30**, and below an end closure wall **36**, the interior of tank **20** is divided by a heat exchanging wall **40** into chambers **42** and **44** which communicate with chamber **32** through openings **46** and **48**, respectively, in wall **30**. Chamber **42** also communicates, through a gas supply duct **50** with a diver's breathing apparatus **52**, while chamber **44** communicates with that apparatus through a gas return duct **54**.

The apparatus **52** may be of conventional construction, preferably of the type comprising means for conveying breathing gas to and from a diver's mouth, adsorption means for removing carbon dioxide and moisture from expired gas, a supply of relatively inert gas, such as helium, and suitable valve means for maintaining the breathing gas mixture in the apparatus at a pressure appropriate for breathing under the different ambient pressures existing at the depths to which the using diver descends. Additionally, the apparatus **52** may comprise other devices common to such apparatus such as breathing bag means for accommodating the changes in volume attendant respiration, oxygen content or partial pressure sensors, and the like. The apparatus **52** with which the invention is associated may be diver carried, may form part of a submersible vehicle, or may be part of an underwater habitat.

The upper part of liquid oxygen and vapor containing chamber **24** is connected to a duct **60** that extends upwardly through chambers **32** and **44** to the exterior of tank **20**. Chamber **24** is adapted to communicate, through duct **60**, a pressure regulating valve **62**, and a duct **64**, with a bed of oxygen adsorption material **66** contained in a pressure resistant tank **70**. Valve **62**, which will be discussed in more detail with reference to FIG. 2 and in the subsequent description of the mode of operation of the invention, serves to maintain a predetermined pressure in chamber **24**, irrespective of ambient pressures.

Oxygen adsorption material **66** may comprise any one of various well known and commercially available materials, such as activated charcoal. Of course, some materials are more efficient than others in performing the function of adsorption of oxygen (or absorption as the case may be), and one commercial product that has been found particularly good is that sold as a molecular sieve material by Union Carbide Corporation in the form of that company's Molecular Sieve Type 4A Pellets. Under proper temperature and pressure conditions, that material is capable of adsorbing approximately twenty pounds of oxygen for each hundred pounds of adsorption material. The amount of material **66** in tank **70** is preferably sufficient to adsorb all of the oxygen with which the chamber **24** is charged at the beginning of operation.

Referring now to FIG. **2**, valve **62** comprises a body **74** having chambers **76** and **78** disposed on opposite sides of a flow passage **80**. Passage **80**, which connects at one end with duct **60** and at the other end with duct **62**, is interrupted by a bore **82** extending from chamber **76** to chamber **78**. A valve member **84** is reciprocable in bore **82** and is characterized by an annular groove **86** that is movable into and out of registry with passage **80** to control flow between ducts **60** and **62**.

A tension spring **90** in chamber **78** acts, between body **74** and a valve member **84**, to urge the latter toward a valve closed position in which flow through passage **80** is prevented. A sealed, evacuated bellows **94** is disposed in chamber **76** and acts, between body **74** and valve member **84**, in opposition to spring **90**. The use of an evacuated bellows renders valve **62** substantially insensitive to temperature changes.

Chambers **76** and **78** are respectively connected by passages **96** and **98** to passage **80**, and hence to duct **60** and the interior of chamber **24**. It will be apparent that the effective area of bellows **94** that is responsive to pressure changes in chamber **76** is greater than the effective area of valve member **84** that is responsive to corresponding pressure changes in chamber **78**. Accordingly, the valve member will seek a balanced position where the excess force exerted by bellows **94** is equalled by the force of spring **90**. A spring **90** is selected that will result in valve **62** being closed whenever pressure in chamber **24** is less than a predetermined pressure, and opened whenever the pressure in chamber **24** exceeds that pressure. In the present example that pressure is 0.38 atmospheres, or approximately 5.59 psia. Flange **84***a* limits movement of valve member **84** to a predetermined open position.

It will be understood, of course, that the portions of tank **20** defining chamber **24**, tank **70**, ducts **60** amd **64**, and valve **62** must be sufficiently rigid to withstand considerable excesses of external pressure without collapse.

## MODE OF OPERATION

Consider the chambers **24** and **32** to have been appropriately precooled and to be charged with a quantities of liquid oxygen **28** and **34**, respectively, at a temperature of −213°F, and the tank **70** to be charged with oxygen adsorbing material **66** such as the mentioned molecular sieve material. Recall that one of the principal objects of the invention is to maintain the temperature of the liquid oxygen **34** at a predetermined temperature, say −213°F, irrespective of ambient pressure changes thereon. Now, breathing gas, at a temperature substantially above that of liquid oxygen **34** in chamber **32**, is caused to pass from apparatus **52** through duct **54**, chamber **32**, chamber **42**, and return by duct **50** to apparatus **52**. Some of liquid oxygen **34**, warmed somewhat by the passing breathing gas, vaporizes to increase the oxygen content of the breathing gas.

Additional heat energy, tending to warm liquid oxygen **34** in chamber **32**, passes from surrounding waters through the insulated walls **22** of tank **20**, and results from the increase in total pressure within chamber **32** as the apparatus is moved to greater water depths. Removal of sufficient heat from liquid oxygen **34** is accomplished in accordance with this invention by maintaining in chamber **24** a constant, low pressure that will allow liquid oxygen **28** to seek equilibrium between liquid and vapor states at the desired temperature of −213°F, thereby serving as a heat sink to which thermal energy can flow from liquid oxygen **34** through heat exchange wall **26** whenever the temperature of the latter exceeds −213°F.

In accordance with the known physical properties of liquid oxygen, if oxygen vapor is removed as necessary from chamber **24** to maintain a low pressure of 0.38 atmosphere, the temperature of the remaining oxygen will hold constant at −213°F. The action of the oxygen adsorbent material **66** in tank **70** is effective to reduce the pressure in that tank, and in duct **64**, to a value considerably below 0.38 atmosphere. Regulating valve **62**, interposed between chamber **24** and tank **70**, serves to vent to tank **70** any pressure in excess of the required 0.38 atmosphere in chamber **28**. Because the quantity of adsorption material **66** is sufficient to take up all of the oxygen with which chamber **24** is initially charged, the desired constant temperature will be automatically maintained until the liquid oxygen **28** is depleted.

It will be recognized that the operation of the heat sink embodying the invention is wholly independent of ambient pressures and temperatures, the regulating valve **62** serving as the sole reference for pressure in the chamber **24** and the resulting temperature that is maintained therein.

Obviously, other embodiments and modifications of the subject invention will readily come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing description and the drawings. It is, therefore, to be understood that this invention is not to be limited thereto and that said modifications and embodiments are intended to be included within the scope of the appended claims.

What is claimed is:

**1.** A cryogenic underwater breathing apparatus of the type wherein liquified gas is allowed to vaporize to augment a breathing gas mixture, said apparatus comprising:

- a first tank including insulated wall portions in part defining first and second adjacent chambers, said first tank also including heat exchange wall means between said first and second chambers and means for circulating breathing gas through said first chamber;
- a body of first liquified gas in said first chamber substantially at a predetermined low temperature;
- a body of second liquified gas in said second chamber also substantially at said predetermined low temperature;
- means defining a third chamber;
- adsorption material disposed in said third chamber and adapted to reduce pressure therein below a predetermined equilibrium pressure for said second liquified gas at said predetermined temperatures;
- a pressure responsive regulating valve;
- duct means connecting said pressure responsive regulating valve between said second and third chambers; and
- said pressure responsive regulating valve being responsive only to gas pressure in said second chamber and operative to vent gas from said second chamber to said third chamber, so as to maintain said equilibrium pressure and said predetermined low temperature.

**2.** A cryogenic underwater breathing apparatus as defined in claim **1**, and wherein said regulating valve comprises:

- a valve body having a flow passage connected at one end to said second chamber and at its other end to said third chamber, said body defining fourth and fifth chambers on opposite sides of said flow passage and communicating only with said one end thereof;
- a valve member disposed between said ends of said flow passage and movable between open and closed positions with respect to said flow passage;
- spring means disposed in one of said fourth and fifth chambers and operative to urge said valve member toward one of said positions; and
- pressure responsive actuating means disposed in the other of said fourth and fifth chambers and operative to urge said valve member toward the other of said positions.

**3.** A cryogenic underwater breathing apparatus as defined in claim **2**, and wherein:

- said first and second liquified gases each comprise liquid oxygen, and said adsorption material comprises a molecular sieve material.

**4.** A cryogenic underwater breathing apparatus of the type wherein liquified gas is allowed to vaporize to augment a breathing gas mixture, said apparatus comprising:

- a first tank including insulated outer walls, said tank including first and second chambers separated by heat exchanging wall means, and additional wall means for guiding circulating breathing gas through said first chamber;
- a body of liquified gas in said first chamber at a predetermined low temperature;
- a body of second liquified gas in said second chamber also substantially at said predetermined low temperature;
- a second tank defining a third chamber;
- adsorption material disposed in said third chamber and adapted to adsorb vapor of said second liquified gas and to reduce pressure in said third chamber below a predetermined equilibrium pressure for said second liquified gas at said predetermined temperature;
- a pressure regulating valve;
- duct means connecting said pressure regulating valve between said second and third chambers;
- said pressure regulating valve comprising a valve body having a flow passage connected at one end thereof by said duct means to said second chamber and at the other end thereof to said third chamber, said body defining fourth and fifth chambers on opposite sides of said flow passage and communicating only with said one end thereof, a valve member disposed between said ends of said flow passage and movable between open and closed positions with respect to said flow passage, spring means disposed in said fourth chamber and operative to urge said valve member toward one of said positions, an expansible and contractable bellows disposed in said fifth chamber and operative upon predetermined pressure change in said second chambers to move said valve member toward the other of said positions, whereby said pressure regulating valve is ambient pressure independent and operative to vent gas from said second chamber to said third chamber so as to maintain said equilibrium pressure and said predetermined low temperature therein.

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