Aug. 1, 1967 B. R. BODELL 3,333,583

ARTIFICIAL GILL

Filed Sept. 25, 1963 2 Sheets-Sheet 1

Fig. 1.

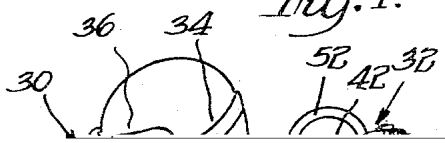

Fig. 2.

Aug. 1, 1967 B. R. BODELL 3,333,583

ARTIFICIAL GILL

Filed Sept. 25, 1963 2 Sheets-Sheet 2

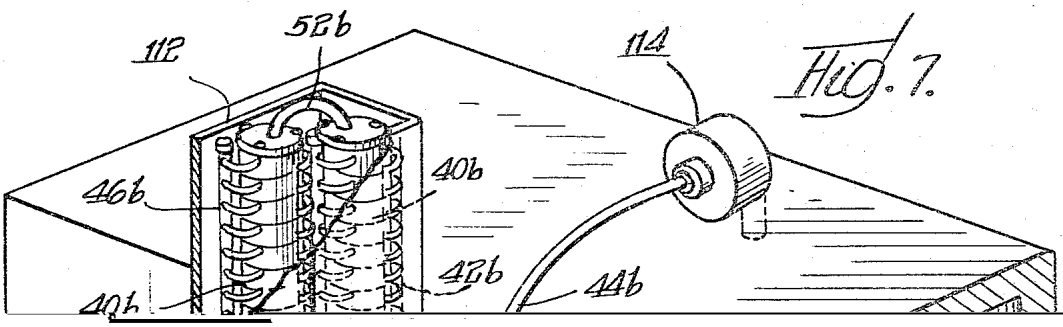

FIG. 7.

United States Patent Office 3,333,583 Patented Aug. 1, 1967

3,333,583

ARTIFICIAL GILL

Bruce R. Bodell, 251 E. Chicago Ave., Chicago, Ill. 60611

Filed Sept. 25, 1963, Ser. No. 311,448
4 Claims. (Cl. 128—142)

This invention relates generally to skindiving, submarining and other underwater activities, the invention relating more particularly to underwater respiration and air purifying devices.

Interest in underwater exploration for recreational and scientific purposes has spurred the development of numerous devices for enabling human beings to breathe while underwater. The prior art underwater respiration devices rely for a source of oxygen either on the earth's atmosphere or on artificially produced and compressed oxygen. When air from the surface is conducted to the submerged person, his depth and mobility are restricted by the available conduit or hose; and surface storms pose a serious hazard to the continuing supply of air. On the other hand, when compressed oxygen is provided in tanks, the bulk and weight of the tanks can prove inconvenient. Moreover, the submerged period for a diver using compressed oxygen is limited by the contents of the tanks.

Therefore, a general object of the present invention is to provide new and improved underwater respiration apparatus.

Another object of the invention is to provide an underwater respiration device that uses the dissolved gases of the surrounding water as an oxygen source.

Still another object of the invention is to provide an underwater respiration device that allows the individual diver great freedom of movement and depth of dive.

And still another object of the invention is to provide an underwater respiration device that is immune to the hazards of surface disturbances.

Yet another object of the invention is to provide an underwater respiartion device that permits dives of indefinite duration.

And yet another object of the invention is to provide an underwater respiration device that is both lightweight and efficient.

An underwater respiration of air purifying device must necessarily be adaptable to a variety of applications. Otherwise, its use would be strictly limited. Hence, it is a further object of the invention to provide an underwater respiration device that is amenable to either individual or group use.

These and other objects and features of the invention will become more apparent from a consideration of the following descriptions.

An underwater air purifying device in accord with the invention includes a tubular member which defines a section of a water transfer passageway. A tubing member of gas transfer material is loosely configurated in this cavity for immersion in the water passing therethrough, the tubing member forming a passageway for air to be oxygenated and purified. Because of the gas transfer properties of the tubing member and because of the partial pressure differentials between the air and the water, the air passing therethrough picks up dissolved oxygen from the water in the surrounding tubular member and delivers carbon dioxide to the water whereby the air becomes purified.

The invention, both to its structure and modes of usage will be better understood by reference to the following disclosure and drawings forming a part thereof, wherein:

FIG. 1 is a schematic perspective view showing a diver equipped with an underwater respiration device constructed in compliance with the invention;

FIG. 2 is an enlarged perspective view of a portion of the respiration device of FIG. 1;

FIG. 3 is a side elevational view of one cell of the respirtaion device, a portion being broken away to reveal internal details;

FIG. 4 is a view taken substantially along the line 4—4 of FIG. 3;

FIG. 5 is a view similar to the showing of FIG. 4 and illustrating a modified form of the invention;

FIG. 6 is an enlarged, sectional view of a header member used in the device of FIG. 5; and

FIG. 7 is a perspective view of underwater living quarters employing an air purification device in compliance with the invention for oxygenating and purifying the air within the chamber.

Referring now in detail to the drawings, specifically to FIG. 1, a diver will be seen equipped with a face mask **30** and an underwater respiration device **32** which is constructed in compliance with the principles of the present invention. The face mask **30** is secured in place by a head strap **34** and includes a resiliently compressible gasket **36** that provides a water-tight seal about the diver's eyes, nose and mouth. The face mask **30** creates an air space into which and from which the diver may breathe.

The respiration device **32** is carried pack style by means of a sling arrangement **38**, although it is to be recognized that other carrying schemes may be equally well employed. For purposes of illustration, the underwater respiration device **32** is shown to include two tiers or principal cells **40** each of which comprises a number of smaller modules or tubular members as will be described hereinafter. Furthermore, each of the cells **40** includes an individual air inlet pipe or manifold **42**; and the manifolds **42** are connected to the face mask **30** by means of appropriate fittings and a bifurcated hose **44**. Each of the major cells **40** is also provided with an air outlet or exhaust pipe **46**; and the discharge ends of these air outlet pipes are connected to an expansible and collapsible rubber bladder **48** by means of a bifurcated hose **50**. A bellows or other expansible and collapsible member may be substituted for the bladder **48** if desired. In any event, the bladder or other similar member which is attached to the air outlet pipes **46** permits the diver to exhale so as to drive his breath through the respiration device **32** and into the bladder **48**, thereafter inhaling and withdrawing his breath through the respiration device for a second pass, oxygen being added to this cycled breath and carbon dioxide being withdrawn therefrom as will be described more fully hereinafter.

The respiration device **32** is arranged to employ the surrounding water as a gas transfer medium and as a source of oxygen. Therefore, the cells **40** are arranged to define therein a water transfer passageway. The internal water transfer passageways of the cells **40** are connected in series fluid circuit by an abbreviated conduit **52**. However, parallel fluid connection is also possible. Water from the surroundings is forced through the water transfer passageways of the cells **40** by means of a pump **54** which is carried by the diver as part of his equipment. The pump **54** includes an inlet **56** that withdraws water from the surroundings, and the pump **54** delivers water under pressure to one of the cells **40** through a hose **58**. The water which is passed through the cells **40** is discharged through an outlet **60**.

It will be realized that various pieces of auxillary apparatus may be incorporated with the underwater respiration device **32**. For example, the respiration device and the various hoses and the bladder **48** may be insulated thermally and a heater may be provided between the pump **54** and the cells **40** in order to conserve the body heat of the diver. Furthermore, the number of cells in the respiration device may be varied so as to increase or decrease the gas transfer efficiency whereby

to accommodate the oxygen requirements of various divers.

Turning to a consideration of FIGS. 2–4 for a more detailed description of one of the major tiers or cells **40**, such a tier or cell is seen to comprise a plurality of tubular units or modules **62** which are advantageously fabricated from a suitable resinous plastic material or other rigid material of construction. The material for use in fabricating the modules **62** is desirably of inert character to avoid corrosion or other reaction with the watery environment. Each of the tubular members or modules **62** is adapted to comprise a section of the water transfer passageway; and the tubular units or modules **62** are aligned on a common axis to be clamped together between end members or closure plates **64** and **66**. Suitable means, such as threaded rods **68** and wing nuts **70** are employed for this latter purpose, the rods **68** passing through the closure plates **64** and **66** so that the wing nuts **70** may be employed in holding the assemblage together. Desirably, the rods **68** are threaded along their entire length so that modules **62** may be added or removed as is desired.

The closure plates **64** and **66** are fabricated from the same material as the modules **62**, or from a material which is compatible with the material of the modules; and stub connectors **72** are attached to the respective closure plates by cooperating threads, a fusion joint or cementing so as to form a fluid-tight joint therebetween, the connectors **72** being employed in attaching the hose **58** and the conduit **52** as is well illustrated in FIG. 3.

Each of the tubular members or modules **62** is fashioned with open ends, and one end wall of each module is provided with an annular groove or channel **74**, the opposite end wall being unbroken. Extending across the

the gases involved, namely oxygen and carbon dioxide. The silicone rubber known under the trade name "Silastic–S–2000" has excellent properties for the purposes of the invention. Other materials which have proved suitable include polytetrafluoroethylene and various ethyl cellulose derivatives. The overall diameter and wall thickness of the tubing member **82** is governed by the desire to maximize the amount of surface or membrane area which is exposed to the flowing water. Silicone rubber tubing having an internal diameter of 0.012 inch and an external diameter of 0.025 inch has proved eminently useful, although tubing having an internal diameter up to $\frac{1}{16}$ of an inch and having a wall thickness of from 5–16 mils is practicable, the length of the tubing, however, being determined in accordance with the lesser or greater area afforded by the specific tubing selected.

In use, the underwater respiration device **32** serves to purify and oxygenate the diver's exhaled breath before it is returned to him for inhaling. Specifically, the diver's exhaled breath passes through the hose **44** and through the air inlet manifolds or pipes **42**, flowing thereafter through the several tubing members **82** and into the air outlet manifolds or pipes **46**. Next, this exhaled breath passes through the bifurcated hose **50** into the bladder **48** expanding the latter element. As this exhaled breath flows through the tubing members **82**, gas transfer takes place through the walls of the tubing members due to the gas permeability of the tubing members and due to the relative difference in the partial pressure of the gases in the exhaled breath and the water. The water being forced through the modules **62** picks up carbon dioxide through the walls of the tubing members and transfers dissolved oxygen through the walls of the tubing mem-

connectors **106** by being stretched over the pointed end thereof.

As is shown in FIG. 5, the individual tubing members **82***a* are connected to each of the headers **100** whereby to establish six parallel fluid circuits between the headers. By providing multiple fluid paths between the headers, a substantial increase in the volumetric air flow is achieved betwen the fittings **88***a* and **90***a*, thus increasing the efficiency of gas transfer and reducing the amount of work necessary to circulate the air.

The embodiment of FIGS. 5 and 6 is also characterized by the tubing members **82***a* being loosely configurated in the cavity of each module **62***a*. By means of this loose configuration and by means of the fabrication of the tubing members **82***a* from a flexible material such as silicone rubber, the tubing members are capable of responding to the currents in the flowing water by relatively free movement whereby to avoid substantially the development of cavitation effects adjacent the tubing members. Greater efficiency in gas transfer is achieved thereby.

The underwater respiration device of the invention is not limited to use by an individual diver. Rather, the underwater respiration device of the invention is likewise amenable to group use for purifying the air in a submarine vessel or in a permanent underwater habitation. Therefore and turning to a consideration of FIG. 7, an underwater housing chamber indicated generally by the numeral **110** is seen to be equipped with an underwater respiration device **32***b*, like numerals having been used to designate parts similar to those found in the respiration device of FIGS. 1–4 with the suffix letter *b* being employed to distinguish those elements associated with the embodiment of FIG. 7. The housing chamber **110** is intended to provide shelter for men leading submarine lives for extended periods, the men remaining submerged and interior of the housing chamber. Furthermore, the water which is extracted from the airstream in this fashion is free of dissolved salts and other impurities and, hence, may provide a highly desirable source of potable water when, for example, the housing chamber **110** is situated in sea water. The condensate from condenser **116** drains by gravity into a tank **118** from whence it may be withdrawn as desired by means of a spigot **120**. The purified and dehumidified air passes from the condenser **116** into the housing chamber **110** through a conduit **122**. The water from the environment is conveniently used as the heat transfer medium for the condenser **116**. In other respects, the air purifying device **32***b* operates in a fashion similar to the device disclosed in FIGS. 1–4 for use by an individual diver.

While particular embodiments of the invention have been shown and described, it should be understood, of course, that the invention is not strictly limited thereto; and it is, therefore, contemplated to cover by the present application any such modifications as fall within the true spirit and scope of the appended claims.

I claim:

1. An underwater air purifying device comprising a tubular member defining interiorly a cavity adapted to comprise a passageway for water containing dissolved oxygen; means for circulating water through said passageway, and one or more lengths of capillary tubing disposed in said cavity for immersion in the water passing therethrough, said tubing being essentially self-supporting and forming a passageway for air to be oxygenated and purified, an air inlet connected to one end of said tubing, an air outlet connected to the other end of said tubing, and means for connecting the air inlet and air outlet to a confined space containing said air to be oxygenated and purified, said capillary tubing being made of a material that is sub-