Aug. 6, 1963 R. G. BARTLETT, JR 3,099,987

RESPIRATORY APPARATUS

Filed March 7, 1961 2 Sheets-Sheet 1

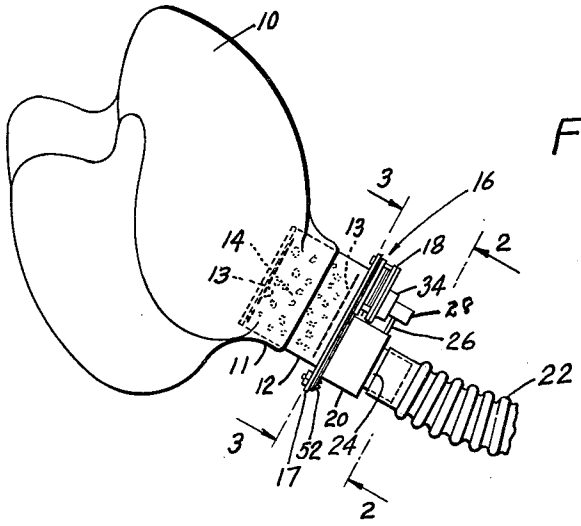

FIG. 1.

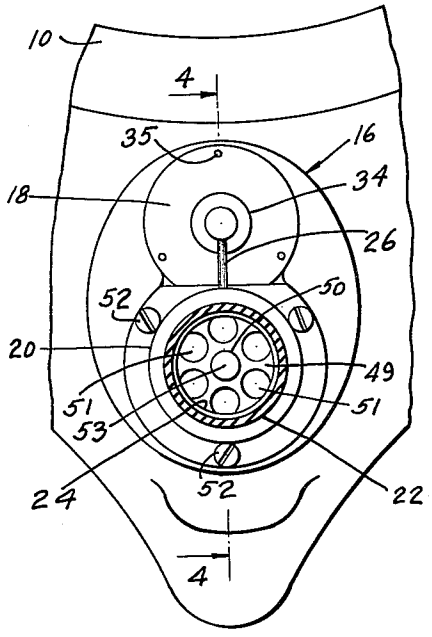

FIG. 2.

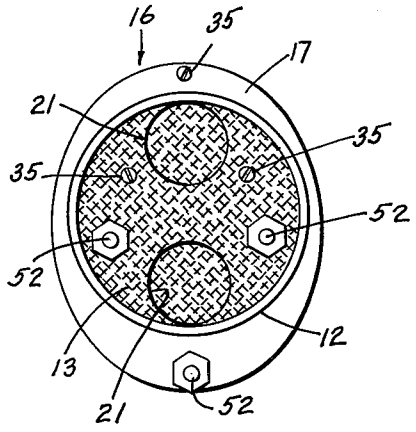

FIG. 3.

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RESPIRATORY APPARATUS

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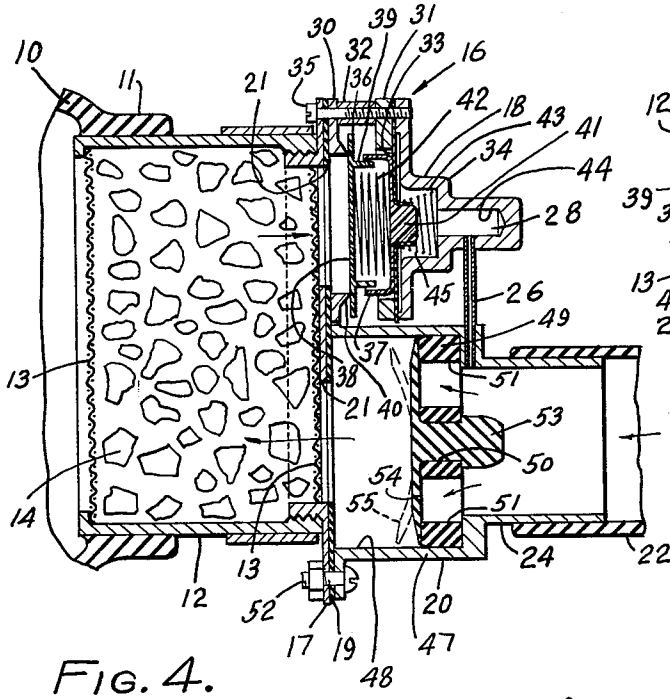

FIG. 4.

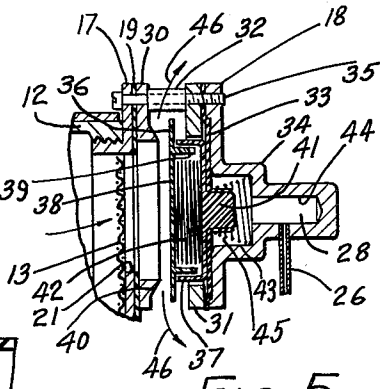

FIG. 5.

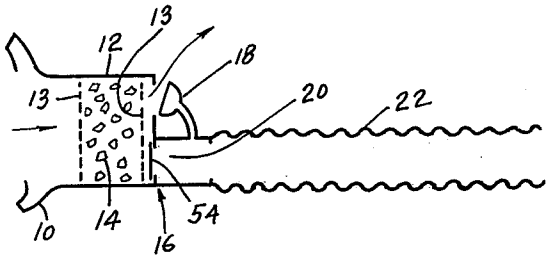

FIG. 6.

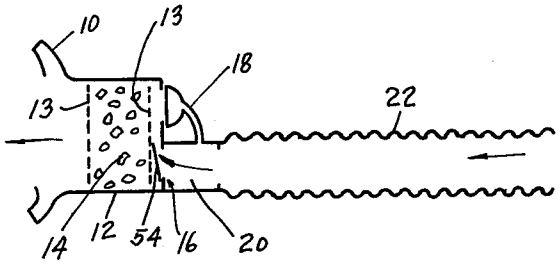

FIG. 7.

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RESPIRATORY APPARATUS

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Filed Mar. 7, 1961, Ser. No. 94,090
1 Claim. (Cl. 128—142)
(Granted under Title 35, U.S. Code (1952), sec. 266)

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.

This invention relates generally to respiratory apparatus as is employed in high altitudes and is particularly concerned with the transfer of moisture from expired to inspired breath for the purpose of humidifying any respirant which may be furnished to the user.

The use of oxygen at high altitudes is a known requirement for the continuation of animal life. Studies of the physiology of respiration have shown that for each altitude there is a minimum concentration of oxygen which must be provided in the fluid breathed if normal oxygenation of the blood is to be maintained. This necessary concentration of oxygen for various altitudes has been determined approximately as follows: 20% at sea level; 27.5% at 10,000 feet; 50% at 20,000 feet; 60% at 25,000 feet; 80% at 30,000 feet; and 100% at 34,000 feet and above.

To prevent the freezing of valves and other components of the oxygen delivery equipment, both the liquid and compressed forms of this gas are supplied to the user in as dry a form as possible. All possible water vapor has been removed. Prolonged breathing of such dry oxygen is frequently accompanied by respiratory discomfort as a result of the desiccation of the mucous membranes which produces irritation, coughing, sore throats, head colds and other deleterious effects on these delicate linings of the respiratory tracts.

In order to prevent these respiratory difficulties due to the dry oxygen, a reliable means of adding moisture thereto was mandatorily required. Although adequate humidification of the inspired dry oxygen could be easily accomplished by passing it over or through water, this method has the disadvantages of additional weight due to the necessary equipment, limited duration of use, and the necessity of carrying a supply of water. Under the exigencies of high altitude operations, whether mountain climbing or aviation, including space travel, the additional weight features become highly important and are practically prohibitive for the use of such extra equipment and supplies.

Other prior art devices have included an attempt to solve this problem. Such partial solutions have included so-called rebreather bags or variously shaped canisters for the collection of moisture from the expired breath. These devices, however, have defeated their purpose by not making such moisture available to the dry oxygen being inspired, i.e., moisture has only been present in that portion of the inspiration due to rebreathed air, and, furthermore, such devices have aided the collection of the moisture by gravity, at least, in the lower portions of the bags and canisters where it quickly became unavailable for any use.

The principal object of my invention, therefore, is to provide a reliable, simple, and self-contained means for humidifying the entire portion of fluid being inspired.

Another object of my invention is to provide a simple humidifier which can easily be adapted to known equipment.

A further object of my invention is to provide a device by which sufficient moisture from the expired breath is recycled to the inspired dry oxygen to produce a relative humidity of approximately 70% in the inspired breath.

A still further object of my invention is to produce a breath humidifier which is self-priming, self-regulating, and whose operation is not limited in time nor is it dependent upon the renewal of an expendable substance.

Other and further objects of my invention will be better understood in connection with the following detailed description and the accompanying drawings wherein:

FIGURE 1 is a side elevation of a breathing mask incorporating my invention;

FIG. 2 is a front elevation, partly broken away and partly in section of the mask and its valving arrangements taken on the line 2—2 of FIG. 1;

FIG. 3 is another view of the valving arrangement taken on the line 3—3 of FIG. 1;

FIG. 4 is an enlarged elevation in cross-section of certain details of my invention taken on the line 4—4 of FIG. 2;

FIG. 5 is an enlarged view of the expiratory valve shown in FIG. 4 in the open position; and

FIGS. 6 and 7 are schematic views illustrating the operation of my invention.

With reference to FIGS. 1, 2, and 3, the mask 10 which is used principally as a means for insuring a reasonably airtight seal with the user's mouth, nose, and face, carries a container 12 which is filled with moisture exchange material 14. The valve structure 16 includes an expiratory valve 18 and an inspiratory valve 20. The usual corrugated flexible tube 22 for the transmission or delivery of the pressurized oxygen is shown attached to the inspiratory valve structure 20 by engaging the tubular enxension 24. While expiratory valve 18 may be of the simple check valve type, it is best constructed in the form shown as a pressure compensated type having a sensing tube 26 leading from the external valve chamber 28 to the inflow tubular extension 24.

With reference particularly to FIGS. 3–5, inclusive, the container 12 may be a cylindrical body of metal, plastic, or other suitable material adapted at one end to be inserted in the mask 10, as into the annular shape 11, and suitably detachably secured at the other end to the valve structure 16. Screens 13 are secured at each end of the container 12 for suitably confining the moisture exchange material 14 therein. Valve foundation plate 17 with its overlying gasket 19 serves as the main connection structure between the mask and container combination and the valve structures. This plate 17 has two large circular holes 21 which serve to channel the expired and inspired fluids through their respective valves.

Expiratory valve 18 has a valve base ring 30, an annular supporting member 31, a plurality of distance pieces 32 inserted between base ring 30 and supporting member 31, flexible gasket 33 and a pressure chamber defining member or cap portion 34. These parts are suitably held together and to valve foundation plate 17 by the machine screws 35. Between base ring 30 and the flexible gasket 33, valve plate 36 and valve plate support 37 are supported by the flexible gasket 33. Valve plate 36 consists of a planar front plate 38 and an annular ring 39 formed integrally on the back of front plate 38. Base ring 30 is provided with annular knife edge 40 on which the planar portion of front plate 38 rests when the valve is closed. Valve plate support 37 is cupped forwardly, as shown, and is provided with a comparatively massive hub 41. The cup portion of support 37 receives telescopically the annular back ring 39 of valve plate 36 whereby this part 36 is guided and supported. Hub 41 fits into a centrally formed aperture in the flexible gasket 33. The gasket may be cemented to the hub 41 and thus forms a flexible support for the working valve parts 36 and 37. A light coil compression spring 42 fits into the expansion cylinder formed by the ring and cup portions of valve parts 36 and

37 and serves to keep valve plate 36 tightly on the knife edge valve seat 40 when the breath is being inspired.

The cap member 34 is provided with an enlarged concentric bore 43 and a smaller extending bore 44. These bores form the pressure chamber 28 previously mentioned. Bore 43 contains a light coil compression spring 45 which operates on the flexible gasket 33. Smaller bore 43 serves as an extension of the sensing tube 26 and transmits the pressurized fluid to the back of the flexible gasket 33.

As shown in FIGS. 4 and 5, when the user is inspiring, the valve plate 38 rests on the knife edge 40 by virtue of the pressures of springs 42 and 45 and the fluid pressure in chamber 28. Upon expiration, valve plate 36 is forced open and the air escapes as shown by the arrows 46 in FIG. 5. Coil springs 42 and 45 are compressed and flexible gasket 33 is moved outwardly against the pressure of spring 45 and the fluid pressure in chamber 28. Thus, with the fluid pressure acting on the back of the working valve parts, compensation is provided for the use of higher respirant pressures necessitated by unusual demand or extremely high altitudes.

Inspiratory valve 20 comprises a cylinder 47 of metal, plastic, or other suitable material having an enlarged bore 48 and a smaller bore defined by the tubular extension 24. This cylinder 47 is suitably secured to the valve foundation plate 17 by the screws and nuts 52. A valve support plate 49, having a central aperture 50 and a plurality of apertures 51 symmetrically disposed with relation to central aperture 50, is cemented or otherwise suitably secured at the shoulder joining the two bores in the cylinder 47. Apertures 51 are for the inward passage of the pressurized respirant being inspired. Central aperture 50 receives the supporting plug 53 of the valve part 54. Valve part 54 and plug 53 are integrally formed of rubber or some other suitable flexible material not affected by the chemical nature of the respirant nor the possibly extremely low ambient temperatures. When the respirant is being inspired, the valve part 54 flexes inwardly as shown in phantom at 55, FIG. 4, thus allowing the respirant free passage through the apertures 51.

In the preferred embodiment of my invention, as thus far described, the moisture exchange material 14 is 20 grams of large crystals (3–8 mesh) of silica gel. During expiration moisture is trapped by surface absorption on the silica gel crystals. During the subsequent inspiration, this moisture is readily released to the dry inspired respirant. Although silica gel is frequently used as a desiccant, its reaction with moisture is a purely physical one and when moist silica gel is exposed to a dry gas, the moisture is quickly and practically totally released. Smaller crystals than the 3–8 mesh specified above provide a greater moisture exchange but increase the resistance to air flow. Crystal size, therefore, must be a compromise which permits free air flow while providing also a surface large enough for efficient moisture exchange.

While silica gel crystals were used in this preferred embodiment due to its inertness, relative stability, wide availability and cheapness, there are doubtless numbers of other chemicals or substances which could serve the function of moisture exchange here disclosed. Such substances could include quantities of precious or semi-precious stones, crystals of silicon carbide or other suitable refractories, or suitably sized crystals of any other material chemically inert to the respirant being used and not subject to disintegration during use whether due to the reaction of the respirant on the material or the mechanical flow of the gas.

FIGS. 6 and 7 illustrate schematically the use of my improved device. FIG. 6 shows the sequence of events during expiration. Here the entire expired breath is passing through and over the moisture exchange material in canister 12 before being exhausted to the atmosphere through the expiratory valve 18. A great percentage of the moisture in the expired breath is thus deposited on the crystals

of the moisture exchange material. FIG. 7 depicts the respirant being inspired. This incoming fluid passes generally over the moisture exchange material and, being very dry, picks up practically all the moisture present on the surface of the exchange material. In this case, of course, the inspiratory valve opens and the expiratory valve closes. It should be noted again that, in my device, the moisture exchange material is in the paths of the entire fluid flow, both expiratory and inspiratory.

In actual quantitative tests of my invention, each test lasting for a period of six hours, it was found that a complete equilibrium was established after the first few breaths and that thereafter there was little change in the magnitude of the moisture exchange for a given subject. Individual subjects showed small, but unimportant, variations in the extent of the moisture exchange and these, it is assumed, where attributable to different breathing patterns. Considering all subjects, there was a moisture exchange of between 60 and 85% with most values falling near 70%. Although there are no previous data on which to base a comparison, it is believed that this level of humidification should be quite conducive to comfort and safety when breathing pure oxygen from a dry source for prolonged periods of time.

Having thus described a preferred embodiment of my invention, I do not intend to be limited thereby as the structures and materials shown may be subject to many modifications by those skilled in the art. All such modifications are considered as falling within the spirit of the invention and the scope of the appended claim wherein I claim:

A respiratory apparatus for users of pressurized respirant comprising:

a face mask adapted to sealingly cover the mouth and nose of the user;

a first conduit leading from said mask for passing all of the expired and inspired fluids from and to the lungs and respiratory passages of the user;

a second conduit leading out of said first conduit;

a third conduit leading out of said first conduit;

a source of pressurized respirant attached to said third conduit;

a moisture transfer means wholly contained within said first conduit, said moisture transfer means consisting of a container adapted to be sealingly secured at one end to said face mask and to form said first conduit, a quantity of granular material adapted to collect condensed moisture on the surfaces thereof and to allow said moisture to evaporate therefrom enclosed within said container, a screen at each end of said container for retaining said granular material therein, and a perforated valve plate on the other end of said container, said valve plate affording connection means from said first conduit to said second and third conduits;

an inspiratory check valve supported by said perforated valve plate in said third conduit for controlling the influx of said respirant to said first conduit and mask; and

an expiratory check valve supported by said perforated valve plate in said second conduit for allowing the controlled escape of expired fluid to atmosphere, said expiratory check valve consisting of an annular base ring having a circular knife edge extending outwardly therefrom, said base ring forming said second conduit, an annular support member spaced outwardly from said base ring, a plurality of hollow cylindrical distance pieces separating said base ring and said support member, a cap portion mounted concentrically and outwardly of said support member, said base ring, distance pieces, support member and cap portion being secured together with fastening means passing therethrough, a flexible gasket mounted between said support member and said cap portion, a cup shaped valve support member

held by said flexible gasket, the cup portion thereof extending inwardly toward said base ring, a valve engaging said base ring knife edge, said valve having an annular ring formed on its outward side, said annular ring fitting telescopically in the cup portion of said valve member whereby said valve is held in sliding juxtaposition to said knife edge, a compression spring mounted between said valve and valve support member for normally pressing said valve adjacent said knife edge, and means for pressurizing the outward side of said flexible gasket from said

third conduit whereby the operation of said expiratory valve is controlled by the fluid pressure of said respirant.

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