PUBLISHED
MAY 11, 1943.
BY A. P. C.

R. MARGARIA

BREATHING APPARATUS FOR RESPIRATION AT HIGH ALTITUDES

Filed March 18, 1941

Serial No. 384,006

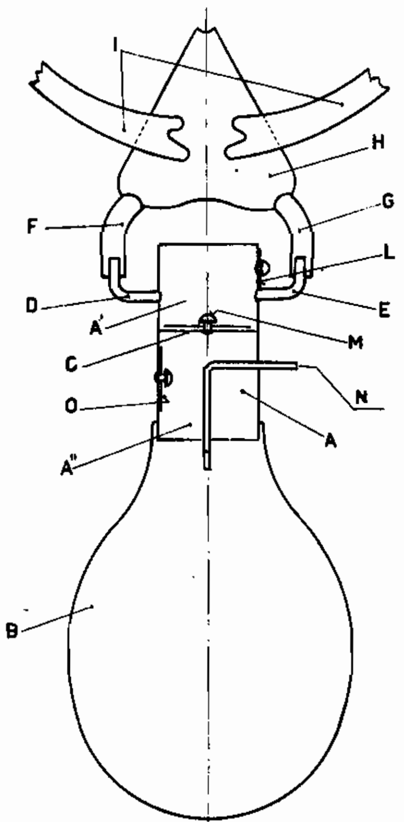

Fig. 1

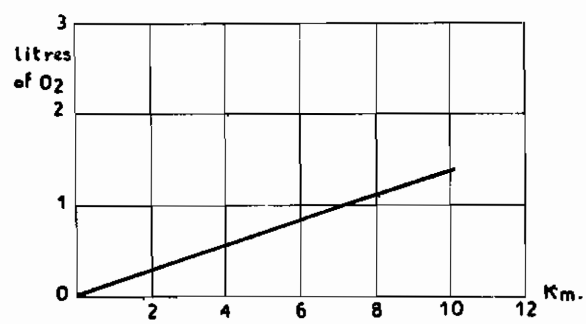

Fig. 2

Inventor

Rodolfo Margaria

By Young, Emery & Thompson
Attorneys

Published May 11, 1943

Serial No. 384,006

ALIEN PROPERTY CUSTODIAN

BREATHING APPARATUS FOR RESPIRATION AT HIGH ALTITUDES

Rodolfo Margaria, Milano, Italy; vested in the Alien Property Custodian

Application filed March 18, 1941

The breathing apparatus used heretofore at high altitudes and generally where air is rarefied are not very rational because they do not allow a sufficient increase in the breathing mixture, and because not all the whole amount of oxygen supplied is utilized for breathing.

Recently Boothby and Lovelace (see the review "Aviation Médicine" No. 9 of the year 1938, page 172) have described a type of breathing mask, answering rather well to its object, but having yet the drawback of allowing the respiration of a part of the expired air, which should be useful to increase the resistance to "anoxaemia".

As one of the applicants has shown (R. Margaria in Giornale di Medicina Aeronautica 1939-2) it has been finally established that such a practice instead of being an advantage is useless and altogether harmful.

The object of the present invention is an apparatus for supplying oxygen for breathing in rarefied air, according to which the supply of this gas to the lungs is adjusted so as to obtain the best possible utilization of the oxygen supplied.

The apparatus is characterized by means supplying first directly to the alveoli of lungs an amount of gas O_2 pure, which in said alveoli is mixed with already enriched air, driven out of the said alveoli to occupy the respiratory channels during each expiration for returning during the subsequent inspiration in said alveoli and by means which subsequently supply the atmospheric air poor in oxygen to the respiratory channels, driving it out in the atmospheric air during the subsequent expiration.

This apparatus allows to supply to the lungs first a suitable amount of pure oxygen and subsequently, the outer atmospheric air poor in oxygen: thus the oxygen enters entirely in the alveoli of the lungs, where it mixes with the inspired surplus of air, whilst in the respiratory channels, where no gaseous exchanges with the blood take place there is only the outer atmospheric air, poor in oxygen.

During the subsequent expiration this poor air of the respiratory channels is immediately driven out and at the end of the expiration there will remain in said channels the rich air formerly contained in the alveoli so that this air, in the subsequent inspiration, will be again drawn into the alveoli and will therefore be utilized.

The calculations of the amount of oxygen to be supplied, may therefore be based on the alveolar ventilation, instead of being based on the whole lung ventilation so that there is a great saving in the supplied oxygen.

The invention is illustrated in a practical embodiment thereof in Fig. 1 of the accompanying drawing, while Fig. 2 shows a diagram permitting the supplying regulation, in relation to the different altitude conditions, and consequently of air rarefaction.

The apparatus consists in two parts: one A of a reduced capacity, has preferably the form of a cylinder, closed at the top and open at the bottom base and is formed with rigid materials, for instance with metal, ebonite, synthetic resins or the like: it is divided by a diaphragm C into two superposed chambers A′—A″. The diaphragm C presents a valve M controlling the passage between the two chambers A′ and A″ as will be disclosed hereinafter.

On the lower chamber A″, open at the bottom, is fitted, perfectly tight, a bag B, preferably in rubber, whilst chamber A′ is connected by pipes D, E which enter into tubes F, G of a rubber nose-cover H, provided with fixture straps I, said cover fitting onto the nose of the operator so that the supply of the gases for breathing is provided solely through the nose cavities. The mouth remains entirely free, so that the pilot or the airplane passenger may talk, eat, vomit, without requiring any removal of the mask and without any interruption in the supply of the oxygen.

The chamber A′ of member A communicates by means of an inhalation check-valve M, with chamber A″ and therefore with bag B, there being thus two chambers of a very different volume capacity, since normally the volume capacity of the bag is about 1½ liters.

Pure oxygen flows constantly in said capacity formed by bag B and by chamber A″ from a tube N traversing the wall of A″ out of a bottle,—(not represented in the drawing)—provided with a pressure reducing valve and with a flux-meter (also not shown in the drawing).

On the side-wall of chamber A″ is provided an inhalation valve O allowing outside air to enter the bag B, but preventing the oxygen contained in said bag from leaking out.

When the user commences an air inspiration, first only valve M opens, and the oxygen contained in the bag B flows into the lungs; only in a second period of time, it can overcome the resistance of valve O which opens and outside atmospheric air, poor in oxygen, is drawn in. Valve L will naturally remain closed.

In this manner the oxygen collecting in bag B enters directly in the lungs alveoli and will be entirely utilized, being mixed only at the end of the inspiration and only partially with the rarefied air, so that a smaller oxygen quantity can be supplied than in the case that the mixing would be formerly effected and utilized for breathing; effectively oxygen enters in all alveoli and respiratory channels are only occupied by the very poor atmospheric air.

In exhaling, the air passes from the nostrils to tubes F G D E into chamber A. Valve M closes and valve L opens, and out of said valve L flows the whole air occupying the respiratory channels, while the enriched air which flows out of the lungs occupies the respiratory channels. In the subsequent inspiration this formerly enriched air, returns to the lungs with a fresh quantity of oxygen, so that a new utilization takes place.

Valves L, M, O are formed with rubber or mica membranes and may have any suitable structure.

In order to better show the advantages of the present invention, in Fig. 2 a diagram is given showing the amount (in liters, at 0° Cent. temperature and 760 m/m mercury pressure) of oxygen to be supplied, in relation to the altitude in kilometers above the level of the sea, which is the most important application for the living in aeroplanes flying at high altitude; similar considerations could naturally be made for air rarefield for others whatever causes.

The amount of oxygen supply to maintain a high partial pressure of oxygen in the alveoli, namely a pressure equal to that obtaining at sea level—varies of course with the ventilation of the lungs (or of the alveoli). It is well known that the latter varies in linear proportion with individual metabolism, at least up to values of the same which are not excessive and that each liter of expired air corresponds to an energy consumption of about 0.25 calories. (See R. Margaria Transactions of the Reale Accademia dei Lincei Series VI Vol. VII part V 1938 at page 359).

A man resting in a chair, consumes 1 calory per minute; when he moves now and then the arms or the legs as a pilot does in usual practice, the metabolism or energy consumption does not exceed two calories per minute. The lungs ventilation, viz. the amount of air inhaled and exhaled every minute, for the case considered of an energetic consumption of two calories per minute, will be 8 liters, as every 0.25 calories consumed correspond to 1 liter of exhaled air.

Supposing the frequency of respiration, namely the number of inspirations per minute, to be 15, the depth of respiration will amount to 533 cubic centimeters and, supposing the clearance volume for respiration to be 150 cubic centimeters the alveolar respiration will amount to 5.75 liters, as obtained by subtracting said clearance volume from the breathing depth and then by multiplying the result by the breathing frequency.

The amount of oxygen to be supplied in order that, in addition with air, it should provide such a dose as would maintain the partial pressure of oxygen as obtained at sea-level, is shown, for the case in consideration, in the diagram Fig. 2.

Said diagram has been plotted, taking into consideration the increase in volume of the gas due to the decrease of atmospheric pressure and considering also that said gas within the lungs is at 37° Cent. and saturated with water vapour, wherein the partial pressure is 47 mm. mercury column.

It is apparent that with the breathing apparatus specified above, both pilot and passengers of a civil aircraft, on using only 1.3 liters of oxygen per minute, can fly up to 10.000 meters altitude, remaining exactly in the same condition, concerning respiration exchanges, as if they were at sea-level. If on the contrary the calculation should be based on lung ventilation (8 liters instead of 5.75 in the above case) the amount of oxygen required in the same conditions would rise to 1.7 liters.

As mentioned above, the apparatus specified is shown merely as an example of embodiment of the invention. It may be varied in dimensions, in the shape of its various parts, provided it should achieve the method for supplying oxygen as claimed in the present invention.

So, for instance, pipe N supplying oxygen, might be extended further downward—towards the bottom of bag B; the expiration valve L, instead of being placed sideways, might be placed in front of chamber A' etc. Also the apparatus might be provided, with some accessory, as for instance a corrugated pipe to be inserted between part A carrying the valves and the nose attachment (or any other suitable point) thus allowing the pilot more freedom in the movements. Also the straps for holding the nose-cover applied to the face might be of any proper shape.

RODOLFO MARGARIA.