Self-Rescuers

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The results of the development of an insulating self-rescuer on chemically bound oxygen, which has improved weight and size characteristics, and meets the requirements of European and Russian standards, are presented.

Keywords: isolating self-rescuer; regenerative product on a matrix.

In the event of a situation leading to the formation of a toxic or harmful ambient atmosphere, such as fires, smoke and similar man-made or natural accidents, as well as terrorist attacks, the advantage of having a device that provides a person with breathable air, as well as providing nominal skin protection covers the head and neck from gases, dropping liquids, solid particles, jets and aerosols. It is desirable to have a device that is easily accessible (easily portable and/or stored) and suitable for a wide range of user sizes (adults, children, elderly, infirm, physically or mentally handicapped or sick people, people with beards, glasses , long hair, etc.) without the need to match facial features or body shapes. It is also preferable that activation and operation are automatic, donning is obvious and convenient, and the device is suitable for both long-term and short-term use with a long shelf life.

Currently, mass-produced filtering respiratory protective equipment has a protective action time of up to 20 minutes and small weight and size characteristics, which allows their use by the civilian population as respiratory protective equipment. They are mainly intended for air purification from carbon monoxide (carbon monoxide) and low concentrations of other aggressive chemical poisoning substances (Hazardous Chemical Substance), and do not have universal protective properties for all hazardous chemical substance for the entire period of use in accordance with the manufacturer's warranties. But their main disadvantage is that when an atmosphere occurs with an oxygen content below the permissible level (18%), filtering protective equipment is not suitable, since they do not supply oxygen.

In these cases, insulating respiratory protection should be used. They differ from filters in that they provide isolation of the human respiratory organs from the environment, cleaning a small closed volume of the gas-air mixture from carbon dioxide formed during human breathing, and adding oxygen to it. Thus, unlike filtering, insulating respiratory protective equipment is not critical to the composition of the external atmosphere, and the user can be in the surrounding atmosphere even in the absence of oxygen in it.

Traditionally, self-contained self-rescuers are devices consisting of an oxygen source, a device for absorbing carbon dioxide emitted by a person, an elastic container for collecting the gas-air mixture on exhalation, and a device for connecting the user's respiratory tract to the self-rescuer. The whole device is housed in a sealed case equipped with a fastening system for storing and carrying the self-rescuer. Self-rescuers are divided into three types depending on the method of ensuring human breathing:

- compressed air self-rescuers;
- self-rescuers on compressed oxygen;
- self-rescuers on chemically bound oxygen.

Compressed air, oxygen candles (solid sources of oxygen) and regenerative products based on potassium superoxide are used as oxygen sources. The most acceptable from the point of view of respiratory physiology would be the use of compressed air, however, its long-term storage, which precedes the intended use of the self-rescuer, without maintenance is problematic. For oxygen candles (their basis is alkali metal chlorates), the burning time and oxygen release are predetermined and designed for the highest oxygen consumption of the user, that is, not adapted to the load. In addition, their use as sources of oxygen in closed cycle apparatuses leads to the need to include carbon dioxide absorbers in their scheme. Products based on potassium superoxide do not have the disadvantages of compressed air and alkali metal chlorates, they are light and easy to store, so they are preferable for use in insulating respiratory protection.

Chemically bound oxygen breathing apparatuses have better characteristics in terms of weight and dimensions compared to self-rescuers using compressed oxygen or compressed air. For the consumer, the most attractive side of chemically bound oxygen self-rescuers are long warranty periods of storage and operation in a state of readiness for immediate use as intended with minimal maintenance.

Roskhimzashchita public corporation has developed a new material for air regeneration (regenerative product). The regenerative substance (potassium superoxide KO_2) according to the method [1] is obtained not in a free state in the form of a powder, but on the surface and in the pores of an inert porous carrier (matrix) by impregnating the matrix with a solution of potassium peroxosolvate followed by its drying. A solution of potassium peroxosolvate is prepared by a known method for the preparation of coordination compounds of hydrogen peroxide [2, 4]. The regenerative product has a larger surface area and better sorption capacity for carbon dioxide compared to the traditionally used granular product. The conducted studies have shown the possibility of obtaining a regenerative product in the form of plates of various geometric shapes with a controlled content of active oxygen. Due to the developed surface, the new product absorbs carbon dioxide not in layers, like granular, but on the entire surface. As a result, the air regeneration process is carried out at lower temperatures. This property of the regenerative product makes it possible to use polymeric materials (for example, polyamide and fluoroplastic) for the manufacture of a self-rescuer instead of the traditionally used metal.

In 2005, the development of a self-contained breathing apparatus (self-rescuer) with a protective action time of 15 minutes, using a regenerative product on a matrix as an oxygen source, began.

The self-rescuer includes:

- a regenerative cartridge and a device for additional oxygen supply in the initial period, placed inside the breathing bag;
- front part with a hood and a half mask.

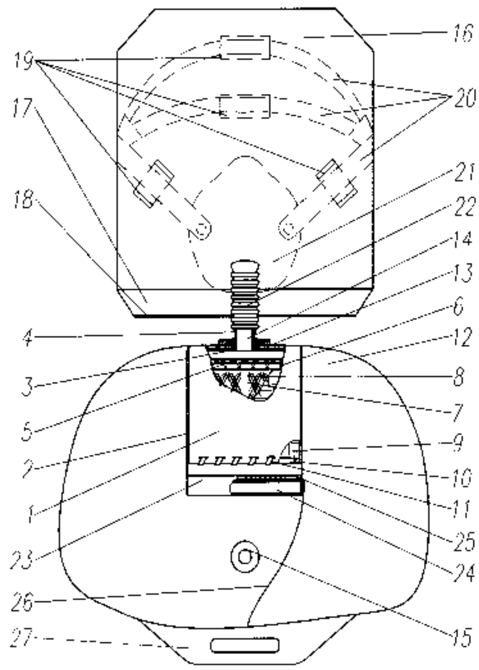
The regenerative cartridge contains a housing with a regenerative product (potassium superoxide on a matrix) placed in it, made in the form of plates equipped with protrusions. The design of the self-rescuer is shown in fig. 1.

The body of the cartridge is made in the form of a shell of foamed polypropylene with a gas distribution device. The shell is a shell equipped with a lid with a central hole for a connecting branch pipe and stiffeners made in the form of fillet welds.

The gas distribution device is made of polypropylene in the form of a cover equipped with a fitting, with a support grid built into it.

A heat exchanger filter in the form of a porous metal plate made of foamed nickel is installed under the support grid.

The plates of the regenerative product are provided with corrugations, which form protrusions located at an angle to the longitudinal axis of the plate.



Drawing 1. Scheme of self-rescuer:
1 - cartridge case; 2 - stiffeners; 3 - gas distribution device; 4 - fitting; 5 - support grid; 6 - filter heat exchanger; 7 - regenerative product; 8 - riffles; 9 - filter shell; 10 - fixing grid; 11 - tape; 12 - breathing bag; 13 - washer; 14 - nut: 15 - overpressure valve; 16 - hood; 17 - neck obturator; 18 - insert; 19 - overlays; 20 - headband; 21 - half mask; 22 - corrugated tube;
23 - capacity; 24 - starting briquette; 25 - ampoule; 26 - fishing line; 27 - handle

Adjacent plates are rotated relative to each other by 180°, thus, gas distribution channels are formed between the protrusions.

The package of plates of the regenerative product, wrapped in a filter shell made of BMD-K or BMD-F glass paper, is placed with an interference fit inside the housing shell and presses the filter-heat exchanger against the support grid. The package is fixed in the cartridge by installing a fixing grid made of polypropylene in the lower part of the cartridge body. The fixing grid is attached to the lower part of the shell of the cartridge with a tape made of fluoroplastic film.

The breathing bag is made of fluoroplastic film and is installed on the connecting pipe of the cartridge. The sealing of the mouth of the breathing bag is carried out by means of an aluminum washer, which is put on the connecting pipe of the cartridge and fixed with a polyethylene union nut. The breathing bag is equipped with a pull-type overpressure valve.

The front part is a hood made of an optically transparent fluoroplastic film, assembled from a fabric by welding. In the lower part of the hood there is an elastic rubber obturator glued to an insert made of activated fluoroplastic film and attached to the hood by welding.

Linings made of the same material as the shell are welded to the inner side of the hood shell. Elastic straps attached to the half mask are passed into the channels formed by the overlays and the hood shell. In the half mask there is a connecting fitting (conditionally not shown), passed through a hole in the shell, and connected to the breathing pipe of the regenerative cartridge with a corrugated rubber tube.

At the initial moment of operation (the first two or three minutes), the device is not able to provide the required amount of oxygen for the user to breathe due to the fact that it has not had time to accumulate yet. Because of this, there may be a lack of oxygen for breathing, which can lead to the removal of the self-rescuer by the user, or a person fainting from oxygen starvation.

To solve this problem, a device for additional oxygen supply in the initial period of time was developed. It is an open container with a regenerative product on a matrix. Above the container is an elastic ampoule with a starting solution. A fishing line passes inside the ampoule, fixed at one end in such a way that when it is pulled, the ampoule opens. The second end of the fishing line is fixed on the breathing bag at the point where the handle adjoins it.

When starting the device, the user straightens the bag by pulling the handle, the fishing line cuts the ampoule, the solution from the ampoule launches a starting briquette that releases initial oxygen. When the user breathes, the exhaled air enters through the fitting into the cover of the cartridge body, cools the filter-heat exchanger, passes through the grid and the filter shell into the plate pack, in which carbon dioxide is absorbed, and the oxygen necessary for breathing is released. The purified air passes through the filter shell and grille into the breathing bag. When inhaling, the air from the breathing bag again passes through the grill, filter shell, plate pack, shell, cools on the filter-heat exchanger, and then through the grill, the cover of the cartridge body and the fitting enters for inspiration. Excess breathing mixture is discharged from the bag through the overpressure valve into the environment.

In 2005, an experimental batch of devices was manufactured and tested according to the methods [3, 5] under various modes. The tests were carried out both on a stand simulating human breathing and on test volunteers.

During the tests, the composition of the gaseous medium in the apparatus and the temperature of the inhaled mixture were studied. The results obtained indicate that the composition of the gaseous medium in the apparatus complies with modern standards [3, 5].

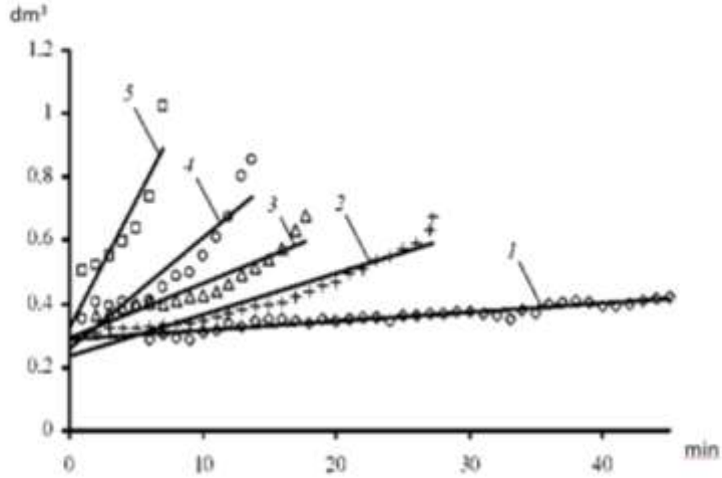
The increase in the concentration of carbon dioxide in the inhaled gas-air mixture of the experimental self-rescuer is explained by the specifics of the breathing pattern and the presence of the harmful volume of the apparatus (it includes the volume of the half-mask, corrugated tube and the space in the cartridge above the regenerative product), which increases as the product is used up and does not take part in air regeneration process.

The effect of harmful volume in a self-contained breathing apparatus can be estimated from the ratio

^{V}"(l.l\ CCO2br Vep^{C}CO2 EX, (1)

where V br = Vgvs P - the volume of one breath, dm_3; Vgvs - apparatus ventilation (gas-air mixture flow rate through the apparatus), dm3/min; n - frequency of respiratory movements of artificial lungs, min-1; Cco_2 br and Cco_2ex are the concentrations of carbon dioxide on the inhalation and exhalation lines of the experimental setup, respectively, % vol; V_{hv} - harmful volume of the respiratory apparatus, dm_3.

The dependence of the harmful volume on the operating time of the self-rescuer for various test modes of the apparatus, calculated by formula (1), is shown in drawing 3. By the form of the curves in drawing 3, it can be assumed that there is some "initial harmful volume" that is the same for any load on the apparatus. To determine it, we will carry out a linear approximation of the experimental data using the least squares method, excluding the value of the harmful volume at the zero minute. The value of the "initial harmful volume" of 0.28±0.04 dm3 was obtained, which corresponds to the measured initial harmful volume of the device, equal to 0.30±0.02 dm^3.



Drawing 2. The growth of the harmful volume during the operation of the device at various loads: 1 - 10 dm3/min, relative rest; 2 - 30 dm^3/min, medium load; 3 - 35 dm^3/min, medium load; 4 - 60 dm^3/min, high load; 5 - 70 dm^3/min, high load

The main and most severe test mode is the nominal mode: pulmonary ventilation - 35 dm^3/min at room temperature. According to the results of tests of the pilot batch, the self-rescuers correspond to the physiological characteristics of the standard [5], surpassing them in the nominal mode in breathing resistance by 45...70%, in the average concentration of carbon dioxide on inspiration - by 35.40%; by the temperature of inhaled air - by 10.15%.

In the nominal mode, the device actually has an average protective action time of 17.7 minutes (with a nominal protective action time of 15 minutes), breathing resistance - 25 - 45 mm of water. Art., the oxygen concentration in the breathing bag reaches 90%, the temperature of the inhaled air-gas mixture does not exceed 45 °C. All these parameters are within acceptable limits [5].

Mass and dimensions of mass-produced insulating self-rescuers with a protective action time of 15 minutes

Table 1

Name of self-rescuer	Weight, kg	Dimensions, mm
Ocenco M-20 (USA)	1,5	172 X 172 X 83
SCRAM (USA)	2,2	240 X 210 X 110
OXY K-pace (Germany)	4,0	350 X 310 X 170
S15(Germany)	3,0	215 X 220 X 120
OXYcrew (Germany)	2,5	260 X 220 X 120
SI 15 (Ukraine)	2,2	240 X0145
Biocell 1 Start (France)	1,85	178 X 189 X 89
PN 15-40 Hood (France)	2,4	315 X 315 X 70
GDZK (Russia) - filtering	0,8	180 X 180 X 130
Experimental self-rescuer	0,8	115 X 190 X 210

The mass and dimensions of the experimental apparatus in comparison with mass-produced Russian and foreign insulating breathing apparatus are given in Table. 1, which for comparison also shows the mass and dimensions of the GDZK - a commercially available filtering self-rescuer.

Conclusion. The experimental apparatus is comparable in weight and dimensions to filtering self-rescuers, but at the same time provides respiratory protection regardless of the composition of the atmosphere.

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