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A POSSIBLE APPROACH TO THE QUALITY OF BREATHING ORGANS PROTECTIVE EQUIPMENT´S EXHALATION VALVE ASSESSMENT

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Abstract: *One of the most important parts of most equipment designated for breathing organs protection is an exhalation valve which basically determinates the quality of breathing organs protective equipment. Its quality and technical properties affect the quality of protective equipment as the whole set in a strong way. That is why an extraordinary attention has to be devoted in terms of the exhalation valve quality assessment. An aim of information is to point to some problems related to the evaluation of the breathing organs protective equipment quality.*

Keywords: Device for breath organs protection of a filtration type, exhalation valve, protective mask, valve chamber

1. Introduction

Promising protection of breath organs can be ensured only with the help of protective devices. The overall quality of devices for breath organs protection is given by the quality of their simple parts. An exhalation valve belongs among the most important parts of a facial mask. Its mission is within exhale "to concede" to the outside of exhaled air and then to quickly close the exhalation valve chamber in order to not allow to penetrate a contaminant from outside into a harmful space of the mask or to keep an amount of the contaminant on the lowest level. Malfunction of the mask's exhalation valve directly threatens the user who works in a contaminated environment. Here is absolutely valid that: "A part costs only a few crowns" affects the quality of the whole mask". This was known by masks´ designers of older types of both military and civilian ones. They used two exhalation valves structurally arranged in a row. The space between the valves was called as exhaled physiological chamber whose task was to dilute the contaminant penetrated from the outside area through the exhalation valve at the time of so called dead phase. Dead phase is the time when the overpressure caused by exhalation stops to be effect which ensures opening of the exhalation valve till the time when alone valve´s elasticity comes to sealing on a seating, thus to really closing of the exhalation valve chamber. During this time into the space behind the valve can thus get a certain amount of the contaminant. The contaminant in the mask with one exhalation valve gets directly into the mask's harmful space, where, although it will be diluted but the air, is inhaled directly by the mask´s user. During the dead phase of exhalation valve enters into the mask´s harmful space also a certain amount of harmful substance in the case of double-valve system.

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This one is diluted in the chamber. Depend on physiological differences of each user the closing time of the inner and outer exhalation valve (internal valve closes early due to early release of pressure caused by breath) can be different, too. In connection with this, the contaminant reaches harmful space of the mask across the inner valve, nonetheless, in significantly smaller amount.

Penetration of the contaminant from outer environment into the mask is a basic evaluative element of the facial mask quality. If we exclude a protective filter, for each mask, however, three possible ways of the contaminant penetration are considered. The most important one is a keeping of sealing line, thus the contaminant can penetrate through a strap of face piece and face touch. Secondly, the contaminant can penetrate through the exhalation valve or through the system of exhalation valves and, finally, through constructive untightness of the mask. If the mask is set right and it is not mechanically damaged then leakages through constructive untightness we can exclude. The extension of permeation through the sealing line can be affected with a choice of a protective mask right size and naturally a size of a retaining system on a head, thus the quality of a keeping system of the mask. The quality of the exhalation valve with the tightness of the sealing line is crucial for mask protective function indemnity. This leakage can significantly affect two observing parameters of the mask. These are a total inward leakage and so called a protection factor [1]. Thus, the quality of the protective valve has a crucial influence on mask´s protective properties and its quality assessment.

2. Demands on the Exhalation Valve within modern Protective Mask

In the nineties the whole row of face protective masks was established into the armament of modern armies and for civilian sphere. Within these masks very resistant material were employed. These materials are typical with high resistance against permeation of under interest toxic compounds. Within civilian mask some constructive bundles till that time unused by military masks were introduced. A typical example is a device for water intake. Moreover, fixative systems were improved in order to protect against tightness of the mask disturbance during the user's movement. Furthermore, filters have been significantly improved from the point of view of their form. The main aim is to decrease the effect of a toggle effect, thus to disturbance of mask tightness in the tight line. On the other hand, relatively widely exhausted valve chambers with one exhausted valve have been introduced without respecting the fact that in army conditions either increasing of the nominal protection factor or decreasing of inward leakage were demanded. This trend can be documented for instance on army masks M-90 (Italian production), M-95 (Finland production), M-2000 (German production), C-4 (Canadian production), SM-3 (Switzerland production) and FM-12 (British production). The last one and S-10 mask is considered as a standard in the area of the breath organs protection in conditions of advanced armies. Concerning civilian mask it is possible to name masks of PROMASK a SARI (Finland production of Kemira company – today SCOTT) or Czech mask CM-6. Up to increased demand for protective masks properties that result from the requirements of NATO, could be the reason that a newly developed mask GSR Scott for the British Army has again two exhalation valves (Figure 1).

The protective mask has to provide the reliable protection within all supposed activities. When analyzing the facial part of the mask the largest demands are put on the exhalation valve. It must maintain its physico-chemical properties for a defined period of time in storage, during training outside the contaminated area and especially in the performance of professional tasks in contaminated areas. It

is therefore logical that on the quality of the exhalation valve should be given the extraordinary attention when they are designed. The quality of valves should be regularly evaluated both for masks which are stored and for masks that are just used.
In the past an experimental measurement of exhalation valve quality [2] has been aimed to evaluate their resistance against natural and accelerated aging and chemical resistance against chemical warfare agents, which was representative by sulfur mustard gas, was performed. In a scope of the exhalation valve mask of OM-90 it was found that after one year period of natural aging the hardness of the polymer mixture over the framework of the required values of the technical conditions increases. Increasing of the hardness of a polymer mixture can ultimately lead to loss of flexibility and elasticity of the valve, to the subsequent extension of the valve dead time, to increase the coefficient of under sucking or complete loss of ability to seal the valve. If this problem is known, then would be possible to maintain a regular exchange of the mask valve correctly. It is the problem of maintenance of the mask and ensuring of sufficient funds to purchase the exhalation valve as a spare part.

Figure 1: Exhalation valve system of GSR mask of SCOTT company [6]

It is very important to realize, that the exhalation valve is in a direct contact with the contaminant in the form of gases and vapors. For this reason the valve should have a high chemical resistance. Between standard measurements with which the army finds chemical resistance of material of an isolation type belongs the measurement of so called breakthrough time with the help of the MIKROTEST method [3]. The essence of this method is an indication of sulfur mustard penetration through researched material using a highly sensitive chemical reaction. This method uses hygroscopic cellulose paper colored with Congo red (pH-indicator) and after drying activated with N-chloro-N-(2-tolyl)benzamide (CNITI-8) as an indicator of sulfur mustard penetration. The principle of indication is based upon the reaction of CNITI-8 amide with sulfur mustard which releases hydrogen chloride converting the alkali form of an acid basic indicator to the acid form, subsequently the Congo red form is converted to the blue form using azo-hydrazone tautometry (Figure 2).
The indicator paper is in direct contact with a measured insulating foil and the change of color to blue occurs at the point of chemical agent penetration. The moment of penetration of the chemical agent is detected in the threshold amount of 0.005 $mg.cm^{-2}$. If this concentration is reached after that it is signaled by the first perceivable blue spot with a diameter of approximately 1 mm. The emergence of a

blue spot is investigated subjectively. One of the main advantages of that method is that the resistance measurements are performed for a real chemical warfare agent. Measurement of resistance of researched materials for other chemicals of interest is conducted in accordance with ČSN EN 6529 norm [5].

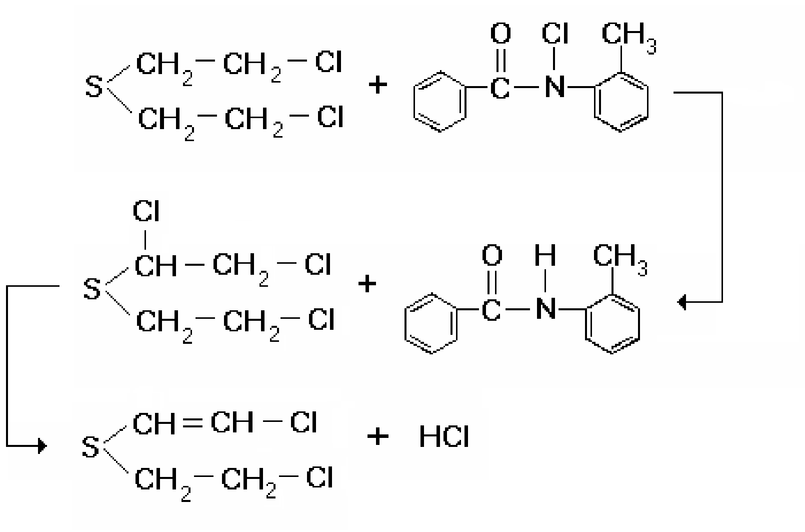

Figure 2: A reaction scheme of sulphur mustard indication [4]

In the past time realized measurements of resistance of exhalation valves in accordance with norms [3,5] pointed to their relatively long resistance against a liquid phase of sulfur mustard within both new valves and those which came through the process of naturally and quicker aging within one year. As shown in table 1 average values of breakthrough time for simple categories of valves achieves hundreds of minutes.

Table 1 Average values of chemical resistance of exhalation valves against sulphur mustard [2]

Used method	Average values of chemical resistance of exhalation valves, [min]		
	New	After natural aging within one year	After quicker aging
MIKROTEST	401	324	314
ČSN EN 6529 1)	1214	1447	1251
1) the norm corresponding to the EN 6529			

The difference between these values is mainly due to different sensitivity of the employed methods. The measured values show that the exhalation valve should be sufficiently resistant to sulphur mustard liquid phase. Due to the fact that the exhalation valve of the mask must be protected against the effects of dirt and damage by a cover which also prevents contamination of the exhalation valve with liquid phase of contaminant it can be assumed that the valve will come into contact with contaminants in the form of gases and vapors. On the basis of earlier experimental work the resistance of polymeric materials for gases is approximately 3 - 5 times higher than for liquids. For this reason, it is possible to assume that at least for chemical warfare agents exhalation valve is durable enough for both phase it means for liquid and gaseous ones. In connection with the measurement of chemical resistance of the exhalation valve it is necessary to consider whether the measurement of chemical resistance for the liquid phase and using both methods are correct. The value of breakthrough time only shows the resistance of the material against penetration with test substances, thus the period from the time effect of the substance on the outside (front) side of the test material to the point of intersection in a detectable concentration that is dependent on the type of detection equipment, and is given by the norm.

When measuring breakthrough times of protective folio and components of polymeric materials these very often to swell. It causes deformation of shape of the product. Reshaping of the exhalation valve leads to the loss of its functionality thus to leakage on the seat and thus the loss of protective properties of the mask. It is obvious that the degree of swelling of the material of the exhalation valve and thus the rate of loss of sealing ability will depend on the type and characteristics of the exhalation valve construction material, of contaminant concentrations in the vicinity of the exhalation valve, ambient temperature, etc. If there is a concurrence of adverse effects it may result rapid loss of sealing ability of the valve and imminent danger to the user of protective equipment operating in a contaminated environment. In particular, the effect of organic solvent vapours may cause loss of sealing ability very early, in minutes, after entering the contaminated area.

Possible loss of protective properties of the exhalation valve due to its mechanical deformation by permeation of solvent into the material, the exhalation valve should be intensively studied and should be a serious criterion for selection of suitable constructive materials. The results of studies may be important for the design of the exhalation valve chamber and in particular the decision on the number of valves.

The exhalation valve can be exposed to different concentrations of contaminant. If the valve chamber contains two exhalation valves it will function correctly when both valves leak and exposed internal valve substantially lower concentrations of pollutants than the outside. Moreover, regarding dynamics of breathing will decrease as a result of its rinsing with the help of breath out air. On one side the internal valve will be protected against permeation by contaminants in this manner. On the other hand, the high concentration gradient between the internal and external environment can affect the dynamics of permeation into construction materials harmful external valve. The proper functioning of the valves, however, will have a decisive impact on resistance of the external valve which will be exhibited during the stay in a contaminated environment to the real concentration of pollutants. Therefore, for that reason it would be appropriate to carry out measurements in static conditions with a well-defined concentration of test substance. Moreover, measurements have to be performed with a simulation of a real constructive set. It means that the valve has to be kept on a reliable seat and this constructive complex should be put together at least in a final stadium of verification of its resistance in a position which responses to the real position within carrying of the protective mask. This could allow the assessment of the impact of the under interest test substance concentration on the "opening time" of the valve and to determinate within exactly specified conditions (concentration, temperature) the moment of loss of protective properties of one of the most important part of the mask. These measurements could undoubtedly have practical significance both in terms of selection of suitable structural materials, as well as for optimizing of the design of the exhalation valve and valve chambers. The obtained data could have a practical impact on decisions about the employment of a particular mask in a contaminated area.

3. Conclusion

Security of persons´ protection in a contaminated environment is one of the biggest challenge especially if they need to stay in the contaminated area for long time. Promising protection is dependent on the correct function and durability of all components, which assembled preservative equipment. Testing of chemical resistance of the exhalation valve and findings of its "opening time" strictly depends on the type of chemical warfare agents its concentration in the external environment, temperature and on other related factors. Information gained from this could be a base for practical use of masks and for selecting appropriate construction materials useful for the improvement of protective equipment.

References

[1] ČOS 841 503 1st issue. Individual protective equipment of breath organs. All armed forces protective masks. Names, definitions and general demands (in Czech).

[2] MECA, Stanislav. ISOLATION. Research of new constructive items and chains for devices of skin protection. EO2 Development and verification of methods of usability of current materials and equipment. DE01 Persistency of selected parameters of constructive materials in conditions of natural and quicker aging (in Czech). [Study]. Brno: VOP-026 Šternberk, division of VTÚO Brno 2009. 38 p.

[3] Methodology of VOP-026 Šternberk. Division of VTÚO Brno. MIKROTEST 23 1301 “Set of breakthrough time of protective materials contaminated with drops and gases of sulfur mustard in static conditions (in Czech).

[4] HALÁMEK, Emil, KOBLIHA, Zbyněk, PITSCHMANN, Vladimír. *Analysis of chemical warfare agents* (in Czech). Vyškov: ÚOPZHN UO Brno, 2007. 143 p. ISBN 978-80-7231-258-0.

[5] ČSN EN ISO 65629 (83 2732). Protective clothing - Protection against chemicals - Determination of resistance of protective clothing materials to permeation by liquids and gases (in Czech). Praha: Czech normalization institute. October 2002.

[6] http://www.armedforces-int.com/article/general-service-respirator.html