

Choosing the Correct Protective Equipment for the Respiratory Tract

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Abstract

In order to protect the respiratory systems of workers in coal mines and other major industries, personal protective equipment must be chosen that is appropriate to the adverse working environment and the user's characteristics. We propose general criteria for selecting protective equipment based on previous investigations of respiratory-system hazards in coal mines and other industries. In order to select the appropriate equipment for different working places, a test regimen examining different oxygen concentrations in the atmosphere and different types and concentrations of pollutants was developed for respiratory protection equipment used in Poland. Special attention was given to high dust concentrations and to conveyor-belt fires in mines.

Introduction

Limiting the effects of chemical hazards is undoubtedly the most important task in a total program of occupational protection. It is not always possible to combat chemical hazards by technical means such as airtight seals, automation and effective ventilation. It becomes necessary to equip workers with protective devices, including respiratory protection apparatus. Such equipment is known in Poland under the general designation as "ODO" equipment.

Because of the large number of potential atmospheric pollutants in industry and the extremely variable work environments, ODO equipment comes in a wide range of types, designed to protect workers against specific hazards occurring at any given job site. In order to ensure the correct choice of ODO equipment from among the many types, it is essential to know the actual conditions of the job site, the working and design principles of the equipment available, and also the basic processes governing the removal of toxic substances from the air. For this purpose the maximum allowable peak, as well as average concentrations of toxic substances in the work environment, must be established.

The protection ability of ODO equipment is measured by the type and quantity of gases, vapors and aerosols produced. ODO equipment should also be comfortable, i.e., have low weight, low breathing resistance (inhalation and exhalation) and an aesthetic appearance. In addition, it must neither impede the movement of the wearer in performing his job nor interfere with his hearing or vision.

It is also important for the worker to hear well and to maintain verbal communication with others nearby. Of greater importance in some workplaces is the freedom of movement (e.g., working in cramped spaces), while in still other sites a major requirement is facilitating rapid and easy change of the respirator's purifying elements.

ODO Classification and Application Criteria

In many countries, there are varied schemes for classifying equipment based on the type of hazard or on the operating principles of the

apparatus considered. In Poland, the classification of individual equipment for the protection of the respiratory tract is regulated by the terms of the Polish Standard PN-77/Z-02005, which lays down rules for "equipment for the protection of the respiratory tract and individual equipment for the protection of the respiratory tract in an air environment." According to this Standard, ODO equipment is divided into two classes: work equipment and escape equipment. Work equipment is further sub-divided into two groups: air-purifying and isolating. As the names imply, one group purifies the outside air, and the other isolates the worker from outside air. In principle, isolating equipment may be used under all conditions of chemical hazards. The type of construction of isolation equipment largely determines the mass, which is usually considerable.

Current models have substantial mass, not less than 2 kg. Air-purifying equipment, a group which includes full-face masks and half-masks, have smaller mass (varying with type, from a few grams up to one kilogram) and is usually many times cheaper to produce than isolating equipment. However, the use of air-purifying equipment is limited by several factors. The choice between isolating or air-purifying apparatus is often governed primarily by the oxygen content in the contaminated air.

It is normally accepted in Poland that 17% (volume) oxygen content in the air represents the limit that decides applicability of the given apparatus type: when oxygen content falls below 17%, it is not safe to use air-purifying apparatus.

If the oxygen content in the air is found to be greater than 17% by volume, choosing the kind of air-purifying equipment depends on the type of contamination and its concentration in the workplace atmosphere. Equipment with an appropriate overall protection coefficient must be selected according to the known concentration. After first establishing the concentration at the job site, the magnitude of this coefficient may be calculated by the following equation (Rozmarynowicz et al., 1978):

$$S = \frac{100}{W}$$

where

S = apparatus protection coefficient and

W - multiple of highest allowable concentration.

For example, when the toxic substance at the workplace has a concentration 10 times the allowable (W = 10), the equipment recommended should

exhibit a protection coefficient not less than 10 (purifying efficiency 90%).

An important parameter determining the suitability of given equipment for a particular job is the resistance offered to inhalation and exhalation by the wearer. If this parameter is set higher than a certain limiting value, the wearer may feel discomfort and fatigue, and injurious effects may even be caused. In Poland, the current upper resistance limit is 200 Pa, however, efforts are being made to achieve breathing resistances not greater than 100 Pa (Rozmarynowicz et al., 1978).

Working while wearing apparatus with a breathing resistance from 30-100 Pa is counted as one degree higher on the scale measuring work difficulty than the same work carried out without the ODO equipment, i.e., light work becomes classified as medium heavy, medium heavy counts as heavy, and heavy as very heavy. Work while wearing an apparatus with a breathing resistance from 100-200 Pa is counted as heavy or very heavy.

Working with protective full-face masks and half-masks can only be done by trained personnel well acquainted with the construction and correct use of the equipment. Training also includes exercises at different breathing rates (normal, deep breathing, etc.) while at rest and during physical exertion. In general, it has been established that the duration of uninterrupted work in a gas mask during heavy activity should not exceed 30 minutes per working hour, or in the case where very heavy work must be performed, only 3 to 5 minutes per 30 minutes working period (Jethod et al., 1973).

Multi-purpose and gas half-masks are recommended depending on the type of substance against which protection is required and the degree of toxicity such as cases where the concentration of the toxic substance in the environment of the working site is not greater than 10 to 15 times the NDS value. Dust half-masks are used in general for dust concentrations not exceeding 400 mg/m³ since higher concentrations require changing masks too frequently.

Half-masks, however, are not recommended for application where the air is polluted with highly toxic substances such as hydrogen cyanide, arsine, etc., irrespective of their concentrations. When substances of this class of toxicity are present, full-face gas masks are required (face type or cap type) to be used in conjunction with suitable absorber canisters (Figs. 1 and 2). Absorber canisters can only be used where the toxic substances occur in a concentration not greater than

0.5% by volume. In compliance with Polish Standard PN-77/Z-02005, masks are classed as either cap masks, which provide an airtight seal on the wearer's head and face, or as face masks, which cover the wearer's mouth, nose and eyes, and which fit the face tightly, kept in place by head straps (see Figs. 1 and 2).

Due to the fact that the use of these absorbers is limited to sites with an oxygen content of 17% by volume, they cannot be used in enclosed spaces such as cisterns, tanks, sewers, etc. To maintain the required air-tightness when wearing masks or half-masks by users with varied facial dimensions, they come in several sizes: half-masks most often in

three sizes and cap-type masks in as many as five sizes. The face-piece must be carefully selected and fitted to suit the actual wearer.

Methods for Evaluating ODO Equipment

To facilitate the rapid, straightforward choice of ODO equipment, we prepared a schedule of recommended types of ODO equipment suitable for a particular hazard (Table 1).

Evaluating ODO equipment includes checking its protective capability in the presence of the given hazard, determining the quality of workmanship, and ensuring that the working parameters comply with requirements. This is done by carrying out a series of tests. The test methods applied depend on both the type and the purpose of the protective equipment. The widely varied work conditions for which the equipment is designed to be used and the complex manufacturing processes make it necessary to correlate the evaluation method with the classification system. From this latter aspect, tests may be divided into model and prototype tests and performance check tests.

Methods applied for model and prototype tests are precise and accurate, while performance checks, limited to determining the most important parameters of the equipment, are rapid and straightforward (Rozmarynowicz et al., 1978). Such tests are usually carried out by the manufacturer and provide the basis for approving that batch of products for distribution and sale.

To ensure selection of equipment appropriate to the working conditions, we developed at the Central Mining Institute test methods which rely on simulating the anticipated workplace conditions. One such method is determining the protective capacity of self-rescue apparatus in the presence of smoke caused by burning conveyor belts in hard coal mines in Poland. We developed a test method and appropriate apparatus which allows smoke production from an airflow across burning belts and coal corresponding to a unit area of belt in a hard coal mine. This test also determines the effect on the worker from the chemical compounds passing through the absorber apparatus. In this method, it is possible to simultaneously measure important working parameters of the equipment, such as breathing resistance and duration of protection, in the presence of carbon dioxide (Tokarzewski et al., 1982). Tests to check the suitability of dust respirators in mining are carried out in a dust chamber with a coal-dust suspension

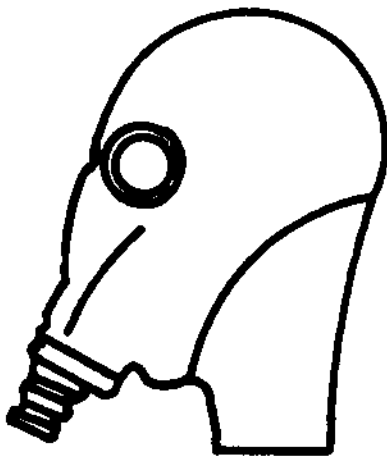


Figure 1. Cap mask.

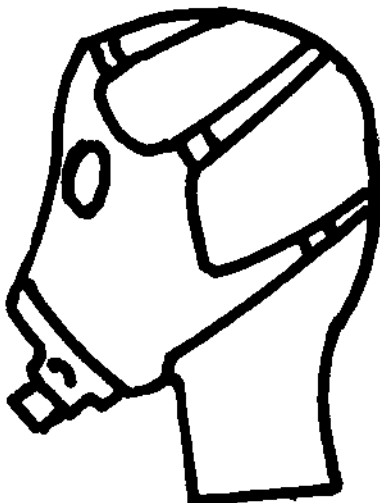


Figure 2. Face mask.

Table 1. Workplace hazards and considerations for the selection of ODO equipment.

Recommended class of equipment	Job-site oxygen content	Recommended equipment	Additional hazards and work requirements	Recommended equipment type	Additional information
Working	<17% by volume	Isolating	Unrestricted movement	Air- or oxygen-regenerating	Work time limited by oxygen or air reserve in cylinder
			Unspecified work time	Hose	Work time unlimited but hindered by length of hose connection
			Small, confined space	Escape, cylinder or regenerating	Work time limited by oxygen or air reserve, or quantity of oxygenating agent
	17% by volume	Isolating	Gases, vapors, and unidentified aerosols	Air or oxygen cylinder, or regenerating	Work time limited by oxygen or air reserve, or quantity of oxygenating agent
			Gases, vapors, and aerosols of unknown concentrations	Air- or oxygen-regenerating	Work time limited by oxygen or air reserve, or quantity of oxygenating agent
		Purifying	Gas or vapor concentration up to 0.5% by volume, or 2% ending on gas, including highly toxic	Face or cap masks with absorber canisters	Work time limited by protection time of absorber
			Dust concentrations greater than 400 mg/m ³	Dust protection, half-masks, protection classes I, II, and II	
Escape	<17% by volume	Isolating	Gases and vapors: low and medium toxic substances in concentrations up to 15 times highest allowable concentration	Gas protective half-masks	
Escape	≥17% by volume	Isolating or purifying	Apply same criteria as for Working Equipment		

of a concentration approximately the same as mean dust conditions in hard coal mines.

Apparatus for protecting against agricultural chemical spray is tested by a method where an insecticide mist is formed in a test chamber and the effective protection is assessed by using living organisms such as house flies.

Effective protection time afforded by protection apparatus designed to protect the respiratory tract against toxic vapors and gases is estimated by methods in which an air-vapor or air-gas mixture is passed through the protective apparatus in a quantity and concentration corresponding to the actual conditions found at the working site, and

then determining the time to "breakthrough," i.e., when the toxic substance is detected beyond the respirator filter in a quantity exceeding the highest allowable concentration.

The protective capacity in the presence of dusts is estimated by preparing a standard air-dust mixture with dust particles of pre-determined size and concentration and measuring the mass collected at the respirator filter and the dust concentration collected beyond the filter. Filtration capacity in the presence of liquid aerosols is checked in the presence of particles of mist formed from various chemical agents. In Poland, the oil-mist test is the one most frequently applied.

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