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Respiratory Protection

Filtering devices for industrial workplaces

Basics, developments and new challenges

The respiratory system is the main weak point of the body for the defence against hazardous airborne substances. Gases and vapours (e.g. corrosive gases, organic vapours), airborne solid particles (e.g. dust, fume), liquid aerosols (e.g. oil mist) and also biological agents can easily pass through the airways to the lungs.

In addition to local toxicity in the respiratory system, inhaled compounds can also elicit effects at extra-pulmonary sites (e.g. central nervous system, liver, kidney, immune system). With respect to occupational exposure, the importance of the respiratory tract as a target for noxious contaminants is shown by cases of chronic lung disease induced by exposure to asbestos and beryllium as well as cases of occupational asthma. In the year 2000 a high number of 6,183 cases of asbestos-related respiratory diseases have been acknowledged in Germany alone.



Worker with hearing protection and filtering half mask

Today there are still a huge number of workers in industries that are daily exposed to hazardous substances in the workplace. In many cases when the tolerable concentration is exceeded and cannot be reduced by other means there is a need for respiratory protection as the last resort.

The most challenging task for responsible and concerned persons is a proper selection of a suitable respirator that fits well, provides sufficient protection and will interfere as little as possible with the wearer and his work.

Types of respiratory protective devices (RPD)

According to their operation differentiation is made between two main categories of RPD:

A) FILTERING DEVICES (RESPIRATORS): they purify the contaminated air for breathing by removing hazardous substances. They must not be used in oxygen deficient atmospheres

B) AIR SUPPLIED DEVICES (BREATHING APPARATUS): they work independently of the ambient atmosphere by providing the wearer with breathable air from a separate source

In the following article the focus is on filtering devices only. Such complete RPD consists of a facepiece and filter(s) or blower with filter(s) as the functional part.

Facepieces (*1)

The facepiece is the part of a respiratory protective device which establishes (forms) the interface between the wearer and the functional part of the device. The most common facepieces are:

- *Full face masks and half masks including filtering half masks which need a good face seal with the wearer's face* ➤

*1 new terminology according to ISO: human interface

- *Hoods, helmets, blouses and also suits - the so called loose-fitting facepieces - being provided with sufficient clean air by powered/powered assisted devices*

Particle filters

Particle filters for full face masks and half masks are divided, according to their filtration efficiency for particles, into the classes P1 (minor efficiency), P2 (medium efficiency) and P3 (high efficiency). They are marked accordingly and with the identifying colour code white, as stated in EN 143. For use in powered or power assisted devices the filters are marked with 'TH' (turbo hood/helmet) or with 'TM' (turbo mask) and the number of the performance level (1, 2 or 3) of the complete device. Particle filters do not protect against gases. Filters certified against the older version of EN 143:1990 can be marked with the additional letters "S" - only for use against solid particles.

Gas filters

Gas filters are subdivided into gas filter types according to their main range of application, and into gas filter classes according to their performance. The classification is based on their capacity. The higher the number the higher their capacity. In contrast with the particle filter the protection in terms of efficiency is the same. Gas filters will not give protection against particles. Gas filters will be marked by a type identifying letter, the number for the class indicating the capacity and a specific colour code according to EN 14387, e.g. B2-grey. Gas filters used in powered or power assisted devices will be additionally marked with 'TH1, 2 or 3' or 'TM1, 2 or 3', depending on the devices class, e.g TM3A2.

Apart from the filter types mentioned in table 1 there are also multi-type gas filters available which are marked accordingly (e.g. A2B2E2K2=ABEK2). These kinds of filters have to meet the safety requirements for every single respective gas filter type of the named gas filter classes and they may be used accordingly.

Combined filters

Combined filters will give protection against gases, vapours and particles. They consist of a gas filtering part and a particle filtering part. Combined filters are marked as particle and gas filters; example: A2B2P3. This applies analogously to combined filtering half masks; Example: FFA1P2.

Filtering devices against particles, gases and vapours (non powered)

The most common non powered respirators are combinations of a full face (EN 136) or a half mask (EN 140) with particle filter(s) (EN 143) or gas/vapour filter(s) (EN 14387). ➤

TYPE	COLOUR CODE	EXPOSURE AGAINST	CLASS	MAXIMUM PERMITTED GAS CONCENTRATION
A	Brown	Organic gases and vapours with boiling point › 65 °C)	1 2 3	1000 ml/m3 (0,1 % by vol.) 5000 ml/m3 (0,5 % by vol.) 10000 ml/m3 (1,0 % by vol.)
B	Grey	Inorganic gases and vapours e.g. chlorine, hydrogen sulfide, hydrogen cyanide - Not against carbon mon- oxide	1 2 3	1000 ml/m3 (0,1 % by vol.) 5000 ml/m3 (0,5 % by vol.) 10000 ml/m3 (1,0 % by vol.)
E	Yellow	Sulfur dioxide, hydrogen chloride and other acid gases	1 2 3	1000 ml/m3 (0,1 % by vol.) 5000 ml/m3 (0,5 % by vol.) 10000 ml/m3 (1,0 % by vol.)
K	Green	Ammonia and organic compounds of ammonia	1 2 3	1000 ml/m3 (0,1 % by vol.) 5000 ml/m3 (0,5 % by vol.) 10000 ml/m3 (1,0 % by vol.)
AX	Brown	Low boiling organic com-pounds (boiling point ≤ 65 °C) of the group 1 and 2 of low boiling compounds	-	Gr 1 100 ml/m3 for max. 40 mins Gr 1 500 ml/m3 for max. 20 mins Gr 2 1000 ml/m3 for max. 60 mins Gr 2 5000 ml/m3 for max. 20 mins
SX	Violet	As stated by the manufacturer	-	5000 ml/m3 (0,5 % by vol.)
NO-P3	Blue+ White	Nitrous gases, e.g NO, NO^2, NOx	-	
Hg-P3	Red+ White	Mercury	-	
CO*)	Black	Carbon monoxide	-	special directions for use
Reactor*)	Orange	radioactive iodine included radioactive iodomethane	-	special directions for use
most: Reactor P3	Orange + White	radioactive iodine included radioactive iodomethane	-	special directions for use

Table 1: Gas filter types

The particle filtering half mask (EN 149) and the gas and combined filtering half mask (EN 405) are devices of their own since they consist entirely or mostly of filter material, through which the inhalation air flows or in which the main filter constitutes an inseparable part of the device. Particle filtering half masks are divided into the classes FFP1, FFP2 and FFP3 according to EN 149. The range of application is the same as for half masks with corresponding classes of particle filters P1-, P2- or P3. Elderly FFP devices marked with the additional letter 'S' may only be used against particles of solid matter (dust, smoke) and aerosols which develop from spraying of solutions or dispersions of particles of solid matter in water. Gas filtering half masks are classified according to EN 405 into types FFA, FFB, FFE, FFK, FFAX and FFSX corresponding to the main field of use as for half masks with the respective gas filters A, B, E, K, AX, SX listed in table 1. Only the classes 1 or 2, e.g. FFA1, and FFB2, are applicable. Combined filtering half masks may have integrated or replaceable particle filter(s), e.g. FFA2P2. A colour marking for gas and combined filtering half masks has not been provided. Otherwise it shall follow the requirements for filters.

"power assisted filtering devices consist of a battery-operated blower and filters for purification of the breathable air from particles, gases and vapours"

Powered and power assisted filtering devices against particles, gases and vapours

Powered and power assisted filtering devices consist of a facepiece, a battery-operated blower which delivers filtered air to the facepiece, and one or several filters for purification of the breathable air from particles, gases and vapours. Therefore they are dependent on the ambient atmosphere and cannot be used in oxygen deficient atmospheres. The blower is connected to the facepiece either directly or by means of a breathing hose. Exhalation air and excess air flow out through exhalation valves or by other means. The energy supply of the blower will be carried by the wearer of the device (battery). These devices have only a small inhalation resistance and show at normal and also at increased ambient temperatures a particularly favourable micro-climate within the facepiece.

They are classified according to the purpose of application and the facepiece employed into the following main groups:

- *Power assisted filtering devices incorporating full face masks and half masks according to EN 13942 with particle filter, gas filter or combined filter*
- *Powered filtering devices incorporating helmets or hoods according to EN 13941 with particle filter, gas filter or combined filter*

For the designation of powered and power assisted devices in the European standards the letters and numbers TM1 up to TM3 and TH1 up to TH3 are employed in connection with the respective filter designations. Thus, T stands for "Turbo", short designation for blower, understood throughout Europe, M for mask and H for hood or helmet. Helmets or hoods used as "open" facepieces in powered devices must not be used with filters only. The turbo filtering devices are classified according to their respiratory protective performance into 3 classes. The protection performance level is related to the complete device and increases from class 1 to 3.



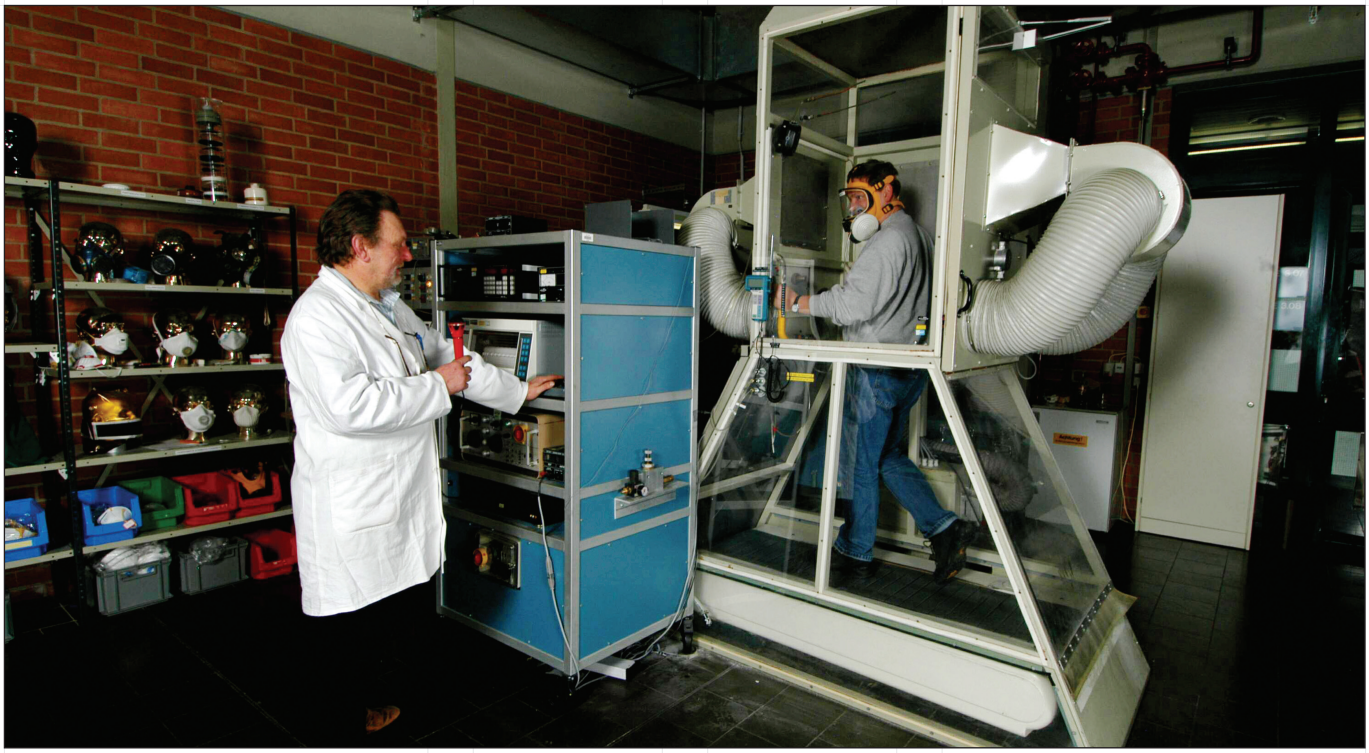
Metal cutting/grinding; particle filtering half mask

Selection

The selection of the respiratory protective devices (RPD) is governed by the suitability of the wearer and by the following conditions of use:

- *Ambient atmosphere, e.g. oxygen content, type and concentration of hazardous substances, temperature, humidity, risk of fire and explosions*
- *Location, e.g. type of room, freedom of movement*
- *Intended purpose, e.g. working duration, work rate, rescuing, escape*

If the conditions of use are not adequately known, as it may be the case at exploration, fire fighting and rescue work, as well as during work in containers and confined spaces, breathing apparatus must be used. Previous to the selection of an RPD it has to be assured that they offer adequate protection against the risks without leading to any increased risk themselves and take account of ergonomic requirements and the worker's state of health. The respiratory ➤



Leakage test in laboratory

protective devices have to be adjusted to the wearer in order to achieve a good tightness. A good tightness of the facepiece is a precondition for the protective performance of the RPD. People wearing beards, having whiskers or deep scars in the area of the sealing of full face masks, half masks and filtering facepieces are not qualified to use them.

Testing & certification

RPDs intended to be placed on the European market are to be tested and certified against the EC -Directive 89/686/EEC (council directive for personal protective equipment) and require an annual control for the final product or a monitoring of the quality system by a notified body. The notified body in charge of the surveillance measures is indicated by a four digit number, e.g. "0121" following the "CE" marking.

Requirements for use of filtering respirators

The use of filtering devices requires that the ambient atmosphere contains 17 percent by volume oxygen at minimum. Filtering devices must not be used in unknown ambient conditions, or if the composition of the ambient atmosphere may change adversely, e.g. in containers and confined spaces. If in doubt whether filtering devices are offering adequate protection (e.g. extent of concentration of harmful substances, effective working duration, undue rise of filter temperature, development of undesirable reagents in the filter) breathing apparatus have to be used. Gas filters should basically only be used against those gases and vapours which can be smelt or tasted by the wearer once the filter is exhausted (breakthrough of the filter). For the use of gas filters against gases and vapours, whose breakthrough the wearer of the device is not able to detect, workplace-specific rules of use must be implemented and be followed, otherwise breathing apparatus has to be used. The reuse of gas filters is seen as very critical in the case of A-type filters and those filters containing this type. A study carried out at BGIA has revealed that A-type filters loaded for half of their capacity with organic vapours and stored for certain days can lead to unexpected early breakthrough due to the partly high mobility of such substances.

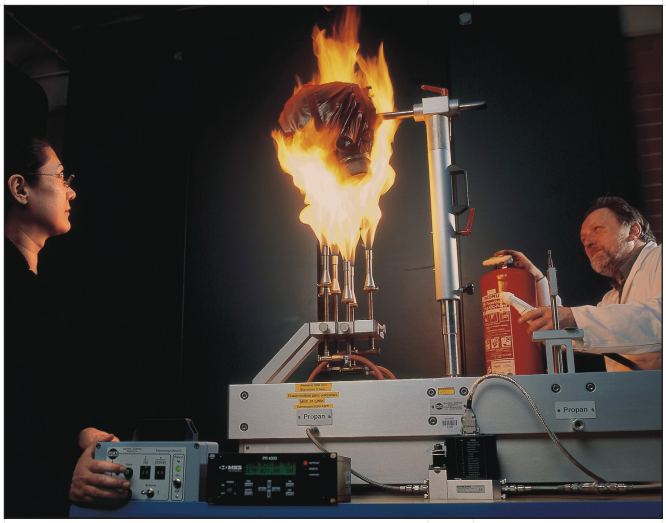
> "the use of filtering devices requires that the ambient atmosphere contains 17% by volume oxygen at minimum"

Design of RPD

Devices containing electrostatic charged particle filter materials can show weaknesses against long term exposure to certain liquid aerosols. Even if no cases of adverse affects to the user's health are known in that context and they are to be regarded as safe in their main area of application, most of the manufacturers have already improved their products to meet enhanced requirements. These requirements are expected to be established in the near future by a European standardisation committee as an amendment of the standard for particle filters (EN 143).

International standardisation (ISO)

In 2002 international standardisation on RPD had been started with a new philosophy in contrast to what has been done in ➤



Flame test in laboratory

standardisation in this area before. The focus is on the needs of the user avoiding being restricted by the design of devices. This new approach will establish essential requirements for a new generation of RPDs derived by a matrix of classes considering the nature of the respiratory hazard and the level of inward leakage of a complete device depending on the work rate and the work duration as physiologic boundaries. Three working groups have been set up, one for general aspects (e.g. selection and use, test methods, definitions, physiology), a group for filtering devices and one for air supply devices.

New challenges

Ultrafine particles are unintentionally appearing as condensation by-products in industries during thermal and chemical processes. Examples are welding fumes, metal and polymer fumes, industrial soot, amorphous silica, and particulate diesel engine emission. Contrariwise they are target substances in the high-tech field of Nanotechnology. Wherever these extremely small particles (below 100 nm; 1 nm = 1 millionth of a millimetre) are from, there is much concern about their potential risk to cause inflammation reactions and tumours of the lungs and in addition to that the fear that available filtering respirators will not give sufficient protection due to the small size of these particles.

> “ultrafine particles are unintentionally appearing as condensation by-products in industries during thermal and chemical processes”

In order to permit assessment of the effectiveness of approved respiratory protective filtering devices against ultrafine particles, the BG Institute for Occupational Safety and Health (BGIA) conducted pilot measurements on selected respiratory filters and measured the penetration characteristics of glass fibre filters of various filter classes (P1, P2, P3) with salt aerosols at particle sizes of < 1000 nm (for the greater part around 40 nm). The scanning mobility particle sizer (SMPS) was employed for this purpose. The short study revealed that the relevant provisions of European standards governing the penetration are reliably met for all three performance categories. The filtration mechanisms already known for particulate air filters seem to be thus also confirmed for respiratory protective devices. Random movement (diffusion) of the ultrafine particles causes them to be filtered off inside the filtering layer. The principle of sieving granulate bulk material, i.e. the finer the particles, the more easily they pass, evidently also fails to apply in this case. Where a suitable filter class is selected, well over 99% of the fine and ultrafine particles should be separated off. Just because this study was only a first shot more research activities are necessary on this important issue in future.

By contrast, a more or less poor fitting of a facemask presents the real problem for the use of respiratory protective devices. This aspect is all too easily neglected during discussions of particle size. ■

Author Details:

Dr. Peter Paszkiewicz has been working for the BGIA for about ten years. He is the head of the sub-division, Personal protective equipment against chemical and biological hazards.

His responsibilities are in the area of filtering respirators, chemical protective clothing, chemical protective gloves and measuring devices for gases in terms of standardisation, testing & certification, research and consultancy. He holds a doctor's degree in physical chemistry.

The Berufsgenossenschaftliches Institut für Arbeitsschutz (BGIA) supports the German Berufsgenossenschaften (institutions for statutory accident insurance and prevention) in solving scientific and technical problems relating to safety and health protection at work. The BGIA also works on behalf of manufacturers and companies within the framework of testing and certification of quality management systems.

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