BRITISH STANDARD

BS 4275:1997
Incorporating Amendment No. 1

Guide to implementing an effective respiratory protective device programme

ICS 13.340.30

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee PH/4, Respiratory protection, upon which the following bodies were represented:

Association of Consulting Engineers
British Compressed Air Society
British Fluid Power Association
British Occupational Hygiene Society
British Safety Industry Federation
Chemical Industries Association
Chief and Assistant Chief Fire Officers Association
Fire Brigades Union
Health and Safety Executive
Home Office
Institution of Fire Engineers
Institution of Mechanical Engineers
Ministry of Defence
Safety Equipment Association
TES (Bretby Limited)
Thermal Insulation Contractors Association
UK Steel Association

The following bodies were also represented in the drafting of the standard, through sub-committees and panels:

AEA Technology
Construction Plant-Hire Association
Imperial College of Science and Technology
International Marine Contractors Association

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13267	30 November 2001	Amendment to Table 7

Contents

Foreword

This British Standard has been prepared under the direction of Technical Committee PH/4. It supersedes BS 4275:1974 which is withdrawn. At the time of publication of this British Standard, no equivalent international standard exists. However, relevant information is contained in CEN/CR 529:1993.

The general recommendations given in this standard have been developed in the light of present knowledge concerning the levels of respiratory protection which can realistically be achieved in workplaces by wearers given reasonable training and supervision. The levels of respiratory protection assigned to the different classes of device in this standard therefore differ substantially from the nominal protection factors in the previous edition of this standard, in CEN/CR 529, or in guidance such as that previously published by the Health and Safety Executive.

A respiratory protective device cannot simply be issued to a wearer on the assumption that it will automatically provide the level of protection assessed in this standard. It should be presented as part of a respiratory protective programme which covers hazard identification, risk assessment, risk control, respiratory protective device selection, fit, training, maintenance, storage and medical surveillance.

The purpose of this standard is to offer guidance for setting up, operating and administering an effective respiratory protective programme involving respiratory protective devices. The attitude of employers and employees is vital in promoting the effective use of respiratory protective devices in the workplace.

Devices purchased after 30 June 1995 will carry the CE Mark. All devices that have been approved by the Health and Safety Executive (HSE) or are claimed by the manufacturer to conform to a standard approved by HSE, which have been in the possession of the user before 30 June 1995 can be used at work beyond that date for as long as they provide adequate protection in the light of the performance levels recommended in this standard, and are maintained in good condition.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 59 and a back cover.

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1 Scope

This British Standard gives guidance on implementing effective respiratory protective device programmes intended to protect against either non respirable atmospheres or atmospheres containing airborne materials at concentrations which could constitute a threat to health, safety or welfare.

This British Standard is applicable to some respiratory protective devices which are intended solely for escape. It does not give complete guidance on such devices, but the principles of selection, use and maintenance described are generally applicable.

This British Standard is applicable to some highly specialized respiratory protective devices, such as closed-circuit oxygen equipment and air line suits for protection against chemical or radiological risks. Protection against biological risks is covered briefly. This British Standard is not applicable to equipment for underwater use.

The guidance given in this British Standard extends to other items of personal protective equipment worn with respiratory protective devices where interactions might either reduce the protection afforded, or interact to create heat strain. Examples of equipment which could interact with respiratory protective devices are ear, eye or head protection; interaction to create heat strain could occur with protective clothing.

2 References

2.1 Normative references

This British Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on page 57. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this standard only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

2.2 Informative references

This British Standard refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on page 58, but reference should be made to the latest editions.

3 Definitions and nomenclature

For the purposes of this British Standard the definitions and illustrated nomenclature given in BS EN 132 and BS EN 134 respectively apply, together with the following.

NOTE 1 The term “fume” excludes gases or vapours.

NOTE 2 The term “facepiece” includes full, half and quarter masks, mouthpiece assemblies, filtering facepieces, semi-hoods, hoods, semi-blouses, blouses and suits.

3.1
assigned protection factor (APF)
level of respiratory protection that can realistically be expected to be achieved in the workplace by 95 % of adequately trained and supervised wearers using a properly functioning and correctly fitted respiratory protective device

3.2
workplace protection factor
measure of the protection provided in the workplace by a properly selected, fit tested, correctly maintained and functioning respiratory protective device when correctly worn and used

3.3
nominal protection factor
maximum percentage inward leakage permitted for a given standard class of respiratory protective device, expressed as the ratio:

$$\frac{100}{\%\ \text{allowable inward leakage}}$$

3.4
atmosphere immediately dangerous to life and health (IDLH)
for the purposes of respiratory protective device selection only, the maximum concentration to which an unprotected person could be exposed in the event of device failure, without affecting their ability to escape or causing irreversible health effects

NOTE 1 If the advisory limit were exceeded, unprotected people would probably not escape unscathed from the exposure.

NOTE 2 The figure can be estimated from toxicity data or from USA DHSS NIOSH Publication No. 90-117 [1] in conjunction with The Control of Substances Hazardous to Health Regulations 1994 (COSHH) [2] assessment of the work.

3.5
emergency breathing facility (EBF)
means of providing the wearer with an adequate level of protection for a sufficient period to enable the wearer to exit the work area, unassisted, to a place of safety, without unacceptable risk

the emergency breathing facility may either be fitted with P3, Gas or GasXP3 filters or supply breathable gas as required for the given environment

NOTE 1 The letter "X" in "GasXP3" symbolizes the classification of the gas filter.

NOTE 2 Each of these alternatives are used in special situations following risk assessment.

3.6
loose fitting facepiece
facepiece designed to form a partial seal with the face, e.g. visors, helmets, hoods, semi-blouses, blouses and full suits

loose fitting facepieces rely on the flow of breathable gas to prevent the ingress of contamination into the facepiece

3.7
tight fitting facepiece
facepiece designed to form a complete seal with the breathing zone or face

includes mouthpieces and quarter, half and full face masks

3.8
semi-hood
loose fitting facepiece, to which air is supplied, that encloses the whole face and is fitted to the face and crown of the head by means of flexible seals

semi-hoods include air fed or ventilated visors

3.9
semi-blouse
garment which resembles a blouse except that it covers the head and upper parts of the body but does not extend as far down the body as a blouse, and which ties or seals at the waist and/or lower arms

semi-blouses include hoods with capes and sleeveless blouses

3.10
competent person
individual who has such practical and theoretical knowledge and actual experience of the type of work, plant or equipment which has to be examined or maintained as will enable him or her to detect defects or weaknesses

NOTE In certain situations practical and theoretical knowledge requires ratification and support by formal validation.

4 Overall protective programme

Where an inhalation hazard exists in a workplace, it is important to assess whether a risk from such a hazard can be controlled other than by the provision of respiratory protective devices. Elements which should be considered in this risk assessment are shown in Figure 1. Where unacceptable inhalation risks in the workplace are identified, the following approaches should be used to prevent or reduce exposure other than by the use of respiratory protective devices. These approaches are shown in order of preferred priority; preventions are listed a) to c) and controls listed d) to k).

NOTE This approach is in line with The Control of Substances Hazardous to Health Regulations 1994 [2].

a) The use of alternative substances which are less hazardous.

b) The substitution of a given substance in a form that is less hazardous, e.g. replacing a fine powder by a coarser powder, pellets, or by a solution.

c) The substitution of a process by an alternative process likely to generate lower airborne concentrations of substances.

d) Total or partially enclosed process and handling systems.

e) Partial enclosure with local exhaust ventilation.

f) Local exhaust ventilation.

g) General ventilation.

h) Reducing period of exposure.

i) The introduction of appropriate working practices and systems of work, e.g. to close and store containers securely when not in use.

j) Use of monitors and warning devices to give a clear indication when unsafe airborne concentrations are present.

k) Good housekeeping.

l) Provision of a respiratory protective device programme (see **8.2**).

All the steps given in a) to l) for preventing or reducing inhalation risks should be thoroughly evaluated, because in many work situations no single step provides adequate reduction of risk. However, the combination of two or more steps may achieve the required reduction of risk.

The provisions of this standard apply both during and after the implementation of all reasonably practicable steps to eliminate or adequately control the foreseeable inhalation risk by means other than by the use of respiratory protective devices.

It should be appreciated that a higher level of respiratory protection may be required while control measures are being implemented. Consequently, it is essential that, where respiratory protective devices are used, the importance of correct training and supervision of the wearers is stressed. This should ensure that the higher levels of respiratory protection required are reliably obtained.

If elimination or control of risks cannot achieve a safe and healthy workplace, assessment is required of the residual inhalation or skin uptake risks. This allows the determination of which respiratory protective devices are required and the extent of the respiratory protective programme. This assessment should cover both on-going routine process, any potential exposures which could occur during routine or emergency maintenance operations and the potential consequences of plant or process failure.

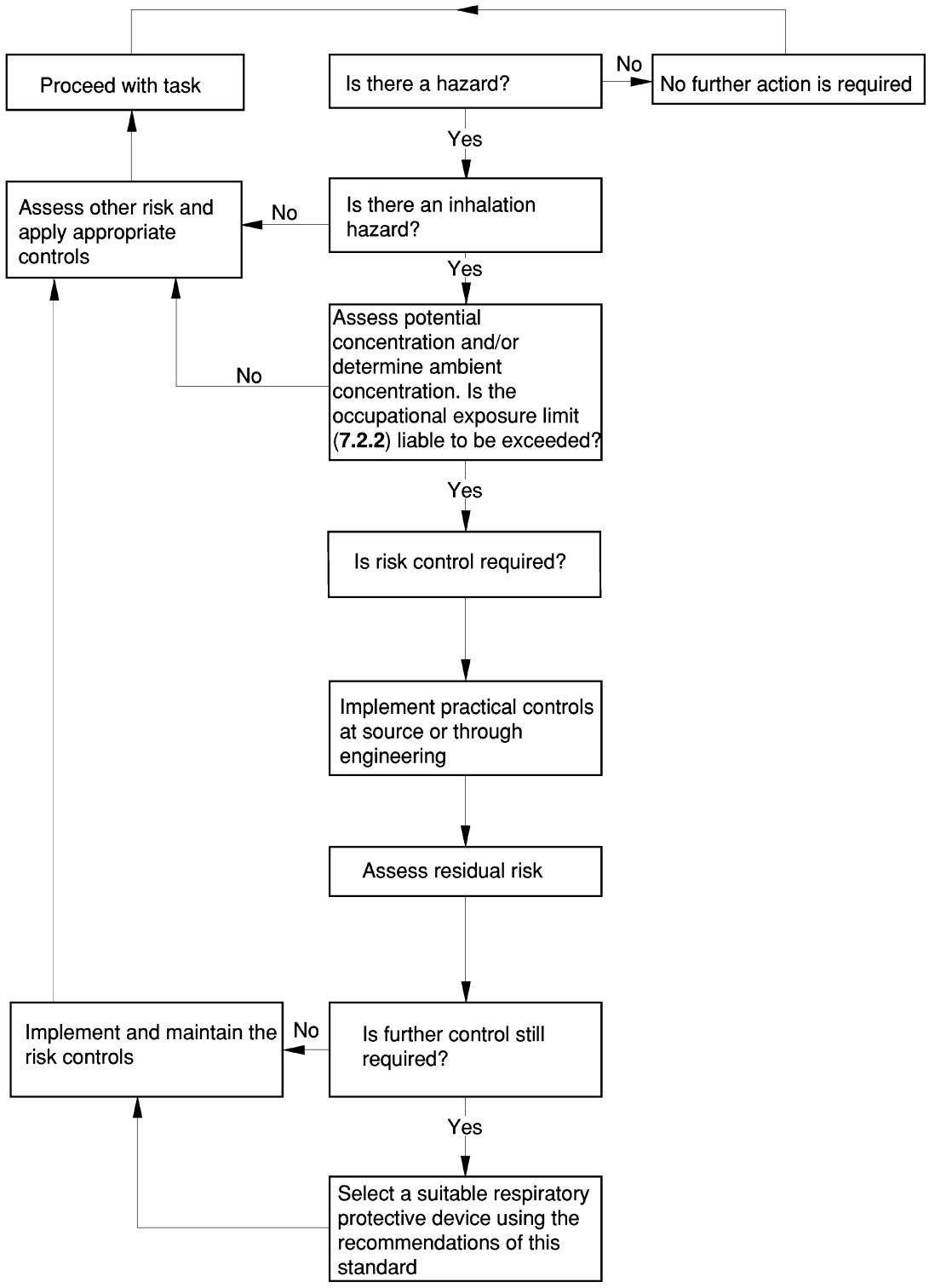


Figure 1 — Elements to be considered in a risk assessment

5 Types of respiratory protective devices

5.1 General

An environment may be contaminated by any combination of particles, droplets, gases or vapours. There may also be insufficient oxygen to support life.

There are two distinctly different methods of providing personal respiratory protection against contaminated atmospheres:

a) by purifying the air breathed, using filters which remove harmful substances by filtering or cleaning the air. Devices that achieve this are known as filtering devices (commonly called “respirators” in the UK); or

b) by supplying the wearer with air or oxygen from an uncontaminated source. Devices that achieve this are known as breathing apparatus.

The type and class of respiratory protective devices which have the potential to provide adequate protection in any given environment depends on the nature of the hazard and the degree of risk.

The environments in which the two major types of respiratory protective devices are appropriate are given in Figure 2.

Filtering devices do not supply oxygen. They should not be used unless it is known that the ambient air contains at least 20 % oxygen, and should not be used in IDLH environments.

Both filtering devices and breathing apparatus consist of two main components: a means of providing breathing gas and a facepiece which directs the breathing gas to the wearers breathing zone. In some devices, the facepiece can seal to the wearer’s face to prevent contaminated air from entering the breathing zone.

Types of facepiece (loose and tight fitting) are defined in clause **3**. Not all combinations of device and facepiece are satisfactory. A range of combinations is available from manufacturers, whose instructions on the acceptability of combinations should be strictly followed.

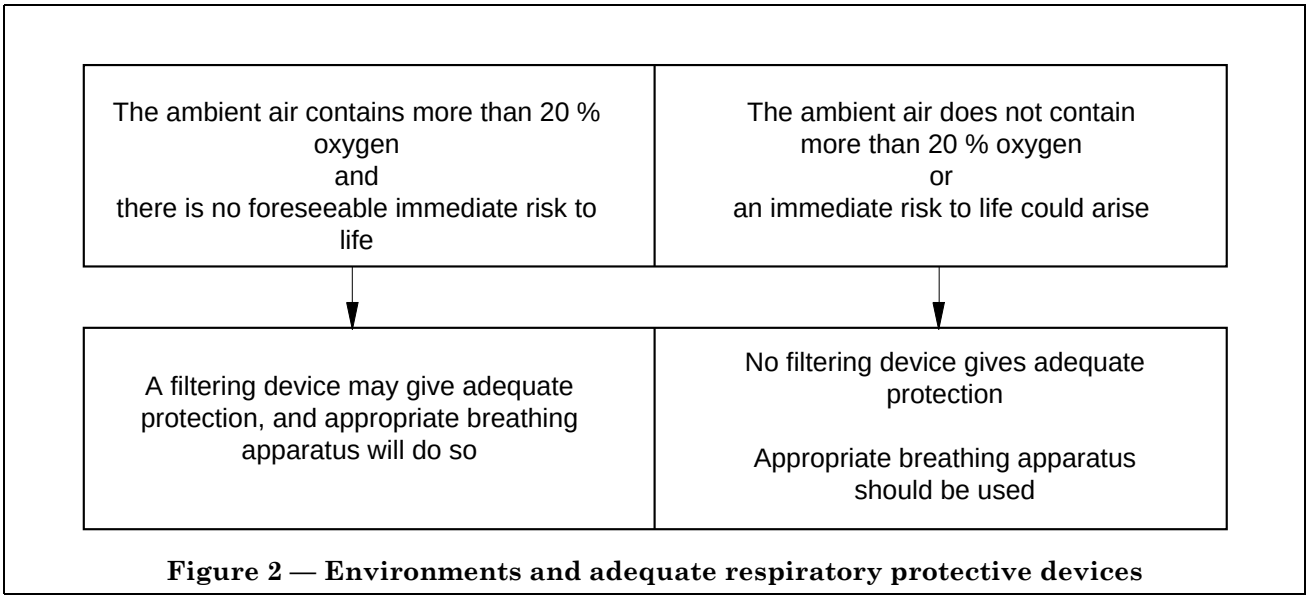


Figure 2 — Environments and adequate respiratory protective devices

5.2 Filtering devices

5.2.1 *General*

Filtering devices include two major components: a filter which removes airborne contaminants and a facepiece which conveys filtered air to the wearer's breathing zone and which prevents contaminants from the environment getting into the breathing zone.

Filters can be for removing particles only, (particle filters); for removing gases and vapours only (gas filters); or for removing both particles and gases or vapours (combined filters).

For a description of specific filtering devices, see Annex A.

5.2.2 *Facepieces*

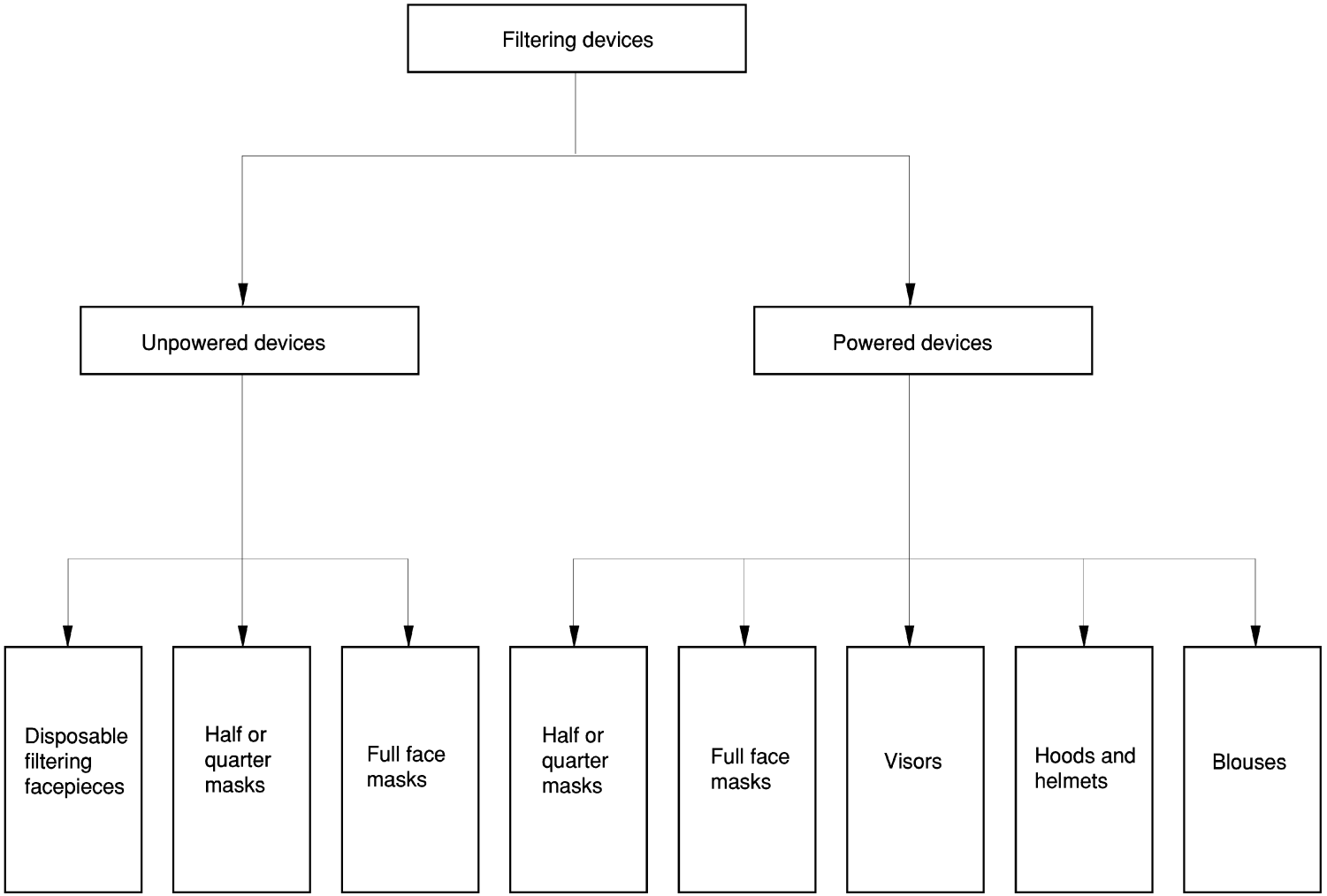
Unpowered filtering devices (see Figure 3) can only function properly if a tight fitting facepiece is used.

Powered filtering devices (see Figure 3) are divided into two categories which are power assisted devices and powered devices.

Power assisted devices should have tight fitting facepieces. Thus in the case of a high airflow demand by the user, the pressure inside the facepiece can, in principle, become negative.

NOTE The common description "positive pressure powered respirator" is therefore somewhat misleading.

Powered devices have loose fitting facepieces and rely for their effectiveness on the constant flow of air, which should be above a minimum stated by the manufacturer, and on the degree of restriction to ingress of contamination offered by the loose closures such as ties, cuffs and wrist seals.



NOTE 1 Each type of filtering device is available in three performance classifications, see Table 1.

NOTE 2 For each type of filtering device, the following types of filter may be available:

a) for particulate materials only; b) for certain gases and vapours only; c) combination types for particulates and some gases and vapours.

Figure 3 — Types of filtering devices

5.2.3 *Particle filters*

Particle filters are divided into filters for use against solid aerosols and filters for use against solid and liquid aerosols. Both types are classified according to their minimum filter efficiency. For disposable-type filtering facepieces, the filter is integral to the facepiece and therefore the complete device is given a single efficiency classification. See Table 1.

Table 1 — Classification of particle filters

Type of device and relevant standard	Efficiency[1]	Marking	
Unpowered BS EN 143	Low efficiency Medium efficiency High efficiency	P1 P2 P3	S[2]
Disposable filtering facepiece BS EN 149	Low efficiency Medium efficiency High efficiency	FFP1 FFP2 FFP3	S or SL[3]
Powered prEN 12941 or prEN 12942	Low efficiency Medium efficiency High efficiency	TH1P or TM1P TH2P or TM2P TH3P or TM3P	S or SL[3]
Valveless filtering half masks prEN 1827	Low efficiency Medium efficiency High efficiency	FMP1 FMP2 FMP3	S or SL[3]

[1] Efficiency is a qualitative term and filters for different types of devices will not have an equivalent performance. Filters have been classified by performance according to the reference standards.

[2] Filters not suitable for liquid aerosols are marked "For use against solid aerosols only" or "S".

[3] "S" denotes use against solid aerosols only. "SL" denotes use against solid and liquid aerosols.

5.2.4 *Gas filters*

Gas filters are specific to the substance or class of substance for which the filters are intended by the manufacturer, and are classified accordingly, e.g. "A" for use against organic compounds with boiling points >65 °C.

The substances against which gas filters and combined filters are intended to provide protection in air filtering devices, and the standards which specify their performance and characteristics are shown in Table 2.

For filtering half-masks, the gas filter code is prefixed with "FF" in the case of devices conforming to BS EN 405 and "FM" for devices conforming to prEN 1827.

Gas filters are coloured in accordance with the classes of substance against which they are intended to provide protection.

The breathing resistance of a given type of gas filter generally increases with capacity, and the breathing resistance of a combined filter is generally higher than that of either the equivalent gas only, or particulate only, filters.

The capacity of a gas filter can vary with both the concentration and nature of the airborne contaminant, and can be lower in high ambient temperatures and/or high relative humidities. The safe duration of use of a gas filter is therefore also affected by these factors. Since the total volume of air drawn through the filter in an unpowered device increases with increasing work rate, the safe duration of use of a gas filter in such devices therefore decreases with increasing workrate.

In addition, if a gas filter which has collected a certain contaminant and is subsequently exposed to a different contaminant which has a greater affinity for the filter medium, the previous contaminant can be released from the filter. Release of contaminant may be of particular importance where the filter is used against several different contaminants. A similar effect can also occur for certain contaminants if the relative humidity increases substantially over the period of use, the filter medium having a greater affinity for water vapour than some contaminants. However, a class 3 filter will last longer than a class 2 filter, and a class 2 filter will last longer than a class 1 filter of the same type in any given environment. If a user finds that they are not obtaining an acceptable lifetime from the filter they should consider using a filter of the same type but of a higher class.

It is therefore not possible to give accurate general guidance regarding the safe duration of gas filters. Users of such filters should obtain the maximum possible information regarding the nature and concentrations of likely gaseous contaminants in their workplace and seek guidance from the filter manufacturer or supplier.

5.2.5 *Combined filters*

Combined filters combine a gas filter with a particle filter. The gas filter can be combined with a P1, P2 or P3 particle filter, except for gas filters Hg and NO (see Table 2) which are always combined with P3.

Table 2 — Gas and vapour filters and combined filters and relevant standards

Substance	Filter type	Colour	Relevant standard
Organic vapours and gases with boiling points >65 °C	A	Brown	BS EN 141 prEN 12941 prEN 12942 BS EN 405 prEN 1827
Inorganic gases excluding carbon monoxide	B	Grey	BS EN 141 prEN 12941 prEN 12942 BS EN 405 prEN 1827
Sulfur dioxide and acidic gases	E	Yellow	BS EN 141 prEN 12941 prEN 12942 BS EN 405 prEN 1827
Ammonia and organic ammonia derivatives	K	Green	BS EN 141 prEN 12941 prEN 12942 BS EN 405 prEN 1827
Oxides of nitrogen	NO-P3		BS EN 141 prEN 12941 prEN 12942
Mercury	Hg-P3		BS EN 141 prEN 12941 prEN 12942
Organic vapours and gases with boiling points <65 °C	AX* FFAX FMAX	Brown	BS EN 371 BS EN 405 prEN 12941 prEN 12942 prEN 1827

Table 2 — Gas and vapour filters and combined filters and relevant standards *(concluded)*

Substance	Filter type	Colour	Relevant standard
Filter types against specific compounds	SX*		BS EN 372 BS EN 405 prEN 12941 prEN 12942 prEN 1827

NOTE 1 Gas filters and combined filters should be used only against the substances identified by the manufacturer.

NOTE 2 Very specific use limitations apply to filters marked with a "*", see clause **6**.

NOTE 3 Most gas filters are graded according to their capacity to absorb contaminants and are graded into low, medium and high capacity filters. Filter capacity is identified by a code having the second digit as a number which identifies capacity; "1" being low capacity and "3" high capacity. For example, a medium capacity filter for use against organic compounds with boiling points above 65 °C, as specified by the manufacturer, is coded A2, FFA2 or FMA2. FF and FM gas filtering facepieces are available only with low and medium capacity filters.

NOTE 4 A combined gas and particulate filter is coded with an additional two digits after the gas filter code which show the efficiency of the particulate filter element. For example, a medium capacity combined gas and particulate filter for use against organic compounds with boiling points above 65 °C, as specified by the manufacturer, and with a high efficiency particulate filter element, is coded "A2P3".

NOTE 5 Where gases, vapours and dusts exist together, a combined filter should be used, even if the dust had not been assessed as a risk.

5.2.6 *Multi gas filters*

Gas filters can be made to protect against contaminants of more than one gas filter type, e.g. A2B2, AXB2E1K1. These multi type gas filters can be made in any combination of type and class. They can also be used to form any combined filter (see **5.2.5**).

5.2.7 *Complete devices*

The overall performance of filtering devices is limited by the sum of contaminant ingress through the filter and leakage between the facepiece and the wearer's face, and leakage through valves, where they are fitted.

With devices fitted with particle or combined filters, the performance against particles is limited by the sum of particle penetration of the filter and leakage between the facepiece and the wearer's face. With devices fitted with gas or combined filters, it is assumed that prior to overloading of the filter capacity, there is no penetration of a gas filter. Overall performance against a gas before overloading occurs is therefore limited only by leakage between the facepiece and the wearer's face, and leakage through valves where fitted.

Loose fitting facepiece devices rely upon the flow of air into the facepiece to prevent inward leakage of contaminant.

The types of filtering devices available and the relevant standards are shown in Table 3.

Table 3 — Filtering device types and relevant standards

	Unpowered devices					Powered devices	
	Half or quarter mask and filter BS 7356 (EN 140)	Filtering half masks without inhalation valves prEN 1827	Valved filtering half masks BS EN 405	Filtering half masks BS EN 149	Full face mask and filter BS 7355 (EN 136)	Power assisted filtering devices incorporating full, half or quarter masks prEN 12942	Powered filtering devices incorporating helmets or hoods prEN 12941
Particle filter	Facepiece BS 7356 and filter BS EN 143	✓	No device	✓	Facepiece BS 7355 and filter BS EN 143	✓	✓
Gas filter	Facepiece BS 7356 and filter BS EN 141 BS EN 371 BS EN 372	✓	✓	No device	Facepiece BS 7355 and filter BS EN 141 BS EN 371 BS EN 372	✓	✓
Combined filter	Facepiece BS 7356 and filter BS EN 141 BS EN 371 BS EN 372	✓	✓	No device	Facepiece BS 7355 and filter BS EN 141 BS EN 371 BS EN 372	✓	✓

5.3 Breathing apparatus

5.3.1 *General*

Breathing apparatus is a respiratory protective device to which breathable air or gas is supplied from an uncontaminated source. Breathing apparatus consists of a means of supplying breathing gas and a facepiece which conveys filtered air to the wearer's breathing zone.

This type of respiratory protective device is manufactured in a variety of product types to meet the application of use and may be conveniently subdivided as follows:

— fresh air hose equipment;

— compressed air line supplied equipment;

— compressed air and compressed oxygen self-contained breathing apparatus.

Types of breathing apparatus and relevant standards are given in Figure 4, Table 4 and Table 5. For a description of specific breathing apparatus, see Annex B.

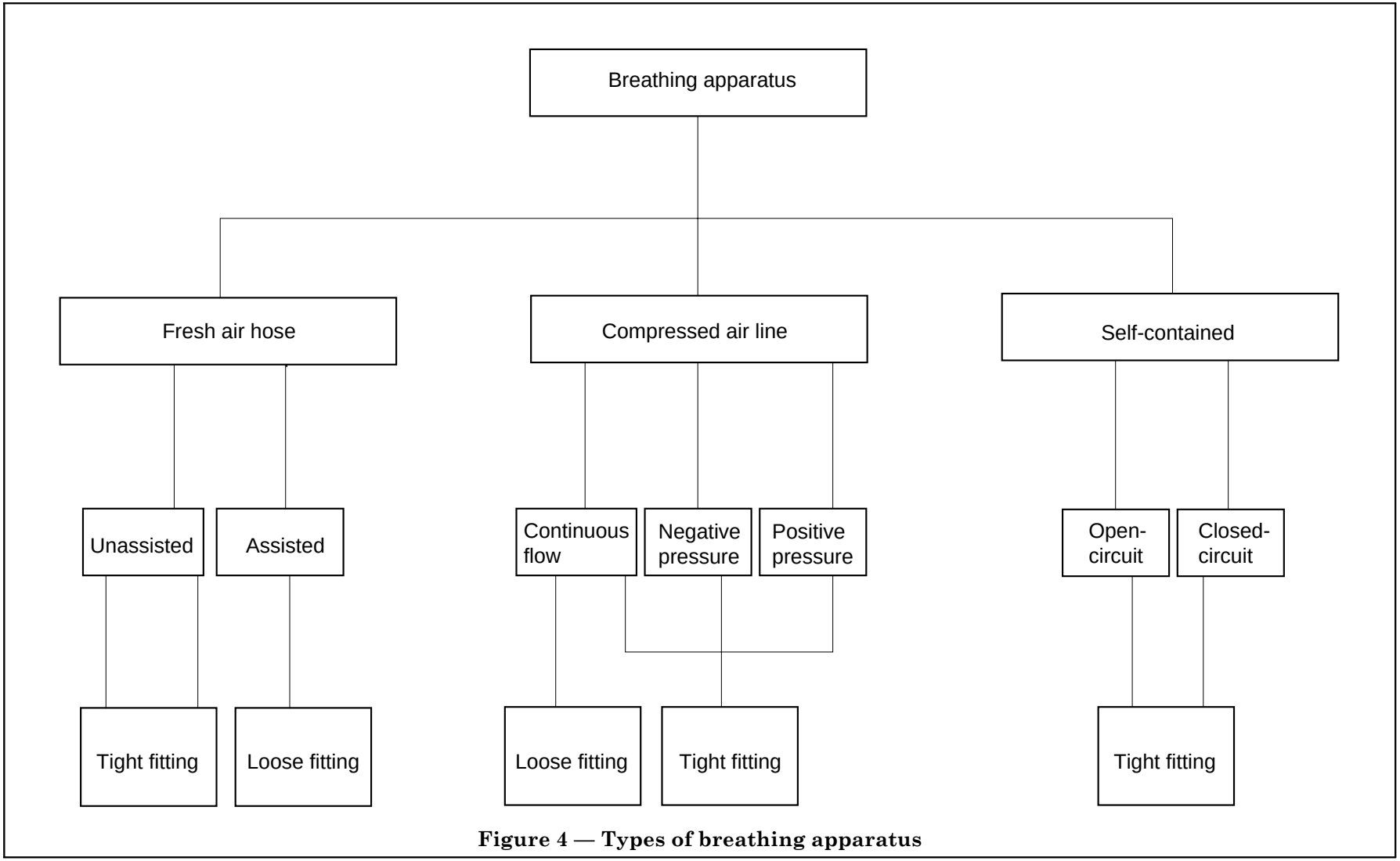


Figure 4 — Types of breathing apparatus

Table 4 — Fresh air hose and compressed air line breathing apparatus

Fresh air hose			Powered fresh air hose hood	Compressed air line hood	Power operated or compressed air line abrasive blasting hood	Compressed air line for use with full face mask, half mask or mouthpiece			Light duty construction compressed air line
BS EN 138			BS EN 269	BS EN 270	BS EN 271	BS EN 139			Helmet or hood prEN 1835 Mask prEN 12419
Unassisted	Manually assisted	Power operated	Power operated	Continuous flow	Power operated or compressed air line	Continuous flow	Negative pressure	Positive pressure	Continuous flow
Heavy duty construction only	Light or heavy duty construction	Light or heavy duty construction	Light or heavy duty construction						Class 1, 2 or 3
Full face mask or mouthpiece only	Half or full face mask or mouthpiece	Half or full face mask or mouthpiece	Hood	Hood	Abrasive blasting hood	Half or full face mask or mouthpiece			Helmet or hood or mask

NOTE 1 Certain devices may conform to more than one standard.

NOTE 2 Standards exist for suits intended for radiological protection (prEN 1073) and chemical protection (prEN 943 and BS 7184) but the manufacturer's guidance should be sought for respiratory protective requirements.

Table 5 — Self-contained breathing apparatus

Open-circuit		Closed-circuit		
Self-contained open-circuit compressed air breathing apparatus		Self-contained closed-circuit breathing apparatus Compressed oxygen or compressed oxygen-nitrogen type		Self-contained closed-circuit chemical oxygen breathing apparatus
BS EN 137		BS EN 145		No relevant standard
Negative pressure	Positive pressure	Negative pressure	Positive pressure	
Full face mask or mouthpiece only		Full face mask or mouthpiece only		Full face mask or mouthpiece only

5.3.2 ***Facepieces***

Breathing apparatus can have air supplied at a constant flow above a specified minimum and in this mode can employ either loose or tight fitting facepieces. Alternatively, breathing apparatus (with tight fitting facepieces only) can be used with demand valves which allow air from a compressed air source to enter the facepiece when the wearer inhales.

5.3.3 ***Fresh air hose equipment***

With this type of breathing apparatus, breathable air is drawn from an uncontaminated source along a short hose.

Using the wearer's lung power, it is likely that unacceptable inhalation resistance will be achieved with hose lengths in excess of 9 m. Longer lengths are used in conjunction with an air mover such as an electrically operated blower.

NOTE It should be noted that a requirement of the standard for power assisted fresh air hose equipment, BS EN 269, is to meet a breathing resistance performance with the power source turned off.

The manufacturer's instructions on the equipment, for example on hose length and bore, should be strictly observed. This equipment should only be used where the contaminant in the working environment has been fully assessed. See Table 4.

5.3.4 ***Compressed air line supplied equipment***

Compressed air line supplied equipment generally falls into two categories, light duty equipment and the more robust heavy duty type of equipment normally used for external industrial applications.

Light duty equipment should be used only in applications where the suitability has been fully assessed. The equipment is chosen for its simplicity and comfort and is often worn for routine, everyday tasks. Manufacturers supply this type of equipment in various forms such as visors, masks, hoods and helmets (see Table 4). Some equipment is fitted with a warning device to alert the wearer that the flow rate is low.

Heavy duty compressed air line equipment incorporating a full face mask with either constant flow or demand valves, a mouthpiece, half mask, hood, helmet or suit is also available. Some of this equipment may be designed and used for confined space entry, tank cleaning, or other applications where an emergency escape may be necessary.

Breathable air can be supplied to the wearer by one of three methods which are as follows.

a) A continuous flow of air is supplied at a constant rate to the facepiece. In some systems the flow rate can be altered by means of a valve on the wearer's belt. This type of system can have either a tight fitting facepiece or a loose fitting facepiece.

b) Negative pressure demand, in which the suction generated in the face mask during inhalation opens a demand valve and allows air into the mask from the compressed air supply. With this equipment, the pressure inside the mask is lower than atmospheric pressure during inhalation.

c) Positive pressure demand device, designed to maintain a pressure slightly above atmospheric inside the mask, even when the wearer is inhaling. If facepiece leakage occurs, any leakage is outward, therefore contaminants would not be inhaled by the user. However, in the case of high air flow demand by the user, the pressure in the facepiece can, in principle, become negative.

On all three systems, the compressed air quality should conform to Annex C and the air flow rate should be at least sufficient to meet the foreseeable needs of the total number of wearers who will use the equipment at maximum work rate. It is not acceptable to connect an air line breathing apparatus to an air supply intended for general works use, unless the air is filtered to meet the quality standards described in Annex C.

5.3.5 *Self-contained breathing apparatus, compressed air, compressed oxygen and chemical oxygen types*

5.3.5.1 *General*

Some of these types of equipment are capable of providing the highest degree of protection of any type of respiratory protective device and are designed for use in the most hazardous circumstances, including those where the atmosphere may be immediately fatal to the unprotected person. Compressed gas breathing apparatus is divided into the types given in **5.3.5.2**, **5.3.5.3** and **5.3.5.4**.

5.3.5.2 *Open-circuit self-contained breathing apparatus*

Air is supplied from high pressure cylinders worn by the user. There are two different methods of supplying compressed air to the wearer, as follows.

a) Negative pressure demand, in which the suction generated in the face mask during inhalation opens a demand valve and allows air into the mask from the compressed air supply. With this equipment, the pressure inside the mask is lower than atmospheric pressure during inhalation.

b) Positive pressure demand, which is designed to maintain a pressure slightly above atmospheric inside the mask, even when the wearer is inhaling. However, the maximum flow through the demand valve may be less than the peak inhalation flow required by a wearer at high physical work rates, so positive pressure within the mask may not be maintained at all times.

Open-circuit self-contained breathing apparatus is extensively used in some industries, and always requires a very high standard of training and maintenance. These factors should be taken into consideration when selecting this equipment for use.

5.3.5.3 *Closed-circuit self-contained breathing apparatus*

In this equipment, oxygen or a breathable gas mixture is supplied from high pressure cylinders worn by the user. The exhaled breath is passed through a carbon dioxide absorber to be recirculated in a closed-circuit to the face mask or mouthpiece. Closed-circuit self-contained air-supplying devices using oxygen or a breathable gas mixture are not generally used in industrial situations and may require special consideration in view of the fire hazards associated with the use of pure oxygen, together with the specialized maintenance required to support this type of device.

5.3.5.4 *Self-contained breathing apparatus for escape purposes*

This equipment is available in compressed-air, compressed-oxygen and chemical oxygen types and is intended for short duration use for emergency escape from hazardous areas. Escape apparatus should be used for escape purposes only and should not be used for normal working, entry to hazardous areas, or rescue.

6 Limitations

6.1 General

The protective performance of a respiratory protective device is generally expressed in terms of its assigned protection factor.

NOTE In the previous edition of this standard, and in other guidance documents, it is assumed that if respiratory protective devices were correctly worn, the protection factor achieved in the workplace was adequately indicated by the performance achieved in the laboratory during the standard tests carried out to assess conformity with the requirements of the relevant standard.

However, extensive research has indicated that even when respiratory protective devices are correctly worn in the workplace, the workplace protection factor could be substantially different from that observed during standard laboratory tests. The levels of respiratory protection inferred in this standard to be achievable in the workplace are based on the results of workplace studies.

This standard sets assigned protection factors to each class of device on the basis of workplace studies. See Annex D.

Where it is necessary to determine the maximum use concentration for a specific respiratory protective device, the occupational exposure limit for the substance given in Health and Safety Executive Guidance Note EH 40/96 [3] (see **7.2.2**) should be multiplied by the assigned protection factor.

The assigned protection factors for filtering devices and breathing apparatus are shown in Table 6 and Table 7.

The assigned protection factors shown in Table 6 and Table 7 can only potentially be achieved if the devices are correctly matched to:

a) the relevant airborne contaminant;

b) the individual wearer and his/her duties;

c) duration of wear;

d) environmental factors such as cold, heat, humidity and work space; and

e) if the devices are to be used on more than one occasion, whether they are maintained in an efficient and hygienic condition.

It is essential that wearers are adequately trained in the limitations of their device, how to fit the device correctly and be adequately supervised at all times when wearing their device. Wearers of tight fitting devices should not have facial hair or stubble under the seal, as this can adversely affect the fit of the facepiece. Other items of personal protective equipment should be selected such that they do not interfere with the fit or performance of the respiratory protective device and vice versa (for example, the device does not displace a helmet, and eye protection does not move or reduce the face seal of a device).

For information on the selection of respiratory protective devices, see clause **7**.

Communication is important, and is easier in a hood or in certain full face masks than in certain helmets, half or quarter masks. Communication is almost impossible with a mouthpiece.

Assigned protection factors higher than shown in Table 6 and Table 7 should not be used unless objective workplace performance data are available for the specific workplace in which the device is to be used.

For limitations relating to specific devices, see Annex A and Annex B.

Table 6 — Assigned protection factors for filtering devices

Assigned protection factor	Half or quarter mask and filter	Filtering half masks without inhalation valves	Valved filtering half masks	Filtering half masks	Full face masks and filter	Power assisted filtering devices incorporating full, half or quarter masks	Powered filtering device incorporating helmets or hoods
	BS 7356 (EN 140) BS EN 141 BS EN 143 BS EN 371 BS EN 372 prEN 12083	prEN 1827	BS EN 405	BS EN 149	BS 7355 (EN 136) BS EN 141 BS EN 143 BS EN 371 BS EN 372 prEN 12083	prEN 12942	prEN 12941
4	**P1**	FMP1	FFGasXP1	**FFP1**	P1	—	—
10	**P2** **Gas** **GasXP3**	FMP2 FMGasX FMGasXP3	**FFGasX** FFGasXP2 FFGasXP3	**FFP2**	P2	TM1 all facepieces	**TH1** **all facepieces**
20	**P3**	FMP3	—	**FFP3**	**Gas**	TM2 all facepieces	**TH2** **all facepieces**
					GasXP3	TM3 particle, gas or combined filters; half or quarter masks	
40	—	—	—	—	**P3**	**TM3 particle, gas or combined filters; full face masks**	**TH3 Semi-hood, hood, blouse, semi-blouse**

NOTE 1 The table gives the assigned protection factors of properly serviced, maintained, used and selected equipment. It may be necessary to consider other measures of safe egress from a hazardous environment.

NOTE 2 The bold text in the table indicates that the assigned protection factor has been derived from the data given in Annex D.

NOTE 3 The letter "X" in "GasXP3" symbolizes the classification of the gas filter.

Table 7 — Assigned protection factors for breathing apparatus

Assigned protection factor	Light duty construction air line	Fresh air hose and compressed air line	Self-contained
	prEN 1835 prEN 12419	BS EN 138, BS EN 139, BS EN 269, BS EN 270, BS EN 271 (with semi-blouse and suit)	BS EN 137 BS EN 145
10	LDH1	Fresh air hose, half-mask	—
20	LDH2 LDM1 LDM2	Air line, half-mask	—
40	LDH3	Fresh air hose, full face mask or hood Negative pressure demand, full face mask Continuous flow air line, hood (EN 270) Continuous flow air line, blasting hood (EN 271) Continuous flow air line, full face mark	**Negative pressure demand, full face mask**
100	LDM3	Fresh air hose, mouthpiece Semi-blouse	Negative pressure demand, mouthpiece
200	—	**Continuous flow air line, suit**	—
1 000	—	Air line, mouthpiece	—
2 000	—	Positive pressure demand, mouthpiece or full face mask	Positive pressure demand, mouthpiece, full face mask

NOTE 1 The table gives the assigned protection factors of properly serviced, maintained, used and selected equipment. It may be necessary to consider other measures of safe egress from a hazardous environment.

NOTE 2 The bold text in the table indicates that the assigned protection factor has been derived from the data given in Annex D.

6.2 Limitations of loose fitting facepieces

In case of failure of the air supply to loose fitting devices, breathing zone concentrations of carbon dioxide can exceed 6 % and oxygen concentrations can decrease to less than 14 % within 1 min. These concentrations constitute a life-threatening asphyxiation risk.

In case of failure of the air supply to the device, wearers may be exposed to full ambient contaminant concentrations unless a suitable EBF is incorporated and correctly used. In addition, if decontamination procedures cannot be followed during removal and escape, wearers and others may be exposed to contaminants and the environment may be contaminated.

Loose fitting devices without an EBF should therefore be used only when it is known that exposure will not exceed the IDLH, and where contamination on the wearer's body and clothing does not pose a risk to others or the environment.

Training and supervision of wearers should include removal of devices, use of EBF and emergency egress procedures to protect others and the environment adequately.

Maintenance and inspection procedures for loose fitting devices should reflect the consequences of failure of the air supply.

6.3 Limitations of tight fitting facepieces

6.3.1 *Negative pressure or negative pressure demand devices*

During inhalation when wearing negative pressure or negative pressure demand devices, the lungs generate a negative pressure within the facepiece. This can allow contaminated air to leak through any gaps between the facepiece and the wearer's face, thus reducing the protection afforded by the device. Negative pressure devices should therefore be carefully matched to each individual wearer's face and correctly fitted to minimize any leakage between the facepiece and the face. It is important that no facial hair such as beard, moustache or sideburns is allowed between the face seal and the face since it can adversely affect the fit of the facepiece. Stubble can affect the seal more than established facial hair, since it acts like stilts and holds the facepiece off the face.

Negative pressure devices impose additional work on the wearer and can thus impose discomfort, and limit the rate at which the wearer can work and the safe duration of wear.

6.3.2 *Powered or continuous flow devices*

Although clean air is supplied into the facepiece of the device, negative pressure within the facepiece can be created if the wearer's peak breathing rate exceeds the rate at which clean air is supplied. With powered devices, the degree of negative pressure may not be severe and the wearer can still draw in filtered air through the filter even if the power supply fails completely. With continuous flow devices, however, it is not possible to draw in air at a higher rate than the supply rate. If such devices are drawn negative, the facepiece sucks on to the face and severe inward leakage can occur.

Powered, continuous flow, or positive pressure demand devices should therefore be matched to the wearer's foreseeable work rates to ensure that the likelihood of generating negative pressures within the facepiece is minimized.

Facepieces should be carefully matched to each individual wearer's face and correctly fitted to minimize any leakage between the facepiece and the face. It is important that no facial hair such as beard, moustache or sideburns is allowed between the face seal and the face since it can adversely affect the fit of the facepiece. Stubble can affect the seal more than established facial hair as it acts like stilts and holds the facepiece off the face.

6.3.3 *Positive pressure demand devices*

Positive pressure demand devices are designed to maintain a pressure slightly above atmospheric inside the mask, even when the wearer is inhaling. If facepiece leakage occurs, any leakage is outward, therefore contaminants are not inhaled by the user. In the case of high air flow demand by the user, the pressure inside the facepiece can, in principle, become negative. However, the increased degree of safety is reflected in the assigned protection factors given in Table 7.

6.4 Additional limitations of breathing apparatus

In any instance of failure of the air supply to breathing apparatus, wearers may be exposed to full ambient contaminant concentrations unless a suitable EBF is incorporated and correctly used. In addition, if decontamination procedures cannot be followed during removal and escape, wearers and others may be exposed to contaminants and the environment may be contaminated.

Training and supervision of wearers should include removal of devices, use of EBF and removal procedures to adequately protect others and the environment.

Where it is essential that breathing apparatus is used, e.g. for firefighters or emergency rescue personnel, training, maintenance and inspection procedures should reflect the consequences of failure of the air supply.

7 Selection

7.1 General

In selecting respiratory protective devices, four major aspects should be addressed.

a) The devices selected should provide adequate protection, (see **7.2**). They should be able to reduce the foreseeable contaminant concentrations inside the facepiece to safe levels, at least below relevant occupational exposure limit(s) (see **7.2.2**) or internally set exposure standards, and preferably as low as possible.

b) The devices selected should be suitably matched to individual wearers, their duties, the likely durations of wear and the nature of the environment; e.g. personal characteristics, physical fitness, work rate, posture, space restrictions, ambient temperature, relative humidity. (See **7.3**.) The devices selected should not impose unacceptable discomfort on the wearers.

c) The devices selected should be compatible with any other items of personal protective equipment which may have to be worn simultaneously with the respiratory protective devices. (See **7.4**.)

d) Users should be aware that devices fall under Directive 89/686/EEC, and CE marking schemes apply.

NOTE 1 All devices that have been approved by the Health and Safety Executive (HSE) or are claimed by the manufacturer to conform to a standard approved by HSE, and which have been in the possession of the user before 30 June 1995, can be used at work beyond that date for as long as they provide adequate protection in the light of the performance levels recommended in this standard, and are maintained in good condition.

NOTE 2 Certain equipment of a specialized nature, notably certain military equipment, does not require CE marking under the Directive.

7.2 Adequacy

7.2.1 *Selection of a filtering device or breathing apparatus*

Respiratory protective devices should be selected in appreciation of:

a) the nature of the inhalation hazard; and

b) the severity of the risk.

The first step in the selection procedure is to decide whether a filtering device or appropriate breathing apparatus should be selected.

The procedure in Figure 5 indicates how to make this decision.

If it is not possible to answer “yes” to any of the questions in Figure 5, the user should either obtain the necessary information to answer the question concerned, or select breathing apparatus.

If the final answer is “yes”, a filtering device may provide adequate protection. However, the final decision as to the use of a device still depends on both the foreseeable ambient concentration of the substances concerned and the specific legal requirements for the given workplace. The period for which adequate protection is provided by a filtering device may be limited.

7.2.2 *Selection of type of device*

Numerous types of respiratory protective devices are available: filtering devices ranging between half or quarter masks fitted with low efficiency filters to full-mask powered high efficiency devices, and breathing apparatus ranging between fresh air hose apparatus to positive pressure demand open-circuit apparatus.

The type of device required depends on the foreseeable airborne concentration relative to the appropriate occupational exposure limit.

Maximum acceptable in-facepiece contaminant concentrations should not exceed the occupational exposure limits (OELs) specified in Health and Safety Executive Guidance Note EH 40/96 [3]. Three types of OELs are specified in EH 40: control limits, maximum exposure limits (MELs) and occupational exposure standards (OESs). For OESs, the limit should not be exceeded inside the facepiece. For control limits and MELs, the concentration inside the facepiece should be as low as reasonably practicable below the exposure limit.

In addition, all OELs can be defined in terms of long term exposure [8 h time weighted averages (TWAs)], short term exposure limits (STELs) and ceiling limits. In no case should any of these limits be exceeded in the facepiece.

Where no occupational exposure limit for the contaminant of concern has been specified, the maximum acceptable in-facepiece concentration can be based on other limits such as the ACGIH Threshold Limit Values [4], or can be set by the user or supplier of the substances of concern, or on the basis of a careful and thorough literature search.

The minimum required protection factor should be calculated as follows:

$$\text{minimum required protection factor} = \frac{\text{concentration of contaminant outside facepiece}}{\text{maximum acceptable in-facepiece concentration}}$$

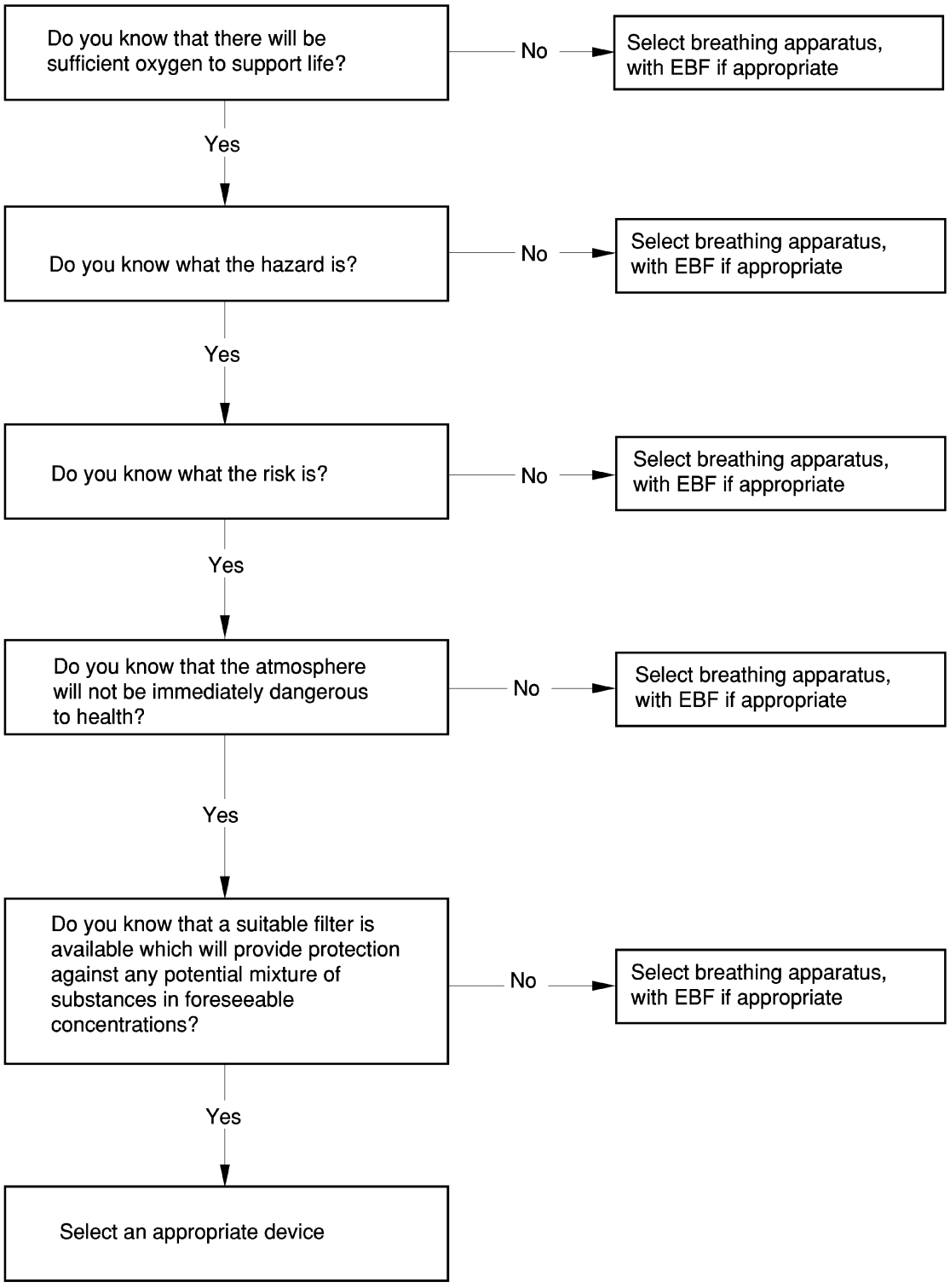
Having calculated the minimum required protection factor, the user should select from those classes of device which have an assigned protection factor, shown in Table 6 or Table 7, greater than the minimum required protection factor.

NOTE An example of such a calculation is given below. Further examples are given in Annex E.

An operative is grinding the metal surface of a plant with a portable grinding machine. He is exposed to 20 mg/m^3 of dust averaged over an 8 h day. The occupational exposure limit for the dust is 5 mg/m^3 averaged over the day.

The minimum required protection factor is 4, i.e. 20 mg/m^3 divided by 5 mg/m^3. Table 6 indicates the filtering devices with an assigned protection factor of 4 that are suitable for particulate dusts. However, this does not provide much of a margin for safety and it would be more appropriate to select devices with an APF of 10.

The dust is only a solid aerosol and Table 1 indicates that a filter(s) marked with the suffix “S” would be acceptable.



NOTE In the lack of any information to the contrary, it should always be assumed that an inhalation risk exists, i.e. dangerous until proven safe.

Figure 5 — Selection of an appropriate device

7.3 Suitability

7.3.1 *General*

Respiratory protective devices are worn by, and should be matched to, individual wearers: a facepiece that fits a large face may not fit a small face. If devices are not matched to the wearer, the device may impose unacceptable discomfort; uncomfortable devices may be worn incorrectly in the attempt to minimize discomfort.

Individual wearers can be assigned to different tasks which involve different levels of exertion, and thus varying breathing rates and/or amounts of body movement. A device which is suitable for a sedentary inspection task may not be suitable for a wearer carrying out hard physical work in a confined space. The type of device provided will therefore depend on the wearer's work rate and activities.

7.3.2 *Matching the device to the wearer's environment*

7.3.2.1 *Facial characteristics*

Individual wearers can have faces of very different sizes and shapes. Facepieces should therefore be matched to each individual wearer and the adequacy of performance checked using one of the test methods described in **8.8**.

If a given type or model of device cannot achieve satisfactory fit to an individual, alternative sizes, types and models should be evaluated.

It is unlikely that any single model of device, particularly an unpowered device, will achieve satisfactory fit for all wearers.

7.3.2.2 *Work rate*

Unpowered devices generally have higher inhalation resistances than powered or air line devices. This high breathing resistance can limit the ability to carry out heavy work or to work for other than short periods, and can cause unacceptable discomfort.

High work rate can affect respiratory protective device performance by both increasing the breathing rates and by causing the wearer to sweat (see **7.3.2.6**).

For unpowered devices, the volume inside the facepiece is drawn increasingly negative with respect to the environment as the work rate increases, and the potential for inward leakage increases. In addition, resistance to breathing becomes increasingly uncomfortable, and this may cause the wearer to remove the device. For powered or power assisted devices or breathing apparatus, the volume inside the facepiece is drawn negative if the wearer's peak inhalation rate exceeds the rate at which breathable gas is supplied to the facepiece. For continuous flow air line equipment fitted with tight fitting facepieces, the wearer cannot inhale at higher rates than the supply rate, the mask collapses on the wearer's face, gross inward leakage is permitted and/or removal of the mask is forced.

To minimize the severity and duration of negative pressure in a facepiece, powered, power assisted filtering devices or breathing apparatus should be provided for workers working hard; increasing gas or air supply rates being required with increasing work rates. These devices should be selected to ensure that the gas supply rate exceeds the wearer's likely peak inhalation rate. See clause **6**.

Typical peak inhalation rates for fit young persons for representative tasks are shown in Table 8. Higher inhalation rates may be generated by less fit, heavier or older persons, for persons exposed to thermal stress or for wearers of heavy personal protective equipment ensembles. For example, a firefighter's peak inhalation rate is increased by about 30 l/min (when working on the level) because of the mass of protective equipment.

Where a task includes a number of different work classifications, the required gas supply rate should be selected to exceed the highest likely inhalation rate. For example, if it is necessary to climb a ladder before carrying out an inspection task, the gas supply rate of the selected device should be at least 250 l/min.

Table 8 — Assessment of required breathable gas supply rates

Work rate	Examples	Peak inhalation rate (l/min)
Low	Sitting at ease: light manual work (writing, typing, drawing, sewing) hand and arm work (small bench tools inspection, sorting light materials) Arm and leg work: driving in normal conditions, operating foot switch or pedal Standing: drilling or milling small parts, coil winding Walking at <3.5 k/h on the level	100
Moderate	Sustained hand and arm work: (hammering in nails, filing); off-road driving, manual asbestos removal below shoulder level Arm and trunk work: pneumatic hammer, weeding, hoeing, picking fruit or vegetables, pulling or pushing light carts or wheel-barrows Walking at <5.5 k/h on the level	150
High	Intense hand and arm work: carrying heavy materials, manual asbestos removal above shoulder level, shovelling, sledge hammer work, hand mowing, digging Walking at 5.5 k/h to 7 k/h on the level Pushing or pulling heavy cart or barrow	200
Very High	Very intense activity at fast to maximum pace: working with axe, intense shovelling or digging, climbing ladder, stair or ramp Walking at >7 k/h on the level	250

NOTE 1 Table derived from Astand, P., and Rodahl, K. [5], Keele, C.A., and Neil, E. [6], Ross, J.A. [7] and BS EN 27243.

NOTE 2 In extreme cases, peak inhalation rates may exceed 660 l/min (Astrand, P., and Rodahl, K. [5]).

7.3.2.3 *Wear duration*

The acceptability of high breathing resistances and discomfort can decrease with increasing wear duration: a device which is acceptable for a short duration may not be acceptable for an extended duration. If devices have to be worn for extended periods, i.e. for hours rather than minutes, careful consideration should be given to powered or air line equipment rather than unpowered devices, and to loose fitting rather than tight fitting facepieces. However, it should always be ensured that only devices that are able to offer adequate protection are selected.

7.3.2.4 *Stooping or bending or work in confined spaces*

Where wearers have to stoop or bend or work in confined spaces, heavy or bulky equipment should only be used if absolutely essential.

7.3.2.5 *Work in hot, humid or cold conditions*

In conditions of extreme cold, the air flow in powered or air line equipment can cause discomfort, particularly where such equipment has long air lines which allow the breathing air to approach ambient temperature. In such conditions, the use of air-fed equipment fitted with vortex or other types of heaters should be considered.

In conditions of high temperatures or high humidities, powered or air line equipment should be considered. In conditions of extreme heat or humidity, the use of air line equipment fitted with vortex coolers or other types of cooler should be considered.

NOTE Vortex heaters and coolers use large quantities of air. They should be used only where the breathing air supply has been shown to be capable of properly supplying the flow and pressure demands of both systems.

7.3.2.6 *Thermal comfort*

The thermal comfort of the user should be considered in all applications. It may be affected by work rate, by environmental conditions and by other personal protective equipment that is worn.

Heat build-up causes sweating. Excessive sweating can cause the facepiece to slip on the face and thus reduce the protection provided by the respiratory protective device. In addition, the heat build-up and discomfort can cause the wearer to loosen protective clothing and so nullify the protection afforded to the body by the clothing. It is essential that if high work rates have to be carried out when wearing a respiratory protective device and protective clothing, steps are taken to provide suitable work-rest, and if necessary active cooling or medical surveillance for the worker. Suitable work-rest recommendations and the corrections necessary to take account of the effects of protective clothing are described in ACGIH (1996) [4]. Information on work-rest and medical surveillance are described in Health and Safety Executive Publication H57 [8], which does not take into account the effects of clothing because it is assumed that loose fitting clothing will be worn.

7.3.2.7 *Contamination*

Care should be taken with components, particularly trailing supply tubes, as various hazardous chemical substances may penetrate through the tube and contaminate the breathing air.

7.4 Compatibility

7.4.1 *Personal protective equipment which can interact with respiratory protective devices*

Wearers of respiratory protective devices may be exposed to multiple risks and may therefore have to wear personal protective devices for protection against each hazard.

NOTE For example, a wearer may be exposed simultaneously to an inhalation and a hearing loss risk and need to wear both a respiratory protective device and hearing protectors.

When selecting types of personal protective equipment that have to be worn simultaneously, care should be taken to ensure that the protective performance of each individual device is not degraded by any other device. In addition, it should be ensured that the overall effect of wearing two or more devices does not generate unacceptable discomfort for the wearer, because if devices impose unacceptable discomfort they can be worn incorrectly in an attempt to minimize discomfort.

All ensembles involving respiratory protective devices being worn with another type of personal protective equipment should be fit-tested as described in **8.8**.

The types of personal protective equipment described in **7.4.1.1**, **7.4.1.2**, **7.4.1.3** and **7.4.1.4** can interact with respiratory protective devices when worn together to reduce the protective performance of either or both of the devices, to exacerbate discomfort or to exacerbate heat stress.

7.4.1.1 *Eye protectors, goggles, spectacles*

The nose pieces of quarter or half masks or filtering facepieces can interact with eye protectors, goggles or spectacles to reduce the performance of either or both. If the facepiece is correctly fitted, it can prevent the eye protectors or spectacles locating correctly. This can permit materials to be projected into the eye or can move the optical axis of prescription spectacles. Conversely, if the eye protectors or spectacles are correctly fitted, the facepiece can lie on top of the eye protector and fail to achieve a satisfactory fit to the face.

In addition, if any leakage occurs around the nose, the humid exhaled air can cause condensation on the eye protector or spectacle lenses.

If both eye and respiratory protection are required, the manufacturer or supplier should be consulted, as they should be able to identify mutually compatible devices. If no such mutually compatible devices are available, consideration should be given to using respiratory protective devices which incorporate the required level of eye protection. See **7.5**.

Where prescription spectacles have to be worn with full facepieces, specially designed spectacle frames that can be mounted inside the facepiece without affecting the face seal should be obtained from the supplier.

7.4.1.2 *Hearing protectors*

The head harness of a respiratory protective device can interfere with the seal between ear muffs and the wearer's head, so reducing the ear muff performance. Where possible, the head harness should be so worn that it does not affect the ear muff seal. Alternatively, ear plugs, if suitable, can be used rather than ear muffs.

7.4.1.3 *Safety helmets*

The front head harness strap and buckle of many full facepieces partially fill the space between the safety helmet shell and the forehead. Since the space between the head and the safety helmet shell is designed specifically to permit the helmet harness to deform under a blow, a smaller space at the forehead reduces the protection afforded in case of a horizontal blow to the front of the head.

In addition, many safety helmets worn with full facepieces have to be tipped rearwards because the helmet interferes with the top of the facepiece. If a substantial downward blow occurs at the front of the helmet, the facepiece can be displaced off the face.

Specially designed integrated respiratory protective devices with impact visor and helmet are commercially available. Where respiratory protection, head protection and eye protection are all required, such integrated devices should be considered.

7.4.1.4 *Protective clothing*

In many situations it is necessary to wear respiratory protective devices together with protective clothing. Protective clothing can reduce the body's ability to lose heat. If a significant proportion of the face is covered by a respiratory protective device, the body's ability to lose heat is substantially further reduced. This can cause heat to be stored in the body, leading to a potential for causing heat-stress related health effects.

In addition, the heat stored in the body can cause excessive sweating, which can cause the facepiece to slip, thus reducing the respiratory protection.

7.5 Protection against multiple risks

Wearers of respiratory protective devices may be exposed to both inhalation and other risks, e.g. exposure to eye irritants, skin damaging substances or noise.

Certain types of respiratory protective devices are designed to afford protection against multiple risks. For example, compressed air line or powered fresh air hose breathing apparatus incorporating a hood for use in abrasive blasting operations is designed to provide both respiratory protection and head, face and eye protection against the blasting medium, while air line full suits provide protection against skin contact with substances that can damage, penetrate or contaminate the skin. Facepieces which cover the eyes can prevent irritation or damage by airborne materials, and some powered or air line helmets and hoods can provide protection against damaging noise exposure.

Such devices are often less uncomfortable than two or more different types of personal protective equipment and should therefore be the preferred option.

In some multiple risk situations it may be preferable to select respiratory protective devices which give protection against multiple risks even if such devices would normally be regarded as over-protection for the given level of inhalation risk.

Typical examples are:

a) use of full-facepieces or other facepieces which cover the eyes to provide respiratory and eye protection against irritant substances. However, if other protection of the eyes is required, e.g. impact, welding, molten-metal splash, or short-circuit electric arc, written assurances should be sought from the manufacturer that the equipment is in accordance with relevant clauses of BS EN 166;

b) use of air line suits to provide respiratory and skin protection;

c) use of certain powered or air line helmets and hoods to provide respiratory and hearing protection.

8 Use

8.1 General principles

Confined spaces present a particular hazard, because of the lack of ventilation and the difficulty of escape. The safe working practices (**8.3**) are particularly important.

Respiratory protective devices should be used only by those who have undergone the requisite training, who have demonstrated that the device can be adequately fitted to them and who have been declared by a competent person as being in suitable physical condition to wear the device.

All devices should be disinfected before storage or use by a different wearer.

8.2 Respiratory protective programme

Respiratory protective devices recommended by this British Standard should be used only as one component of a respiratory protective programme. The respiratory protective programme should itself only be one component of an overall programme to prevent, reduce or control inhalation risks in the workplace (see clause **4** and Figure 1).

A full written specification of the respiratory protective device programme should be prepared and be made available. This specification should relate the respiratory protective device programme to all other aspects of the control of inhalation risks. The programme should also identify competent persons for all tasks.

8.3 Safe working practices

Procedures should be set up to ensure that no filtering device is used in a potentially oxygen deficient atmosphere, or one that is immediately dangerous to life, and that no device is used in situations where the potential protection level is inadequate.

When any respiratory protective device is used in IDLH atmospheres a safe system of working should be used, including:

a) thorough checks on correct fitting;

b) the presence of an attendant in a place of safety in visual or audio contact with the wearer;

c) for compressed air line breathing apparatus, adequate air storage;

d) suitable and agreed communication signals with which wearers and attendants are intimately familiar;

e) it is recommended that the air-line devices should be provided with an auxiliary air supply, which functions as an EBF;

f) a method of emergency egress from the environment should be planned and provided, including the provision of an EBF and a rescue procedure.

8.4 Issue of devices

The appropriate device for each job should be specified by a competent person. The supervisor should ensure that only appropriate devices are issued.

All reusable personal issue devices should be indelibly marked to identify the individual wearer to whom the device is issued. All devices should be thoroughly disinfected after each period of use, in accordance with the manufacturer's instructions.

8.5 Wearer selection

All potential wearers should be assessed by a competent person as to their suitability for wearing respiratory protective devices with regard to:

a) general physical fitness, and any other special requirements;

b) physical fitness on a day-to-day basis (e.g. do not have severe hay fever, or a runny nose);

c) facial characteristics;

d) psychological make-up (e.g. they are not claustrophobic, subject to disorientation or balance problems);

e) features likely to interfere with the face sealing, such as vision correctors, facial hair or dentures.

8.6 Instruction and training

Wearers should be informed of the potential health and safety consequences of incorrectly using any risk control technique, including their respiratory protective device.

Training and instruction should include at least the following:

a) the health effects of exposure;

b) how to fit the device correctly;

c) how to recognize when the device should be worn;

d) the importance of conscientiously wearing the device;

e) application and limitations of the device;

f) how to assess whether the device is complete and in good condition;

g) how to assess when the device has deteriorated in use;

h) the approximate time for which the device should give protection in the wearer's work situation;

i) procedures to be adopted in case of emergency;

j) the importance of not removing the device until in a known safe area;

k) the importance of reporting all defects immediately they are detected;

l) how to carry out a routine face fitting test, where appropriate;

m) decontamination procedures.

Records of the training should be kept by the employer.

8.7 Supervision

Supervisors should be aware of their responsibilities to monitor the use of respiratory protective devices. This may need to be specified in writing in their list of duties and responsibilities.

Supervisors should ensure that:

a) only the specified devices are issued and used;

b) the correct filters are fitted to filtering devices;

c) devices are complete and in good condition;

d) fit tests have been carried out as required;

e) the device has not had unauthorized modification;

f) devices are correctly fitted at times when required to be worn;

g) wearers are clean shaven, if appropriate at the beginning of each wear period;

h) facial marking is observable when the devices are removed;

i) used devices are put into the servicing system;

j) an adequate supply of breathing quality air is available;

k) decontamination materials and facilities are provided.

The supervisor should record all complaints or observations regarding device failure and report them to a named competent person for action. Some failures, especially those of breathing apparatus, are reportable to the HSE under The Reporting of Injuries Diseases and Dangerous Occurrences Regulations 1995 [9].

8.8 Fitting and performance tests

8.8.1 *General*

Fitting tests only identify gross misfits and do not guarantee adequacy of fit. These tests are not a substitute for correct and careful fitting of the device, and should only be carried out in an uncontaminated area. Reference should be made to the manufacturer's instructions for the most appropriate method.

8.8.2 ***Performance testing with a substance with a distinctive odour***

Apply a strong smelling substance of low toxicity such as amyl acetate around the area of the face seal of respiratory protective devices fitted with suitable filters or air-supplying devices. If the substance cannot be detected, the wearer should remove the device and check that he/she can smell the substance. If the smell is detected with the device removed, a satisfactory seal may have been obtained.

If leakage is detected, re-adjust the facepiece and re-test. If the facepiece fails again, reject the facepiece and test an alternative size or model.

This method is generally only useful for relatively low performance devices, e.g. filtering facepieces, half masks and certain types of powered device, where the device is fitted with a gas filter of appropriate type.

8.8.3 ***Performance testing with a substance with a distinctive taste***

Apply a strong tasting substance of low toxicity such as sodium saccharine around the area of the face seal of respiratory protective devices fitted with suitable filters or air-supplying devices. If the substance cannot be detected, the wearer should remove the device and check that he/she can taste the substance. If the taste is detected with the device removed, a satisfactory seal may have been obtained.

If leakage is detected, re-adjust the facepiece and re-test. If the facepiece fails again, reject the facepiece and test an alternative size or model.

This method is generally only useful for relatively low performance devices, e.g. filtering facepieces, half masks and certain types of powered device, where the device is fitted with a particulate filter of appropriate type.

8.8.4 ***Performance fit testing***

Portable quantitative fit test apparatus is now available which can measure the level of fit more accurately. Although a positive result still does not guarantee that the required level of fit will always be obtained, a good assessment is possible, including evaluation of the effects of high breathing rates and head movements. This type of test often generates a certificate, which is useful for record keeping and training purposes.

Quantitative fit testing may not be possible with all types of device. Certain filtering facepieces and powered filtering devices do not have the necessary type of filter and therefore may give erroneous results.

8.9 Routine fit tests

8.9.1 ***Negative pressure test for tight fitting facepieces***

Fit the tight fitting facepiece to the face. Block off inlet joints and gently inhale until the facepiece collapses slightly on to the face. Hold the breath for about 10 s.

If leakage is detected, re-adjust the facepiece and re-test. If a satisfactory fit is achieved, return the device to its original working condition.

If the facepiece fails again, do not use it, and report the occurrence to the supervisor (see **8.7**).

8.9.2 ***Test for filtering facepieces***

Cup the facepiece with the hands, blocking off the exhalation valve if fitted. Exhale sharply. If leakage is felt, particularly into the eyes, re-adjust the facepiece and re-test.

If the facepiece fails again, do not use it, and report the occurrence to the supervisor (see **8.7**).

8.9.3 ***Ongoing tests***

With quarter and half mask devices the wearer should watch out for the sensation of air being blown into the eyes on exhalation. If such sensation is detected the device should be readjusted in a clean area.

8.9.4 ***Facial marking***

With tight fitting devices, a facepiece fitted to pass any one of the above tests will leave marks on the face in a short period. The wearer and supervisor should check when the device has been removed that these facial markings are present.

If no such markings are observed, this may indicate that a satisfactory fit had not been maintained.

If the marks are too prominent, the facepiece may have been distorted on the face. In addition, such marks could indicate that the facepiece imposed undue discomfort.

8.10 Storage

Suitable storage facilities for new, partly-used or cleaned and serviced devices should be available to prevent loss, damage or contamination. The facilities should be in accordance with manufacturer's instructions. Respiratory protective devices should not be stored in dirty or contaminated work areas. Once unsealed, many filters deteriorate quite rapidly in storage. The shelf life refers to sealed packs.

Clean devices should not be stored with dirty workwear or vice versa.

8.11 Return of devices for cleaning, servicing and maintenance

Suitable facilities for returning used devices for servicing and cleaning should also be provided.

9 Maintenance

9.1 General principles

Maintenance of respiratory protective devices should only be carried out by a competent person in accordance with the manufacturer's instructions. This responsibility should not be delegated.

Devices should be cleaned and serviced as soon after use as possible to ensure that the devices are not damaged or degraded by moisture or the substances to which they have been exposed.

It is a requirement of COSHH [2] that equipment is regularly inspected, tested and maintained in accordance with the manufacturer's instructions for use and with approved codes of practice, such as Health and Safety Executive Publication L5 [10].

9.2 Procedures

Uncleaned devices should be regarded as contaminated by the substances for which the devices were provided. Servicing staff may be at risk and suitable controls should be required.

Used filters or other components should be disposed of in accordance with clause **10**.

9.3 Cleaning and decontamination

Devices should be appropriately disassembled, non-reusable parts should be disposed of, and the devices thoroughly cleaned and disinfected after every shift's use with the cleaning agents recommended by the manufacturer. Proper cleaning and decontamination requires care and the manufacturer's instructions should be followed. Delicate parts, for example exhalation valves, require particular care and attention during cleaning.

9.4 Servicing

After each period of wear each device should be cleaned, disinfected and maintained in accordance with the manufacturer's instructions.

Servicing should be carried out only by competent persons using parts designed for the particular respiratory protective devices. No attempt should be made to replace components or to make adjustments or repairs beyond the manufacturer's recommendations. Valves and regulators should be passed to the manufacturer or to a competent person for adjustment or repair. Equipment should not be modified without the knowledge and agreement of the manufacturer.

Immediately after use, used and partly used cylinders or other containers of compressed air or oxygen on self-contained breathing apparatus should be replaced by fully charged cylinders and the absorbents of closed-circuit apparatus renewed.

It is dangerous to use organic-based oils and greases for lubricating cylinder valves, gauges, reducing valves or other such fittings on oxygen equipment.

9.5 Filter changing

Particulate filtering devices should be renewed as soon as increased breathing resistance becomes evident. Gas filtering device canisters and cartridges should be renewed not later than the expiry of the maximum service life (assuming exposure to maximum concentration), as stated by the manufacturer. Those for devices which are not personal issue items should be changed after every shift.

After servicing, powered devices should be reassembled and the air supply rates checked using the device provided by the manufacturer. If flow rates are below the manufacturer's specified minimum and if no defects in the battery or fan unit are noted, the filter should be replaced. If flow rates are still low, the problem should be referred to the supervisor (see **8.7**) for corrective action.

9.6 Testing and inspection

Thorough examinations and, where appropriate, tests of devices other than of one-shift disposable filtering devices, should be made at least once every month and more frequently where conditions are particularly severe. However, for quarter or half-masks used only occasionally for short periods against dusts of relatively low toxicity, longer intervals between inspections may be suitable. In any case, such intervals should not exceed 3 months.

The examination should comprise a thorough visual examination of all parts of the device, in particular of the integrity of straps, facepieces, filters and valves.

In the case of devices incorporating compressed gas cylinders or electric motors, tests should be made of the condition and efficiency of these parts, including tests on cylinder pressure.

In the case of breathing apparatus, the volume flow and quality of the air supply should be tested at least monthly.

Any defects observed should be remedied before further use.

9.7 Record keeping

Maintenance records should include:

a) name and address of employer responsible for the device;

b) particulars of the device;

c) date of examination and clear identity of person carrying out the examination;

d) condition of the device and particulars of any defect observed;

e) in the case of compressed gas cylinder devices, the presence and quality of the gas and the cylinder pressure;

f) in the case of powered fresh air hose or compressed air line devices, the volume flow and air quality;

g) any comments made or received by wearers and supervisors.

Records have to be retained for the period of time specified in relevant legislation, in any case not less than 5 years.

10 Disposal

The disposal of filters and/or facepieces should be carefully considered before the devices are first used. Manufacturers should provide guidance on the materials used in the construction of filters. This information, and the type of contaminants collected on the device during use, should be taken into account when disposing of the device. Before such disposal, the device should be rendered unusable or marked accordingly.

A device which has been contaminated by hazardous materials should be disposed of in accordance with relevant environmental legislation. Disposal of the devices as contaminated waste in special landfills or by incineration may be necessary, together with other waste generated by the process such as gloves, disposable overalls and packaging material.

11 Auditing

The complete respiratory protective device programme should be regularly audited, to ensure that the programme continues to be effective.

NOTE The procedures specified in BS EN ISO 9002 can be used for quality system assessment.

The period between routine programme audits should take account of the potential consequences of programme failure, i.e. audits should be carried out more often in high risk areas than in low risk areas, and of the results of previous audits, i.e. if programme failures have previously been observed, audits should be carried out more often. In all cases, audits should be carried out at least every six months.

Annex A (informative)
Description of respiratory protective devices — Filtering devices

A.1 Nuisance dust masks

A.1.1 *Description*

A light weight mask fitted with a filter suitable only for coarse particles. These masks do not comply with the minimum standard specified for any filtering device and do not give protection against gases or vapours.

A.1.2 *Limitations*

These masks should not be used to control occupational exposures and should be used only for substances for which an occupational exposure limit has been assigned, see Health and Safety Executive Guidance Note EH 40/96 [3], and where the foreseeable contaminant concentration is below this limit. The masks should not be used for substances for which a maximum exposure limit (see **7.2.2**) has been assigned.

A.1.3 *Performance*

No British Standard has been prepared for these devices. Neither has an APF been set.

A.2 Quarter and half mask devices [BS 7356 (EN 140)], masks fitted with gas or combined filters (BS EN 141), particle filters (BS EN 143), gas filters (BS EN 371 or BS EN 372)

NOTE Much of the equipment given in **A.2**, **A.3**, **A.4** and **A.5** has similar APFs and differs only in configuration, comfort and skin protection.

A.2.1 *Description*

The mask encloses the breathing zone and can be fitted with one or more filters which are replaceable. The inhaled air is drawn through the filter(s) and through an inhalation valve if fitted. The exhaled air passes through an exhalation valve to the environment.

The total mass of the filters fitted to the mask does not exceed 300 g.

The overall performance of the device depends on the grade of filter fitted or integral to the mask.

A.2.2 *Limitations*

Due to the very complex shape of the nose and chin areas of the face, it can be difficult to achieve a satisfactory seal on some wearers. The nosepiece can affect the ability to achieve satisfactory fit for safety or prescription spectacles. The mask can affect the intelligibility of the wearer's speech.

A.2.3 *Performance*

Low performance devices. APFs vary from 4 to 20 with the type of filter fitted to the device.

When fitted with particulate filters, the APF against particles is 4 for devices fitted with P1 filter(s), 10 for devices fitted with P2 filter(s) and 20 for devices fitted with P3 filter(s).

When fitted with gas filters the APF of the device against gases is 10.

When fitted with gas and particulate filters the APF of the device is given by the APF assigned to the relevant filter; i.e. 10 against gases and 10 against particles if fitted with P2 filter or 20 against particles if fitted with a P3 filter.

A.3 Valved filtering half masks to protect against gases or gases and particles (BS EN 405)

A.3.1 *Description*

The mask encloses the breathing zone and incorporates filters and inhalation valves. The inhaled air is drawn through the filter(s) and through the inhalation valve. The exhaled air passes through an exhalation valve to the environment. The overall performance depends on the grade of filter.

A.3.2 *Limitations*

Due to the very complex shape of the nose and chin areas of the face, it can be difficult to achieve a satisfactory seal on some wearers. The nosepiece can affect the ability to achieve satisfactory fit for safety or prescription spectacles. The facepiece can affect the intelligibility of the wearer's speech.

A.3.3 *Performance*

Low performance devices. APFs vary from 4 to 20 with the type of filter fitted to the device.

When fitted with particulate filters the APF against particles is 4 for devices fitted with P1 filter(s), 10 for devices fitted with P2 filter(s) and 20 for devices fitted with P3 filter(s).

When fitted with gas filters, the APF of the device against gases is 10.

When fitted with gas and particulate filters, the APF of the device is given by the APF assigned to the relevant filter; i.e. 10 against gases and 10 against particles if fitted with a P2 filter or 20 against particles if fitted with a P3 filter.

A.4 Half masks without inhalation valves to protect against gases and particles or particles only (prEN 1827)

A.4.1 *Description*

The mask encloses the breathing zone and has one or more filters. The filters are replaceable and the inhaled air is drawn through the filter(s).

A.4.2 *Limitations*

Due to the very complex shape of the nose and chin areas of the face, it can be difficult to achieve a satisfactory seal on some wearers. The nosepiece can affect the ability to achieve satisfactory fit for safety or prescription spectacles. The mask can affect the intelligibility of the wearer's speech.

NOTE Only filters marketed for use with these devices should be used.

A.4.3 *Performance*

Low performance devices. APFs vary from 4 to 20 with the type of filter fitted to the device.

When fitted with particulate filters, the APF against particles is 4 for devices fitted with P1 filters, 10 for devices fitted with P2 filters and 20 for devices fitted with P3 filters.

When fitted with gas filters, the APF of the device against gases is 10.

When fitted with gas and particulate filters, the APF of the device is given by the APF assigned to the relevant filter; i.e. 10 against gases and 10 against particles if fitted with a P2 filter or 20 against particles if fitted with a P3 filter.

A.5 Filtering half masks to protect against particles (BS EN 149)

A.5.1 *Description*

The mask encloses the breathing zone and incorporates the filter. It may or may not have an exhalation valve. In some devices the fit can be adjusted by the use of a deformable nose strip. These devices should be disposed of at the end of each shift or as recommended by the manufacturer.

A.5.2 *Limitations*

Due to the very complex shape of the nose and chin areas of the face, it can be difficult to achieve a satisfactory seal on some wearers. The nosepiece can affect the ability to achieve satisfactory fit for safety or prescription spectacles. The mask can affect the intelligibility of the wearer's speech.

A.5.3 *Performance*

Low performance devices available in three grades with APFs of 4 for FFP1, 10 for FFP2 and 20 for FFP3 devices.

A.6 Full face masks [BS 7355 (EN 136)], masks fitted with gas or combined filters (BS EN 141), particle filters (BS EN 143), gas filters (BS EN 371 or BS EN 372)

A.6.1 *Description*

These devices cover the eyes, nose and mouth. All masks for use in unpowered devices are fitted with inner face cups which cover the mouth and nose. The inner cup reduces steaming-up of the visor and re-inhalation of the air exhaled by the wearer. Some devices are fitted with speech diaphragms to improve the ability to transmit the wearer's speech; some devices also have a means to fit special spectacles within the mask. The total mass of the filter(s) fitted to the mask should not exceed 500 g. The visor provides protection for the eyes against dusts and gases. However, facepieces should not be used in situations where impact or other protection for the eyes is required, unless the device is shown to provide the appropriate eye protection.

A.6.2 *Limitations*

Performance can be markedly reduced by facial hair which comes between the facepiece and the face and by the legs of spectacles. The tight fitting facepieces can cause discomfort and/or heat build-up during hard work, or in hot environments.

A.6.3 *Performance*

Low to moderate performance devices with APFs of 4 with P1 filter(s), 10 with P2 filter(s), 20 with gas and combined filters and 40 with P3 filter(s).

A.7 Power assisted particle filtering devices incorporating full face masks, half masks or quarter masks (prEN 12942)

A.7.1 *Description*

These consist of a fan and filter and battery pack which supplies filtered air to the facepiece. The fan and filter can be carried on the belt or can be mounted directly onto the facepiece. The battery, if separate from the fan and filter unit, is generally carried on the belt. Battery life is a minimum of 4 h with up to 12 h on some units. The facepiece is generally either a half mask or full face mask.

Not all full face masks are fitted with inner cups. Where fitted, the visor of full face masks provides non-impact protection for the eyes against dusts and gases. However, visors cannot be assumed to provide protection unless it is shown that they provide the appropriate eye protection. This information is given in the instructions for use.

All devices are supplied with a means to check that the manufacturer's minimum design condition, e.g. air supply rate, is exceeded prior to use.

Breathing resistance of such devices is generally lower than for equivalent negative pressure devices.

The lower breathing resistance is advantageous during hard physical work or for long wear durations. The flow of air over the wearer's face is advantageous during hard work, when wearing protective clothing which reduces the body's ability to lose heat or in hot environments.

In case of fan unit failure, the wearer is able to inhale through the filters and so receive emergency respiratory protection, although at a greater inhalation resistance and considerably reduced protection levels than in the power on mode.

A.7.2 *Limitations*

The tight fitting facepieces can cause discomfort during hard work or in hot environments. These devices tend to be bulkier and/or heavier than the equivalent facepiece used in the negative pressure mode due to the presence of either a facepiece-mounted fan unit or a breathing hose connecting the facepiece to the fan unit.

A.7.3 *Performance*

Low to moderate performance devices available with three levels of protection. Used for gas, particulate or combined protection. The APFs are:

a) 10 for TM1 devices;

b) 20 for TM2 devices;

c) 20 or 40 for TM3 devices.

A.8 Powered particle filtering devices incorporating helmets or hoods (prEN 12941)

A.8.1 *Description*

Consists of a fan and filter and battery pack which supplies filtered air to the facepiece. The fan and filter can be carried on the belt or built into the headpiece in the case of some visors or hoods. In some visor devices, the visor is supported on a helmet. In some such helmet devices, the helmet meets the standard of performance required for safety helmets. The battery, if separated from the fan and filter unit is generally carried on the belt. Battery life is a minimum of 4 h with up to 12 h on some units. The facepiece can be a visor, a hood, or a semi-blouse, and generally the design is such that air is exhaled at the edges of any face sealing or through exhalation valves.

The eye coverings provide protection for the eyes against dusts and gases. However, visors should not be used in situations where impact protection of the eyes is required, unless the device has been demonstrated to provide appropriate eye protection. This information is given in the instructions for use. Helmet devices offering head protection in accordance with BS EN 397 are available.

Devices of Class TH3 are fitted with a warning device which indicates during use if the air supply flow rate falls below the manufacturer's minimum design flow rate. Devices of class TH2 may also have a flow warning device.

The flow of air over the face can be advantageous during hard work or in hot environments.

A.8.2 *Limitations*

The protection afforded by some semi-hood devices can be seriously reduced by wind velocities over the body which exceed about 2 m/s. If wind velocities are likely to exceed about 2 m/s, these devices should not be used unless the manufacturer can guarantee their performance under the foreseeable wind conditions.

In the case of battery or fan failure there is a risk of a build-up in the breathing zone of the carbon dioxide exhaled by the wearer. This can result in an asphyxiation risk. Devices fitted with a supplementary form of protection, such as an EBF, can reduce these effects, but should only be used to allow immediate escape, and not to continue to stay in the area. Carbon dioxide build-up in the breathing zone can reach dangerous levels in a minute or so; thus all devices not fitted with an EBF have to be removed immediately. This limits the use of such devices to concentrations of contaminant that are not immediately dangerous to life or health.

A.8.3 *Performance*

Low to moderate performance devices available with three levels of protection. Used for gas, particulate or combined protection.

The APFs are:

a) 10 for TH1 devices;

b) 20 for TH2 devices;

c) 40 for TH3 devices.

A.9 Filtering devices with non-mask mounted filters (prEN 12083)

A.9.1 *Description*

Unassisted tight fitting facepiece devices with particulate or gas and combined filters typically mounted on a body harness with the facepiece connected to the filter via a flexible breathing hose. This permits a higher capacity, and thus heavier, filter to be used than could be mounted on the facepiece.

The mass supported by a half mask should not exceed 300 g and that supported by a full-mask should not exceed 500 g. The mass of the complete device should not exceed 5 kg.

The increased gas capacity permits longer filter lifetime for a given contaminant concentration and work rate.

A.9.2 *Limitations*

As described for the facepiece, see **A.2** and **A.6**.

A.9.3 *Performance*

Low or moderate performance devices. The APFs are the same as mask mounted filters given in the relevant parts of **A.2**, **A.3**, **A.4**, **A.5** and **A.6**.

Annex B (informative)
Description of respiratory protective devices — Breathing apparatus

B.1 Fresh air hose

B.1.1 *General*

Fresh air hose equipment consists of a facepiece connected by a large diameter air hose to a source of breathable air. The hose inlet is fitted with a strainer to remove coarse particles and needs to be securely anchored in an area of breathable air. The air for respiration may be drawn into the facepiece by the breathing action of the wearer or may be forced through the hose by a manually or power operated blower.

Care should be taken with components, particularly trailing supply hoses, as hazardous chemicals may penetrate through the hose and contaminate the breathing air.

Fresh air hose equipment is available with either tight or loose fitting facepieces. Loose fitting facepieces are only permitted with power operated blowers.

In case of failure of the manual or power operated blower, the wearer of tight fitting facepieces can inhale through the hose, although the inhalation resistance is higher than when the blower is operating.

Manually assisted or power operated devices may be fitted with a breathing bag to compensate for variation in the air flow supply and to provide for peak inhalation requirements.

B.1.2 *Fresh air hose breathing apparatus for use with full face mask, half mask or mouthpiece assembly (BS EN 138)*

B.1.2.1 *Description*

Powered or unpowered breathing apparatus with half mask, full face mask or mouthpiece assembly connected by a large diameter air hose to a source of breathable air. The device may additionally incorporate a hood. The hose inlet is fitted with a strainer to remove coarse particles and needs to be securely anchored in an area of breathable air.

Fresh air hose equipment is available with either light duty, Class 1, or heavy duty, Class 2 construction. Unassisted equipment is available only as Class 2 equipment and excludes a half mask. Apparatus manufactured and designed to meet the requirements of BS EN 138 does not have to be fitted with an EBF. Where the device does not have an EBF, the user should assess the overall suitability of the respiratory protective device for the task.

B.1.2.2 *Limitations*

The limited length of the hose and its bulk can restrict wearer mobility.

B.1.2.3 *Performance*

Low to moderate performance devices with APFs of 10, 40 and 100 for half mask, full face mask or mouthpiece assembly respectively.

B.1.3 *Powered fresh air hose breathing apparatus incorporating a hood (BS EN 269)*

B.1.3.1 *Description*

Powered fresh air hose devices fitted with a hood, and without a tight fitting facepiece. BS EN 269 requires a warning device to be fitted which alerts the wearer when the minimum design air supply rate is not being achieved.

Equipment is available with either light duty, Class 1, or heavy duty, Class 2, construction. Apparatus manufactured and designed to meet the requirements of BS EN 269 does not have to be fitted with an EBF. Where the respiratory protective device does not have an EBF, the user should assess its overall suitability for the task.

In case of failure of devices not fitted with an EBF, it is essential that the hood is removed within one minute of air flow failure. This limits the use of such devices to situations where removal of the device in the contaminated atmosphere does not constitute an unacceptable risk. Devices not fitted with an EBF which supplies breathable gas should not be used in oxygen deficient atmospheres or in IDLH atmospheres.

B.1.3.2 *Limitations*

In case of failure of the blower no guaranteed protection is afforded by these devices and there is also a build-up in the breathing zone of the carbon dioxide exhaled by the wearer.

B.1.3.3 *Performance*

Moderate performance devices with APF 40.

B.2 Compressed air line

B.2.1 ***General***

B.2.1.1 *General description*

Compressed air suitable for respiration is supplied through a flexible tube attached to a compressed air source.

The source of the compressed air may be a compressor, centrally located compressed air cylinders or compressed air cylinders carried on a mobile trolley. If the air is supplied from compressed air cylinders, the source has to be fitted with an alarm device which warns the wearer or an attendant when the cylinder pressure falls below a predetermined level.

Care should be taken with components, particularly trailing supply tubes, as hazardous chemical sources may penetrate through the tube and contaminate the breathing air. In case of contamination of the compressed air supply, or failure of either the compressor or main compressed air storage unit, or in case of operation of the alarm, sufficient compressed air should be available in storage to enable every wearer to stop work in a safe manner, travel to a place of safety, undergo decontamination as necessary and remove the equipment.

An alarm device should be provided to warn that the primary air supply has failed when the amount of air in reserve falls to a predetermined level. The supply of air to the facepiece can be continuous or governed by a negative or positive pressure demand valve.

The flow of compressed air can be advantageous during hard work or in hot environments. A “vortex” device may be carried on the belt and used in conjunction with an excess air supply to achieve either cooling or heating of the body as required. Care should be taken in selection of the air line in case of very hot or cold working conditions to prevent excessive cooling or heating of the air as it passes through the air line.

The compressed air supply can cause drying of the eyes if the air is too dry and extreme cooling and discomfort if the air is too cold.

Equipment is available with communication facilities incorporated in the air line.

B.2.1.2 *General limitations*

In case of failure of the compressed air supply, the wearer cannot inhale through the small diameter air line and associated control valves. Tight fitting facepieces should be removed immediately unless the device is fitted with an EBF. This limits the use of such devices to situations where removal of the device in the contaminated atmosphere does not constitute an unacceptable risk.

Air line apparatus not fitted with an EBF which supplies breathable gas should not be used in oxygen deficient atmospheres or in atmospheres immediately dangerous to health or life.

B.2.2 ***Compressed air line breathing apparatus for use with full face mask, half mask or mouthpiece assembly (BS EN 139)***

B.2.2.1 *Description*

Breathing apparatus with a half mask or full face mask or mouthpiece assembly to which compressed air is supplied. The device may additionally incorporate a hood. The exhaled air passes through an exhalation valve to the ambient atmosphere.

Apparatus can be continuous flow or negative or positive pressure demand equipment. Negative pressure demand equipment should be provided with a manually operated means of providing a minimum air supply rate of 60 l/min per wearer. Normal and peak consumption can be substantially in excess of this figure.

Apparatus manufactured and designed to meet the requirements of BS EN 139 does not have to be fitted with an EBF. Where the device does not have an EBF, the user should assess the overall suitability for the task.

Continuous flow equipment should have a minimum air flow rate of 120 l/min per wearer.

B.2.2.2 *Limitations*

In case of failure of the compressed air supply, the facepiece should be removed immediately unless the device is fitted with a suitable EBF. This limits the use of such devices to situations where removal of the device in the contaminated atmosphere does not constitute a risk.

B.2.2.3 *Performance*

Low to potentially high performance devices with APFs from 20 to 2 000.

B.2.3 ***Compressed air line breathing apparatus incorporating a hood (BS EN 270)***

B.2.3.1 *Description*

Continuous flow compressed air line breathing apparatus with a loose fitting facepiece as a hood.

BS EN 270 requires that a warning device is fitted which alerts the wearer when the minimum design air supply rate is not being achieved during use.

Apparatus manufactured and designed to meet the requirements of BS EN 270 does not have to be fitted with an EBF. Where the device does not have an EBF, the user should assess the overall suitability for the task.

B.2.3.2 *Limitations*

In case of failure of the compressed air supply the facepiece should be removed immediately unless fitted with an EBF. This limits the use of such devices to situations where removal of the device in the contaminated atmosphere does not constitute an unacceptable risk. Devices not fitted with an EBF which supplies breathable gas should not be used in oxygen deficient atmospheres or in atmospheres immediately dangerous to health or life.

B.2.3.3 *Performance*

Moderate performance devices with APF of 40.

B.2.4 ***Light duty construction compressed air line breathing apparatus incorporating helmet or hood (prEN 1835)***

B.2.4.1 *Description*

Light duty compressed air line devices for use where high mechanical robustness is not required, and in areas where the air line is restricted to a maximum length of 10 m.

This apparatus is available in three performance classes. The highest performance class, LDH3, is equivalent to the performance of devices meeting BS EN 270.

prEN 1835 requires that class LDH3 devices be fitted with a warning device which immediately alerts the wearer when the minimum design air supply rate is not being achieved.

It also requires that the lower performance class devices, LDH1 and LDH2 be fitted with a similar warning device unless the helmets/hoods are constructed in a loose fitting manner and it has been demonstrated in the prescribed laboratory test that carbon dioxide does not build up to dangerous levels in the wearer's breathing zone when the air supply is turned off.

Apparatus manufactured and designed to meet the requirements of prEN 1835 does not have to be fitted with an EBF. Where the device does not have an EBF, the user should assess the overall suitability for the task.

B.2.4.2 *Limitations*

Devices are intended for use only where the risk of damage to the compressed air line is low, and are restricted to using a maximum of 10 m of compressed air line.

Except for Class LDH1 and LDH2 devices not fitted with a warning device, there is a build-up of carbon dioxide in the wearer's breathing zone if the air supply fails. This can result in an asphyxiation risk unless an EBF is fitted. Devices not fitted with a warning device and/or an EBF are limited in their application to situations where removal of the device in the contaminated atmosphere does not constitute an unacceptable risk.

In case of failure of devices not fitted with an EBF, which have not passed the laboratory tests showing no undue build-up of carbon dioxide, the helmet/hood has to be removed within one minute of air flow failure to avoid the risk of asphyxiation.

B.2.4.3 *Performance*

Low to moderate performance devices with APFs of 10 (LDH1), 20 (LDH2) and 40 (LDH3).

B.2.5 ***Light duty construction compressed air breathing apparatus incorporating full face mask, half mask or quarter mask (prEN 12419)***

B.2.5.1 *Description*

Light duty compressed air line devices for use where high mechanical robustness is not required and in areas where the air line is restricted to a maximum length of 10 m.

This apparatus is available in three performance classes. The highest performance class, LDM3, uses only full face masks. Classes LDM1 and LDM2 use half or quarter masks. LDM2 is restricted to devices using half masks with special connectors.

prEN 12419 requires that class LDM2 devices and LDM3 devices with special connectors are fitted with a warning device which immediately alerts the wearer when the minimum design air supply is not being achieved.

Apparatus manufactured and designed to meet the requirements of prEN 12419 does not have to be fitted with an EBF. Where the device does need an EBF, the user should assess the overall suitability for the task.

B.2.5.2 *Limitations*

Devices are intended for use only where the risk to damage to the compressed air line is low, and are restricted to using a maximum of 10 m of compressed air line.

In case of failure of the compressed air supply, the facepiece should be removed immediately unless the device is fitted with a suitable EBF because failure of the air supply will result in immediate asphyxiation. This limits the use of such devices where removal of the device in the contaminated atmosphere does not constitute an unacceptable risk.

B.2.5.3 *Performance*

Low to potentially high performance devices, depending on class. Assigned protection factors are 20 (LDM1 and LDM2) or 100 (LDM3).

B.2.6 ***Compressed air line or powered fresh air hose breathing apparatus incorporating a hood for use in abrasive blasting operations (BS EN 271)***

B.2.6.1 *Description*

Breathing apparatus which incorporates a hood or semi-blouse that provides protection for the wearer's head, shoulders and the upper part of the chest against rebounding abrasive materials.

The visor has to meet the impact energy requirements of BS EN 166.

The hood can be supplied with breathable air by either a power operated blower via a fresh air hose or from a compressed air line. The compressed air can be supplied by a compressor or a compressed air reservoir. If the air is supplied from a compressed air reservoir, the source has to be fitted with a warning device which warns the wearer or the attendant when the pressure falls below a predetermined level. Apparatus manufactured and designed to meet the requirements of BS EN 271 does not have to be fitted with an EBF.

BS EN 271 requires that the apparatus is fitted with a warning device which alerts the wearer when the minimum design air supply rate is not being achieved.

B.2.6.2 *Limitations*

In case of failure of the fresh air or compressed air supply the abrasive blasting operation should be stopped immediately and the facepiece removed within one minute unless fitted with an EBF.

B.2.6.3 *Performance*

Moderate performance devices with APFs of 40.

B.2.7 *Compressed air line protective clothing for use against chemical and radioactive contamination*

Detailed guidance on the selection, use and maintenance of this type of equipment is outside the scope of this standard. Users are therefore advised to refer to BS 7184, prEN 943, and prEN 1073, and to seek guidance from the manufacturers for respiratory protective requirements.

B.3 Open-circuit self-contained breathing apparatus (BS EN 137)

B.3.1 *Description*

Breathing apparatus in which the wearer is supplied with breathable air on demand via a lung governed demand valve and/or pressure reducer connected to compressed air cylinder(s) carried by the wearer. The apparatus can be either negative or positive pressure demand.

Only full face masks or mouthpiece assemblies may be used with open-circuit self-contained devices.

The period of protection of such apparatus is limited by the breathing air supply and the wearer's work rate. Nominal durations can range from about 15 min to 110 min using multiple lightweight 300 bar[1)] cylinders.

BS EN 137 requires a warning device to be fitted which draws the attention of the wearer to the remaining supply of breathable gas if it falls below a predetermined level during use.

The maximum permissible weight of the fully charged equipment and facepiece is limited to 18 kg. The weight of the equipment can cause difficulty if the wearer is required to bend, stoop or repeatedly raise and lower the torso. The bulk of the equipment can cause difficulty in confined spaces. The equipment should be worn only by medically screened, well trained and well supervised wearers.

The equipment is complex and should be cleaned, serviced, maintained and inspected only by competent persons.

B.3.2 *Limitations*

Duration is limited by the weight of the equipment acceptable to the user and by the potential for heat storage in the wearer's body.

B.3.3 *Performance*

Moderate to high performance apparatus. APFs are 40 for a negative pressure full face mask device, and a negative pressure demand mouthpiece assembly device, and 2 000 for positive pressure full face mask or mouthpiece assembly devices.

B.4 Self-contained closed-circuit breathing apparatus

B.4.1 *General*

B.4.1.1 *General description*

Devices in which the wearer exhales through a scrubber which removes carbon dioxide and water vapour into a breathing bag. Oxygen from a compressed gas cylinder, a liquid gas container or a chemical source is added to the recirculated, cleaned, exhaled air to replace the oxygen absorbed by the wearer. The inhaled gas can be very hot due to the chemical reaction which absorbs the carbon dioxide and water and/or the reaction which generates oxygen.

Only full face masks or mouthpiece assemblies may be used with closed-circuit self-contained breathing apparatus. Durations up to 4 h can be achieved by some devices, including equipment designated as being for escape. All apparatus should be fitted with a warning device which draws the attention of the wearer to the remaining supply of breathable gas if it falls below a predetermined level.

The bulk of the equipment can cause difficulty in confined spaces. The equipment should be worn only by medically screened, well trained and well supervised wearers.

The equipment is complex and should be cleaned, serviced, maintained and inspected only by suitably trained, supervised and routinely practised staff. It is unusual apparatus which is only used for special purposes.

[1)] 1 bar = 100 kPa.

B.4.1.2 *General limitations*

Duration is limited by the weight of the equipment acceptable to the user and by the potential for heat storage in the wearer's body.

The presence of oxygen-enriched air inside the facepiece can cause additional risk in situations where highly flammable substances may be present.

B.4.1.3 *General performance*

Moderate to high performance apparatus. APFs are 40 for a negative pressure full face mask device, 100 for a negative pressure demand mouthpiece assembly device and 2 000 for positive pressure full face mask or mouthpiece assembly devices.

B.4.2 ***Self-contained closed-circuit compressed oxygen/nitrogen devices (BS EN 145)***

Replacement oxygen is supplied from a high pressure cylinder, the mass of which restricts the quantity of gas which can be carried and thus limits the available duration of use.

B.4.3 ***Self-contained closed-circuit chemical oxygen devices***

B.4.3.1 *Description*

Device in which the water vapour exhaled by the wearer reacts with a substance such as a superoxide to generate oxygen. The oxygen source also absorbs the exhaled carbon dioxide. Some devices are provided with a chlorate candle starter which is manually fired to generate sufficient oxygen to support the wearer until the normal chemical reaction can generate sufficient oxygen.

NOTE BS EN 401 and BS EN 1061 are relevant to this type of respiratory protective device, but only specify apparatus for escape.

B.4.3.2 *Limitations*

Some devices can be slow to start to generate oxygen. The inhaled gas can be uncomfortably hot to breath.

The oxygen generators of such devices are hermetically sealed to prevent degradation and cannot be reused if the full capacity has not been used.

Annex C (normative)
Compressed air for breathing apparatus

C.1 Air quality

C.1.1 *General*

All systems supplying compressed air for breathing purposes should provide air which:

a) is free from any substance at a concentration which could potentially adversely affect health or safety or cause subjective discomfort;

b) will not interact with ambient contaminants which could foreseeably leak into the breathing zone;

c) will not foreseeably affect the correct functioning of the breathing apparatus to which it is supplied.

C.1.2 *purity*

When tested at a pressure of 1 bar absolute, the breathing gas supplied to the wearer should meet the criteria given in Table C.1.

Table C.1 — Criteria for air purity

Substance	Criteria
oxygen	20 % to 23 % by volume (dry air)
carbon monoxide[1]	Not more than 5 ml/m^3
carbon dioxide	Not more than 500 ml/m^3
oil mist	Not more than 0.5 mg/m
odour/taste	Without significant odour or taste
contaminants	No substance should be present at a concentration greater than 1/10 of the assigned occupational exposure limit or users' internal occupational exposure limit
water (liquid)	There should be no free liquid water
water (vapour)[2]	Air up to 40 bar for compressed air line breathing apparatus should have a pressure dew point sufficiently low to prevent condensation and freezing. Where the apparatus is used and stored at a known temperature, the pressure dew point should be at least 5 °C below the likely lowest temperature. Where the conditions of usage and storage of the compressed air supply is not known, the pressure dew point should not exceed −11 °C. For air between 40 bar and 200 bar, the water content should not exceed 50 mg/m^3. For air above 200 bar, the water content should not exceed 35 mg/m^3.

[1] The water content of the air supplied by the compressor for filling cylinders should not exceed 25 mg/m^3.

[2] The results of water vapour content tests carried out at 1 bar absolute should be corrected to take into account the effect of the higher working pressure, see BS 6754:1986. An approximation to the actual pressure dewpoint at working pressures up to 40 bar can be found by applying the following simplified formula:

$$D_w = D_t \times P_w$$

where

D_w = density of water vapour corrected for the higher working pressure in grams per cubic metre;

D_t = density of water vapour given by the test device measured at atmospheric pressure when the temperature is 20 °C, with the result converted to grams per cubic metre when necessary;

P_w = working pressure of the compressed air system in bar absolute.

By matching D_w to the density column given in annex C of BS 6754:1986, the corresponding temperature can be found. For compliance with this standard, the result should be at least 5 °C below the lowest likely ambient temperature.

For tests not carried out at 1 bar absolute and 20 °C the conversion is far more complex and the manufacturers of the test equipment should be consulted.

C.1.3 *Multiple contaminants*

Clauses **6.1** and **7.2.2** discuss the setting of maximum acceptable contaminant concentrations in the facepiece. Since there is some expected inward leakage of contaminants from the surrounding atmosphere, it is necessary to consider the effect of any contaminant already present in the supplied air. For example, some (in particular methylene chloride, cyanides, hydrogen sulfide and aromatic amines) are liable to have additive effects with any carbon monoxide in the supplied air.

The Health and Safety Executive Guidance Note EH 40/96 [3] should be consulted for calculating exposure limits of mixtures. The person assessing the job should take into account the nature of the foreseeable concentrations in the atmosphere, and whether any contaminants can interact with foreseeable contaminants in the breathing air, and adjust the APF downward accordingly.

C.1.4 *Effect of elevated pressure*

Where the air is being breathed at pressures above 1.3 bar absolute, the exposure limit for each contaminant in milligrams per cubic metre of air at the breathing pressure is constant, so that the exposure limit, volume by volume, at the breathing pressure should be reduced in proportion to the absolute pressure.

For example, at ordinary pressure of 1 bar absolute, the limit for carbon monoxide is 50 ppm *V/V* (i.e. 58 mg/m^3). At 2 bar absolute the limit is 25 ppm *V/V* but the exposure limit in milligrams per metre, 58 mg/m^3, remains the same. Very specific regulations apply in these conditions (see Annex F).

C.2 Elements of a suitable compressed air system

C.2.1 *General*

An example of each major component for a compressed air supply system is outlined in **C.3**.

Any supply system should contain components with sufficient capacity for their duty and incorporating the level of complexity sufficient to ensure compliance with the quality recommendations given in Table C.1.

Strategies to accomplish this may include some or all of these components; individual circumstances will determine which are required and precisely in what order they are assembled.

A competent person should be consulted when planning or installing a compressed air system to ensure compliance with the basic health and safety requirements of The Personal Protective Equipment Regulations 1992 [11], and The Pressure Systems and Transportable Gas Containers Regulations 1989 [12], and to ensure that suitable pipework is specified.

Wet compressed air systems, especially when warm and oily, require special attention, because these conditions provide ideal breeding grounds for legionella and other microbiological organisms. See Health and Safety Commission Publication L8 [13].

Regular testing for air flow and quality is required. See Health and Safety Executive Publication L5 [10].

C.2.2 *Atmospheric air source*

Hazardous substances can enter the system inlet from five main sources:

a) routine discharges to the environment from own and other sources;

b) spillages or accidental or emergency releases;

c) back flow from non-breathing apparatus operating from the breathing air supply;

d) contaminants from off-site processes such as neighbourhood plant, bonfires;

e) vehicle exhausts.

To minimize the possibility of hazardous substances being drawn into the system, the inlet should be located upwind and as far away as possible, both vertically and horizontally, from the above sources.

If, on occasion, unforeseen activities are likely to cause contaminants to be drawn into the system exceeding the capacity of the air treatment devices, all wearers should be withdrawn for safety and the system shut down during such process operations, to prevent contamination of the system. In principle, the air intake should be moved to a safer place before the activity restarts.

C.3 An example of a compressed air system incorporating a compressor

C.3.1 *General*

The main elements of a complete breathing air system are shown in Figure C.1.

This diagram incorporates most of the common elements found in a compressed air system.

Dependent upon the assessment of the breathing air requirements, some of the elements may not be required.

Examples of the components used and recommendations for their function are given in **C.3.2**, **C.3.3**, **C.3.4**, **C.3.5**, **C.3.6**, **C.3.7**, **C.3.8**, **C.3.9**, **C.3.10, C.3.11**, **C.3.12, C.3.13, C.3.14**, **C.3.15**, **C.3.16**, **C.3.17**, **C.3.18**, **C.3.19**, **C.3.20**, **C.3.21**, **C.3.22** and **C.3.23**.

C.3.2 *Air intake filter*

Intake filters are primarily designed to protect the compressor from wear and damage caused by coarse particulate contaminants, and normally offer no protection against microscopic particles, gases or vapours.

C.3.3 *Compressor*

The compressor should be able to supply every foreseeable wearer connected to the system with the air flow specified by the manufacturers of the breathing apparatus in use.

The compressor should also be able to supply enough air for auxiliary equipment, e.g. purge air for an adsorption dryer or vortex system.

If it is intended to supply air tools, paint sprayers or shot blast equipment from the breathing air compressor, this should be considered when assessing the required compressor capacity.

If non-breathing apparatus is operating from the breathing air supply and back flow of contaminants from such equipment is a possibility, then suitable non-return valves should be fitted.

Compressors can release oil or other lubricants into the outlet air in addition to any materials ingested into the air intake. These are easily removed by good quality filtration except at high air temperatures. The use of non-lubricated compressors may reduce the burden on the filters, but complete filtration is still required and special care should be taken to control the output air temperature.

Only oils or lubricants known to be suitable or recommended by the manufacturer for breathing air systems should be used.

Overheating compressors can generate contaminants such as carbon monoxide. All compressors should be assessed for explosion risk, overheating and decomposition of oil and other components as appropriate. See also **C.5.1** and BS 6244.

All compressors used for supplying breathable air should therefore be fitted with suitable temperature sensors which shut the compressor down if the temperature exceeds the manufacturer's maximum limit for breathing air use and suitably warns the supervisor and wearers that the compressor has been shut down.

If temporary compressors are used, e.g. during main compressor maintenance, the air supply should not be used until it has been tested and shown to meet the air quality requirements given in **C.1**.

General works air supply systems should not be used to supply breathing air unless fitted with a suitable combination of filters and air treatment devices. See **C.3.4**, **C.3.5**, **C.3.6**, **C.3.7**, **C.3.8**, **C.3.9**, **C.3.10**, **C.3.11**, **C.3.12**, **C.3.13**, **C.3.14**, **C.3.15**, **C.3.16**, **C.3.17**, **C.3.18**, **C.3.19**, **C.3.20**, **C.3.21**, **C.3.22** and **C.3.23**.

Provided appropriate and suitable compressor monitoring is used, and appropriate air treatment equipment is installed, any type of compressor may be employed.

C.3.4 *Aftercooler*

Compressing air increases the temperature and raises the pressure dewpoint. Most of the heat from a compressor is removed by the aftercooler, and as the air cools, airborne water vapour condenses to form many liquid water droplets and mist. Oil vapour will also condense.

Some compressors are fitted with integral aftercoolers and automatic condensate drains.

C.3.5 *Water and oil separator*

The water and oil separator removes the gross excess of water and oil mist and is usually a coarse filter or centrifugal condensate trap and condensate drain.

C.3.6 ***Coalescing filter(s)***

One or more coalescing filters remove fine droplets or airborne water and oil mist. As coalescers are often made from a very fine filter material they also trap tiny dust particles and can eventually become blocked. Condensate should be regularly drained, either automatically or manually, from the filter(s).

C.3.7 ***Dryer***

A dryer may be required to further reduce the levels of water vapour to those given in **C.1.2**. It may also be required to provide dry air for filters and catalysts. Dryers should be assessed for their potential to deplete oxygen from the compressed air supply. Dryers should be fed with air which is free from oil and water droplets or particles.

C.3.8 ***Particle filter***

A particle filter will be required when desiccant dryers are used.

C.3.9 ***Gas filter(s)***

Suitable filter(s) should be fitted to remove gases and oil vapours from the air supply unless it is known that the air cannot become contaminated with such substances.

Such filters have a limited capacity.

C.3.10 ***Catalyst***

A catalyst should be provided to remove carbon monoxide or ozone unless it is known that the inlet cannot become contaminated by these gases.

For compressors driven by petrol or diesel engines it should be assumed that the inlet can be contaminated by carbon monoxide, particularly for units where the engine exhaust and the compressor air inlet are in close proximity.

The air that is fed to the catalyst should be dry. Some types are run at high temperature.

Catalytic devices require periodic reactivation or replacement.

C.3.11 ***Second particle filter***

A particle filter should be fitted to trap any particles released from the previous filter or catalyst stages.

C.3.12 ***Minimum pressure device***

A minimum pressure device may be required to ensure that the filtration and drying equipment operates at the design flow and pressure.

Some dryers include such devices as standard.

C.3.13 ***Non-return valve***

A non-return valve should be fitted to prevent any of the reserve air storage from leaking back through the filters, dryer and compressor equipment.

C.3.14 ***Reserve air storage***

Reserve air storage does not constitute an EBF and only provides air for a limited time in the event of failure of the compressor or system upstream of the reserve air storage receiver, provided a non-return valve is suitably sited.

The reserve air capacity should be sized appropriate to the working environment, the number of users, the use of ancillary equipment and the duration necessary to evacuate to a safe area.

Stored air, if not changed regularly, may become stale, and if stored wet may lead to a loss of oxygen caused by the build-up of rust in steel air receivers and cylinders, or corrosion in alloy cylinders.

Stored compressed air should not routinely be used to supply breathable air during maintenance operations when the compressor is shut down unless additional storage capacity is provided during such operations (see **C.3.19**).

See clause **6.11** of BS EN 139:1995 for additional information on mobile high pressure air supply systems.

C.3.15 *Control units*

Control units, if required, should be appropriate to the respiratory protective equipment and may be provided for individuals or groups of wearers, provided they require the same supply pressure. These may include filters, a pressure regulator, an alarm device, flow rate detectors, flow controllers and outlet couplings, or only some of these. The units may be either fixed to a wall or moveable.

Control units for filling cylinders may be provided for high pressure systems.

C.3.16 *Couplings*

Pipelines and outlets should be colour coded and identified, with matching colour codes on the equipment to be plugged or connected. Where engineering standards allow, connectors should be non-interchangeable.

Coupling design should prevent unintended disconnection. See clause **6.5.2** of BS EN 139:1995.

Where multiple connection points are fitted, the coupling design should be self-sealing to prevent loss of air when a hose is uncoupled.

Where it is necessary to have several connection points close together, connectors should be clearly identified, or control measures taken, to reduce the possibility of one wearer disconnecting another wearer's air supply.

C.3.17 *Purity monitoring facility*

An initial assessment of the hazard should be made and a monitoring strategy for air purity should be drawn up by a competent person.

The monitoring strategy may be made up from one or more of the following points, see Figure C.1.

a) Monitoring at the air intake will warn against the presence of contaminant gases and is most effective where sudden increases in local pollution level are possible. Where the alarm is arranged to stop the compressor, any potential for polluting the reserve air supply is minimized.

b) Monitoring after the compressor but before the dryer will also detect any pollutants evolved by the compressor.

c) Monitoring after the entire filtration system will establish the quality of the air available at the point of use, but reliance on this as the only monitor may not indicate any heavy contamination in the system.

d) Monitoring at point of use will provide a measure of not only the supply cleanliness but will also reveal pollutants that affect or arise from the supply pipework and hoses.

Although continuous monitoring is desirable, a monthly test of the foreseeable expected contaminants, in addition to oil, water, carbon dioxide, carbon monoxide and oxygen depletion, may be adequate when operated in conjunction with other properly designed control measures.

For multiple outlets, such tests should be carried out at a proportion of all the available outlets, paying particular attention to those at the extreme ends of pipework systems.

Monitoring systems that are unable to detect all foreseeable contaminants should be supplemented by monthly checks of those contaminants not covered. Electronic sensors that do not include data logging should have alarm conditions logged manually and the log maintained in the quality record.

In any case, the system should be tested at least once per month, and more frequently if conditions are particularly severe, to ensure that the compressed air supply meets the criteria given in **C.1**.

The quality of air supplied by mobile breathing air compressors should be tested immediately prior to the first use at any new location.

C.3.18 *Compressor system controls*

Compressor management devices will be required to ensure that the compressors run correctly. These devices can include load control, oil level, filter blockage, pressure and temperature alarms, electrical overload and pressure relief.

C.3.19 ***Standby compressor***

A second, or standby, compressor should provide 100 % of the air needed in the event of the main compressor failing or being taken out of service for maintenance.

A second or third compressor might be used when a maximum demand has to be catered for, rather than running one large compressor on light load.

C.3.20 ***Air receiver***

Many compressor systems need air receivers as a means to regulate the pressure for load control purposes. It may also be desirable to have a receiver for additional storage and to assist in condensate removal. These receivers should not be considered as part of the reserve air storage.

C.3.21 ***Alarm***

An alarm should be provided that will inform the users or their supervisor that the air supply system has failed to maintain a minimum safe condition. This may be a measure of the reserve pressure, the compressor supply pressure, the compressor temperature, the air flow, the gas monitor condition or any other relevant criteria.

Where possible, the wearers should be informed automatically so that an orderly exit from the work site can be made. Where this is not possible, a supervisor constantly in attendance should inform the wearers of the situation without endangering his/her own health. No attempt to cancel an alarm should be made until the evacuation is completed.

Alarms should not be easily confused with other signals and should be loud enough to be heard in the prevailing environment but not so loud as to prevent appropriate communications. Where there are a number of reasons for requiring an evacuation from a work site no attempt need be made to differentiate between the given signals, since this may serve to confuse the workers.

C.3.22 ***Condensate drainage***

Condensate should be regularly drained from the system and disposed of in an appropriate manner. Direct discharge to ground or sewer should not be permitted.

C.3.23 ***Distribution pipework and/or flexible tubes***

C.3.23.1 The distribution pipework and/or flexible tubes should be appropriate to the demand and suitable for the environment in which they are to be tested.

Any assessment of distribution pipework and/or flexible tubes should take into account:

a) burst and operating pressure;

b) temperature resistance;

c) crush and kink resistance;

d) strength of couplings;

e) chemical resistance;

f) chemical permeability;

g) abrasion resistance;

h) anti-static requirements and explosion risk;

i) design, identification and use of isolation valves.

C.3.23.2 Good practice normally dictates:

a) regular inspection for damage;

b) clean storage with ends capped;

c) identified and marked for use with breathing air;

d) restricted to use with breathing air;

e) protection from crushing (vehicles machinery).

Except for drummed and spiral coiled tubes, loose tubes should be used uncoiled.

C.4 Special requirements for air for self-contained breathing apparatus

It should be noted that water vapour can condense to form liquid water which can cause corrosion and can freeze in sub-zero ambients.

Water vapour can also condense and freeze due to rapid expansion, and the resulting ice or corrosion products can cause control valves and demand valves to block or malfunction.

To prevent this happening, the air used to fill cylinders should meet the requirements of **C.1**. In addition, it is essential to ensure that empty cylinders are protected from the ingress of contaminants and that they are clean and dry before filling with air. See **C.1.2**.

C.5 Maintenance, testing and inspection

C.5.1 *Maintenance*

The general principles for compressor maintenance as described in BS 6244 should be followed.

Maintenance of all components of a compressed air breathing system should be carried out by competent persons based on a preventative maintenance programme rather than repair as required following failure. Exhaust valves on reciprocating compressors should be regularly examined, because damage to such valves could indicate overheating, and thus the generation of carbon monoxide and other decomposition products.

Maintenance should include the routine checking of the operation of all temperature sensors, cut-outs and alarms.

Compressor oil or lubricant levels should be checked on a daily basis and the results recorded. These daily records should be checked at least once per week to determine whether oil consumption is within the manufacturer's limits, and corrective action should be taken if they are not.

Only oil or lubricants known to be suitable for breathing air systems should be used.

All filters and catalysts should be changed as recommended by the manufacturer or supplier.

C.5.2 *Testing and inspection*

In addition to the general requirements described in clause **9**, the volume flow and quality of the supplied air should be thoroughly tested at least once every month to check for the presence of all foreseeable contaminants. Such tests should be carried out more frequently where the contaminants are likely to be present at the compressor intake, in high humidity conditions and where the breathing apparatus is being used close to its APF.

Where mobile breathing air compressors are used, these tests should be made immediately prior to the first use at any new location.

Where temporary compressors are used, these tests should be made immediately prior to the first use.

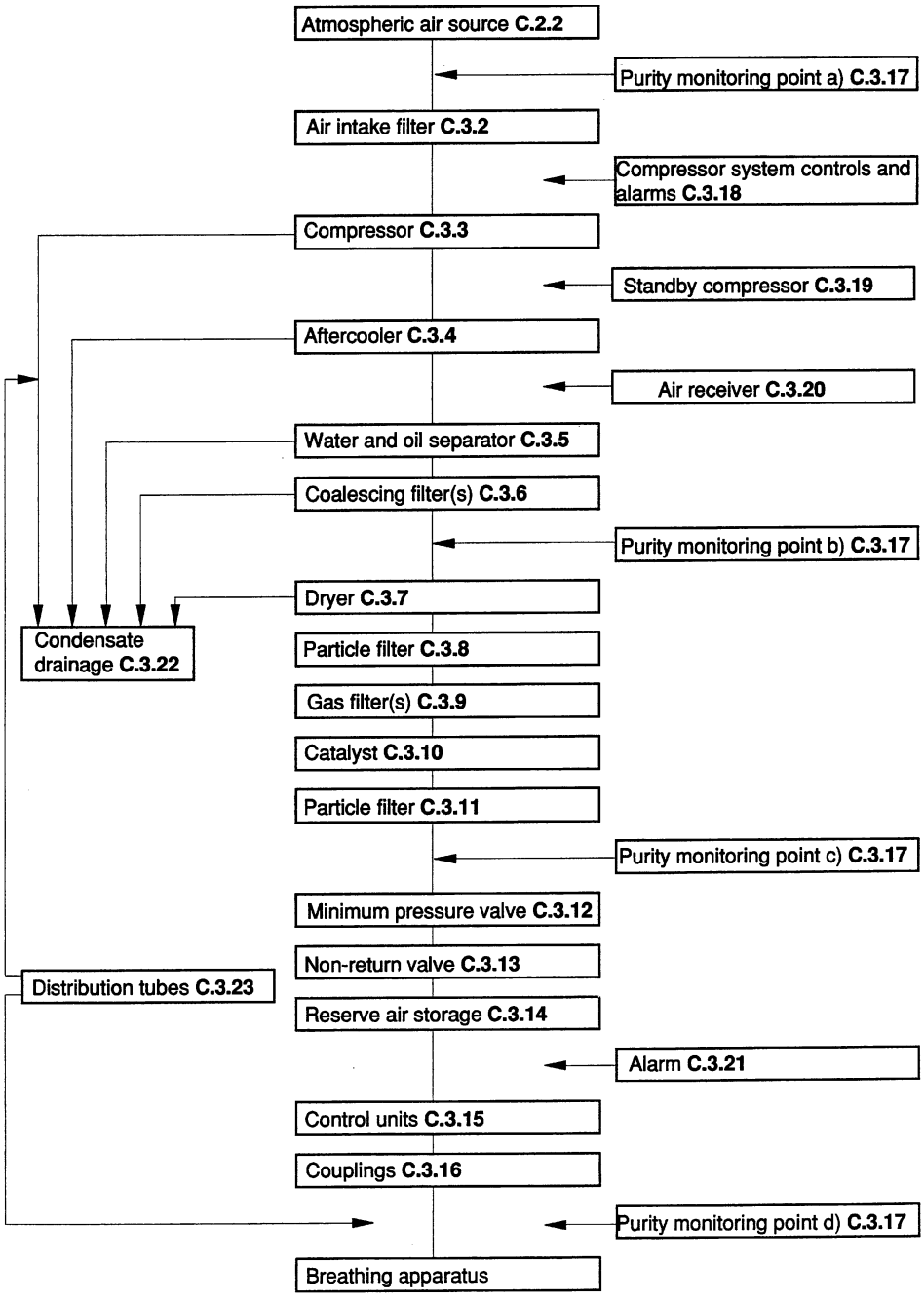


Figure C.1 — Elements of a compressed air system

Annex D (informative)
Derivation of assigned protection factors

D.1 Background

D.1.1 The APF set for each class of respiratory protective device in this British Standard is based as far as possible on the level of protection which has been reported from studies measuring the performance of that class of device in real workplaces. The relevant documents are given in **F.2**. From the data provided in such "workplace protection factor" (WPF) studies, an index of performance was derived for each class of device. Workplace protection factor results were obtained for most types of filtering devices but few results were obtained for breathing apparatus.

Most of the workplace protection factor studies had been carried out in the USA on devices which had not been demonstrated to comply with the current relevant CEN standards. For the purposes of setting APFs for devices complying with CEN standards, it was necessary to assign European standard classifications to American devices.

D.1.2 For filtering devices, the following assumptions were made.

a) Half masks fitted with dust or mist filters were assumed to be equivalent to half masks conforming to BS 7356 (EN 140) fitted with P1 filters conforming to BS EN 143.

b) Half masks fitted with dust, mist or fume filters were assumed to be equivalent to half masks conforming to BS 7356 (EN 140) fitted with P2 filters conforming to BS EN 143.

c) Half masks fitted with high efficiency filters were assumed to be equivalent to half masks conforming to BS 7356 (EN 140) fitted with P3 filters conforming to BS EN 143.

d) Corresponding assumptions were made regarding the equivalence of American and European filtering facepieces for devices not sold in Europe.

e) Full face masks fitted with high efficiency filters were assumed to be equivalent to full masks conforming to BS 7355 (EN 136) fitted with P3 filters conforming to BS EN 143.

Although numerous results were available from WPF studies for powered hoods and helmets, it was not possible to differentiate between THP1 and THP2 powered helmet filtering devices, since it was not possible to assign European standard classifications to the individual devices tested.

D.1.3 Workplace protection factor data were not available for most classes of breathing apparatus. For breathing apparatus without field data, the following assumptions were made.

a) The performance of a fresh air hose full face mask or a negative demand air fed full face mask were assumed to be equivalent to a full face mask conforming to BS 7355 (EN 136) fitted with a P3 filter conforming to BS EN 143.

b) The performance of power assisted and powered fresh air hose and compressed air line devices would be the same as for the corresponding powered filtering device fitted with a high efficiency filter and the same facepiece.

D.2 Validity of workplace protection factor data

D.2.1 *General*

The validity of workplace protection factor results depend upon the following factors:

a) the study protocol;

b) the measurement technique used to measure contaminant concentrations in the facepiece.

D.2.2 *Study protocol*

Workplace protection factor studies can be carried out following three general protocols:

a) studies carried out without significant deliberate intervention by the investigators. In such "As is" studies no additional training or supervision is provided by the investigators, and intervention is limited to correction of any actions or behaviour which could expose the wearers to significant risk to health. Measurements are made only when devices are worn.

All workplace protection factor studies carried out in the UK have followed an "As is" protocol.

Unless the quality of training and supervision during "As is" studies is clearly inadequate, they are considered to give the most realistic indication of the protection factors which are likely to be achieved in workplaces in the UK. It should be appreciated, however, that the presence of the investigators can cause both employers and employees to improve their respiratory protective device use procedures, since few employers are likely to allow potentially adverse data to be reported for premises for which they are responsible. "As is" studies can thus generate an optimistic WPF;

b) studies in which the investigators carry out fit tests to ensure that the respiratory protective device provided can achieve satisfactory performance on the given wearer. The wearers are trained by the investigators and are often supervised during the study by the investigators on an essentially one-to-one basis. The American Industrial Hygiene Association (AIHA) defined such a protocol in 1985 [14].

Most workplace protection factor studies carried out in the USA have followed the AIHA protocol.

For the purposes of setting an APF, it is considered that the care taken during studies to the AIHA Protocol regarding device selection and wearer training and supervision is unlikely to be representative of most workplaces, certainly of those in the UK, and therefore likely to generate optimistic indications of performance. Such optimistic indications of performance, if adopted as an APF, could result in wearers being supplied with devices which, when used under realistic conditions, could prove unable to provide adequate protection;

c) studies which include in-facepiece measurements during periods when the respiratory protective device is not worn although airborne contaminants may be present. Because such "programme protection factor (PPF)" studies include periods of non-wear, very low protection factors can be generated. Since an effective respiratory protective device programme includes supervision to limit such non-wear, PPF studies are likely to generate pessimistic estimates of performance. Such pessimistic indications of performance, if adopted as APF, could result in wearers being supplied with unnecessarily high performance devices which could result in additional discomfort for the wearer and unnecessary cost to the employer.

For the purposes of setting an APF, no data sets from PPF studies were used in setting the APF and have therefore not been referenced in this document.

Although an "As is" protocol is considered to be the most suitable type of study on which to set an APF, only 8 studies were identified which followed such a protocol, compared with 23 which followed the AIHA protocol. For the purposes of this British Standard, it proved necessary to include the AIHA protocol studies in setting an APF.

D.2.3 *Measurement techniques in the facepiece*

Most studies carried out in the USA were based on filter cassettes located outside the facepiece which were connected to a probe fitted inside the facepiece. The probe takes its sample from within about 3 mm to 6 mm of the outer surface of the facepiece. Such a probe tends to underestimate the in-facepiece test agent concentrations by a mean of 25 % for unpowered full face masks and half masks.

Workplace protection factors based on this sampling procedure adopted in the majority of the studies analysed could overestimate protection factors by factors of up to 1.7 for both full face masks and half masks, depending on the specific mask.

Overall, most of workplace protection factor results on which the APF are based underestimated the in-mask contaminant concentrations and therefore overestimate likely workplace performance.

D.2.4 *Data analysis*

For the purposes of summarizing the data, the index derived for each device was the 95th percentile (i.e. the protection given on 19 fittings out of 20). This index is statistically equivalent to that adopted in standards such as BS 7355 (EN 136), which require the leakage results for all test subjects in laboratory tests to meet the relevant compliance criterion.

Adoption of this index was agreed at the 1994 Autumn meeting of the European Chapter of the International Society for Respiratory Protection.

For each class of device for which workplace protection factor data were available, the geometric mean of the reported 95th percentiles, weighted for the number of individual results reported in each study, was calculated. If a study 95th percentile differed from the weighted mean 95th percentile by a factor greater than 5, such data were excluded, and the weighted mean 95th percentile recalculated. This exclusion rule was followed since it is considered that such a difference reflects gross differences in either the device, study protocol or nature of the airborne contaminant and suggests that such data are not homogeneous with the rest of the data.

Such exclusion was necessary for only four classes of device.

For filtering devices, APFs were set at the value of the nominal protection factor or the workplace protection factor index, whichever was the lower.

In total, 1 613 workplace protection factor results were available for filtering devices and 284 results for breathing apparatus.

Table D.1 and Table D.2 show the number of individual workplace protection factor results which were available for each class of filtering device and breathing apparatus respectively.

D.3 Conclusion

Data has been used from studies which followed the AIHA study protocol and which used in-facepiece probes that underestimated in the in-facepiece contaminant concentrations. However, it is considered that the protection factors shown in Table 6 and Table 7 represent the best estimates and assumptions from the available data on the basis of professional judgement.

Accordingly, this British Standard will be reviewed and appropriately amended on receipt of any valid WPF data, submitted to BSI (via the Secretary, Technical Committee PH/4). The confidentiality of the source of the data will be respected where required.

Table D.1 — Number of individual WPF results for classes of filtering device

Assigned protection factor	Half or quarter mask and filter	Filtering half masks	Full face masks and filter	Power assisted filtering devices incorporating full face masks, half or quarter masks	Powered filtering devices incorporating hoods, helmets or semi-blouses
4	P1:30	FFP1:167	no data	—	—
10	P2:81 Gas:109	FFP2:20	no data	no data	THP1, hoods or helmets: 246 THP2, semi-blouses: 18
20	P3:410	FFP3:62	Gas:7	no data	—
40	—	—	P3:121	TMP3:234	TH3, hoods or helmets: no data semi-blouses: 72

Table D.2 — Number of individual WPF results for classes of breathing apparatus

Assigned protection factor	Non self-contained	Self-contained
4	—	—
10	no data	—
20	—	—
40	no data	Negative pressure demand, full mask: 2
100	no data	no data
200	Air line, full suit: 220 Air line, semi-blouse: 64	—
1 000	no data	no data
2 000	no data	no data

Annex E (informative)
Examples of the calculation of assigned protection factors

E.1 Components are being sprayed with an isocyanate based coating solution. The operative is exposed to the aerosol spray mist at levels of 0.012 mg/m^3 averaged over the 8 h day (8 h TWA) but peak concentrations of 1.05 mg/m^3 during a number of 15 min periods during the day. The occupational exposure limit TWA is 0.02 mg/m^3 and the STEL is 0.07 mg/m^3 over any 15 min period.

The 8 h TWA limit is exceeded by 6 times (0.012 mg/m^3/0.02 mg/m^3) but the STEL is exceeded by 15 times (1.05 mg/m^3/0.07 mg/m^3).

The APF for the device should exceed 15. Table 6 indicates the range of such devices with APFs of 20. A gas filter device is required for the aerosol mist produced by this spraying process. Table 2 indicates that an A filter(s) would need to be fitted to a full facepiece to protect against the vapour, and a particulate filter to protect against the solid particles.

However, the isocyanate substance has a maximum exposure limit (MEL). Accordingly, it is advisable to restrict the concentrations inside the device to approximately half this limit. On this basis, filtering devices with an APF of 40 would be selected from Table 6, i.e. a power assisted full face mask (TM3) with an AP3 filter, or a power assisted hood (TH3) with an AP3 filter.

Further caution is still required. Isocyanate mist can cause sensitization of the respiratory tract, even at exposure levels below the occupational exposure limit. The properties of this substance are such that no taste or smell can be detected with leakage into the device, i.e. there is no warning. In addition, this substance may cause sensitization of the skin and eyes.

Health and Safety Executive Guidance Note EH 16 [15] recommends the use of air line equipment when spraying materials containing isocyanates. Therefore, it is normal practice to use breathing apparatus rather than filtering devices. From Table 7, light duty air line devices LDH3 or LDM3, or other compressed air line devices with an APF of 40 or above would be considered.

Such isocyanates are normally sprayed with organic solvents which act as a carrier medium. The respiratory protective device would have to be selected to reduce exposures to such solvents, but this aspect has not been considered for this example.

E.2 Metal components are cleaned by hand with an ammonium based solution over a single 15 min period in a day. The operative is exposed to 70 ppm of ammonia during this period. The components are subsequently sprayed with a paint mixture, inside a ventilated enclosure, for the remainder of the day. The paint mixture contains titanium based pigments and white spirit. The operative is exposed to 300 ppm of white spirit over the 8 h day. However, the peak levels reach a maximum of 1 300 ppm in some 15 min spells. The atmosphere is not oxygen deficient.

The occupational exposure limit for ammonia is 25 ppm, time-weight averaged over an 8 h day with a short term limit of 35 ppm averaged over any 15 min period. In this case, the former limit will not be exceeded, i.e. the averaged exposure is less than 3 ppm for the day. However, the maximum exposure limit is exceeded, and the assessment indicates that use of a respiratory protective device is the only solution.

The minimum required protection factor is 2, i.e. $\frac{70}{35}$ ppm. Table 6 indicates the gas filtering devices with an APF of 10 which could be suitable.

As indicated in Table 2, the gas filter would have to conform to a K1 type.

The occupational exposure limit for white spirit is 100 ppm time-weight averaged over an 8 h day. However, the operative is exposed to high peak levels during the course of the day and white spirit has a maximum exposure limit of 125 ppm averaged over any 15 min period. Therefore, the minimum required protection factor for such exposures is just over 10, i.e. $\frac{300}{100}$ ppm.

If the maximum exposure limit were not exceeded, the minimum required protection factor would be taken as 3, i.e. $\frac{300}{100}$ ppm

Table 2 and Table 6 indicate that similar types of respiratory protective devices to those used against ammonia would be suitable in this case, although an A1 type of gas filter would be necessary.

A gas filtering device with an APF of 20 would need to be selected from Table 6. This would have to be fitted with an A2 gas filter (see note 3 to Table 2). It follows that this device would have to be worn for the complete spraying operation to cover for these peak and the averaged daily exposures.

So far, the selection process for the spraying work has only considered the white spirit vapours released. The operation will also release an aerosol mist containing titanium pigments. These compounds do not have a specific occupational exposure limit, but it is necessary to apply a nuisance limit of 5 mg/m^3 (see HSE EH40) for total inhalable aerosols averaged over an 8 h day.

NOTE There is also a respirable aerosol limit but this will be ignored for the purposes of this example.

The monitoring survey on the spraying operation indicates that the pigment exposure levels are 50 mg/m^3 averaged over the day.

Accordingly, the minimum required protection factor is 5, i.e. $\frac{50}{10}$ mg/m^3.

Considering the aerosol mist only, Table 6 indicates that a particulate filter with an APF of 10 would be suitable. The device would be fitted with a P2 filter. However, the selection process has already concluded that a device with a protection factor of 20 is required for the spraying work. It follows that the device needs to be fitted with a combined gas and particulate filter of the appropriate classification, i.e. A2P2 or A2P3. Table 1 indicates that the particulate filter needs also to be suitable for liquid aerosols. Therefore, either A2P2SL or A2P3SL combined filters would be suitable.

In reality, it is unlikely that different devices would be worn for the cleaning and spraying operations. Accordingly, the device used for paint spraying could be fitted with a combined filter for ammonia, white spirit and aerosol mists, e.g. A2K1P2SL or A2K1P3SL.

It is known that an APF of 20 is required and, therefore, the filter would have to be fitted to a full face mask or a power assisted half mask (TM3) or a powered hood (TH2). In practice, the selection process would also have to consider eye and skin protection relevant to the spraying operation. Therefore, a power assisted half mask device would probably be replaced by a power assisted full face mask device (TM3), although the other devices are still suitable.

The use of breathing apparatus could be considered. Table 7 includes light duty (LDH2, LDH3 and LDM3) and compressed air line breathing apparatus devices with APFs of 20 to 40, which may be considered in this case in order to provide respiratory and face protection.

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