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Eye and face protection — Guidance on selection, use and maintenance

Protection des yeux et du visage — Lignes directrices pour le choix, l'utilisation et l'entretien

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 94 *Personal safety — Personal protective equipment*, Subcommittee SC 6 *Eye and face protection*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 85, *Eye-protective equipment,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is intended to provide guidance on how to select, use and maintain eye and face protectors. A workplace eye and face safety programme should be introduced and a hierarchy of control followed where workers are exposed to a recognised risk of injury to the eyes and/or face. Examples of areas and processes where eye and/or face hazards may exist are shown in Tables 2, 4 and 5.

The aim of an eye and face safety programme is to protect the eyes and face of the worker through the process of elimination or control of hazards and, where necessary, the wearing of appropriate protection.

While responsibility for the successful implementation of an eye and face safety programme rests with senior management, every effort is required to secure the participation and involvement of employees or their representatives in all phases of the programme. Experience has shown that programmes lacking this involvement have less chance of success.

A critical examination of working conditions, particularly lighting, layout and planning of buildings and processes, forms a necessary part of an eye and face safety programme.

Selection of a suitable programme may be assigned to safety personnel within the organisation or advice may be sought from outside sources. Elements that have been found in successful eye and face safety programmes include the following:

a) An assessment of hazards.

b) Determination of workplace hazard areas.

c) Elimination or confinement of hazards (where possible).

d) Vision screening.

e) Referral for optometric, ophthalmological examination or both, where necessary.

f) The universal wearing of suitable eye and face protectors for those persons at risk.

g) Educational campaigns on eye safety.

Eye and face protectors are items of personal protective equipment (PPE) intended to prevent the harmful effects that physical (e.g. flying particles, dust, splashing and molten materials), optical (e.g. solar and artificial radiation and high intensity radiation generated during operations such as welding and furnace work), chemical (e.g. pressurised materials, harmful gases, vapours and aerosols) and biological hazards may have to the eye and face.

For eye and face protectors to be effective they should be used at all times when the user is in a potentially hazardous environment. When selecting eye and face protectors, attention should be given to factors influencing comfort and user preference.

Those involved in selling eye and face protectors to the general public for use in non-workplace settings should adhere to the principles and guidance in this standard to ensure that users of personal protective equipment are fully informed about making the safest choice for a particular task and environment as well as how to use the protective equipment in the safest manner. This should also apply to those businesses that hire out power equipment. Safety guidance based on this document should be provided to prospective customers to ensure that they select and use the correct protective equipment to reduce the risk of eye and face injury.

Eye and face protection — Guidance on selection, use and maintenance

1 Scope

This document gives guidance to specifiers and users on the control of eye and face hazards including physical, mechanical, chemical, optical radiation and biological and on the selection, use and maintenance of eye and face protectors.

This document applies to

— occupational use,

— tasks that are performed similarly to those in an occupation but not in the workplace, e.g. "do-it-yourself", and

— schools, educational and research establishments.

This document does not apply to eye and face protection for

— ionizing radiation,

— low frequency radio waves,

— microwaves,

— sports or vehicular usage, and

— sunglasses for general (not occupational) use – see ISO 12312-1.

NOTE The ISO 18527 (all parts) sets requirements for eye protectors for some sports.

Brief advice on protection when using lasers is included but for detailed advice, see IEC/TR 60825-14.

This document is neither a whole nor partial substitute for risk assessment, which is an essential part of any eye and face protection programme.

Although this document has been written to help specifiers and users, any recommendations in this document are to be interpreted as guidance only and not intended to replace any national regulatory requirements. Risk assessment is the sole responsibility of the employer and not the PPE manufacturer or its authorised representative.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4007, *Personal protective equipment — Eye and face protection — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4007[1)] and the following apply[2)].

1) The terms and definitions for risk and hazard have been included here for the reader's convenience.

2) The abbreviation PPE means personal protective equipment.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

NOTE ISO/IEC Guide 51:2014, Clause 4, states: The term “safe” is often understood by the general public as the state of being protected from all hazards. However, this is a misunderstanding: “safe” is rather the state of being protected from recognized hazards that are likely to cause harm. Some level of risk is inherent in products or systems. The use of the terms “safety” and “safe” as descriptive adjectives is avoided when they convey no useful extra information. In addition, they are likely to be misinterpreted as an assurance of freedom from risk. The recommended approach is to replace, wherever possible, the terms “safety” and “safe” with an indication of the objective – for example, the phrase “protective spectacles” should be used in preference to “safety spectacles”.

3.1
hazard
potential source of harm

[SOURCE: ISO/IEC Guide 51:2014, 3.2]

3.2
risk
combination of the probability of occurrence of harm and the severity of that harm

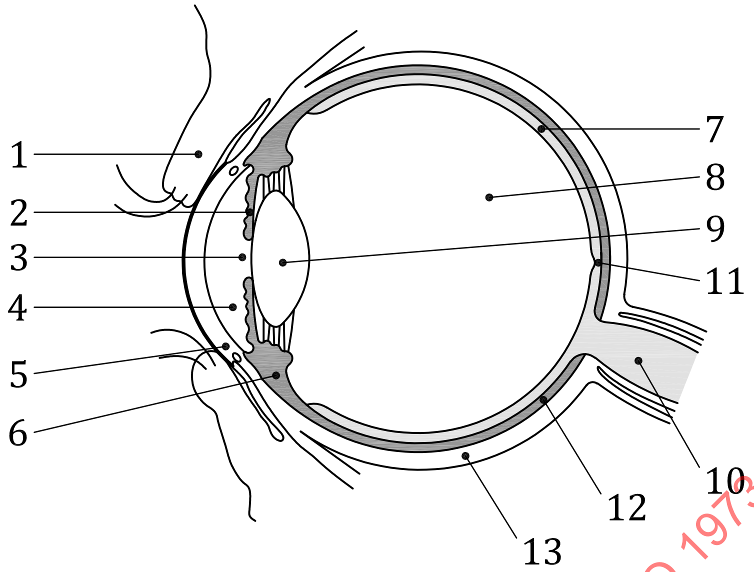
Note 1 to entry: Note 1 to entry: The probability of occurrence includes the exposure to a hazardous situation, the occurrence of a hazardous event and the possibility to avoid or limit the harm.

[SOURCE: ISO/IEC Guide 51:2014, 3.9]

4 General

4.1 Structure of the human eye

See Figure 1.



Key

1 eyelid
2 iris
3 pupil
4 anterior Chamber (filled with aqueous humour)
5 cornea
6 ciliary muscle
7 retina
8 vitreous chamber (filled with vitreous humour)
9 crystalline lens
10 optic nerve
11 macular region of retina
12 pigment epithelium and choroid
13 sclera

Figure 1 — Outline of the human eye (cross section)

a) Light emitted, transmitted or reflected by an object in the field of vision travels toward the eyes.

b) Light passes through the CORNEA (transparent "front window" of the eye), which provides two-thirds of the focusing power of the eye.

c) The PUPIL (the opening at the centre of the pigmented IRIS) changes size to vary the amount of light that reaches the retina.

d) The CRYSTALLINE LENS provides the remaining focusing power of the eye.

e) The RETINA (rear inner lining of the eye that contains light-sensitive and image processing cells and nerve fibres) converts light into neural signals. The MACULAR region is located near the centre of the retina and is dense with photoreceptors; its function is to process central vision in fine detail.

f) The OPTIC NERVE is the collection of nerve fibres that carry these signals to the brain.

4.2 Hazards and risks to the eye and face

4.2.1 Surrounding structures of the eye

The structures surrounding the eye, including the eyelids, skin, muscles and the orbital bones are susceptible to permanent damage. Objects of sufficient energy can cause bone fracture, contusions, lacerations and penetration of these tissues. Damage to the muscles and bones around the eye can result in a temporary or permanent disruption to binocular vision.

4.2.2 Peri-orbital skin

The skin of the eyelids is thinner than the skin in the rest of the body and is therefore more susceptible to physical damage such as bruising and lacerations, while the geometry of the lower lid makes it more vulnerable to UV radiation damage, including some skin cancers.

4.2.3 Tears

The lacrimal gland, which is situated in the orbit above and temporal to the eye, secretes the watery content of tears. Tiny glands in the conjunctiva secrete mucous. Meibomium glands in the upper (mainly) and lower lids secret an oily substance. These components combine into a structured layer of tears. Tears drain down to the nose through the naso-lacrimal ducts (often called simply the "tear ducts") that start as openings in the edges of the eyelids near the nose. The glands can be damaged directly by chemicals. Chemicals can also be absorbed into the body through the conjunctiva, the nasal mucosa or digestive system if washed through the tear ducts. Microorganisms may also enter the body by this route.

4.2.4 Cornea and conjunctiva

The cornea is about 0,6 mm thick at its centre and is composed of several layers. The outermost layer of the cornea, the epithelium, is highly sensitive to foreign bodies, including fine particles and dust, that can irritate and damage it. The resulting discomfort and soreness can last from a few minutes to several days. The epithelium regenerates very rapidly, so minor lesions heal quickly leaving no permanent damage. Minor ingress of foreign matter can be readily dispersed by the tears whereas larger amounts will require dispersal with a copious stream of water or other more intensive remedies conducted within a specialized medical environment. Even minor damage to the epithelium may facilitate infection which can result in clouding and permanent vision loss.

The main component of the cornea, about 90 % of its thickness, is the stroma. This relies on a very regular structure for its transparency so that any physical damage results in scar tissue that is irregular and, therefore, not transparent. Hence, more severe damage to the cornea that goes deeper than the epithelium such as lacerations, penetration, etc, will give opaque scar tissue which can result in clouded or permanent loss of vision.

Alkalis and strong acids will cause serious, often permanent, damage to the conjunctiva and cornea, which could lead to blindness. Alkalis are particularly damaging to the surface of the eye, rapidly causing irreversible damage. Conjunctivitis can also be caused by allergic reactions to many chemical substances, pollens, and biological agents. Even minor splashes or a fine aerosol spray of such substances can cause irritation.

The innermost layer of the cornea is a single layer of cells that form the endothelium. These cells do not regenerate after damage, the remaining cells enlarge to spread out over the surface. If this number falls below a threshold, the cornea becomes oedematous and is unable to maintain its transparency.

Exposure to sufficiently intense sources of infrared radiation from artificial sources can result in burns to the cornea (IR-B and C), retina and the lens (IR-A). Exposure to sufficiently high levels of UV radiation result in an acute painful inflammation of the epithelium of the cornea and conjunctiva. This acute effect is typically associated with exposure to electric arc welding and is commonly known as arc-eye or welder's flash. Long term exposure to UV can also result in chronic conditions such as pinguecula (a scar on the exposed conjunctival tissue nasally and temporally), pterygium (an abnormal mass of thickened conjunctiva and blood vessel growth into the cornea, most frequently on the nasal side), exposure keratitis (inflammation) and endothelial polymegethism (irregular cell sizes and shapes).

4.2.5 Iris and lens

Flying objects of sufficient mass and velocity can penetrate the cornea to injure the iris and the lens. Blunt trauma, e.g. walking into objects or falling onto furniture, impact from a large object such as a football or basketball, can result in damage to the iris, and can also cause cataract or subluxation (displacement) of the lens. Physical damage to the lens and its associated muscles can result in permanent loss of focus and increased susceptibility to certain diseases e.g. glaucoma. Damage to the iris can result in problems with light sensitivity (photophobia).

4.2.6 Retina

As well as being damaged by penetrating objects, the retina is also susceptible to blunt trauma to the exterior of the eye. This can result in retinal detachment and visual field loss. Acute damage, i.e. damage caused essentially immediately after an event rather than cumulatively, may be caused by high intensity optical radiation, e.g. lasers or viewing the sun. Visible light, especially blue-light, can cause photochemical damage within the light-sensitive cells of the retina. This painless loss of vision occurs several hours after the injurious exposure and may take several months to recover; permanent vision loss is possible. Some chemicals or medicines, e.g. drugs used to treat skin conditions, can photosensitize the retina so that less UV radiation or visible light is needed to cause damage.

4.2.7 Optic nerve

Blunt trauma to the eye can also result in damage to the optic nerve.

Though rare, intra-orbital penetration of objects, between the eye and the orbital bones, can occur and can result in damage to the optic nerve and the brain.

Exposure to certain chemicals can cause inflammation of the optic nerve, a condition known as optic neuritis. In the longer term, this can lead to degenerative changes known as optic atrophy. The resulting poor vision is often called “toxic amblyopia". This is more likely, however, to be caused by systemic absorption, e.g. drinking methanol or inhaling lead-contaminated dust, than resulting from chemical splashes in the eye.

4.2.8 Choroid and retinal pigment epithelium

The choroid lies between the retina and sclera; it has the functions of providing an absorbing layer for light passing through the retina and providing nutrients and oxygen to and removing carbon dioxide from the outer layers of the retina by being a highly vascular tissue. The outermost layer of the retina, the retinal pigment epithelium provides the major function of metabolising the waste products from the photosensitive tips of the rods and cones; it also acts as an intermediary, transporting nutrients, etc. between the choroid and outer layers of the retina. If there is a retinal detachment, which can occur following a blow to the eye, the retinal pigment epithelium stays attached to the choroid with the neural layers separating.

4.3 The eye's defence system

The natural defence mechanisms help limit the eyes' exposure to some hazards. The eyelids, eyelashes and blink reflex provide a mechanical barrier. The blink reflex, particularly in response to a bright flash of light, will quickly reduce the amount of radiation entering the eye. The constriction of the pupil in response to the bright light will reduce the amount of radiation entering the eye in the longer term. The bony cavity containing the eyeball itself, as well as the brow and forehead, provide further protection as they protrude beyond the eye, particularly in children. The combination of lipids and oils in the tears, as well as the conjunctiva, provide a further barrier to injury. Natural mechanisms alone are insufficient, however, to prevent many injuries.

Table 1 gives an over-view of hazards to the various parts of the eye.

Table 1 — Some causes and consequences of damage to the eye

	Mechanical			Chemical			Optical radiation			Biological
Structure of the eye	Small	Medium	Large or fast	Acids	Alkalis	Other	UV	Visible	IR	
Cornea	Irritation. Epithelial damage. Repairable	Laceration. Scarring. Longer term damage	Rupture. Loss of contents Total loss of sight	Opacification Keratitis	Opacification. Very damaging, rapid penetration	Irritation, lacrimation	*Short term* Snow blindness. Welder's flash, arc-eye, photokeratitis *Long term.* Pterygium	None	Pain. Opacification from IR lasers	Infection
Iris		Laceration. Prolapse through corneal laceration. Detachment at the circumference (iridodialysis)							IR radiation incident on the iris will increase the temperature of the lens	
Crystalline lens		Traumatic cataract, Displacement of lens					*Long term* UV Radiation causing photo-degradation of the lens structure causing cataract		High ambient temperatures (e.g. above 38 °C) may accelerate aging of the lens (cataract)	
Vitreous		Intra-ocular foreign body. Siderosis (rusting)								
Retina		Haemorrhages. Commotio retina. Detachment				Optic neuritis	Lasers Photochemical damage, thermal damage, photoacoustic damage (pulse lasers)			
Adnexa (skin, eyelids, lacrimal system, orbital bones)	Laceration and contusion	Orbital fracture. Damage to lacrimal system, Epiphora (overflowing tears)		Chemical burns. Permanent scarring			Thermal burns			

4.4 Colour perception

The level of colour perception required to carry out work-related tasks will vary. Some tasks will only require the worker to detect the presence/absence of a coloured object, and so colour recognition is not important. Nevertheless, a coloured filter could make simple detection difficult because of the reduction in brightness contrast. Other tasks require the worker to recognize and identify the colour of objects. Examples could include identification of coloured wires, pipes, signal lights, or gas cylinders. In other tasks, the worker must be able to discriminate and identify accurately relatively small differences in colour, such as interpreting pH indicators, diagnostic strips, and the colour of different fuels.

Filters impair colour perception by selective absorption of wavelengths within the visible spectrum (i.e., coloured filters), lowering the light levels entering the eye to values equivalent to night-time levels (i.e., grey welding filters), or both (coloured welding filters). However, the filters also help with colour discrimination in limited and specific circumstances. Cobalt blue filters help in identifying the temperature of molten metal by reducing the intensity of the light to below levels at which the visual system's discrimination ability saturates. Viewing the molten metal through the cobalt blue filter also accentuates the shift in its colour as the temperature of the metal changes.

Determining the effects of a filter on colour vision can be challenging because the effects are dependent on the filter's spectral transmittance characteristics, the spectral emittance of the signal light or light illuminating the object of regard, and the spectral reflective properties of the object(s).

Generally, filters that meet international guidelines for identifying traffic signal light colours would be appropriate to use when signal lights are used, since they are similar to traffic signals, or the coloured objects are similar in colour to roadway signage (red, blue, brown, green).

If colour detection and identification of signal lights similar to traffic signal lights is important, then the values of the relative visual attenuation coefficients (quotients) for traffic signal detection, Q_{red}, Q_{yellow}, Q_{green} and Q_{blue} should be met. All sunglare eye protectors for driving, marked GL0 to GL3, comply with a limit on these values as do UV filters marked "UL", IR filters marked "IL" and welding filters marked "WL" so these are indicated when colour detection of signals is an issue. However, these filters may not be suitable for other transportation modes such as the railways because the signal lights are different, and the viewing distances are longer.

If the task requires discrimination or identification of small differences in colour, then grey filters are recommended. The luminous transmittance should be greater than 10 % unless the average lighting in the area is very bright (equivalent to mid-day clear sky or brighter).

About 8 % of the male and 0,5 % of the female population suffer from colour vision deficiencies. These individuals vary from being so little affected that they may never know and there may be no practical or occupational consequences to being unable to distinguish colours along the red-green colour axis. However, very few indeed are truly "colour-blind" as they can distinguish blueness and yellowness entirely normally. The issues of occupational consequences for these people are not a subject here except that they may be more affected by tinted lenses and filters than people with normal colour vision, so extra care may need to be exercised.

The first step in a risk assessment is to assess the need for colour detection and/or recognition in the workplace. Is there a need to detect or recognise colour accurately and quickly? What are the consequences of error, trivial though to dire? What is the likelihood of error, common through to rare? One indication would be if the medical standards already exclude some or all of the people with colour vision deficiencies.

There are then some engineering solutions that might be applied to reduce the risks. As well as colour coded, the signals, for instance, could be shape coded, they might vary in size, danger or warning signals could be larger, they could vary in number (two lights means danger or warning), the important light could flash and/or could be accompanied by an audible warning (bell or siren).

A short practical experiment may help to identify when the colour of the filter might be an issue.

a) Collect pieces of material/equipment (e.g. cables with the same cable colour coding that is used at the workplace).

b) Make sure that the person is in a safe area with illumination (type and intensity) consistent with their workplace.

c) Clean the eye protector and inspect it for damage (replace the eye protector if necessary, according to the user instructions).

d) Put the eye protector on according to user instructions.

e) Quickly sort the samples (e.g. cable pieces) by colour.

f) Assess the person's capacity to undertake the job is consistent with the requirements of the role.

g) Carry out a risk assessment of the specific factors in implementing the best solution. See also CIE S 017[27].

Control strategies where good colour detection and recognition appear important include to ensure that

— the colours used comply with the appropriate standards. See, for example CIE 39.2[28] and CIE S 004[29].

— the general colour rendering of the light sources, R_a is sufficiently high. A minimum R_a of 80 is recommended. In more demanding colour work a minimum R_a of 90 may be necessary. CIE 13.3[30].

— the illuminance levels meet the relevant requirements, see for instance, ISO 8995 (all parts).

5 Hazards and their consequences

5.1 General hazards

Table 2 gives a general classification of hazards but see Table 4 for additional details. These lists of hazards are examples only and are not exhaustive.

Table 2 — General classification of eye and face hazards, with some examples

Type of hazard	Examples of hazard
Mechanical	Flying objects, high pressure liquids
Chemical	Splashes, fine droplets, particles
Optical radiation	Sunlight, welding, UV curing, lasers
Ionizing radiation	X-rays (outside the scope; see IEC 61331-3)
Biological	Microorganisms (viruses, bacteria, fungi), bodily fluids
Heat and flame	Furnace work, gas welding, glass blowing

This document briefly addresses some elements of risk assessment and management relating to some specific elements of eye and face protection. Measures should be adopted that will avoid or minimise exposure to hazards. For detailed information, it is recommended that the reader consults appropriate guidance on the subject from other publications e.g. ISO 31000.

An adequate risk assessment should be conducted to assess the presence and severity of potential hazards to the eyes or face. The information detailed in this clause addresses some common workplace hazards and potential health effects that could be sustained as a result of workplace activities.

5.1.1 Mechanical hazards

5.1.1.1 Sources

Mechanical operations pose the most obvious sources of danger where damage to the eye can occur from flying debris, collision with static objects, ingress of fine particles, abrasion from fibrous materials or foliage, falls onto blunt objects. Burns from hot liquids and molten solids pose the dual danger of blunt injury and burns. Physical damage to the eye represents about 70 % of all eye injuries[39]. There is a range of mechanical hazards that can result in blunt or penetrating trauma to the eye, including projectiles at speed or liquids under pressure. Workers at high risk of eye and face injuries include metal workers, miners, workers in medium to heavy manufacturing industries, commercial fishing, forestry and agriculture.

In quarrying work and the construction industry, there are obvious hazards from flying chips and dust clouds. Similar hazards exist in mining operations, stone-masonry, sculpting and building repair. Forestry and landscaping operations present a range of potential hazards from sharp foliage, 'kick-back' from chain saws and flying fragments from broken power tools and machinery. Exploding flasks in laboratories, dust clouds generated during automobile sanding operations and grit generated by shot blast operations are other examples of mechanical hazards which are common causes of eye injury.

5.1.1.2 Health effects

The damage that can be caused to the eye by mechanical hazards ranges from mild irritation from ingress of fine dust to total loss of sight due to high velocity/high mass impacts or major direct encounter with molten metal. The cornea of the eye can easily be scratched by fine dust particles. This can result in discomfort or soreness lasting for a few minutes or several days depending on the severity of the abrasion. Minor damage to the cornea may provide a route for opportunistic infections by bacteria or acanthamoeba to occur. More severe damage to the cornea will result in clouded vision, or permanent loss of focus. Sharp flying objects of sufficient energy will lacerate the cornea and/or conjunctiva and may penetrate the cornea or sclera to injure the iris and the crystalline lens. Physical damage to the lens and its associated muscles can result in permanent loss of focus. Minor ingress of foreign matter can be readily dispersed by fluid secreted by the tear glands whereas larger amounts will require dispersal with a copious stream of water or other more intensive remedies conducted within a specialized medical environment.

5.1.2 Chemical hazards

5.1.2.1 Sources

As with mechanical hazards, there are many sources of chemical hazards which include very fine powders, aerosols, liquids, fumes, vapours and gases. Chemical hazards can be less immediately obvious than mechanical hazards; for example, fine cement dust entering the eye in small quantities may not present a serious mechanical hazard but the strong alkaline nature of such materials can cause severe corneal burns.

Alkalis continue to penetrate the tissues of the eye, especially the cornea, causing tissue destruction long after the initial exposure. Industrial processes that use potentially sight threatening alkaline or acidic chemicals include lime production, fertilizers, battery production and the processing of leather and food.

Many insecticides used in crop spraying are generated in aerosol form and can pose a hazard to agricultural workers. Paint spraying, varnishing and many other lacquering and treatment processes involve chemicals generated in aerosol form. Even if the base substance itself is harmless, it could be carried by a more damaging solvent or propellant.

The hazards associated with liquid chemicals are usually more obvious than from aerosols, fumes or gases and principally relate to splashes from containers during decanting and mixing, particularly where uncontrolled mixing leads to boiling by exothermic reaction.

Smoke and fumes generated by combustion are another potential cause of eye irritation and other more serious damage. A considerable number of vapours and gases can have a harmful effect on the eye. These include common industrial substances such as acetone, chlorine, formaldehyde, hydrogen sulphide, sulphur dioxide and toluene. Fume hazards are visible and warn of their presence whereas many harmful vapours and gases are invisible. Apart from leakages from containers and pipework, hazards also exist from vaporization of liquid chemicals during decanting, mixing and disposal. Readily available domestic and commercial cleaning products, such as bleach and caustic soda, used in a range of applications are also known to be very harmful to the eye.

5.1.2.2 Health effects

Acids and alkalis can cause serious eye burns, even blindness. Even minute splashes or fine aerosol spray of such substances can cause irritation or conjunctivitis. Exposure to certain other chemicals can cause inflammation of the optic nerve, a condition known as optic neuritis. Conjunctivitis can also be caused by allergic reactions to many chemical substances, pollens, and biological agents.

5.1.3 Radiation hazards

5.1.3.1 Electromagnetic spectrum

Table 3 shows a diagrammatic representation of the electromagnetic spectrum, which is divided into radiation bands. Each band overlaps the next and cannot be separated as categorically as the diagram suggests. The effects of the radiation depend on the wavelength(s), intensity and duration of the incident radiation. Laser beams are not separately identified on the diagram as these are at various wavelengths within the optical radiation spectrum and are high-energy beams of very narrow bandwidth. This clause covers eye and face protection against only non-ionising optical radiation [ultraviolet (UV), visible and infrared (IR)].

Table 3 — The electromagnetic spectrum

a) Electromagnetic spectrum (metres)

$<10^{-12}$	10^{-12} to 10^{-8}	10^{-8} to $4{,}0 \cdot 10^{-7}$	$3{,}8 \cdot 10^{-7}$ to $7{,}8 \cdot 10^{-7}$	$7{,}8 \cdot 10^{-7}$ to– 10^{-3}	10^{-3} to 10^{-1}	10^{-1} to 10^{6}
Gamma rays	X Rays	UV	Visible	Infrared	Microwaves	Radio waves

b) Optical radiation (nanometres)

UV			Visible	Infrared		
100 to 280	280 to 315	315 to 400*	~380 to ~780	780 to 1 400	1 400 to 3 000	3 000 to 10 000
UV-C	UV-B	UV-A	Visible	IR-A	IR-B	IR-C
NOTE There is an overlap of the ranges for UV-A and Visible. In some standards, 380 nm is taken for the long wavelength limit of UV-A, e.g. ISO 12312-1.						

5.1.3.2 Sources

Optical radiation hazards encountered in industry and commerce are numerous, the most common being discomfort and disability glare from strong sunlight or artificial light. Outside the visible spectrum, optical radiation hazards include IR radiation and UV radiation. Laser beams, whether visible or in the IR or UV can also be hazardous. Welding operations, both gas and electric, are a potent source of UV and IR radiation as well as visible glare. Processes that generate heat, such as steel-making furnaces, glass blowing and welding all generate potentially harmful IR radiation.

At the other end of the visible spectrum, short wavelength UV emissions are associated with such sources as germicidal lamps, welding operations and mercury or xenon discharge lamps. Lasers are being increasingly used in a wide range of applications such as metal processing, optical alignment and medical surgery. Risks can arise from accidental exposure to direct radiation or to stray radiation (diffused or reflected) during repair or servicing. Class 3 hand-held laser pointers are potentially hazardous. Class 2 laser pointers may be hazardous if viewed for an extended period of time.

Much concern has been expressed in recent years on the potential radiation hazards of visual display unit (VDU) screens. The levels of UV, visible and infrared radiation emitted from VDU screens has been shown to be a small fraction of occupational safety limits. The luminance and blue-light content of VDU, smart phone and tablet screens are substantially below those found in the outdoor environment. Visual and ocular symptoms when using VDUs should be addressed by considering the visual and general ergonomic and environmental factors, including lighting factors.

Intense light sources (ILS) are used on humans and animals for cosmetic and medical dermatological applications. The equipment uses optical radiation in the spectral range 250 nm to 3 000 nm. ISO/TR 22463 gives guidance on patient eye protection during ILS and laser procedures, while for equipment that does not use laser radiation procedures, ISO 12609-2 gives guidance on the choice of eyewear for both ILS operators and patients. ISO 12609-1 specifies the requirements for ILS protectors.

5.1.3.3 Health effects

Exposure to low-levels of IR radiation may cause discomfort to the eye, lids, and facial skin but does not cause harmful effects. Prolonged or repetitive high-level exposure to IR-A rays can have a long-term effect on the crystalline lens (glassblowers' cataract, for example). Exposure to sufficiently intense sources (infrared laser, etc.) can result in burns in the cornea (photo-keratitis with IR-B and C) or in the retina and the lens (IR-A).

In the visible region, illumination with handheld lasers is a danger, both for retinal damage and causing high levels of discomfort and disability glare.

Exposure to sufficient levels of UV radiation results in an acute effect and painful inflammation of the cornea and conjunctiva (photokeratitis and photoconjunctivitis). This effect is typically associated with exposure to electric arc welding and is commonly known as "arc-eye" or "welder's flash". Repeated high level but subacute exposures of the eyes to UV radiation may result in photo-degradation leading to degenerative changes to the eyelids, conjunctiva, cornea and crystalline lens (e.g. pterygium, corneal haze, cataract). UV exposures are also associated with melanomas of the eyeball and surrounding tissues. Chronic high-level exposure to blue-light may play a role in the development of neovascular macular degeneration.

5.1.4 Biological hazards

5.1.4.1 Sources

Biological hazards (also known as bio-hazards) refer to agents of disease, i.e. pathogens that are harmful to human health. These organisms include some parasites, viruses, bacteria, fungi and protein. These materials are often found in blood and other body fluids as well as animal and plant by-products.

The primary routes of transmission include

a) contact (direct and indirect),

b) exhaled droplets, and

c) other airborne droplets.

These may be in the form of droplets, splashes or particles that may be carried directly through the air entering the body through broken skin or exposed membranes, such as the eye's conjunctiva. Contaminated material may also be carried indirectly by touching the eye with contaminated fingers or other objects (for example in microbiology labs). Important factors in assessing the risk and determining the correct use of protective equipment include the source, mode of transmission, pressure, type of contact, contact duration and type of task.

Finally, biological hazards in the medical, veterinary and dental environments from splashes of blood and body fluids and tissue containing pathogens require similar protective measures to those for chemical hazards.

Some typical occupations/workplaces/ circumstances where people's eyes may come into contact with biological hazards capable of transmitting disease include

— medical staff, laboratory technicians,

— healthcare services,

— employees in environmental hygiene services such as liquid waste, rubbish collection and disposal, and

— agriculture, fishery, veterinary services, and manufacturing industries that use plant or animal-based raw materials such as the food industry, paper products, textile, leather, furs and related products.

5.1.4.2 Health effects

The health effects of biological contamination of the eye include infection, irritation or allergy.

Some common infections that involve the eye include keratitis and conjunctivitis (e.g. acanthamoeba, pseudomonas, staphylococcus, adenovirus, herpes simplex and other viruses). Systemic infections may involve the eye (e.g. hepatitis viruses B and C, human immunodeficiency virus, herpes, other viruses and rhinovirus).

Eye protectors such as protective spectacles/shields/visors against biological hazards are likely to be used together with respirators or other protective clothing; the issue of compatibility of appropriate eye protectors is therefore important and should be taken into account.

5.1.5 Convection heat

5.1.5.1 Sources

Heat results from furnace work e.g. metal casting, foundry work and glass manufacture. Naked flame is used in glass blowing and gas gouging.

5.1.5.2 Health effects

The health effects of heat and flame on the eye could include "dry eye", discomfort and cataract.

5.2 Application specific hazards

The previous clause provides advice on general workplace hazards and consequent health effects. Although it is impossible to account for every possible application, considerations relating to certain specific applications are given in this clause.

5.2.1 Laser hazards

5.2.1.1 Sources

Laser systems are widely encountered in industry, medicine, science and technology. The key to safe laser practice is to pay attention to the class of the laser in use (see IEC 60825-1). Laser Classes and the required warning labelling are described in IEC 60825-1. Class 1 laser systems are inherently safe and no eye protection is needed. Class 1M, 1C laser products include visible lasers. Class 2 and 2M laser products are visible lasers. They are required to have warning labels. This is sufficient protection unless there is a need for more than momentary viewing in which case a risk analysis should be carried out. Class 3R and 3B have a more extensive warning and if the beam should be observed or may enter the eye, eye protection will be needed. Class 4 laser products are harmful to eyes and skin so that protection is always necessary even to diffuse reflections of the beam. In many applications, the potentially hazardous laser beams are completely enclosed (embedded laser products) and classified as "Class 1," such as in computers, CD-ROM drives, video players and in many manufacturing production lines. However, hazardous open beams exist in many surgical applications of the laser, as well as in research and development laboratories. Accessible open beams that could require eye protection may also exist in some industrial laser material processing applications (generally “Class 4” laser systems). The servicing of embedded laser products, when the outer covers are opened or removed, can also give access to potentially hazardous levels of laser radiation.

There is a wide variety of different laser types, and laser emission (generally at one particular wavelength that is a characteristic of the type of laser) can occur at wavelengths from the ultraviolet region (e.g. excimer lasers), throughout the visible to the far-infrared spectral region. Laser beams can pose a hazard at considerable distances from the laser itself, extending over many metres (even km when used outdoors) because of the high collimation of the beams; this characteristic represents a unique occupational hazard in this respect.

5.2.1.2 Health effects

Laser radiation poses a significant hazard of injury to the eye and the more powerful (Class 4) laser beams can pose a significant hazard of injury to the skin. Potential hazards vary significantly with laser wavelength, and are of greatest concern in the retinal hazard wavelength region from approximately 400 nm to 1 400 nm (1,4 µm), since the focusing properties of the eye can increase the concentration of light/radiation at the retina by up to 100 000 times compared to the concentration of light/radiation (irradiance) outside the eye at the cornea. Depending on the wavelength(s) of a laser, injuries can occur to the cornea (far-infrared and far-ultraviolet) and to the lens (some UV and IR wavelengths) as well as the retina. Of particular concern are pulsed lasers in the visible and near-infrared regions that can injure the eye within the aversion response time to bright light (of the order of 0,25 s). Historically, many serious injuries that lead to loss of vision have occurred from pulsed lasers – particularly where the beam is not visible but in the near-infrared (IR-A), such as a Nd:YAG 1064-nm beam. Burns of the skin can also occur but are generally of secondary interest compared to the eye. A large number of injuries have also been reported from continuous-wave lasers (cw lasers) e.g. misuse of higher-power laser pointers.

5.2.2 Welding hazards

5.2.2.1 Sources

Eye and face hazards during arc welding and allied processes are mainly of a mechanical or radiation type. Sparks and spatter from the welding process, slag from chipping, dirt and particles from grinding give rise to high or medium velocity particles that may also be hot. Welding fumes consist of fine particles and gases. Welding arcs are sources of intense UV and IR radiation as well as visible glare and the use of an eye and face protector is vital both for visibility and to avoid injury and blindness. Between welding operations, the welding shield may be removed from its position in front of the face and the welder can be exposed to radiation from co-workers’ welding arcs. Not only welders but other workers in the vicinity who may be exposed to radiation from nearby welding or cutting activities are at risk.

5.2.2.2 Health effects

The impact of high velocity particles can cause mechanical damage of the eye or skin. The intense heat of welding and sparks can cause burns. Particles and gases from the welding fumes can cause eye irritation.

UV radiation from the welding arc can cause “arc-eye” or “welder’s flash” which is a painful inflammation of the cornea. The symptoms usually occur a few hours after exposure to UV radiation and include a feeling of sand or grit in the eye, blurred vision, intense pain, tearing, burning and headache. The arc-eye condition is temporary, but if UV exposure is repeated regularly, the cornea and lens will be permanently damaged. The damage could result in loss of corneal transparency and development of cataracts (clouding) in the lens. As well as the welder, UV radiation may affect persons who are close to the welding situation. Exposure to UV radiation can also cause skin burns similar to sunburn, and increase the welder’s risk of skin cancer.

The intense heat from IR radiation can cause thermal burns to the skin and cornea. The amount of optical radiation reaching the eye depends on the welding process being used (MIG, TIG, plasma, etc), any shielding gases being used (and the gases and fumes emitted by the arc) and the current being used.

Intense visible light associated with arc welding can cause damage to the macula and retina. However, discomfort glare will occur at much lower luminance levels than required for an injury and the natural response is to close the eyes, shield them or turn away from the glare source avoiding such damage.

5.2.3 Electric arc hazards

5.2.3.1 Sources

An electric arc flash is a fault current, e.g. generated by a short-circuit travelling through ionized air – the so-called plasma. Together with tremendous amounts of convective heat, an arc flash comes along with excessively high doses of electromagnetic radiation (i.e. levels of UV, IR and high energy visible light typically higher than that emitted while arc welding). The explosively expanding heat generates toxic air, extreme noise (i.e. an explosion known as peak impulse noise) and a rapidly progressing pressure wave – most probably accompanied by flying debris (e.g. fragments, molten metal).

An arc flash incident usually is caused by a system fault or a handling mistake in a high current electrical environment, regardless of whether this is a low, medium or high voltage system.

5.2.3.2 Health effects

Depending on the arc energy, the materials involved and the distance to the arc, the following hazards typically shoud be considered:

— direct thermal effects caused by convective heat: burns to the skin and the eyes;

— electromagnetic radiation hazards to the eyes;

  — lens/cornea:

    — cataract, photo-kerato-conjunctivitis in the range of intense UV light as emitted by the arc (UV-A, UV-B and UV-C);

    — thermal hazards in the range of IR radiation;

    — retina: photo-chemical hazards in the range of visual light;

  — hazards to the skin;

    — pigmentation and burns in the UV range;

    — thermal cell death in the range from visible light to IR radiation.

The aforementioned hazards might cause severe, often irreversible, injuries or might even be lethal. No severe injuries are known, however, from those persons who have been protected by sufficiently selected and correctly worn personal protective equipment.

NOTE Further hazards, e.g. hazards coming from the noise or the toxic gases, are not sufficiently investigated to be discussed in this document.

5.2.4 Glass blowing hazards

5.2.4.1 Sources

Sodium flare is a common hazard faced by those working with glass. A bright yellow flare (589 nm) is created when an oxygen-rich flame reacts with sodium in the glass. While the visible component of the flame's light causes discomfort and disability glare for the worker, it is not harmful to the eyes. The solution is to provide a filter with high luminous transmittance but low spectral transmittance in the region of 589 nm. Glass blowing is, however, accompanied by potentially hazardous levels of UV and IR.

The type of optical radiation hazard varies with the type of glass being heated in gas flame or furnace.

5.2.4.2 Health effects

Refer to 5.2.2.2 for information on the health effects of UV and IR exposure.

6 Control of eye and face hazards

6.1 General

The hierarchy of control should always be followed. The use of engineering methods, such as many of those listed below, to reduce the risk of injury to the eyes and face should always be the primary objective rather than relying on PPE. Where it is not possible to eliminate hazards, measures should be adopted to minimise the hazards (see Figure 2). Measures such as those described below may be used where hazards and risks have not already been eliminated:

a) isolation of the hazardous operation;

b) suitable screens or guards to shield from flying fragments, particles or radiation, e.g. providing shade from sunlight;

c) exhaust hoods or booths to extract dust, gases or fumes;

d) water sprays for damping down dusty areas;

e) windbreaks to reduce dust being raised by air turbulence;

f) catchments, splash guards and baffles to confine dangerous liquids;

g) increasing distance or limiting exposure duration to diminish the effect of optical and biological hazards;

h) scheduling to reduce or minimise exposure e.g. workers to be scheduled to work outdoors during periods that minimise exposure to high UV levels;

i) administrative measures such as managing the flow of people moving through environments to ensure appropriate social distancing and minimise exposure to biological hazards.

Where it is not possible to entirely eliminate eye and face hazards, PPE measures should be adopted that will minimize the risks.

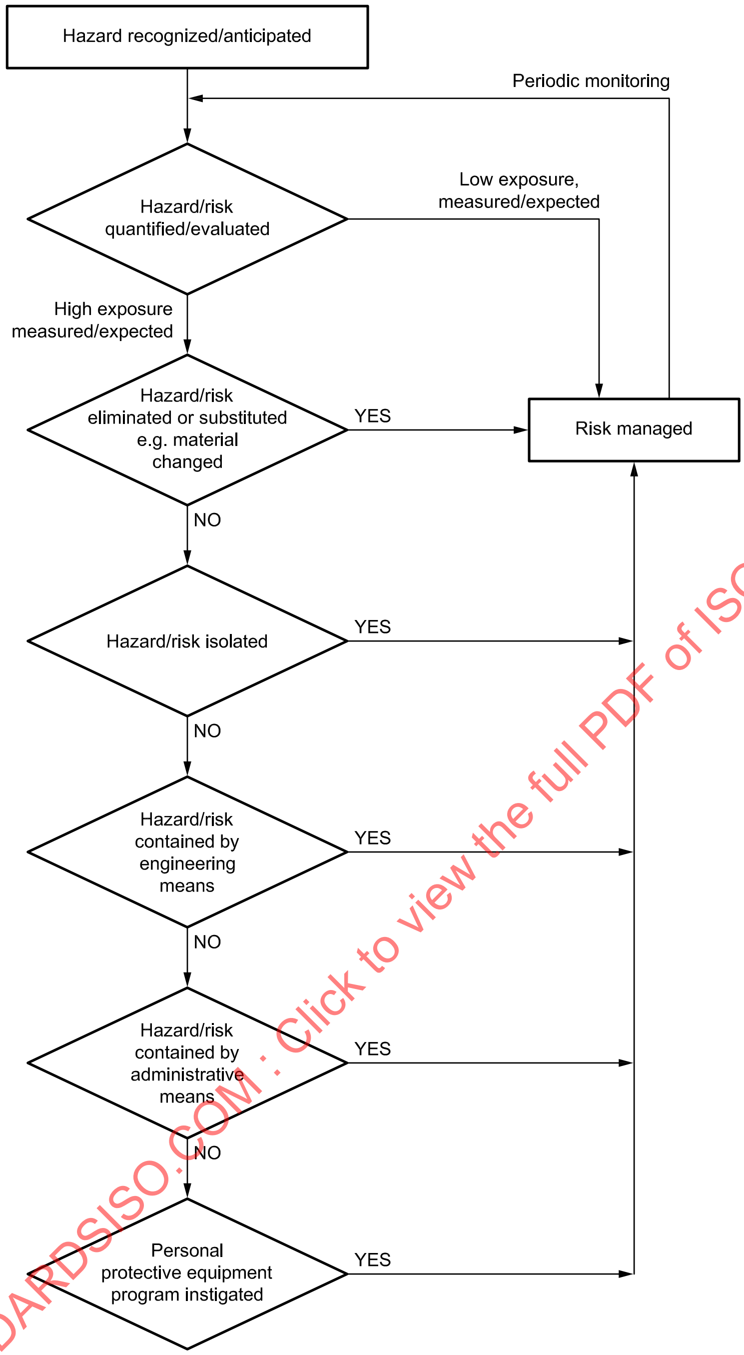


Figure 2 — Steps to risk control

6.2 Screens

6.2.1 General

Screens can be used to isolate the hazard from the worker where engineering or administrative control methods are ineffective. Screens are available in different variations ranging from fixed, moveable or adjustable on individual machines to large fixed or mobile screens to shield the affected working area or to separate adjacent work stations. It is important to match the design, construction and material choice of the screens to the conditions of use to achieve adequate protection. In addition, a regular maintenance and replacement programme should be instigated.

6.2.2 Recommended materials for screens

Always ensure the screens are constructed from suitable materials appropriate for the intended application. The chosen screen should offer the same level of protection to unshielded eye and face outside the enclosure as the protection provided by appropriate eye and face protection device inside the enclosure.

A list of suitable materials for a particular application may include some of the following:

a) sheet metal;

b) woven metal;

c) canvas;

d) toughened or laminated glass;

e) clear or opaque plastics.

Materials that have relatively large and highly reflective surfaces e.g. galvanised sheeting should not be used for welding screens unless they are treated with light-absorbing substance(s).

6.2.3 Selection of light-transmitting screens and curtains for arc welding operations

There are screens and curtains that provide a uniform high level of protection from the ultraviolet and visible light hazards arising from welding operations. They are intended to protect passers-by and individuals working near a welding operation and therefore do not need to provide as much protection as that required by the welder. See 7.2.6.1.8 for more details.

The specification for transparent welding curtains, strips and screens used for shielding workplaces from their surrounding where arc welding processes are used is defined in ISO 25980. Welding curtains, strips and screens that fulfil this standard are not intended to replace welding filters. To meet the requirements of ISO 25980, the luminous transmittance and reflectance properties should be stated by the manufacturer or supplier.

6.2.4 Illumination of the work area

Care should be taken to ensure that the operator retains a clear view of the task. Opaque screens should be arranged so as to avoid the formation of disturbing shadows. Transparent screens should be kept clean and relatively free from scratches. Local lighting should be provided where necessary.

NOTE Suitable lighting conditions for different tasks are recommended in ISO 8995 (all parts).

6.3 Exhaust systems

Local exhaust systems are not specifically designed for the purpose of providing protection for the eyes and face. Exhaust systems incorporated in machines for grinding and wood working operations might not trap fast-moving fragments or particles that represent a significant eye and face hazard. Personal eye and face protection against these hazards is usually necessary.

6.4 Other methods

For outdoor activities, shade is a method of reduction of harmful exposure to sunlight. Exposure to sunlight might be reduced by administrative means, such as the scheduling of times spent outdoors.

Shade should be created by permanent objects such as trees or by the use of canopies and screens constructed of fabric with the highest UV effectiveness (UVE) of 95,0+ rating (AS/NZS 4174[35]). This will reduce rather than eliminate exposure.

For all forms of non-ionizing radiation, another general method of control is the provision of low gloss surfaces in the work environment. Matt paints should be used and high gloss white surfaces avoided in the selection and design of plant and equipment.

Non-ionizing radiation exposure can also be reduced by increasing the separation of the hazard from the observer by distance. For example, the risk to passers-by from a welder 300 m away is likely to be minimal and the UV protective characteristic of a Shade Number 11 welding filter can be matched by moving away from the arc to a distance of at least 200 m.

7 Selection and use of personal protective equipment (PPE)

7.1 General

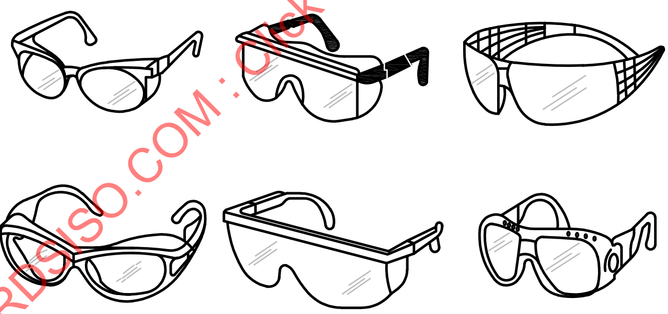
Always follow the hierarchy of control in eliminating the hazard at source. The use of PPE is the last line of defence which should be carefully selected to ensure adequate protection against hazards, taking into account environmental conditions, e.g. high humidity.

There is a variety of protectors available on the market designed for protection against a range of eye and face hazards. When selecting an appropriate protector, care should be taken to ensure that the protector is suitable for the individual, fits well and is comfortable to wear for duration of the complete task. Ensure the wearer is satisfied with the style, type and size of the selected eyewear.

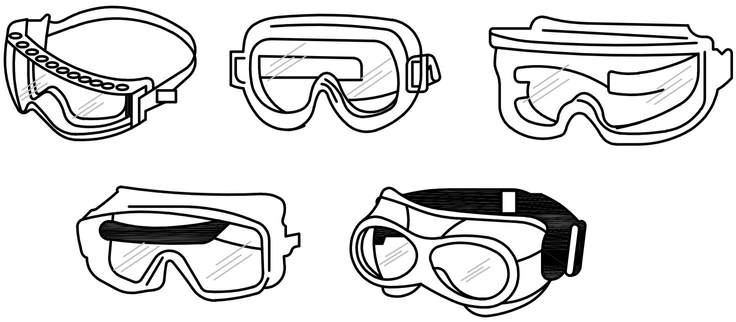
7.2 Types of eye and face protectors

7.2.1 General

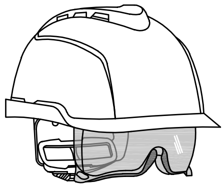
Figures 3 to 5 show the different types of eye and face protector. Spectacle eye protection against mechanical hazards is limited to the two lowest levels of impact protection (see Basic use and C in Table 11).



a) Examples of spectacles



b) Examples of goggles



c) Example of an eye shield

NOTE Ventilation (direct and indirect) is commonly available.

Figure 3 — Examples of spectacles, goggles and eye shields

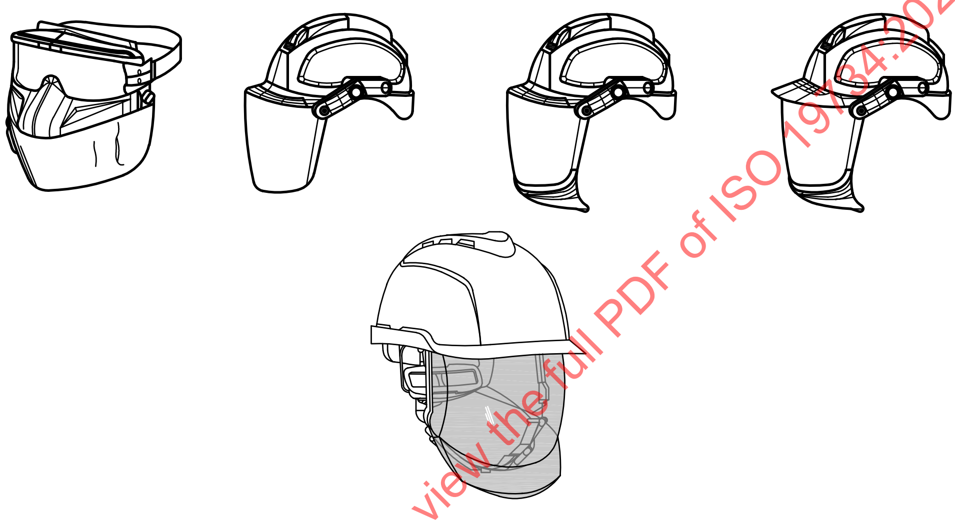
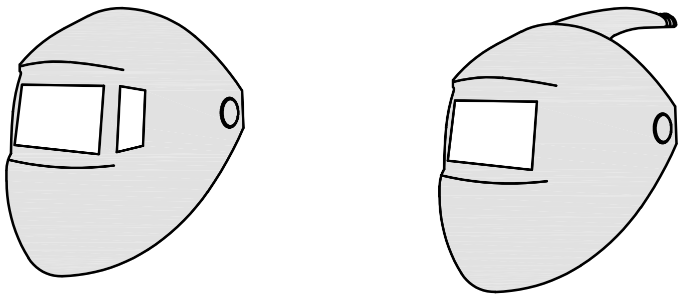
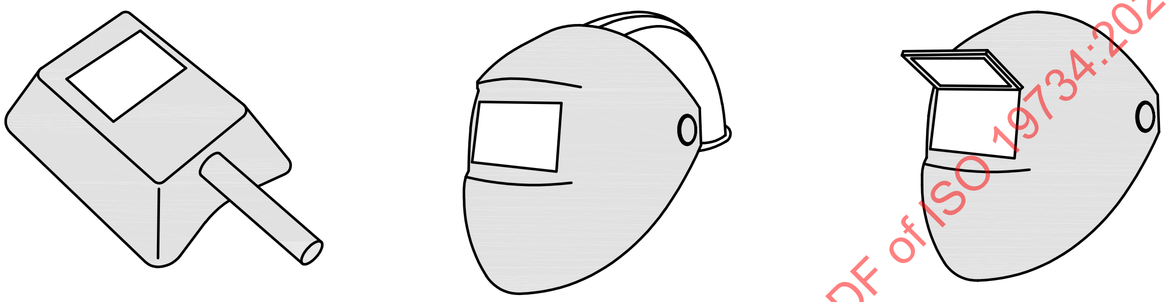


Figure 4 — Examples of face shields



a) Welding shield with peripheral awareness filters

b) Welding shield with supplied air



c) Hand held welding shield

d) Welding shield mounted on hard hat (helmet)

e) Welding shield with flip-up filter

Figure 5 — Examples of welding protectors

7.2.2 Selection process

7.2.2.1 General

The hazards and risks associated with a particular task or area should be evaluated and the most appropriate type of protector selected. See Table 4 for information on general hazards and appropriate protection. The types of protector recommended as suitable for a specific application are set out in Table 5, other than those for protection against laser radiation, welding and working with high voltage live electrical wiring which are covered in 7.2.5. Colour perception when driving or operating machinery is critical but these tasks may not be the main reason a person is using an eye protector in the workplace. Careful selection of appropriate eye protectors should be undertaken if they may continue to be worn for driving and machinery operation.

In the selection of eye and face protectors, the following should be considered:

a) The nature and the direction of the hazards relative to the eyes and face.

b) For a combination of hazards, more than one eye and face protector may be needed, e.g. welding goggles and a suitable face shield.

c) Compatibility of the protector with other personal protective equipment products needed for the specific application

d) The conditions under which the operator is working. In particular, working in confined spaces may give rise to reflected hazards, requiring protection from optical radiation incident from the side and rear.

e) Any issues of solvent resistance of, or damage to, the frame and/or lenses or filters.

f) The visual requirements of the task.

g) The condition of the operator's eyesight.

h) The appropriateness of the frame as a protector frame.

i) The design and shape of protective spectacles should be in alignment (as much as possible) with the shape of the wearer's face, i.e. the gaps formed between the frame edges and the face should be minimized by selecting a frame that closely follows the individual's facial contours.

j) Guidance should be given to the user on the verification of the type of eye protector for the intended use.

k) Guidance should be given to the user on the maintenance, use, cleaning and storage of the protector.

The guidelines above are general in nature and knowledge of a specific environment and the incident/accident history at the worksite, in particular, may indicate that a higher level of protection is needed than a general approach might suggest. The choice of eye and face protector should be reviewed regularly. If incidents are still occurring then a higher performance eye and face protector is indicated.

Known hazards should be removed or minimized to the extent possible. Eye and face protectors are not a substitute for engineering controls and sound safety practices. They should be used in conjunction with engineering controls and sound safety practices.

Selecting protectors that do not provide suitable protection can leave the wearer susceptible to discomfort or injury relating to exposure to hazards. The wearer, surrounding environment and activity should be considered carefully to ensure that the selected protector can be worn during all periods of exposure.

7.2.2.2 Hazard based selection

Tables 5 and 6 provide guidelines to the types of processes and hazards potentially encountered requiring eye protection. The level of eye protection suggested should be considered a minimum level of protection.

For many activities, the hazard presented is not only to the operator but also to fellow workers or spectators, who should either be removed from the area, be protected by a suitable screen or wear personal protective equipment.

Care should be taken to recognize the possibility of multiple and simultaneous hazard exposures and the chosen protector should be able to protect against the highest level of each hazard.

The general requirements for eye and face protectors are specified in ISO 16321-1, with the additional requirements for welding protectors in ISO 16321-2 and for mesh protectors in ISO 16321-3.

NOTE Users requiring specific advice on laser protection can consult ISO 19818-1 and the IEC 60825 series.

Table 4 — Table of general hazards to the eye and face

NOTE Some hazards need other compatible personal protective equipment, e.g. a respiratory protector, a hearing protector, a head protector. To ensure that the combination provides the correct protection and comfort in use, their compatibility should be verified. Apart from earmuffs attached to head and/or face protection devices where EN 352-3 applies in Europe, the compatibility between these types of PPE can be assessed by any available data from the manufacturer.

Type of hazard	Examples of typical processes	Possible engineering or administrative controls	Suitable eye and face protectors (compatibility concerns)	Marking See Tables 10 and 11
Physical - Mechanical				
Flying particles of low mass and low velocity	Manual hammering, chipping, horticulture, gardening, dental and surgical procedures	Fixed or mobile screens	Spectacles -Low energy impact resistance	C
Flying particles of low mass and medium velocity	Machine cutting, woodworking, lawn mowers, hedge trimmers, electric power tools	Fixed or mobile screens/ guards. Dust extractors. Water damping.	Spectacles, over-spectacles or Goggle – medium energy impact resistance	C D
Flying particles of low mass and high velocity	Machining metal, grinding	Machine guards	Goggle or face shield – high energy impact resistance	E
Flying objects of medium mass and high velocity	Explosive power tools e.g. nail guns	Evaluate options according to task(s)	Face shield – High mass impact resistance (Hard hat)	HM
Objects of high mass	Falling tools	Overhead protective barriers	Face shield – High mass impact resistance (Hard hat)	HM
Collision with sharp edged or blunt objects	Forestry, fence erection	Evaluate options according to task(s)	Face shield high energy impact resistance (Hard hat and hearing protector)	E
Liquids released at high pressure	High pressure water cutting, pressure washers, hazard leakage	Splash shield and face shield	Goggle or face shield	6
Dust, gases and vapours				
Nuisance dust	Woodworking, buffing, flying particles	Local exhaust ventilation system	Goggle with direct or indirect ventilation (Respirator or full facepiece respirator)[a]	5
Gases, vapours, smoke, fumes and very fine particulate matter	Spray painting, chemical handling, polishing, incineration, mining, welding	Local exhaust ventilation system	Sealed goggles with suitable full face mask or powered air respirator system	5
Large particle dust	Road work, mining operations, demolition work	Indoors- exhaust systems Outdoors- damping down, sealing of surfaces	Dust proof goggles (Respirator, hard hat and hearing protector)[a]	4

Type of hazard	Examples of typical processes	Possible engineering or administrative controls	Suitable eye and face protectors (compatibility concerns)	Marking See Tables 10 and 11
Thermal				
Hot sparks	Furnace operations, gas cutting and welding, metal forging, grinding	Evaluate options according to task(s)	Eye protector with face shield medium energy impact resistance (Hearing and respiratory protector)	D
Molten metal (see below for the splash hazard)	Metal casting, galvanising baths	Evaluate options according to task(s)	Face shield with IR and molten metal/ hot solids protection (Hearing and respiratory protector)	R shade number xx, Impact protection (C, D, or E), 9
High temperature exposure from radiant heat	Furnace work, open flames, thermal lance work, metal smelting	Evaluate options according to task(s)	Face shield with IR and molten metal/ hot solids protection	7
Electric arc	See Table 5			
Splash/spatter and molten metal				
Chemical	Cleaning, handling corrosive solutions		Splash resistance	CH
Biohazard	Medical, veterinary, dentistry, surgical	Evaluate options according to task(s)	Appropriate eye and face protectors suitable for the hazard e.g. low energy impact resistance or protection from gases & vapours enhanced optical performance lens(es) depending upon whether a single-lensed goggle covering both eyes or one with two lenses is used or faceshield	C1 5
Molten metal (see above for thermal hazard)	Casting, molten slag	Evaluate options according to task(s)	Goggles only if risk assessment indicates that molten metal hazard is not a significant risk to facial injury, otherwise face shield. High mass impact resistance (Full body protection)	HM
Electric arc	See Table 5			
Optical radiation				
NOTE The letters G, R, U and W may be followed by the letter L indicating that the filter meets the requirements for colour detection of signal lights; the letter R may also be followed by a second letter R indicating enhanced IR reflectance.				

Type of hazard	Examples of typical processes	Possible engineering or administrative controls	Suitable eye and face protectors (compatibility concerns)	Marking See Tables 10 and 11
Visible light (glare)	Sunglare, furnaces	Screens or filters	Spectacles or goggles	G # (#=1 to 3)
Intense visible light	Intense Light Sources (ILS)	Screens or filters	Spectacles or goggles	F# or B # (#=1 to 6)
Solar UV	Ultraviolet	Screens or sunshades	Spectacles or goggles	G# (#=0 to 4)
UV	Weathering, germicidal lamps, UV curing Glass fibre manufacturing	Screens	Spectacles, goggles or face shields	U# (#=1,2 to 5) SF1
IR	Cutting, brazing, furnaces, Glass blowing	Screens	Spectacles, goggles or face shields	R# (#=1,2 to 10) SF1
Lasers	Many.	Screens	Spectacles or goggles	See Annex B, ISO 19818-1
Electric arc	See Table 5			
Certain occupations will appear in more than one section in this table, and thus require more than one mark.				
[a] This indicates that there may be compatibility concerns over using the different types of PPE together.				

Table 5 — Table of hazards by application

Type of hazard	Examples of typical processes	Possible engineering or administrative controls	Suitable eye and face protectors (Compatibility concerns)	Marking See Clause 10
Welding				
Electric arc welding	TIG, MIG, MAG, MMA, air-arc gouging	Administrative or engineering controls	Face shield or welding helmet fitted with passive or automatic welding filter	W # (#=8 to 15) W #/# (#=1,2 to 5/ #=8 to 15)
Cutting	Plasma jet cutting	Administrative or engineering controls	Face shield or welding helmet fitted with passive or automatic welding filter	W # (#=9 to 13) W #/# (#=1,2 to 5/ #=9 to 13)
Gas welding	Gas welding, braze welding	Administrative or engineering controls	Welding goggles or welding helmet fitted with welding filter	W # (# to 4 to 7) (where skin hazard is identified, use of a welding face protector may be more appropriate)
Cutting	Oxygen cutting	Administrative or engineering controls	Welding goggles or welding helmet fitted with welding filter	W # (# to 5 to 7)
Physical- Mechanical	Hammering, slagging, grinding etc.	Administrative or engineering controls	See Table 4: Physical- Mechanical hazards	See Table 4: Physical- Mechanical hazards
Nearby electric arc welding	Work in areas where electric arc welding occurs	Welding curtains	Goggles or welding helmet	W #2.5 to #15 (depending on distance from welding source)
Electric arc				
Electrical fault arc/arc flash Convective heat IR and UV radiation Molten metal Molten plastic Intense glaring light Flying particles – low mass and high velocity	Live working/ electricians work at energized systems	Education/ work safety properties for live working, increasing of distance to potential arc sources while working at energized systems, reducing the arc burning time (e.g. by replacing regular fuses with maintenance fuses), reducing the potential short circuit amperage by changing the power supply during live working (e.g. single sided supply), etc.	Specifically tested visor kits, hoods or combinations of specifically tested visor kits or goggles with open hoods or balaclavas	IEC 62819 ARC RATING, ATPV = xx cal/cm ^{2} and/or ELIM = yy cal/cm^2, LT Class z (z = 0; 1; 2) typical for USA or USA affiliated countries or IEC 62819 ARC PROTECTION CLASS a (a = 1; 2), LT Class z (z = 0; 1; 2) mandatory for EU countries Additional marking as per ISO 16321 (all parts) apply NOTE 1 Both markings can be shown on a product tested accordingly. NOTE 2 Other national bodies may have different marking requirements.

NOTE The suggested welding shades in Table 5 are based on common industrial practice. For more detailed guidance on welding shade selection see 7.2.6.1.2.

7.2.2.3 Human- factors-based selection of eye and face protectors

7.2.2.3.1 Fit and coverage

Eye injuries are known to occur despite the presence of an eye and face protector, as a result of poor fit, inadequate coverage and/or inappropriate selection. Arrangements should be made when issuing eye and face protectors to ensure that

a) the type of eye and face protector is chosen appropriate to the risk, and

b) the size of the protector selected for the individual provides complete coverage of the defined area to be protected, and

c) gaps between the frame and face are as small as possible.

The size of protectors should be categorised by the following frame marking:

1-C12, 1-S, 1-M, 1-L, or 2-S, 2-M, 2-L, as defined in ISO 18526-4. C12 is for a child aged around 12 years, 1-series for general use, while the 2-series are for Asian wearers, and S, M and L are small, medium and large respectively.

These can be used in isolation or combination to describe the size of eyewear. In this context, each marking is determined by several factors including head width, ethnicity and coverage of the orbital region.

7.2.2.3.2 Eye protection for adolescents and children

Adolescents are over-represented in the eye injury statistics. Particular care should therefore be taken to ensure that the size of the eye protector chosen provides appropriate fit and coverage.

7.2.3 Eye and face protection for those requiring vision correction

Prescription spectacles or ready-to-wear near-vision spectacles that do not comply with ISO 16321 should never be used as an eye protector because they may fracture more easily on impact and become a secondary hazard to the wearer and, secondly, may not have sufficient area of protection.

In the options provided below, the eye protectors may provide both the vision correction and protection functions [options a) and f)] or the protective function and the vision corrective function are provided by different devices [options b) to e)].

For persons requiring vision correction in addition to eye and face protection, the following options are available.

a) Prescription eye protectors appropriate for the task and hazard complying with ISO 16321-1 and ISO 21987. These include single vision, multifocal and progressive-power lenses.

b) Non-corrective eye protectors complying with ISO 16321-1 fitted with a prescription insert (lens carrier) behind the protective lens and with lenses fitted in the insert. The lenses in the insert should comply with ISO 21987.

c) Non-corrective eye protectors complying with ISO 16321-1 with the vision correction provided by contact lenses.

   NOTE The wearing of contact lenses generally neither provides any protective function nor necessitates any extra protection. See 7.2.4.1.

d) Non-corrective eye shields or face shields complying with ISO 16321-1 that are intended to be worn over spectacles and having sufficient rigidity and/or spacing behind the protective lens to avoid contact with a prescription spectacle.

e) Non-corrective spectacles and goggles intended as “over-spectacles” complying with ISO 16321-1 and with sufficient rigidity and/or spacing behind the protective lens to avoid contact with prescription spectacle behind.

NOTE 1 In the case of d) and e) above, it is important to ensure that the corrective device and the eye protector are compatible when worn together.

Special attention should be given to ensuring that the fit and coverage of the eye protector provided by the eye protector is maintained and there is no interference to or modification of the visual correction.

NOTE 2 Because of the extra separation provided between eye protector and prescription spectacle, eye shields and face shields are preferred.

f) Single-vision ready-to-wear near vision eye protectors complying with ISO 16321-1 and ISO 16034 that are appropriate for the task and hazard.

Ready-to wear near vision spectacles can be used as either a temporary solution or a solution for extended use. It is recommended that wearers seek advice from their eyecare professional regarding longer term use.

NOTE National regulations can limit the type of lenses in ready-to-wear spectacles to single-vision lenses only.

7.2.4 Material choice

7.2.4.1 General

Some lens and, especially, frame materials are adversely affected by some solvents. They may degrade if they come into contact with droplets, splashes or vapours. Damage, such as clouding or cracking of the lens, can occur after even brief chemical contact. Prolonged exposure to such chemicals is likely to result in faster degradation of the protector with resulting deterioration in its mechanical protection properties.

7.2.4.2 Mesh protectors

Mesh eye and face protectors are not appropriate to protect against molten metal splash, short circuit electric arc, liquid, splashes or droplets, coarse dusts, fine dusts or gases.

They may be used against high speed particles and are rated for impact in the same way as conventional eye protectors. Since they do not transmit as much light as an un-tinted lens, use of them in low light conditions is best avoided.

Mesh type eye and face protectors may be spectacles, goggles, eye shields or face shields. They are useful in

— forestry applications where abrasion from foliage could cause deterioration of the surface of clear lenses,

— high radiant heat situations where a mesh may provide greater protection to the eyes, and

— situations where fogging is an intractable problem.

Mesh protectors are often selected for these applications because they are resistant to scratching and more comfortable to wear in physically demanding occupations or hot/humid environments.

7.2.4.3 Frame selection

Metal frames are not compatible with electrical hazards. For the selection of suitable face protection for electrical hazards, see 7.6.2.3 for further information.

Certain plastic materials might not be suitable for eye protectors (both frames and lenses) that are used in environments where chemical solvents are present, see 7.2.4.1.

NOTE For further information refer to the latest safety data sheets for the relevant chemicals.

7.2.5 Comfort, vision and fit

7.2.5.1 General

Comfort is an important factor in acceptability of and compliance in wearing an eye and face protector. Wearers of uncomfortable products will be tempted to remove them, or not even wear them, in the hazardous environment. If inadequate attention is given to achieving a good fit then the eye protector may not provide the intended level of protection. Single size non-adjustable spectacles are in common use but these cannot be expected to provide satisfactory comfort and fit to all wearers.

Comfort is a very subjective assessment. However, it is a well-known fact that the more comfortable a piece of personal protective equipment, the more likely the user is to wear it. Whilst wearers might be categorized in terms of size, it is a fair statement to say that there are no two wearers the same. It is therefore essential that a choice of eye protectors is selected so as to accommodate a range of wearers' sizes and shapes. The eye protector should provide optimum fit, taking into account the shape and size of the wearer's head.

The design of the eye protector should provide for maximum adjustment. It is essential that

— where straps or headbands are provided, their positioning, fixing, adjustment, and the materials from which they are made should take into account the range of head shapes and sizes of the prospective wearer.

— if provision is made for the fixing of accessories, such as earmuffs, helmets, etc., these recommendations should be considered both in the design and positioning of the fixing point.

Eye and face protectors should be selected with the assistance of a suitably trained person who can assess the fit and make adjustments if necessary. Aspects of comfort and fit should be considered when selecting suitable eye protectors and spectacle type protectors including:

— adjustable sidearms and special hinges that allow the front to be tilted with respect to the face;

— customisable sidearms that can be shaped over their entire length for optimum comfort and fit;

— weight and balance (centre of gravity) of the eye protector;

— nose-bridge design and frame curvature.

Integrated eyewear fitted to a safety helmet can increase comfort because it eliminates the need for sidearms, which can cause interference with the seal of earmuffs when worn together.

Goggles should enclose the orbital cavities, are generally heavier than spectacles and are often considered as less comfortable. Factors influencing fit and comfort of goggles include

— width, position and adjustability of the headband,

— face flange profile,

— different size options to provide a secure comfortable fit on all individuals, and

— deformable face foam seal.

7.2.5.2 Vision and productivity

A significant factor in productivity and performance is vision. Properties of the eye protector that can influence the wearer's visual perceptions include field of view, optical quality including refractive power and spatial deviation, colour perception, reflections and shade variations such as angular dependence. The field of view is important because the wearer needs to have an unobstructed view to undertake the appropriate tasks.

7.2.5.3 Refractive correction

The vision and refractive status of the wearer is an important consideration in the selection and supply of eye protectors. It is important to determine that the worker has adequate vision, and if not, has suitable refractive correction to undertake their task in a safe and successful manner. Should a refractive correction be required, an appropriate lens design for the task is an important consideration.

7.2.6 Application based selection

7.2.6.1 Welding applications

7.2.6.1.1 Eye and face protection for welders

During arc welding and cutting operations, protection should be provided against UV and IR radiation. At the same time, the visible radiation should be reduced to a comfortable level. Adequate eye and face protection in these cases can be obtained by the use of a welding face shield (welding helmet) or welding hand shield fitted with filters having shade numbers 8 to 15, inclusive.

In gas welding and cutting, and resistance welding and brazing, suitable eye protection should be provided to guard against possible UV and IR radiation and to reduce the visible radiation to a comfortable level. For such processes, sufficient protection will usually be given by goggles fitted with welding filters of shade number 4 to 7, inclusive.

Where a welder is also likely to be exposed to stray radiation from similar processes nearby, it is essential that the welder has some protection against radiation and mechanical impact while the helmet or hand shield is not in use by wearing protective spectacles. The protective spectacles will also offer the welder protection against impact during the removal of slag after welding.

7.2.6.1.2 Welding filter selection

Many factors are involved in selecting the shade number of a protective filter which is suitable for welding or related techniques.

— For arc welding, air-arc gouging, and plasma jet cutting, the current is an essential factor in making an accurate choice possible.

— For gas welding and related techniques, such as braze-welding, this document refers to the flow rate through the burner;

In addition, for arc welding, the type of arc and the type of parent metal should also be considered. Other parameters have a significant influence, but it is difficult to evaluate their effect. These are, in particular:

— the position of the operator in relation to the flame or the arc. For example, depending on whether the operator leans over his work or adopts an arm's length position, a variation of at least one shade number might be necessary;

— local lighting;

— the human factor.

For these various reasons, this standard gives only those shade numbers that practical experience has confirmed to be valid in normal circumstances for the personal protection of operators with normal sight carrying out work of a specified type.

The shade number of the filter to be used can be read from Tables 6 to 8, at the intersection of the column corresponding to the gas flow rate or the current and the line specifying the work to be carried out.

Table 6 to Table 8 are valid for average working conditions, in which the distance from the welder's eye to the pool of molten metal is approximately 50 cm and the average ambient illuminance is approximately 100 lx.

The final choice of a shade number should be determined by the welder to provide correct visibility and values in Table 6 are only a starting point. Optical filtration will be adequate if the scene is comfortable to view.

The following terms are used according to ISO 4063:

— the symbol MMA corresponds to manual metal arc welding;

— the symbol MAG corresponds to metal arc welding with non-inert gas shield;

— the symbol TIG corresponds to tungsten inert gas;

— the symbol MIG corresponds to metal arc welding with inert gas shield;

— air-arc gouging corresponds to the use of a carbon electrode and a compressed air jet used to remove the molten metal).

Table 6 — Recommended use of the different shade numbers for arc welding

Welding Process	Current A																				
	1,5	6	10	15	30	40	60	70	100	125	150	175	200	225	250	300	350	400	450	500	600
MMA	8						9		10		11		12			13			14		
MAG	8							9	10		11			12				13			14
TIG			8		9			10		11			12			13					
MIG with heavy metals								9		10		11			12		13		14		
MIG with light alloys										10		11		12		13		14			
Air-arc gouging	10											11	12		13		14		15		
Plasma jet cutting									9	10	11	12			13						
Micro plasma arc welding		4	5	6		7	8		9	10		11		12							
	1,5	6	10	15	30	40	60	70	100	125	150	175	200	225	250	300	350	400	450	500	600

NOTE The term "heavy metals" applies to steels, alloy steels, copper and its alloys, etc.

Table 7 — Shade numbers[a] to be used for gas welding and braze welding

Work NOTE q is the flow rate of acetylene in litres / hour.	$q \leq 70$	$70 < q \leq 200$	$200 < q \leq 800$	$q > 800$
Welding and braze welding [a]	4	5	6	7
[a] According to the conditions of use, the next higher or lower shade number can be used to control glare and still provide appropriate protection.				

Table 8 — Shade numbers[a] to be used for oxygen cutting

Work NOTE q is the oxygen flow rate, in litres / hour.	$900 < q \leq 2\,000$	$2\,000 < q \leq 4000$	$4\,000 < q \leq 8\,000$
Oxygen cutting [a]	5	6	7
[a] According to the conditions of use, the next greater or lower shade number can be used to control glare and still provide appropriate protection.			

7.2.6.1.3 Automatic welding filters and vision

One purpose of an automatic welding filter is to provide better vision for the welder, in that the filter has greater transmittance to start the weld, and then darkens rapidly once the arc has struck. Properties of the welding protector that can influence the wearer's visual perceptions include field of view, optical quality including refractive power and spatial deviation, colour perception, reflections and shade variations such as angular dependence. The field of view is important because the welder needs to have an unobstructed view to undertake the appropriate tasks.

If a protector with an automatic welding filter is frequently used in the down position between the welding tasks (for preparation and grinding), a large field of view and high transmittance in the light state is important. This is often the case when the eye and face protector is used together with respiratory protection.

NOTE Auto Darkening Filters (ADF), also known as Automatic Welding Filters (AWF), are commonly used in welding applications. These use sets of battery powered liquid crystal filters to limit the transmittance of light. Typically, they also include passive UV and IR filters to protect the welder from these hazards. In this case, even without the batteries, the ADF will protect from UV and IR.

7.2.6.1.4 Ventilation and temperature

Build-up of CO_2 inside the welding shield can occur in some instances. This can result in fatigue and might contribute to headache.

When working at low temperatures, exhaled air may cause fogging of the welding filter. This again shows the importance of allowing the user to wear the welding shield as a part of the selection process.

A high reflectance of the outer surface of the protector may help keep the temperature down when working in hot environments or welding with high current but this may cause discomfort glare to fellow workers.

A powered air supply would be helpful to keep the user at a comfortable temperature and minimise fogging.

7.2.6.1.5 Ergonomics, comfort and adjustment

Ergonomics looks at whether or not the welding eye and face protector is comfortable for the wearer. If the protector is not comfortable then the user might not wear the protector at all times even when essential. Users given the opportunity to try on and select the protector from an appropriate selection for the job are more likely to wear a comfortable protector.

The perception of comfort is subjective. An individual's perception will vary by the task and by the requirements for each specific welding task. The perception of comfort might include the following: pressure on the head, weight, balance, field of view, visibility, air quality, temperature, user interface, etc. Before selecting a protector, worker position, environmental constraints, welding methods, high or low current, other associated tasks (i.e. grinding), etc should be considered. Frequency as well as duration of use for the specific welding task might also be considered in choosing the proper protector. The environment, for example, outdoor, indoor, reflecting walls, narrow space, overhead welding, nearby welders and ambient light also play an important role for the understanding of comfort and the selection of a protector.

Head-mounted welding protection is often designed to be adjustable, and to accommodate a wide range of physical characteristics. The protector should be tried on before selecting a product. The headband should be securely adjusted to ensure that the protector does not slip when a person changes the head position (e.g. bending over, looking down) or during the time that the welding protector is needed. Pressure on the head should not cause discomfort for the wearer.

A welding eye and face protector that meets all the performance requirements of a standard will only protect the wearer sufficiently if it is suitably selected for the tasks and used properly. An individual's perception will vary by the task and its requirements.

Factors to consider when choosing welding eye protectors include

— worker position,

— environmental including outdoor, indoor, reflecting walls, narrow space, overhead welding, nearby welders and ambient light,

— welding methods, high or low current,

— other associated tasks (i.e. grinding),

— frequency as well as duration of use for the specific welding task, and

— weight, balance and stability of the protector, especially in situations such as long duration welding, static welding, or if the welding situation requires uncomfortable body positions.

After a suitable protector has been selected, the welder may need assistance to adjust the protector for a proper fit. In the case of an automatic welding filter, the welder may also need instructions to understand the functionality, adjustments and settings.

7.2.6.1.6 Eye protection for welders' assistants

Any welder's assistant who is required to remain in the vicinity of welding operations should be protected against the possible harmful effects of UV and IR radiation and, in addition, should be protected against excessive visible radiation. Protective spectacles incorporating a filter of up to Shade Number 3,0 will in many cases give sufficient protection to the eyes from stray or inadvertent radiation. The spectacles should be equipped with permanently attached side shields with similar filtering properties.

Welders' assistants should not look at an arc or look in the near vicinity of an arc unless provided with eye protection similar to those of the welder.

7.2.6.1.7 Eye protection for persons not engaged in welding operations

Persons (other than welders and welders' assistants) whose duties require them to remain for short periods in the vicinity of arc welding operations or to pass through areas in which such operations are carried out should be protected against the possible dangerous effects of erythemal ultraviolet radiation. In general, protective spectacles with side shields complying with ISO 16321-1 give sufficient protection for such situations.

7.2.6.1.8 Eye protection against stray radiation

Arc welding and similar operations should be carried out in screened enclosures. Where this is not possible, the use of mobile screens is recommended to shield other persons from stray radiation. Galvanized sheeting used for screening or other materials that have relatively large and highly reflective surfaces should be painted or treated with some form of light-absorbing substance. In assessing the presence and magnitude of a risk to other workers and passers-by in the vicinity of welding processes, it is useful to take account of the effects of the exposure time and the distance from the welding process. Table 9 contains the time limits which should be set for each distance. Where the exposure time limit is greater than eight hours, then there is no risk recorded. Table 9 can be entered using the shade number of the welding filter normally used for the actual process. The relationship between exposure time limit and distance can be read off. For example, if the welder is using a process for which the recommended filter is a shade 10 and the remaining personnel do not approach closer than 25 m, they are not at risk if they spend less than a total of 123 minutes in that location during any eight-hour working day. Workers at this location for an eight-hour day are, therefore, at risk. Casual passers-by will not be at risk. The exposure time/distance function is related to the welding process, the current and the shielding gas. In constructing Table 9, some assumptions had to be made and the following values were adopted to represent a worst-case scenario for each situation.

NOTE 1 Further information can be found in ISO 25980.

NOTE 2 Welding in confined spaces is particularly problematic for stray reflected light, requiring protection from optical radiation incident from the side and rear. Protection can be provided by the use of hoods or spectacles with tinted side shields.

Table 9 — Guidelines for maximum permissible exposure time with no personal protection

Repre-sent-ative shade Number	Distance m									
	2	5	10	25	50	75	100	150	200	250
8	40 min	4 h	No risk beyond 7 m							
9	84 s	9 min	35 min	4 h	No risk beyond 37 m					
10	47 s	5 min	20 min	123 min	8 h	No risk beyond 50 m				
11	12 s	74 s	5 min	31 min	123 min	5 h	No risk beyond 99 m			
12	8 s	47 s	3 min	20 min	78 min	3 h	5 h	No risk beyond 124 m		
13	4 s	24 s	96 s	10 min	40 min	90 min	3 h	6 h	No risk beyond 175 m	
14	2 s	15 s	58 s	6 min	24 min	54 min	97 min	4 h	6 h	No risk beyond 225 m
15	0,5 s	4 s	16 s	1 min	7 min	15 min	27 min	1 h	1,5 h	3 h
16	0,2 s	1 s	7 s	44 s	3 min	6 min	11 min	26 min	47 min	1 h

7.2.6.2 Laser eye protection

At the time of writing this document, a standard, ISO 19818-1, giving guidance on selection and use of laser eye protectors is in preparation.

Eye protection can be in the form of spectacles (having frames that rest on the ears) or goggles (secured by a band around the head). Such protectors incorporate optical filters to reduce the transmission of laser radiation to the eye. Combined eye and face protection may take the form of a mask or respirator, along with optical filters, to protect the skin and eyes from exposure to laser radiation. Both eye protection and combined eye and face protection may be employed as a protective measure within a controlled laser area. Total beam enclosure combined where necessary with the use of remote viewing (e.g. television) systems should, however, always be considered first as an alternative to reliance on personal eye and face protection.

Eye and face protectors should only be used if all of the following conditions are satisfied:

a) there exists a risk that an accidental exposure of the eyes or skin could occur that exceeds the Maximum Permissible Exposure (MPE);

b) it is not reasonably practicable to ensure adequate protection entirely by the use of engineering and/or administrative controls;

c) the eye and face protector has the necessary performance specification with regard to

   1) the reduction in the maximum reasonably foreseeable laser exposure to safe levels,

   2) the capability of the eye and face protector to withstand the maximum reasonably foreseeable laser exposure long enough for corrective action to be taken to terminate exposure, and

   3) the ability of the wearer to be able to use the eye and face protector without discomfort and without unacceptable visual impairment.

The eye and face protector is used only within a controlled area that effectively encloses the laser hazard and from which persons not wearing such protection are excluded

When using eye and face protectors, their compatibility with other protectors such as respirators, earmuffs, helmets, etc should be considered.

Where the use of laser eye and face protection is being considered, the specification and selection of the protector should be carried out with care, taking into account the wavelength and other specifications of the laser or laser system for which the protection is required, the circumstances under which accidental exposure could occur, and the applicable safe exposure limit (the MPE). Normally, the MPE for the eye should be used but where the MPE for the skin is more restrictive than that for the eye, the MPE applicable to the skin should be used instead. Whenever the anticipated worst-case exposure to laser radiation is greater than the MPE for the skin, eye and face protection should always be used in preference to just eye protection.

NOTE A laser eye protector designed for one wavelength can provide no protection at other wavelengths. See Annex B for details of the markings of laser protectors.

The protector should be capable of reducing the laser exposure to below the applicable MPE. This capability is dependent on the protector's spectral transmittance (usually expressed in terms of its optical density OD, the logarithm to base 10 of the reciprocal of the transmittance) at the laser wavelength(s). In addition, the protector should be able to withstand the incident laser exposure without its protective properties being compromised; this applies to protective filters and frames. Mechanisms by which protection could be compromised include burns, cracks, photobleaching including reversible photobleaching, delamination of coatings and saturable absorption. This capability is dependent on the protector's resistance to laser radiation, sometimes called the Resistance Category (RC). In some current standards for eyewear, these two parameters are linked, meaning that choice of the correct OD automatically results in an appropriate level of resistance or RC. However, it is possible that the two parameters, OD and resistance or RC, may be specified independently based on risk assessment of foreseeable accidental exposure; in this case the product standard covering the eyewear should be consulted to ensure that the meaning of a stated resistance or RC is understood.

It is not normally advisable to use an eye protector (as opposed to an eye and face protector) as a protective measure against laser radiation where there is a risk of injury to the skin; that is, where the potential exposure exceeds the skin MPE. Under such circumstances, the use of alternative methods to reduce the risk of accidental exposure, including enclosure of the laser beam or face (and hand) protection, should be investigated. In certain applications, however, including some medical procedures and for servicing high-power laser systems, this may not be feasible, and adequate supporting control measures should be adopted in addition to the use of eye protection, in order to reduce the risk of harm.

When choosing appropriate eye and face protectors, the following should be considered:

a) the reasonably foreseeable worst-case exposure and the beam diameter at locations where accidental ocular or facial exposure could occur (these parameters enable the ability of the eye and face protector to withstand the incident laser radiation to be established);

b) the maximum length of time over which accidental exposure could occur before laser emission is terminated or the individual wearing the protector takes avoiding action to prevent continuing exposure;

c) the actual exposure;

d) the applicable value of the ocular and skin MPE, both specified in the same units as the effective exposure;

e) the wavelength of operation. Laser eyewear – and, potentially, an eye and face protector - utilises filter materials to provide protection over certain defined wavelength ranges. Ultra-short pulse lasers may show a considerable broadening of the central laser wavelength which should also be covered. Use of the incorrect eyewear will usually mean that insufficient protection is provided;

f) the optical density $D(\lambda)$ of the eye and face protector at the laser wavelength. The optical density should be sufficient to reduce the transmitted radiation to below the MPE applicable for the maximum reasonably foreseeable exposure time.

   NOTE Some national standards (applicable in Europe and elsewhere) adopt a different system for the specification of laser eye protectors that is not directly equivalent to the optical density requirement.

g) the type of laser operation, cw or pulsed, and pulse duration;

h) resistance of eye and face protector material, filters and frame, to withstand exposure to laser radiation under a worst-case exposure scenario without compromising the required level of protection for the duration of accidental exposure.

Other important factors include:

i) visible light transmission (luminous transmittance), and the ability to see warning lights or other indicators through the filters;

j) general design, comfort, ventilation, peripheral vision, and provision for spectacle correction (either by using goggle-style protectors that fit over normal spectacles, or protective spectacles that incorporate the wearer's own optical correction);

k) degradation or modification of the absorbing material of the filter, including radiation-induced transparency (photobleaching or saturable absorption);

l) mechanical strength of materials and resistance to shock; environmental stability to exposure to elevated temperature, high humidity and UV during storage and transportation;

m) the angular dependence of the protection, i.e. the variation of optical density with angle of incidence. This can be a relevant factor where protection is provided by multilayer dielectric coatings rather than by absorption within the filter material;

n) reflection from filters and frames, especially for eye protectors with dielectric coatings;

o) saturable absorption of eye protector materials to pulses shorter than 10^{-5}s;

p) any relevant national requirements or regulations.

Eye and face protectors should be permanently marked to indicate:

— the operating wavelength;

— the optical density at the operating wavelength, or a scale number that represents this information in a coded form;

— where applicable, the maximum irradiance or radiant exposure that the eye or face protector can withstand without its protective properties being compromised.

Other eyewear considerations include the following:

— Where different kinds of eye and face protector are in use, it can be helpful to use colour-coding or other means to link each protector with its particular laser.

— For work with visible laser emission, it can sometimes be desirable to be able to see the laser beam for alignment purposes or other operational reasons. In this case the eyes' protective filters should be specified on the basis of reducing an accidental exposure to the MPE for a time base of 0,25 s where protection is afforded by the natural aversion response.

— Eye and face protectors are designed to protect against accidental exposure to laser radiation. They should not be used to protect against deliberate exposure or the intentional viewing of a laser beam. Eye and face protectors should be checked periodically for signs of wear or damage. The date of checking should be recorded and the eye and face protector replaced when necessary. Eye and face protectors should also be examined for suitability on each occasion prior to use.

— Eye protectors against laser attacks with handheld laser should be easy to put on as quickly as possible and also possible to carry in near reach when not used.

At high incident power or energy levels, absorption of the incident radiation in the filter material can result in severe stress build-up and sudden failure of the filter. For this reason, an eye and face protector that has been subjected to a single incident of accidental exposure at a high level of exposure should be replaced.

7.2.6.3 Electric arc

This clause discusses protection against an electric arc resulting from switching high voltage and current equipment, e.g. live high voltage power lines.

Prior to any product selection, a comprehensive hazard and risk analysis as given in NFPA 70e[37], IEEE 1584[34] hazard or BGI 5188/DGUV[36] should be performed.

NOTE 1 Due to different test methods used around the world, eye and face protectors are marked differently in various regions. Those products tested and approved against standards in accordance with the European PPE Regulation (EU) 2016/425[38] show arc protection classes and/or ELIM figures (see below), while protectors tested to NFPA 70e or comparable standards are marked by ATPV ratings (see below).

A hazard and risk analysis should be performed to the standard system applicable in the nations of usage, i.e.

— NFPA 70e, IEEE 1584 hazard in the USA or nations referring to NFPA 70e or using comparable standard;

— BGI 5188/DGUV for EU countries.

Due to different test approaches, the results of one method are, unfortunately, not transferable or comparable to the other. Several types of protector available on the market are tested to both standards' systems. Therefore, if a specific protector product family is preferred, it is recommended to check to which standard these products are tested and whether the test methods comply with national policies [e.g. NFPA 70e for USA (non-utility companies) or PPE Regulation (EU) 2016/425 for European countries].

With the results of the hazard and risk analyses in hand, the arc rating or the arc protection class that the protector provides is determined. Nevertheless, further consideration should be taken:

Is 360° protection needed?

If YES, select

— a combination of an open hood with a face shield kit, or

— a combination of a balaclava hood with a face shield kit, or

— a combination of a balaclava hood with a goggle, or

— a closed hood / switch hood (bee keeper style),

If NO, select

— a face shield kit.

NOTE 2 In some jurisdictions, the combination of face shield with protective spectacles is mandatory.

NOTE 3 In some jurisdictions, helmets are mandatory for workplaces where the risk of an arc flash is considered.

Workplaces are considered to be very high risk if the hazard and risk analysis require protection ATPVs higher than 8 cal/cm^2 or where the arc protection class 2 is not sufficient. At these workplaces, even protectors rated or classified accordingly may fail to protect its user e.g. due to high pressure wave or toxic gases.

Any product or component should, at least, have successfully passed the tests identified in the hazard and risk analyses. Combinations of different protectors may not necessarily increase the protection level. Only tests of the combination can provide evidence of compatibility and suitability.

In general, other personal protective equipment that are used in combination with products described in this guidance document should comply with the standards or specifications specific for these other products.

Textile components of the protector should meet the relevant design requirements according to IEC 61482-2:2018, 4.2, and all the requirements for materials according to IEC 61482-2:2018, 4.3.

When a helmet is part of protective equipment, the helmet should meet the requirements of the applicable national or regional standard.

NOTE 4 For example, national/regional standards such as EN 50365[26], EN 397[25], ANSI Z89.1[31] and ANSI Z89.2[32] are applicable.

Eye and face protectors requiring a supply of breathing air (e.g. some designs of balaclavas or hoods) should also meet the requirements of applicable national standards and/or the Technical Specifications of ISO 16976 (all parts).

If according to the manufacturer's instructions, a helmet, a breathing air supply equipment and/or a hood of a body protective clothing is to be used together with eye, face and/or head protective devices in order to achieve the intended eye, face and head protective performance, the combination of all these devices should have been tested as worn during the intended use.

7.2.6.4 Electric arc protective equipment combinations

See Annex A for further information.

7.2.6.5 Furnace workers

Cobalt blue lenses are widely used in the industry because they markedly improve a worker's visual ability to judge the temperature of the melt by specifically filtering the intense yellow wavelengths found in this application. They improve this skill about twentyfold. They generally do not provide impact protection or UV protection and should not be relied upon to provide eye protection. If cobalt blue filters are used, then they should either provide adequate protection against these hazards or be used in conjunction with goggles or a face shield.

Generally, a shade 3 lens provides a suitable balance of visible light transmittance to prevent unwanted glare and allows workers to see their work clearly. This will also provide adequate levels of protection against the UV and IR hazards present.

Workers operating near molten metal processes might be exposed to molten metal splash hazards. Suitable protectors should be selected, taking into consideration the need to protect both the eyes and the face, depending on the nature of the work being conducted. A relatively low shade number (3 or 5) will typically be sufficient to protect workers from the IR hazards present.

7.3 Checking the fit

7.3.1 Fit, comfort and compliance

Eye and face protectors should be selected with the assistance of a competent person who can assess the fit and make adjustments, if necessary.

Eye protectors that meet all the performance requirements of a standard will only protect the wearer if the eye and surrounding soft tissues are fully covered by the eye protector. The correct coverage is from the eyebrow to the cheek bone and laterally from the nose to the bony area on the temporal side of each eye. Insufficient coverage and gaps caused by an eye protector that does not stay in place during the time that protection is needed may expose the wearer to surrounding physical or optical hazards. Consideration should be given to different types of protective eyewear. Close fitting eyewear or goggles are chosen due to the environments they are being used in. In these circumstances the eyewear should fit to provide the least gap possible or preferably no gap at all within the range of eyewear available for their situation. Proper fitting of eyewear should be based on comfort, field of view, security, coverage and gaps.

Once the user has selected a comfortable eye protector, the competent person should assist the user with the proper fit for him or her. If a spectacle style has been chosen that has adjustable features such as sidearm/temple length, tilt of the front with respect to the face (pantoscopic angle) and nose pad position, adjust accordingly. Sidearm/temple length should be adjusted to ensure the sidearm/temple fit correctly on the ears; pressure from the side/temple should not cause discomfort. The correct pantoscopic angle ensures that the lens is well positioned in relation to the eye. The nose pad provides security around the nose; ensure that the nose pad does not raise the eyewear away from the face and that it is comfortable on the nose. The correct adjustments should also minimize the gaps between the eye protector and the eye area.

It is recommended that the fit of the protector be assessed as regularly as necessary to ensure adequate coverage and comfort for the wearer, taking into account changes to the environment, the wearer's physical condition or the hazards that they are exposed to in their role and to verify that the protector has not got out of adjustment.

The viewing area is important as the wearer needs to have an unobstructed view to undertake the appropriate tasks. The wearer should be able to see in all directions of eye rotation without major obstruction to their field of view. The eye protector frame should not interfere with the visual ability to do work tasks.

The sidearm/temple or headband should fit firmly to the head so that the eye protector does not slip from its initial fitted position when the person changes head position (e.g. bending over, looking down) or during the time that the eye protection is needed.

Gaps should be assessed, since physical and optical hazards may reach the eye through these gaps. There should be minimal gap between all edges of the eye protector and the soft tissues surrounding the eye. There should be no clear path for a flying projectile to proceed through any gap to the wearer's eye. Gap size should be related to the risk assessment. An environment that has been assessed as high risk for flying particles may need sealed eyewear with a gasket and therefore the gap needs to be less than 6 mm. If the environment has been deemed to need a general protective spectacle then a gap of 6-8 mm should be considered allowable. Gaps greater than 8 mm should be carefully considered for suitability in context to the working environment.

It is recommended that the fit of the eye protector is assessed every two years or whenever changes occur to a wearer's physical condition (e.g. significant weight change or changes to facial features). Fitting of eye protector should be completed for each model that the end user may wear.

NOTE There are some tools available on the market that allow for assessment of fit criteria such as gaps and coverage. These can be used as part of a robust fit checking programme.

7.3.2 Ensuring compliance with an eye protection programme

To maximise compliance with an eye protection programme, the following factors should also be considered:

a) The personal preference of the wearer for a particular protector frame. Comfort and appearance of the protector are usually the main factors in wearer preference. Lightness, ventilation and unrestricted vision are important considerations.

b) A number of different frame styles/shapes/sizes should be offered. This will help to determine a best-fit option for the wearer, particularly adequate protection and coverage. Nasal contours can vary significantly between people, requiring different bridge shapes for spectacle-type eye protectors.

c) The on-the-job experiences in using the eye and/or face protector.

This guidance document contains recommendations while product performance standards contain minimum requirements. There is no substitute for local knowledge as a baseline for a comprehensive workplace related eye protection programme.

8 Care and maintenance

8.1 Hygiene and cleaning

Eye and face protectors should be maintained in a usable condition in accordance with the manufacturer's instructions. Reasonable care should be taken during the use and storage of protective equipment so that it is not subject to unnecessary abuse. Measures should be undertaken to ensure adequate education on the proper use, application, inspection, maintenance and cleaning, storage, fitting and limitations of eye and face protectors. These may include:

a) The provision of proper facilities for storage, cleaning, servicing and replacement of eye and face protectors and filters or lenses.

b) A system to ensure that all personnel are familiar with the arrangements for cleaning, repairing and replacing damaged or faulty equipment, and for correcting or adjusting uncomfortable protective equipment.

c) In establishments where a large number of protectors are used, the staff of a central inspection and cleaning station should be instructed to recognize and replace damaged and defective protectors.

