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**Eye and face protection — Sunglasses  
and related eyewear —**

Part 2:

**Filters for direct observation of the sun**

*Protection des yeux et du visage — Lunettes de soleil et articles de  
lunetterie associés —*

*Partie 2: Filtres pour l'observation directe du soleil*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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](http://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](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 6, *Eye and face protection*.

ISO 12312 consists of the following parts, under the general title *Eye and face protection — Sunglasses and related eyewear*:

- *Part 1: Sunglasses for general use*
- *Part 2: Filters for direct observation of the sun*

# Eye and face protection — Sunglasses and related eyewear —

## Part 2: Filters for direct observation of the sun

### 1 Scope

This part of ISO 12312 applies to all afocal (plano power) products intended for direct observation of the sun, such as solar eclipse viewing.

Information on the use of filters for direct observation of the sun is given in [Annex A](#) and [Annex B](#).

This part of ISO 12312 does not apply to the following:

- a) afocal (plano power) sunglasses and clip-ons for general use intended for protection against solar radiation;
- b) eyewear for protection against radiation from artificial light sources, such as those used in solaria;
- c) eye protectors specifically intended for sports (e.g. ski goggles or other types);
- d) sunglasses that have been medically prescribed for attenuating solar radiation;
- e) prescription sunglass lenses.

### 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12311:2013, *Personal protective equipment — Test methods for sunglasses and related eyewear*

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

### 3 Terms and definitions

For the purposes of this document, the terms and the definitions given in ISO 4007 apply.

### 4 Requirements and associated test methods

#### 4.1 Transmittance

##### 4.1.1 General

The transmittance requirements of filters for the direct observation of the sun are given in [Table 1](#). Transmittance values shall be measured or calculated at the boxed centre of the filter for normal incidence, as described in ISO 12311:2013, 7.1.1, 7.1.2, 7.3.2, 7.3.3, and 7.5.

Table 1 — Transmittance requirements for filters for the direct observation of the sun

|   |             |
|---|-------------|
| Maximum luminous transmittance ( $\tau_V$ )           | 0,003 2 %   |
| Minimum luminous transmittance ( $\tau_V$ )           | 0,000 061 % |
| Maximum solar UVB transmittance ( $\tau_{SUVB}$ )     | $\tau_V$    |
| Maximum solar UVA transmittance ( $\tau_{SUVA}$ )     | $\tau_V$    |
| Maximum solar infrared transmittance ( $\tau_{SIR}$ ) | 3 %         |

Uncertainty of measurements of transmittance shall not be greater than 25 % of the measured value.

The measurement of spectral transmittance of filters with high optical density can be best accomplished with the use of a dual-beam spectrophotometer and comparison beam attenuators. The comparison beam attenuator should be a physical barrier, such as a perforated mesh, equivalent to a known uniform level of absorption across the entire waveband of measurement.

#### 4.1.2 Uniformity of luminous transmittance

The relative difference in the luminous transmittance value between any two points of the filter shall not be greater than 10 % (relative to the higher value). This requirement shall apply within a circle 40 mm in diameter around the boxed centre or to the edge of the filter less the marginal zone 5 mm wide, whichever is greater.

### 4.2 Material and surface quality

#### 4.2.1 Requirements

Except in a marginal area 5 mm wide, filters shall be free from defects likely to impair vision in use, such as bubbles, scratches, inclusions, dull spots, pitting, scouring, pocking, scaling, and undulations. Metal coated filter materials shall not exhibit more than one pinhole defect not greater than 200  $\mu\text{m}$  in average diameter within any 5 mm diameter circular zone.

#### 4.2.2 Test method

A filter shall be illuminated from one side by an intense white light source (e.g. projector beam or light table) and the opposite side viewed through a low power magnifying lens. Metal coated filters showing visible pinhole defects shall be examined in a light microscope at 25 $\times$  to 40 $\times$  magnification.

NOTE A magnifying lens of 4 $\times$  to 10 $\times$  magnification can be used.

### 4.3 Mounting

#### 4.3.1 General

Filters may be made with or without a mounting. If mounted, a filter shall be held securely so that it cannot be dislodged by normal handling or by gusts of wind. Mountings may be handheld or shaped in the form of spectacles to be worn on the face in front of any corrective (spectacle or contact) lenses worn by the user.

#### 4.3.2 Dimensions

The filter or filters and mounting assembly shall be of a size sufficient to cover both eyes of the user simultaneously and in no case shall have overall dimensions less than 115 mm in width and 35 mm in depth in the plane parallel to the facial plane. Spectacle shaped mountings may have a triangular cut-away area to accommodate the crest of the nose, not to exceed 15 mm in apical height and 35 mm width at the base and may have separate filters, one for each eye, provided that the overall dimensions are satisfied.

### 4.3.3 Material quality

The filter and mounting shall be free from roughness, sharp edges, projections, or other defects which could cause discomfort or injury during use. No part of the filter or mounting which is in contact with the wearer shall be made of materials which are known to cause any skin irritation.

## 5 Labelling

The filter and/or its packaging shall show the following information in the language(s) of the country where the product is to be offered for sale:

- a) name and address of manufacturer of the product;
- b) instructions for use in looking at the sun or a solar eclipse;
- c) warnings that viewing the sun without an appropriate filter can result in permanent eye injury;

EXAMPLE "Direct viewing of the sun is dangerous if the proper precautions are not taken. Adequate eye protection specifically designed for viewing the sun is essential and shall be worn so that no direct radiation from the sun can reach the eye other than that passing through the filter."

- d) warnings that filters that are damaged or separated from their mountings should be discarded;
- e) advice on storage, cleaning, and maintenance, as appropriate;
- f) obsolescence deadline or period of obsolescence, as appropriate.

## Annex A (informative)

### Use of filters for direct observation of the sun

For the direct observation of the sun, only specially designed protective filters should be used. Welding filters are designed to protect the eyes against ultraviolet, visible, and infrared light whereas the filters for direct observation of the sun need only to provide protection against visible light. Welding filters as specified in ISO 16321 with scale numbers 12 to 15 are equally suitable for use with the unaided eye, however, they should not be used in conjunction with telescopes (in front of the objective) for the observation of the sun. The selection of the welding filter scale number is a matter of personal preference in comfort (according to atmospheric conditions and personal glare sensitivity). Filters with category W12 should be adequate to protect the eyes, but the solar image can be uncomfortably bright. Some observers might find that the solar image viewed through a W14 filter is too dim. [Table A.1](#) compares the transmittance properties of welding (W) and solar filters. In the visible spectral range, the transmittance values are for luminous transmittance as specified in ISO 12311:2013, 7.1.2 and denoted as  $\tau_v$ .

**Table A.1 — Comparison of transmittance properties (%) of solar and welding filters**

| Filter Category              | Ultraviolet spectral range |                     | Visible spectral range |           | Infrared spectral range<br>Maximum 780 nm to<br>1 400 nm |
|------------------------------|----------------------------|---------------------|------------------------|-----------|--|
|                              | 280 nm to<br>315 nm        | 315 nm to<br>380 nm | Maximum                | Minimum   |  |
| Solar for direct observation | $\tau_v$                   | $\tau_v$            | 0,003 2                | 0,000 061 | 3  |
| Welding W12                  | 0,000 3                    | 0,001 2             | 0,003 2                | 0,001 2   | 12   |
| Welding W13                  | 0,000 3                    | 0,000 44            | 0,001 2                | 0,000 44  | 8  |
| Welding W14                  | 0,000 16                   | 0,000 16            | 0,000 44               | 0,000 16  | 6  |
| Welding W15                  | 0,000 061                  | 0,000 061           | 0,000 16               | 0,000 061 | 4  |

NOTE Ultraviolet welding filter transmittances are maximum levels of spectral transmittance measured at 313 nm and 365 nm. Infrared transmittance is mean transmittance in the specified waveband.

Eye protectors for direct observation of the sun should be worn so that no direct radiation from the sun can reach the eye other than that passing through the filter.

During eclipses of the sun, eye protectors shall be worn whenever a part of the disk of the sun is **not** covered by the moon (i.e. during partial eclipse). The only time it is safe to view the sun without an eye protector is when the moon completely covers the sun in total eclipse.

#### **Retinal safety calculation**

Detailed calculations and analysis of retinal hazards from direct viewing of the sun demonstrate that a thermal injury of the retina is normally not possible unless the pupil is well dilated or unless the solar disc is viewed through a telescope<sup>[1][2]</sup>. The temperature rise in the irradiated retinal image is insufficient to produce a retinal burn for the unaided eye; even with a 3 mm diameter pupil (which would be quite large for bright daylight) will normally be less than 4 °C<sup>[1][2][3]</sup>.

The sun, instead, poses a photochemical hazard (“blue-light hazard”) not from momentary viewing but from prolonged staring (as during a partial eclipse) for minutes. The terrestrial radiance of the sun when overhead is approximately  $1,3 \times 10^7 \text{ W}\cdot\text{m}^{-2}\cdot\text{sr}^{-1}$  and spectral weighting of the solar spectrum with the blue-light-hazard function  $B(\lambda)$  provides effective blue-light radiance values ranging from  $4 \times 10^5 \text{ W}\cdot\text{m}^{-2}\cdot\text{sr}^{-1}$  to  $1,8 \times 10^6 \text{ W}\cdot\text{m}^{-2}\cdot\text{sr}^{-1}$ , depending upon solar elevation angles greater than 10° above the horizon.

The maximum staring durations that relate to these blue-light radiances from the ACGIH limits<sup>[4]</sup> vary from only 0,6 s for solar zenith to 2,5 s for the sun at 10° above the horizon (very clear sky conditions)<sup>[5]</sup> <sup>[6]</sup>. Of course, actual injuries will only occur at greater durations since the exposure limits incorporate a large safety factor and the limits assume a relatively large pupil size of 3 mm, whereas, the pupil will be typically 1,5-2 mm under such viewing conditions.

Nevertheless, to provide an example for calculating a required attenuation factor, consider a staring duration of 1 000 s (~17 min). One would need an attenuation factor of  $(1\ 000\ \text{s}) / (0,6\ \text{s}) = 1\ 670$ , which would correspond to a neutral filter having a luminous transmittance of 0,06 %. However, practice shows that one would find it very difficult to stare at the sun with a filter transmitting 0,06 %. Most observers would find a luminance of ~10 kcd·m<sup>-2</sup> as an upper value of luminance that could be comfortably viewed. Since the luminance of the overhead sun<sup>[7]</sup> is  $1,6 \times 10^9\ \text{cd}\cdot\text{m}^{-2}$ , a minimum attenuation factor of 160,000 would be required for comfortable viewing (i.e. visual transmittance <0,000 6 % at solar noon. Hence, the filter transmittances in this part of ISO 12312 are far lower than required to prevent retinal injury (solar maculopathy). Since the luminance of the solar disc decreases with solar zenith angle, the comfortable luminous transmittance can be higher than 0,000 44 %. Finally, at sunset, the solar disc is safe to view on the horizon without protection as the blue light has been scattered out of the image<sup>[2]</sup><sup>[6]</sup>.

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## Annex B (informative)

### Solar eclipse eye safety: User's guide<sup>[23]</sup>

A solar eclipse is probably the most spectacular astronomical event that many people will experience in their lives. There is a great deal of interest in watching eclipses and thousands of astronomers (both amateur and professional) and other eclipse enthusiasts travel around the world to observe and photograph them.

A solar eclipse offers students a unique opportunity to see a natural phenomenon that illustrates the basic principles of mathematics and science taught throughout elementary and secondary school. Indeed, many scientists (including astronomers) have been inspired to study science as a result of seeing a total solar eclipse. Teachers can use eclipses to show how the laws of motion and the mathematics of orbits can predict the occurrence of eclipses. The use of pinhole cameras and telescopes or binoculars to observe an eclipse leads to an understanding of the optics of these devices. The rise and fall of environmental light levels during an eclipse illustrate the principles of radiometry and photometry while biology classes can observe the associated behaviour of plants and animals. It is also an opportunity for children of school age to contribute actively to scientific research — observations of contact timings at different locations along the eclipse path are useful in refining our knowledge of the orbital motions of the moon and earth while sketches and photographs of the solar corona can be used to build a three-dimensional picture of the sun's extended atmosphere during the eclipse.

Observing the sun, however, can be dangerous if the proper precautions are not taken. The solar radiation that reaches the surface of earth ranges from ultraviolet (UV) radiation at wavelengths longer than 290 nm to radio waves in the metre range. The tissues in the eye transmit a substantial part of the radiation between 380 nm to 400 nm to the light-sensitive retina at the back of the eye. While environmental exposure to UV radiation is known to contribute to the accelerated aging of the outer layers of the eye and the development of cataracts, the primary concern over improper viewing of the sun during an eclipse is the development of "eclipse blindness" or retinal burns.

Exposure of the retina to intense visible light causes damage to its light-sensitive rod and cone cells. The light triggers a series of complex chemical reactions within the cells which damages their ability to respond to a visual stimulus and, in extreme cases, can destroy them. The result is a loss of visual function which can either be temporary or permanent, depending on the severity of the damage. When a person looks for a long time at the sun without proper eye protection, this photochemical retinal damage might be accompanied by a thermal injury thought to arise from absorption of the light by the retinal pigment epithelium. The resulting local heating effect can destroy photoreceptors, creating a small blind area. The danger to vision is significant because photic retinal injuries occur without any feeling of pain (the retina has no pain receptors) and the visual effects do not become apparent for at least several hours after the damage is done<sup>[20]</sup>. Viewing the sun through binoculars, a telescope, or other optical devices without proper protective filters can result in immediate thermal retinal injury because of the high irradiance level in the magnified image.

The only time that the sun can be viewed safely with the naked eye is when the moon completely covers the disk of the sun during a total eclipse. *It is never safe to look at a partial or annular eclipse, or the partial phases of a total solar eclipse without the proper equipment and techniques.* Even when 99 % of the sun's surface (the photosphere) is obscured during the partial phases of a solar eclipse, the remaining crescent sun is still intense enough to cause a retinal burn even though illumination levels are comparable to twilight<sup>[8][9][13]</sup>. Failure to use proper observing methods can result in permanent eye damage and severe visual loss. This can have important adverse effects on career choices and earning potential because it has been shown that most individuals who sustain eclipse-related eye injuries are children and young adults<sup>[19][11][14]</sup>.

The same techniques for observing the sun outside of eclipses are used to view and photograph annular solar eclipses and the partly eclipsed sun<sup>[22][16][18][21]</sup>.

- The safest and most inexpensive method is by projection. A pinhole or small opening is used to form an image of the sun on a screen placed about a metre behind the opening.
- Multiple openings in perfbboard, a loosely woven straw hat, or even interlaced fingers can be used to cast a pattern of solar images on a screen. A similar effect is seen on the ground below a broad-leaved tree; the many “pinholes” formed by overlapping leaves creates hundreds of crescent-shaped images.
- Binoculars or a small telescope mounted on a tripod can also be used to project a magnified image of the sun onto a white card. All of these methods can be used to provide a safe view of the partial phases of an eclipse to a group of observers, but care shall be taken to ensure that no one looks through the device.

The main advantage of the projection methods is that nobody is looking directly at the sun. The disadvantage of the pinhole method is that the screen shall be placed at least a metre behind the opening to get a solar image that is large enough to be easily seen.

The sun can only be viewed directly when filters specially designed to protect the eyes are used. Most of these filters have a thin layer of chromium alloy or aluminium deposited on their surfaces that attenuates both visible and near-infrared radiation. A safe solar filter should transmit less than 0,003% (optical density ~4,5) of visible light and no more than 3% of the near-infrared radiation from 780 nm to 1 400 nm.

NOTE In addition to the term transmittance (in percent), the energy transmission of a filter can also be described by the term optical density (dimensionless) where optical density,  $d$ , is the common logarithm of the reciprocal of transmittance,  $\tau_v$ , or  $d = \log_{10}(1/\tau_v)$ . An optical density of 0 corresponds to a transmittance of 100 % while an optical density of 1 corresponds to a transmittance of 10 % and an optical density of 2 corresponds to a transmittance of 1 %, etc..

- One of the most widely available filters for safe solar viewing is shade number 14 welder’s glass, which can be obtained from welding supply outlets.
- A popular inexpensive alternative is aluminized polyester that has been specially made for solar observation.

NOTE This material is commonly known as “mylar,” although the registered trademark “Mylar®”<sup>1)</sup> belongs to Dupont, which does not manufacture this material for use as a solar filter. Note that “space blankets” and aluminized polyester film used in gardening are NOT suitable for this purpose.

Unlike the welding glass, aluminized polyester can be cut to fit any viewing device and does not break when dropped. It has been pointed out that some aluminized polyester filters can have large (up to approximately 1 mm in size) defects in their aluminium coatings that can be hazardous. A microscopic analysis of examples of such defects shows that despite their appearance, the defects arise from a hole in one of the two aluminized polyester films used in the filter. There is no large opening completely devoid of the protective aluminium coating. While this is a quality control problem, the presence of a defect in the aluminium coating does not necessarily imply that the filter is hazardous. When in doubt, an aluminized polyester solar filter that has coating defects larger than 0,2 mm in size or more than a single defect in any 5 mm circular zone of the filter should not be used.

- An alternative to aluminized polyester is “black polymer” in which carbon particles are suspended in a resin matrix. This material is somewhat stiffer than polyester film and requires a special holding cell if it is to be used at the front of binoculars, telephoto lenses, or telescopes. Intended mainly as a visual filter, the polymer gives a yellow-white image of the sun (aluminized polyester produces a blue-white image). This type of filter might show significant variations in density of the tint across its extent; some areas might appear much lighter than others. Lighter areas of the filter transmit more infrared radiation than may be desirable.

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1) Mylar® is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

The advent of high resolution digital imaging in astronomy, especially for photographing the Sun, has increased the demand for solar filters of higher optical quality. No filter should be used with an optical device (e.g. binoculars, telescope, camera) unless it has been specifically designed for that purpose and is mounted at the front end.

- A metal-coated 1 mil resin film can be used for both visual and photographic solar observations. A much thinner material, it has excellent optical quality and much less scattered light than polyester filters.
- Filters using optically flat glass substrates are available from several manufacturers but are more expensive than polyester and polymer filters.

In the past, experienced solar observers used filters made with one or two layers of black and white film that was fully exposed to light and developed to maximum density. These films had a silver-based emulsion. Since modern black and white films are less likely to contain silver, this type of solar filter is no longer recommended.

The following materials are *unsafe* and should not be used. The fact that the sun appears dim or that no discomfort is felt when looking at the sun through these materials is no guarantee that the eyes are safe:

- “black” developed colour film;
- film negatives with images in them;
- smoked glass;
- sunglasses (single or multiple pairs);
- photographic neutral density filters;
- polarizing filters;
- CDs and DVDs.

Solar filters designed to thread into eyepieces that are often provided with inexpensive telescopes are also unsafe. These glass filters often crack unexpectedly from overheating when the telescope is pointed at the sun and retinal damage can occur faster than the observer can move the eye from the eyepiece. Avoid unnecessary risks. Local planetariums, science centres, or amateur astronomy clubs can provide additional information on how to observe the sun safely.

There are some concerns that ultraviolet-A (UVA) radiation (wavelengths from 315 nm to 380 nm) in sunlight can also adversely affect the retina.<sup>[12]</sup> While there is some experimental evidence for this, it only applies to the special case of aphakia where the natural lens of the eye has been removed because of cataract or injury and no UV-blocking spectacle, contact, or intraocular lens has been fitted. In an intact normal human eye, UVA radiation does not reach the retina because it is absorbed by the crystalline lens. In aphakia, normal environmental exposure to solar UV radiation can indeed cause chronic retinal damage. The solar filter materials discussed in this article, however, attenuate solar UV radiation to a level well below the minimum permissible occupational exposure for UVA<sup>[4]</sup>, so an aphakic observer is at no additional risk of retinal damage when looking at the Sun through a proper solar filter.

In the days and weeks before a solar eclipse, there are often news stories and announcements in the media warning about the dangers of looking at the eclipse. Unfortunately, despite the good intentions behind these messages, they frequently contain misinformation and might be designed to scare people from viewing the eclipse at all. This tactic can backfire, however, particularly when the messages are intended for students. A student who heeds warnings from teachers and other authorities not to view the eclipse because of the danger to vision and later learns that other students did see it safely, might feel cheated out of the experience. Having now learned that the authority figure was wrong on one occasion, how is this student going to react when other health-related advice about drugs, acquired immunodeficiency syndrome (AIDS), or smoking is given?<sup>[18]</sup> Misinformation can be just as bad, if not worse, than no information.