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Personal protective equipment — Test methods for sunglasses and related eyewear

Équipement de protection individuelle — Méthodes d'essai pour lunettes de soleil et articles de lunetterie associés

Reference number
ISO 12311:2013(E)

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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. www.iso.org/directives

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

This corrected version of ISO 12311:2013 incorporates the following correction:

- a visible XML tag has been removed from the table in Figure G.1.

INTERNATIONAL STANDARD **ISO 12311:2013(E)**

Personal protective equipment — Test methods for sunglasses and related eyewear

1 Scope

This International Standard specifies reference test methods for determining the properties of sunglasses given in ISO 12312 (all parts). It is applicable to all sunglasses and related eyewear.

Other test methods may be used if proven to be equivalent.

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 37, *Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties*

ISO 48, *Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRHD and 100 IRHD)*

ISO 1042:1998, *Laboratory glassware — One-mark volumetric flasks*

ISO 3696:1987, *Water for analytical laboratory use — Specification and test methods*

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

ISO 8596, *Ophthalmic optics — Visual acuity testing — Standard optotype and its presentation*

ISO 11664-1, *Colorimetry — Part 1: CIE standard colorimetric observers*

ISO 11664-2, *Colorimetry — Part 2: CIE standard illuminants*

ISO 12312-1:2013, *Eye and face protection — Sunglasses and related eyewear — Part 1: Sunglasses for general use*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

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

4 Prerequisites

The following parameters shall be specified prior to testing [see ISO 12312 (all parts)]:

- the number of specimens;
- specimen preparation;
- any conditioning prior to testing;
- characteristics to be assessed subjectively (inappropriate);

— pass/fail criteria.

5 General test requirements

Unless otherwise specified, the values stated in this International Standard are expressed as nominal values. Except for temperature limits, values which are not stated as maxima or minima shall be subject to a tolerance of ± 5 %. Unless otherwise specified, the ambient temperature for testing shall be between 16 °C and 32 °C. Where other temperature limits are specified they shall be subject to an accuracy of ± 1 °C. Relative humidity shall be maintained at (50 ± 20) %.

Unless otherwise specified, the filters shall be tested at the reference points as defined in ISO 4007.

6 Test methods for assessing the construction and materials

6.1 Prior assessment of construction, marking and information

Prior to applying the test methods, a visual inspection shall be carried out with normal or corrected vision, without magnification. Marking and information supplied by the manufacturer and safety data sheets (if applicable) or declaration relevant to the materials used in its construction shall also be assessed.

6.2 Test method for assessment of filter material and surface quality

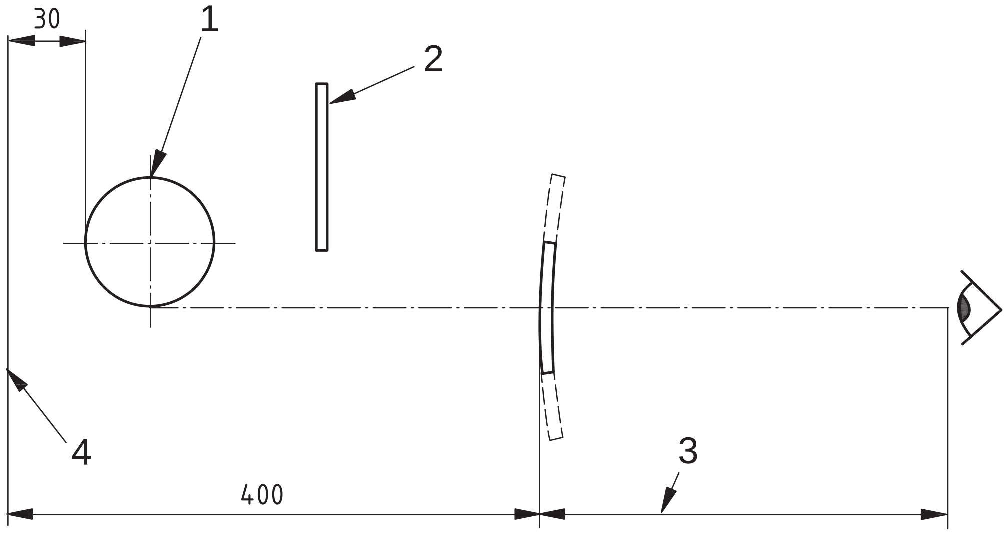
6.2.1 Principle

The quality of the filter material and surface is assessed by visual inspection.

6.2.2 Apparatus

A suitable apparatus is shown in Figure 1.

Dimensions in millimetres



Key

1 lamp

2 adjustable opaque dull black mask

3 near vision distance (≈300)

4 dull black background (200 × 360)

Figure 1 — Arrangement of apparatus for assessment of quality of material and surface

6.2.3 Test procedure

Carry out the assessment of the quality of material and surface by visual inspection with the aid of a “light box” or illuminated grid.

NOTE One method of inspection in current use consists of an illuminated grid as a background to be viewed through the filter which is held at various distances from the eye. Another method is to illuminate the filter by means of a fluorescent lamp mounted within a dull black chamber and with the amount of illumination adjusted by means of an adjustable opaque black mask. A suitable arrangement is shown in Figure 1.

6.2.4 Verification and test report

Except for a marginal area 5 mm wide at the edge of the eye protector, any significant defects likely to impair vision in use shall be recorded in the verification and test report.

7 Test methods for measuring spectrophotometric properties

7.1 Measurement of spectral transmittance $\tau(\lambda)$

7.1.1 Spectral transmittance

7.1.1.1 General

Test methods shall be used which have relative uncertainties in spectral transmittance less than or equal to those given in Table 1.

Table 1 — Relative uncertainty of measured spectral transmittance

Spectral transmittance value		**Uncertainty %**
Less than %	to %	
100	17,8	±2 absolute
17,8	0,44	±10 relative
0,44	0,023	±15 relative
0,023	0,0012	±20 relative
0,0012	0,000023	±30 relative

The general methods of evaluating the components of uncertainty are set out in ISO/IEC Guide 98-3. Annex A shows how uncertainty of measurement is to be applied in the reporting of results and compliance and Annex B is a guide to the sources of uncertainty in spectrophotometry, their minimization and evaluation.

The location and direction of measurement of transmittance shall be as specified in ISO 12312-1. If the measurements are not made normal to the surface of the filter, then particular attention should be paid to the effects of beam displacement (see Annex B). If the direction of measurement is not specified then it shall be measured normal to the surface of the filter when unmounted.

Calculations shall be carried out at not more than 5 nm intervals ($\Delta\lambda$ = 5 nm) in the ultraviolet-visible region (280 nm to 780 nm) and not more than 10 nm in the infrared region (780 nm to 2 000 nm). The necessary data at these intervals are provided in Annexes D, E, F, H and I.

7.1.1.2 Test procedure

Place the filter in order to follow the location and direction of measurement of transmittance as specified in ISO 12312-1.

7.1.2 Calculations of luminous transmittance τ_V

Luminous transmittance is calculated as a percentage from the spectral transmittances and with reference to a standard observer and a source or illuminant. For the purposes of this International Standard all calculations use the CIE 2° Standard Observer [ISO 11664-1 and CIE Standard Illuminant D65 (ISO 11664-2)].

$$\tau_V = 100 \times \frac{\int_{380}^{780} \tau(\lambda) \cdot S_{D65}(\lambda) \cdot V(\lambda) \cdot d\lambda}{\int_{380}^{780} S_{D65}(\lambda) \cdot V(\lambda) \cdot d\lambda} \quad (1)$$

where

λ is the wavelength of the light in nanometres;

$\tau(\lambda)$ is the spectral transmittance of the filter;

$V(\lambda)$ is the spectral luminous efficiency function for photopic vision;

$S_{D65}(\lambda)$ is the spectral distribution of radiation of CIE Standard Illuminant D65 (see ISO 11664-2).

The values of $S_{D65}(\lambda).V(\lambda)$ are given in Annex D.

NOTE These calculations are normally carried out as summations and not as integrations. The equivalent summations are provided in Annex C.

7.2 Measurement of uniformity of luminous transmittance

7.2.1 Unmounted filters covering one eye

7.2.1.1 Test method

Locate the defined reference point defined in ISO 4007. Determine a circular area around the reference point with diameter *d* calculated as follows (see Figure 2):

a) for filters equal to or greater than 50 mm in vertical depth at the reference point, *d* = (40,0 ± 0,5) mm;

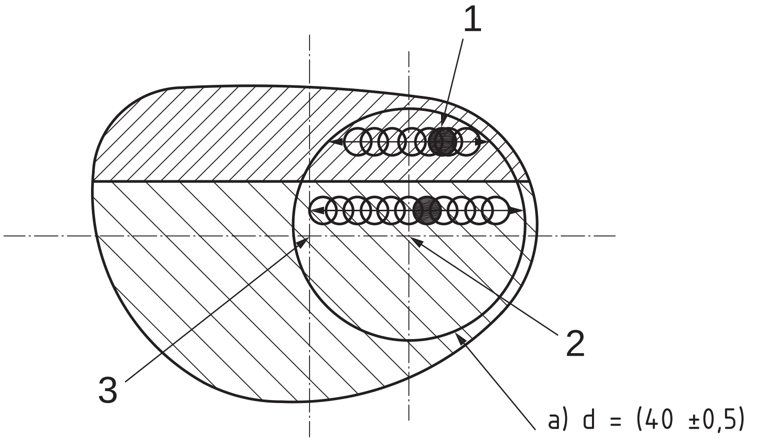
b) for filters less than 50 mm in vertical depth at the reference point, *d* = [vertical depth of filter (h) - 10 ± 0,5] mm.

A 5 mm wide portion around the edge of the filter shall be excluded from this circular area.

Scan this circular area with a 5 mm nominal diameter light beam white light or a narrow spectral band with a maximum spectral energy at (555 ± 25) nm and measure the luminous transmittance with a detector whose spectral responsivity approximates that of the CIE 2° Standard Observer (ISO 11664-1). The effects of displacement of the light beam by any prismatic effect of the filter (see B.3.4.1) shall be compensated for, and variations in thickness shall be corrected as in Annex L.

For filters with bands or gradients of different luminous transmittance, the requirement for variations in luminous transmittance applies in this circular area but perpendicular to the gradient (see Figure 2). Two example scans perpendicular to the gradient are shown in Figure 2.

Dimensions in millimetres



Key

1	light beam 5 mm diameter
2	reference point
3	geometric or boxed centre

Figure 2 — Luminous transmittance uniformity measurement for filters with bands or gradients of different luminous transmittance

The filter and the light beam are positioned so that the incident light falls normally on the surface of the filter at the reference point or parallel to that direction at other locations on the filter.

Measure and record the maximum value of luminous transmittance τ_{vmax}, and the minimum value of luminous transmittance τ_{vmin}.

7.2.1.2 Calculations

Calculate the value of Δ_{F} as percentage, from the following formulae:

$$\Delta_{\mathrm{F}} = 100 \times \frac{(\tau_{\mathrm{vmax}} - \tau_{\mathrm{vmin}})}{\tau_{\mathrm{vmax}}} \qquad (2)$$

where

τ_{vmax} is the maximum value of luminous transmittance;

τ_{vmin} is the minimum value of luminous transmittance.

7.2.1.3 Test report

Record Δ_{F} as the uniformity of luminous transmittance.

7.2.2 Mounted filters and unmounted filters covering both eyes

7.2.2.1 Test method

Locate the defined reference points defined in ISO 4007. Define two circular areas around the reference points with diameter *d*, calculated as follows:

Circular areas are determined around each of these centres with diameters d, calculated as follows:

a) for filters equal to or greater than 50 mm in vertical depth at the reference point, $d = (40,0 \pm 0,5)$ mm;

b) for filters less than 50 mm in vertical depth at the reference point, d = [vertical depth of filter (h) - 10 ± 0,5] mm.

A 5 mm wide portion around the edge of the filter shall be excluded from this circular area.

Scan this circular area with a 5 mm nominal diameter light beam white light or a narrow spectral band with a maximum spectral energy at (555 ± 25) nm and measure the luminous transmittance with a detector whose spectral responsivity approximates that of the CIE 2° Standard Observer (ISO 11664-1). The effects of displacement of the light beam by the any prismatic effect of the filter (see B.3.4.1) shall be compensated for and variations in thickness shall be corrected as in Annex L.

For filters with bands or gradients of different luminous transmittance, assessments of variations in luminous transmittance shall be for sections parallel to the line joining the reference points.

Measure and record the value of luminous transmittance τ_{VL} at the left eye reference point and the value of luminous transmittance τ_{VR} at the right eye reference point.

7.2.2.2 Calculations

Divide the absolute difference between the values of the luminous transmittance at the two reference points τ_{VL} and τ_{VR} by the higher value of the luminous transmittance at one of the two reference points and express this ratio, as a percentage Δ_P.

$$\Delta_P = 100 \times \frac{\left|\tau_{\mathrm{VR}} - \tau_{\mathrm{VL}}\right|}{\max\left(\tau_{\mathrm{VR}}, \tau_{\mathrm{VL}}\right)} \tag{3}$$

where

τ_{VL} is the value of luminous transmittance at the reference point of the left filter;

τ_{VR} is the value of luminous transmittance at the reference point of the right filter.

EXAMPLE If one filter transmits 38,0 % and the other transmits 40,0 %, then the result is 100 × (2,0/40,0) = 5,0 %.

7.2.2.3 Test report

Record the value Δ_P as a percentage.

7.3 Calculation of ultraviolet transmittance

7.3.1 Solar UV-transmittance τ_{SUV}

The calculation of τ_{SUV} (see ISO 4007) as a percentage is:

$$\tau_{SUV} = 100 \times \frac{\int_{280}^{380} \tau(\lambda) \cdot E_s(\lambda) \cdot S(\lambda) \cdot \mathrm{d}\lambda}{\int_{280}^{380} E_s(\lambda) \cdot S(\lambda) \cdot \mathrm{d}\lambda} = 100 \times \frac{\int_{280}^{380} \tau(\lambda) \cdot W(\lambda) \cdot \mathrm{d}\lambda}{\int_{280}^{380} W(\lambda) \cdot \mathrm{d}\lambda} \tag{4}$$

where

λ is the wavelength in nanometres;

$\tau(\lambda)$ is the spectral transmittance;

$E_S(\lambda)$ is the solar radiation at sea level for air mass 2;[7]

$S(\lambda)$ is the relative spectral effectiveness function for UV radiation;[8]

$W(\lambda)$ = $E_S(\lambda) \cdot S(\lambda)$ and is the complete weighting function of this product.

The values of $E_S(\lambda)$, $S(\lambda)$ and $W(\lambda)$ are given in Annex E.

7.3.2 Solar UVA-transmittance τ_{SUVA}

Solar UVA-transmittance is the result of the mean of the spectral transmittance between 315 nm and 380 nm and appropriate weighting functions.

The calculation of τ_{SUVA} (see ISO 4007) as a percentage is as follows:

$$\tau_{SUVA} = 100 \times \frac{\int_{315}^{380} \tau(\lambda) \cdot E_S(\lambda) \cdot S(\lambda) \cdot \mathrm{d}\lambda}{\int_{315}^{380} E_S(\lambda) \cdot S(\lambda) \cdot \mathrm{d}\lambda} = 100 \times \frac{\int_{315}^{380} \tau(\lambda) \cdot W(\lambda) \cdot \mathrm{d}\lambda}{\int_{315}^{380} W(\lambda) \cdot \mathrm{d}\lambda} \tag{5}$$

where

λ is the wavelength in nanometres;

$\tau(\lambda)$ is the spectral transmittance;

$E_S(\lambda)$ is the solar radiation at sea level for air mass 2;[7]

$S(\lambda)$ is the relative spectral effectiveness function for UV radiation;[8]

$W(\lambda)$ = $E_S(\lambda) \cdot S(\lambda)$ and is the complete weighting function of this product.

The values of $E_S(\lambda)$, $S(\lambda)$ and $W(\lambda)$ are given in Annex E.

7.3.3 Solar UVB-transmittance τ_{SUVB}

Solar UVB-transmittance is the result of the mean of the spectral transmittance between 280 nm and 315 nm and appropriate weighting functions.

The calculation of τ_{SUVB} (see ISO 4007) as a percentage is as follows:

$$\tau_{\mathrm{SUVB}} = 100 \times \frac{\int_{280}^{315} \tau(\lambda) \cdot E_{\mathrm{S}}(\lambda) \cdot S(\lambda) \cdot \mathrm{d}\lambda}{\int_{280}^{315} E_{\mathrm{S}}(\lambda) \cdot S(\lambda) \cdot \mathrm{d}\lambda} = 100 \times \frac{\int_{280}^{315} \tau(\lambda) \cdot W(\lambda) \cdot \mathrm{d}\lambda}{\int_{280}^{315} W(\lambda) \cdot \mathrm{d}\lambda} \qquad (6)$$

where

λ is the wavelength in nanometres;

$\tau(\lambda)$ is the spectral transmittance;

$E_{\mathrm{S}}(\lambda)$ is the solar radiation at sea level for air mass 2;[7]

$S(\lambda)$ is the relative spectral effectiveness function for UV radiation;[8]

$W(\lambda)$ $= E_{\mathrm{S}}(\lambda).S(\lambda)$ and is the complete weighting function of this product.

The values of $E_{\mathrm{S}}(\lambda)$, $S(\lambda)$ and $W(\lambda)$ are given in Annex E.

7.4 Calculation of solar blue-light transmittance τ_{sb}

Solar blue-light transmittance is the result of the mean of the spectral transmittance between 380 nm and 500 nm and appropriate weighting functions. The calculation of τ_{sb} (see ISO 4007) as a percentage is as follows:

$$\tau_{\mathrm{sb}} = 100 \times \frac{\int_{380}^{500} \tau(\lambda) \cdot E_{\mathrm{s}}(\lambda) \cdot B(\lambda) \cdot \mathrm{d}\lambda}{\int_{380}^{500} E_{\mathrm{s}}(\lambda) \cdot B(\lambda) \cdot \mathrm{d}\lambda} = 100 \times \frac{\int_{380}^{500} \tau(\lambda) \cdot W_{\mathrm{B}}(\lambda) \cdot \mathrm{d}\lambda}{\int_{380}^{500} W_{\mathrm{B}}(\lambda) \cdot \mathrm{d}\lambda} \qquad (7)$$

where

λ is the wavelength in nanometres;

$\tau(\lambda)$ is the spectral transmittance;

$E_{\mathrm{S}}(\lambda)$ is the solar radiation at sea level for air mass 2;[7]

$B(\lambda)$ is the blue-light hazard function;[9]

$W_{\mathrm{B}}(\lambda)$ $= E_{\mathrm{S}}(\lambda) \cdot B(\lambda)$ and is the complete weighting function of this product.

The values of $E_{\mathrm{S}}(\lambda)$, $B(\lambda)$ and $W_{\mathrm{B}}(\lambda)$ are given in Annex E.

7.5 Calculation of solar IR transmittance τ_{SIR}

The calculation of solar IR transmittance τ_{SIR} (see ISO 4007) as a percentage is obtained by integration between the limits 780 nm and 2 000 nm as follows:

$$\tau_{\mathrm{SIR}} = 100 \times \frac{\int_{780}^{2000} \tau(\lambda) \cdot E_{\mathrm{S}}(\lambda) \cdot \mathrm{d}\lambda}{\int_{780}^{2000} E_{\mathrm{S}}(\lambda) \cdot \mathrm{d}\lambda} \tag{8}$$

where

λ	is the wavelength in nanometres;
$\tau\ (\lambda)$	is the spectral transmittance;
$E_S(\lambda)$	is the spectral distribution of solar radiation at sea level for air mass 2.[7]

The values of $E_S(\lambda)$ are given in Annex F.

7.6 Measurement of absolute spectral reflectance $\rho(\lambda)$

The test methods to be used shall have relative uncertainties in spectral reflectance less than or equal to those given in Table 2. The angle of incidence is to be ≤ 17°

Table 2 — Relative uncertainty of measured spectral reflectance

Spectral reflectance value		Uncertainty %
Less than %	to %	
100	2,5	±5 % relative
2,5		±10 % relative

If measurements are made without the use of an integrating sphere, care shall be taken to ensure that all the reflected light is collected since the beam reflected from a curved surface will be divergent or convergent and part of it may fall outside the detector. See Reference[10] for guidance.

7.7 Absolute luminous reflectance ρ_V

The calculation of ρ_V as a percentage is obtained by the ratio of the luminous flux reflected by the filter Φ_R to the incident flux Φ_I as follows:

$$\rho_V = 100 \times \frac{\Phi_R}{\Phi_I} = 100 \times \frac{\int_{380}^{780} \rho(\lambda) \cdot V(\lambda) \cdot S_{D65}(\lambda) \cdot d\lambda}{\int_{380}^{780} V(\lambda) \cdot S_{D65}(\lambda) \cdot d\lambda} \tag{9}$$

where

λ	is the wavelength in nanometres;
$\rho(\lambda)$	is the spectral reflectance of the filter at wavelength λ;
$V(\lambda)$	is the relative sensitivity of the human eye as defined in ISO 11664-1;
$S_{D65}(\lambda)$	is the spectral energy distribution of CIE Standard Illuminant D65 as defined in ISO 11664-2.

The values of $S_{D65}(\lambda) \cdot V(\lambda)$ are given in Annex D.

7.8 Calculation of relative visual attenuation quotient for signal light detection Q_{signal}

The quotient of signal detection has the following relationship of τ_{signal} and τ_v

$$Q_{\text{signal}} = \frac{\tau_{\text{signal}}}{\tau_{\text{v}}} \tag{10}$$

where

$$\tau_{\text{V}} = 100 \times \frac{\int_{380}^{780} \tau(\lambda) \cdot S_{\text{D65}}(\lambda) \cdot V(\lambda) \cdot \text{d}\lambda}{\int_{380}^{780} S_{\text{D65}}(\lambda) \cdot V(\lambda) \cdot \text{d}\lambda} \tag{11}$$

and

$$\tau_{\text{signal}} = 100 \times \frac{\int_{380}^{780} \tau(\lambda) \cdot E_{\text{signal}}(\lambda) \cdot V(\lambda) \cdot \text{d}\lambda}{\int_{380}^{780} E_{\text{signal}}(\lambda) \cdot V(\lambda) \cdot \text{d}\lambda} \tag{12}$$

where

λ	is the wavelength in nanometres*;*
$\tau(\lambda)$	is the spectral transmittance;
$V(\lambda)$	is the relative sensitivity of the human eye as defined in ISO 11664-1;
$S_{\text{D65}}(\lambda)$	is the spectral energy distribution of CIE Standard Illuminant D65 as defined in ISO 11664-2;
$E_{\text{signal}}(\lambda)$	is the spectral energy distribution of the red, yellow, green and blue traffic signals.

The values of $S_{\text{D65}}(\lambda) \cdot V(\lambda)$ are given in Annex D and the values of $E_{\text{signal}}(\lambda) \cdot V(\lambda)$ for incandescent signals are given in Annex H and for LED signals in Annex I.

7.9 Wide angle scatter

7.9.1 Principle

A hazemeter is used to measure the amount of light which deviates from an incident beam by being scattered forward when the beam passes through a specimen, compared to the amount scattered by the test instrument and the amount transmitted by the specimen.

7.9.2 Apparatus

7.9.2.1 Incandescent light source approximating CIE Standard Illuminant A (ISO 11664-2).

7.9.2.2 Hazemeter with integrating sphere, light trap, photodiode and reflectance standard (see Figure 3) as follows:

a) The integrating sphere shall have:
   1) a total port area not exceeding 4,0 % of the total internal reflecting area of the sphere;
   2) the entrance and exit ports separated by at least 170°;
   3) the exit port subtending 8° at the centre of the entrance port;
   4) the photodiode (90 ± 10)° from the entrance port; and
   5) all internal surfaces (including the reflectance standard for the exit port) covered with a substance of high reflectance for wavelengths between 380 nm and 780 nm.

   NOTE 1 A barium sulfate paint may be suitable.

b) The light trap shall have a reflectance of less than 0,1 %.

c) The photodiode shall provide proportional measurements of the radiant flux to within 1 % of the incident flux, across the range of intensity used within the test.

d) These components shall be arranged so that the irradiating beam shall:
   1) have the axis of the beam passing through the centre of the entrance and exit ports;
   2) be unidirectional, with no ray of the beam deviating from the direction of the axis of the beam by greater than 3°;
   3) when there is no specimen obstructing the beam, have a circular cross-section at the exit port, while the diameter of the exit port shall exceed the diameter of the irradiating beam so that there is an annular zone around the beam subtending (1,3 ± 0,1)° at the entrance port;
   4) when a specimen covers the entrance port, not form an angle greater than 8° between the axis of the beam and the normal to the surface of that specimen; and
   5) when there is no specimen obstructing the beam, be completely absorbed by the light trap (if used).

NOTE 2 Although wide angle scatter measurements are made most commonly by the use of a hazemeter, a spectrophotometer can be used, provided that it meets the geometric and spectral requirements of this subclause. A spectrophotometer is necessary when the luminous transmittance, τ_V of the filter is below about 15 %.

7.9.3 Specimen

The size of the specimen can vary with the size of the entrance port and the surface curvature of the integrating sphere. The specimen shall be large enough to completely cover the entrance port but shall be small enough to be tangential to the wall of the integrating sphere.

7.9.4 Test procedure

Carry out the procedure as follows.

a) Measure the incident light (τ_1) without the specimen in position, without the light trap in position and with the reflectance standard in position.

b) Measure the total light transmitted by the specimen (τ_2) with the specimen in position, without the light trap in position and with the reflectance standard in position.

c) Measure the light scattered by the instrument (τ_3) without the specimen in position, with the light trap in position, and without the reflectance standard in position.

d) Measure the light scattered by the instrument and specimen (τ_4) with the specimen in position, with the light trap in position and without the reflectance standard in position.

e) Repeat step (b) so that four readings are obtained, rotating the specimen between readings by 90°.

f) Repeat step (d) so that four readings are obtained at the same positions as in step (e).

7.9.5 Calculation

The following shall be calculated:

The average values of τ_2 and τ_4 ($\bar{\tau}_2$ and $\bar{\tau}_4$) .

a) The total transmittance from the formula:

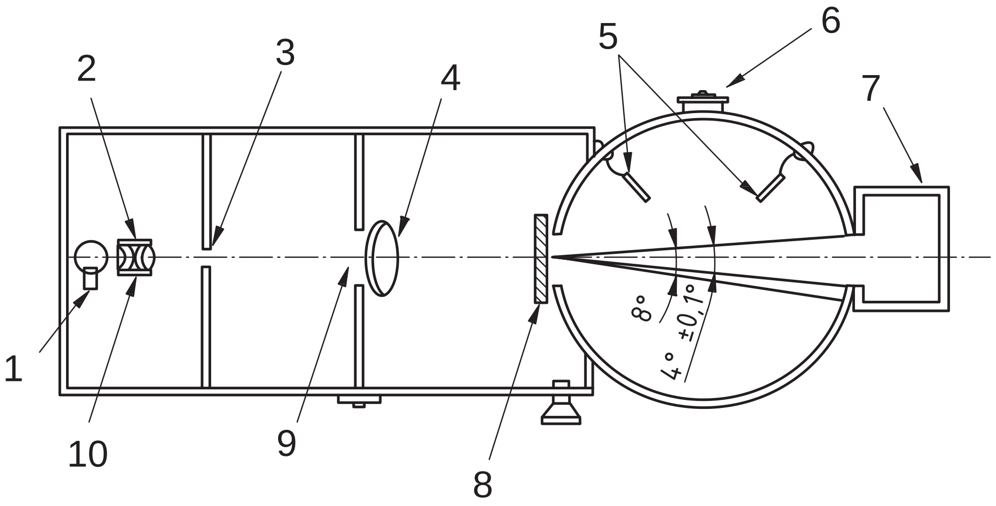
$$\tau_t = \frac{\overline{\tau_2}}{\tau_1} \tag{13}$$

b) The scattered light from the formula:

$$\tau_d = \left[\bar{\tau}_4 - \tau_3 . \frac{\bar{\tau}_2}{\tau_1} \right] \Big/ \tau_1 \tag{14}$$

c) The wide angle scatter, expressed as a percentage, from the formula:

$$\text{wide angle scatter} = \frac{\tau_\mathrm{d}}{\tau_\mathrm{t}} \times 100 \tag{15}$$



Key

1	source
2	condenser
3	entrance window
4	lens
5	baffles
6	photocell
7	light trap
8	specimen
9	aperture
10	filter

Figure 3 — Diagram of typical equipment for the measurement of wide angle scatter

7.9.6 Test report

Report the wide angle scatter value.

7.10 Polarizing filters

7.10.1 Plane of transmission

7.10.1.1 Apparatus

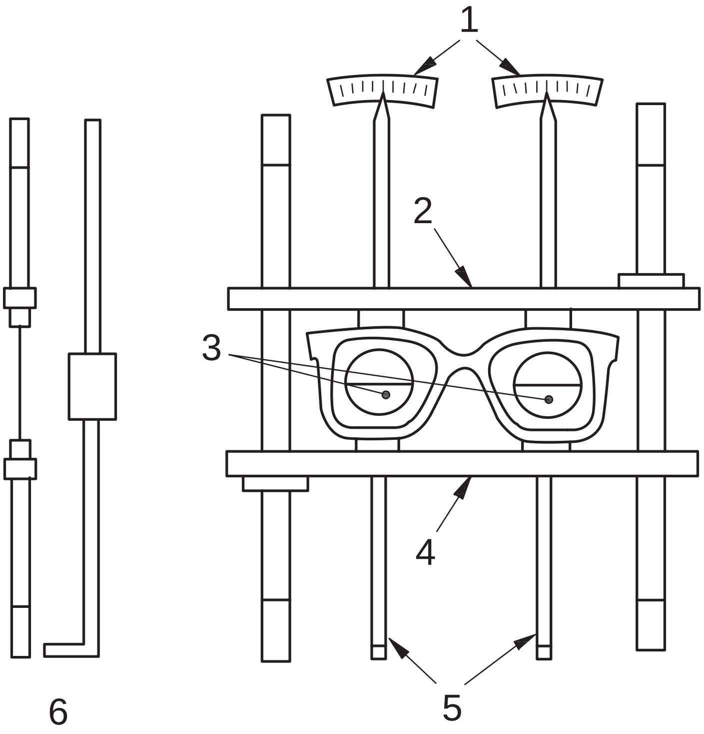
7.10.1.1.1 Pair of individually mounted split field polarizers cut to give planes of transmission at a + 3° and a - 3° angle about the horizontal, or the prescribed axis. The top and bottom halves of the polarizers shall be joined together and glass mounted, with the line of the join horizontal or perpendicular to the prescribed axis. The polarizers shall be capable of being rotated by means of a lever carrying a corresponding pointer. The pointer transverses a scale calibrated in degrees left or right of zero. The split fields shall be illuminated from behind by a diffused light source (see Figure 3).

7.10.1.2 Test procedure

Mount the sunglass on the apparatus (see Figure 4), with the front towards the split fields on a horizontal register bar and ensure that the split field appears in the centre of the filter by means of vertical adjusters and that the pantoscopic angle and the face form angle are 'as worn'.

For the left filter, move the lever from side to side until the top and bottom halves of the illuminated split field appear of equal luminance when viewed through the filter.

Read off the pointer position to give the deviation in degrees (plus or minus) of the plane of transmission of the filter from the horizontal or the prescribed orientation. Repeat the procedures for the right filter.



Key

1 scales

2 top register bar

3 split-field polarizers

4 bottom register bar

5 split-field rotation lever

6 side view

Figure 4 — Apparatus for the determination of the plane of transmission

7.10.2 Polarizing efficiency

7.10.2.1 Principle

The luminous transmittance for visible light is measured with plane polarized light with the plane of oscillation set to provide the maximum and the minimum transmittance of the lens. This can be done by a spectrophotometric method and calculation method (the reference method) or, in a broadband method using a detector with the sensitivity of the human eye (peak at 555 nm) and a source equivalent to CIE Standard Illuminant D65.

7.10.2.2 Test procedure for the spectrophotometric method

Carry out the procedure as follows.

a) Mount the linear polarizers with their planes of transmission parallel in the reference and sample beams of the spectrophotometer. The linear polarizers shall have a polarization at least one order of magnitude better than the requirement being tested against [e.g. if the requirement for the filter is a polarizing efficiency of 80 % (9:1) then the linear polarizers shall have an efficiency of at least 97,5 % (90:1)].

b) Mount the polarizing filter in the spectrophotometer.

c) With the spectrophotometer wavelength set to (550 ± 5) nm, rotate the filter to the point of maximum transmittance.

d) At this orientation, measure the spectral transmittances, $\tau_{\mathrm{pmax}}(\lambda)$ in the range 380 nm to 780 nm at 5 nm intervals.

e) Rotate the filter 90° and measure the spectral transmittances, $\tau_{\mathrm{pmin}}(\lambda)$, in the same way.

f) Calculate the luminous transmittances for the two conditions in the same way as set out in 7.2 providing two values of luminous transmittance, τ_{pmax} and τ_{pmin}.

$$\tau_{\mathrm{pmax}} = 100 \times \frac{\int_{380}^{780} \tau_{\mathrm{pmax}}(\lambda) \cdot S_{\mathrm{D65}}(\lambda) \cdot V(\lambda) \cdot d\lambda}{\int_{380}^{780} S_{\mathrm{D65}}(\lambda) \cdot V(\lambda) \cdot d\lambda} \quad (16)$$

$$\tau_{\mathrm{pmin}} = 100 \times \frac{\int_{380}^{780} \tau_{\mathrm{pmin}}(\lambda) \cdot S_{\mathrm{D65}}(\lambda) \cdot V(\lambda) \cdot d\lambda}{\int_{380}^{780} S_{\mathrm{D65}}(\lambda) \cdot V(\lambda) \cdot d\lambda} \quad (17)$$

where

λ	is the wavelength in nanometres;
$V(\lambda)$	is the relative sensitivity of the human eye as defined in ISO 11664-1;
$S_{\mathrm{D65}}(\lambda)$	is the spectral energy distribution of CIE Standard Illuminant D65 as defined in ISO 11664-2.

g) Calculate the polarizing efficiency P as a percentage as given in ISO 4007.

$$P = 100 \times \frac{\tau_{\mathrm{pmax}} - \tau_{\mathrm{pmin}}}{\tau_{\mathrm{pmax}} + \tau_{\mathrm{pmin}}} \quad (18)$$

NOTE Polarization is sometimes described by the polarizing ratio (R_{pol}).

$$R_{pol} = \frac{\tau_{p\mathrm{max}}}{\tau_{p\mathrm{min}}} :1 \quad (19)$$

7.10.2.3 Test procedure for the broadband method

A light source and filter combination to give a correlated colour temperature of (6 500 ± 1 000) K (approximating CIE Standard Illuminant D65 in the visible region, see ISO 11664-2) is used to produce a collimated beam of diameter (5 ± 2) mm to illuminate the filter under test at the reference point defined in ISO 12312-1. The light is polarized using the same specification linear polarizer as in 7.10.2.2 a). The light is incident on a detector with approximately the spectral sensitivity of the CIE 2° Standard Observer (ISO 11664-1). The responsivity of the detector shall be linear to within ± 0,5 % in the range of illuminance measured.

The filter or the linear polarizer is rotated to the point of maximum transmittance. At this orientation, the luminous transmittance, τ_{pmax}, is recorded. The filter or linear polarizer is then rotated 90° and the luminous transmittance, τ_{pmin}, is recorded.

7.11 Photochromic filters

7.11.1 Light source(s) to approximate the spectral distribution of solar radiation for air mass *m* = 2 for testing

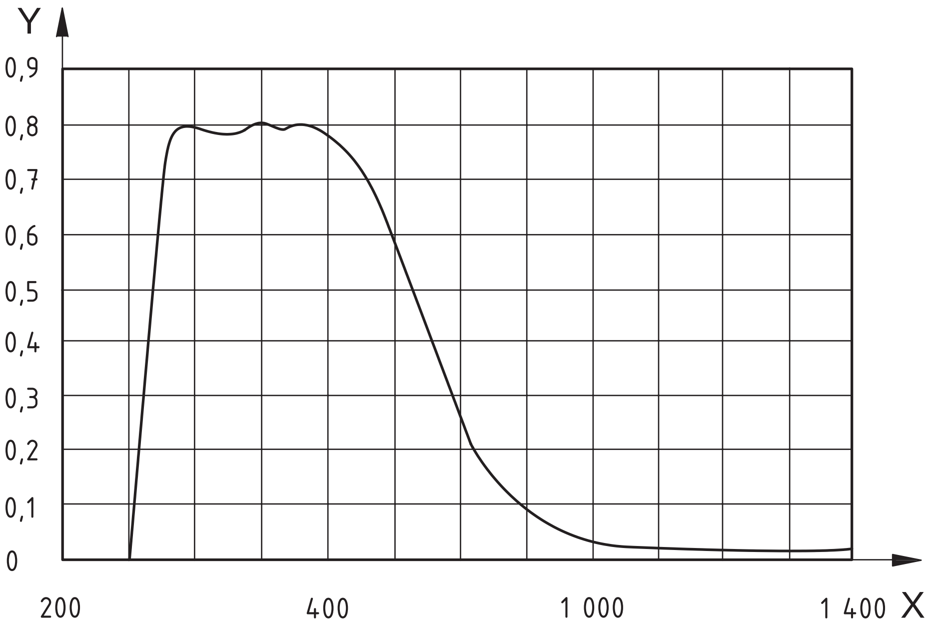
Testing shall be done with a Xenon high pressure lamp with filters chosen so that the specified illuminance of (50 000 ± 5 000) lx and the irradiance values (with permitted tolerances) given in Table 3 are reached.

Table 3 — Irradiance for testing the darkened state of photochromic lenses

Wavelength range nm	Irradiance W·m^{-2}	Tolerance W·m^{-2}
300-340	< 2,5	-
340-380	5,6	±1,5
380-420	12,0	±3,0
420-460	20,0	±3,0
460-500	26,0	±2,6

7.11.1.1 Radiation source using one lamp

Use an ozone free high pressure xenon arc lamp, a heat absorbing filter and a cut-on filter as specified in Figure 5.



Key

X wavelength (nm)

Y transmittance (absolute value)

Figure 5 — Spectral transmittance of the combination of the heat absorbing filter and the cut-on filter for the measurement of photochromic lenses

This transmittance curve can be achieved using, for example, a clear white crown glass, e.g. B 270 with a thickness of 5 mm and a heat absorbing filter e.g. a Schott KG 2 with a thickness of 3 mm or a Pittsburg 2043 of 2 mm thickness[1].

7.11.1.2 Radiation source using two lamps

This is done in order to approximate as closely as possible the spectral distribution of solar radiation for air mass $m = 2$, and may be more closely approximated with the use of two ozone free high pressure xenon arc lamps. The radiation of the two lamps is superimposed by means of a semi-transparent mirror. If different filtering is used in front of the two lamps, the solar spectrum can be approximated more closely than with one lamp.

The principle may be expanded by the use of more than two lamps in order to even better approximate the solar spectrum in the relevant spectral ranges.

7.11.2 Conditioning for luminous transmittance in the faded state

Unless the manufacturer specifies a different procedure to reach the faded state in the information supplied with the product, photochromic filters shall be conditioned by the following procedure.

a) Store filters in the dark at (65 ± 5) °C for (2 ± 0,2) h.

b) Store filters in the dark at (23 ± 5) °C for at least 12 h.

c) Expose filters to (15 000 ± 1 500) lx at (23 ± 1) °C for 15 min using a source similar to the one described in 7.11.1.

d) Store filters in the dark at (23 ± 1) °C for 60 min.

7.11.3 Measurement

7.11.3.1 Principle

Most photochromic materials respond to normal room lighting and all measurements should therefore be made in absence of extraneous light. Care should be taken to ensure that the radiation used for the measurements does not cause darkening or bleaching of the sample.

The surface temperature of the filter shall be maintained within ± 1 °C of the nominated temperature (see Table 4).

Measurements may be carried out in a water bath. However, immersion of the specimen in water reduces the refractive index change and, therefore, the reflectance at the filter surface, thereby increasing the measured transmittance relative to the transmittance values that would be measured in air. The transmittance values determined using water immersion shall be corrected to provide the equivalent air values. Calibration of the equipment can be checked using a reference sample with a refractive index differing by not more than ± 0,01 from the refractive index of the filter under test.

7.11.3.2 Faded state

Measure spectral transmittance from 280 nm to 780 nm (or to 2 000 nm if IR is included) according to 7.1.

For the requirements specified in ISO 12312-1, calculate the luminous transmittance in the faded state, τ_{V0} in accordance with 7.1. These requirements are the solar ultraviolet transmittances (7.3.1 to 7.3.3), the solar blue-light transmittance (see 7.4), the relative visual attenuation quotients for signal light detection, Q_{red}, Q_{yellow}, Q_{green} and Q_{blue} and, if required, the solar infrared transmittance (see 7.5).

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[1] Schott KG 2 and B270 are trade names of products supplied by SCHOTT AG and Pittsburg 2043 is the trade name of a product supplied by Corning INC. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

7.11.3.3 Darkened states

The characteristic luminous transmittance values of photochromic filters are defined in ISO 4007 and, unless otherwise stated, are determined for the conditions given in Table 4.

Where testing at 15 000 lx is specified, the irradiance values and the permissible tolerances of these values are those given in Table 3, but multiplied by a factor 0,3.

Table 4 — Measurement conditions for the different characteristic luminous transmittance values

Characteristic luminous transmittance value	Surface temperature of the test specimen °C	Illuminance at the surface of the sample lx
τ_{V0}	23 ± 1	0 Faded state
τ_{V1}	23 ± 1	50000 ± 5000

The requirements specified in ISO 12312-1 shall be measured and calculated from the spectral transmittance values measured in the darkened state (τ_{V1}) after 15 minutes' irradiance with (50 000 ± 5 000) lx at (23 ± 1) °C. These requirements are the solar ultraviolet transmittances (see 7.3.1 to 7.3.3), the solar blue-light transmittance (see 7.4), the relative visual attenuation quotients for signal light detection, Q_{red}, Q_{yellow}, Q_{green} and Q_{blue}, and, if required, the solar infrared transmittance (see 7.5).

8 Test methods for measuring optical properties

8.1 Test method for spherical, astigmatic and prismatic refractive powers

8.1.1 Principle

Spherical, astigmatic and prismatic refractive powers of lenses or complete sunglasses are measured by means of a telescope method (reference method). This method requires a relatively wide measurement field. Therefore difficulties can appear in applying this method to filters which exhibit irregular distributions of optical powers across the field of measurement. In such cases the method described in 8.3 can be used for a spatially resolved determination of optical powers.

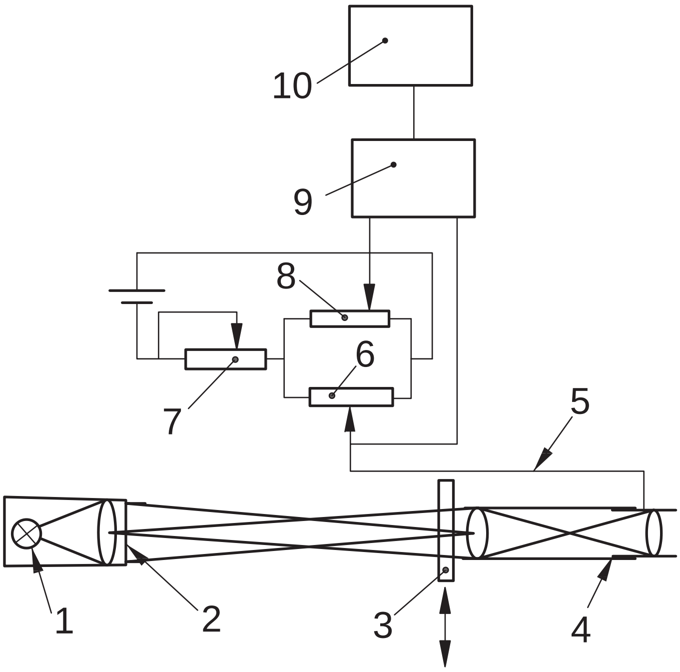
NOTE The recommendations given are for reference. Alternative designs that can be demonstrated to produce results that are equivalent to those obtained with the reference method may also be used. For example, a focimeter can be used for the measurement of those optical properties for which equivalent results can be achieved compared with the telescope method.

8.1.2 Apparatus

8.1.2.1 Electronic recording of visual assessment as shown in Figure 6.

NOTE A mechanical indication of eyepiece movement is also possible.

Figure 6 gives a schematic drawing of the telescope set-up. In this test the re-focusing distance of the telescope's eyepiece is taken as a measure for the optical power of an inserted test object. The set-up shown uses an electronic recording for measurement. Usually the position for the sharp image is assessed visually. This technique may be replaced by means of digital image processing.



Key

1	lamp
2	telescope target
3	sample
4	telescope
5	re-focusing
6	displacement sensor
7	calibration
8	zero point
9	digital voltmeter
10	computer

Figure 6 — Schematics of the telescope set-up

8.1.2.2 Telescope with an aperture of nominally 20 mm and a magnification between 10× and 30×, fitted with an adjustable eyepiece incorporating a reticle. The focusing adjustment has a scale of refractive power capable of calibration of the telescope by using the methods as described in Annex K or by utilizing any other applicable method delivering the same precision.

8.1.2.3 Illuminated target, consisting of a black plate incorporating the cut-out pattern shown in Figure 7, behind which is located a light source of adjustable luminance with a condenser, if necessary, to focus the magnified image of the light source on the telescope objective.

The large annulus of the target has an outer diameter of (23,0 ± 0,1) mm with an annular aperture of (0,6 ± 0,1) mm. The small annulus has an inner diameter of (11,0 ± 0,1) mm with an annular aperture of (0,6 ± 0,1) mm. The central aperture has a diameter of (0,6 ± 0,1) mm. The bars are nominally 20 mm long and 2 mm wide with a nominal 2 mm separation.

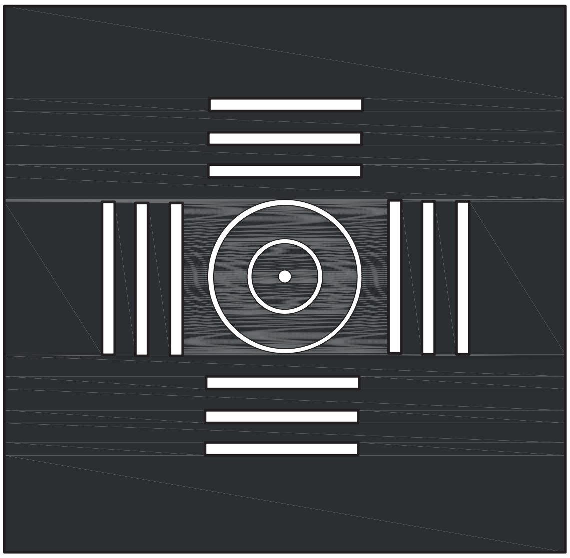


Figure 7 — Telescope target (dimensions are given in 8.1.2.3)

8.1.2.4 Filter, with its maximum transmittance in the green part of the spectrum, which can be used to reduce chromatic aberration.

8.1.3 Calibration of the apparatus

The telescope shall be calibrated to achieve an uncertainty of measurement less than or equal to 0,01 m^{-1}. This can be accomplished by using the method of variable distance (see Annex K) or by using calibration lenses, e.g. lenses that have positive and negative spherical refractive powers of 0,06 m^{-1}, 0,12 m^{-1} and 0,25 m^{-1} (tolerance ± 0,01 m^{-1}).

8.1.4 Test procedure

8.1.4.1 General

Carry out the procedure as follows.

The telescope and illuminated target are placed on the same optical axis (4,60 ± 0,02) m apart.

The observer shall focus the reticule and the target and align the telescope to obtain a clear image of the pattern. This setting is regarded as the zero point of the focusing scale of the telescope. The telescope shall be aligned so that the central aperture of the target is imaged on the centre of the cross-line graticule. This setting is regarded as the zero point of the prism scale.

The filter is positioned in front of the telescope mounted in the as-worn position as specified by the manufacturer. Measurements of spherical and astigmatic power shall be taken using the procedures specified in 8.1.4.2. If during measurement using the telescope a doubling or other aberration of the image is observed, then the filter can either be classified as defective or subjected to further examination using the method described in 8.3.

For the positioning of the unmounted filter the following cases can apply.

a) Filter covering one eye:

    1) when the as-worn position is specified by the manufacturer, the positioning is as specified;

   2) when the as-worn position is unknown or not specified by the manufacturer, the positioning is normal to the telescopic axis and the tests are conducted at the boxed centre (see ISO 4007).

b) Filter covering two eyes:

   1) when the as-worn position is specified by the manufacturer, the positioning is as specified;

   2) when the as-worn position is unknown or not specified by the manufacturer, the positioning is normal to the telescopic axis and the tests are conducted at the reference points (see Figure 8).

For the positioning of mounted filters the following cases shall apply.

c) Filters covering one eye:

   1) when the as-worn position is specified by the manufacturer, the positioning is as specified;

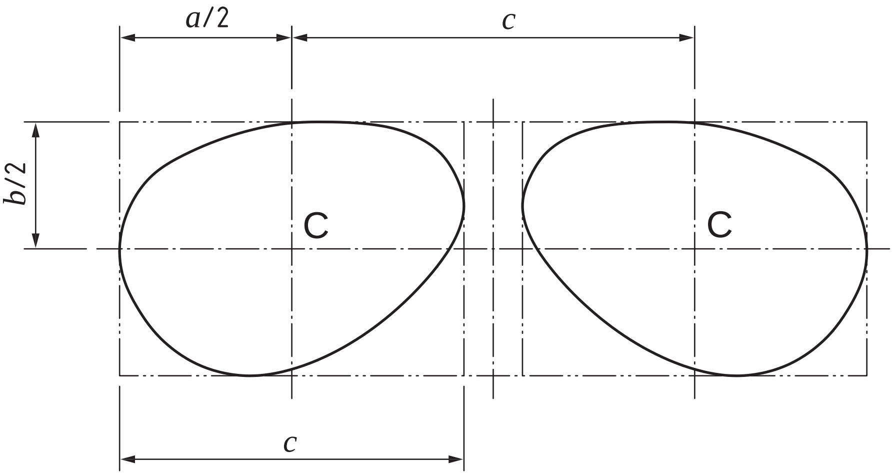
   2) when the as-worn position is unknown or not specified by the manufacturer, the positioning is in the as-worn position as specified in ISO 4007.

d) Filters covering both eyes:

   1) when the as-worn position is specified by the manufacturer, the positioning is as specified;

   2) when the as-worn position is unknown or not specified by the manufacturer; the positioning is in the as-worn position as specified in ISO 4007.

If, in addition to b)2) for mounted and unmounted filters, no interpupillary distance is specified by the manufacturer, a default value of 64 mm for adult's sunglasses and 54 mm for children's sunglasses shall be applied.



Key

C reference points

b distance between the tangents to the top and bottom of the filter

c the specified interpupillary distance

a horizontal boxed ocular size

Figure 8 — Determination of the reference points for filters

8.1.4.2 Spherical power and astigmatic refractive power

The target, or the filter, is rotated in order to align the principal meridians of the filter with the bars of the target. The telescope is focused firstly on one set of bars (measurement D_1) and then on the perpendicular bars (measurement D_2).

The spherical power is the mean $\frac{D_1 + D_2}{2}$, the astigmatic power is the absolute difference $\left|D_1 - D_2\right|$, of the two measurements.

During this process the best focus shall be used across the whole target for each meridian.

8.1.4.3 Prismatic power for unmounted filters covering one eye

The filter shall be placed in front of the telescope in the as-worn position and the deviation of the point of intersection of the lines of the reticule recorded. The prismatic power can be determined taking into account the following and by using linear interpolation:

a) if the point of intersection is on the outside edge of the large circle, the prismatic power is 0,25 prism dioptre;

b) if the point of intersection is on the inside edge of the small circle, the prismatic power is 0,12 prism dioptre.

8.1.5 Test report

The measured values (spherical, astigmatic and prismatic power) shall be reported.

8.2 Test method for the prism imbalance of complete sunglasses or filters covering both eyes

8.2.1 Principle

This method determines the prism imbalance (relative prism error) in the as-worn position at the two reference points of mounted filters in complete sunglasses, or at the two reference points on the filter if it is of one piece construction.

8.2.2 Apparatus

The arrangement of the reference method is shown in Figure 9. The uncertainty for the determination of the difference in prismatic refractive power is equal to or less than 0,05 prism dioptre. Other methods can be used, e.g. using two parallel laser sources for illumination, provided they are capable of measuring within the required uncertainty.

8.2.3 Test procedure

a) The diaphragm LB_1 is illuminated by the light source L_a. The position of these is adjusted so that it produces a single image on the screen in plane B when the eye protector (P) is not in position.

b) The eye protector is placed in front of the lens L_2, in the as-worn position, on the headform of a size appropriate to the specimen being tested and conforming to the description as indicated in Annex G.

NOTE If a justifiable reason exists, e.g. design for fitting a specific ethnicity or population group, the assessment should be carried out on an alternative headform designed to represent the specific target population.

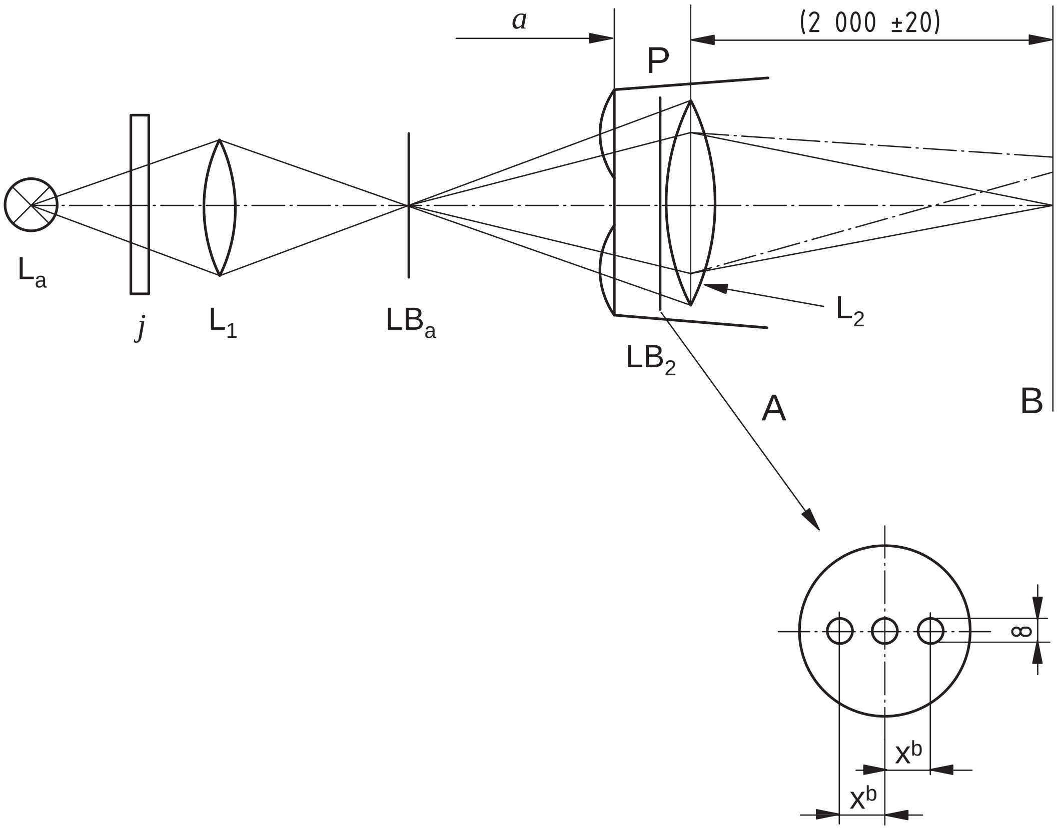
c) Select the appropriate diaphragm LB_2. The distance X^b from the centre of the diaphragm to the left and right circular opening is equal to half of the interpupillary distance. As default value an interpupillary distance of (64,0 ± 0,4) mm for adult sunglasses and (54,0 ± 0,4) mm for children's sunglasses is used. Other values for the interpupillary distance can be chosen if requested by the manufacturer.

d) Measure the vertical and horizontal distances between the two displaced images arising from the two filter regions of the eye protector.

These distances in centimetres are divided by 2 to give the horizontal and vertical prismatic differences in prism dioptres (centimetres per metre).

If the light paths which correspond to the two eye regions cross in the horizontal direction the prism imbalance is “base in”; if the light paths do not cross, it is “base out”.

Dimensions in millimetres (nominal unless toleranced)



Key

L_a	light source, e.g. small filament lamp, laser with wavelength of (600 ± 70) nm
j	interference filter with peak transmittance in the green part of the spectrum (required only if a filament lamp is used as the light source)
L_1	achromatic lens, focal length between 20 mm and 50 mm
LB_a	diaphragm, diameter of aperture 1 mm nominal
P	eye protector
LB_2	diaphragm as shown in detail A
L_2	achromatic lens, 1 000 mm nominal focal length and 75 mm nominal diameter
B	image plane
X^b	half of the interpupillary distance
a	as small as practicable

Figure 9 — Arrangement of apparatus for measurement of prismatic difference

8.2.4 Verification and test report

The measured values shall be reported.

8.3 Test method for local variations in refractive power

8.3.1 Principle

This test method scans a parallel beam of light of nominal diameter 5 mm across the filter; its deflection is detected by a photodiode, and the resulting plot of deflection against point of incidence on the filter is used to measure refractive properties over smaller zones than the telescope method of 8.1. The resolution in terms of optical power is better than 10^{-3} dioptres (m^{-1}). A sketch of this principle is given in Figure 10.

If two parallel rays, 1 and 2, pass through the test filter at different points, they meet in the focal plane at a distance, *f*, from the test filter. Its refractive power is then 1/*f*. In the case of a test filter with different curvatures in two mutually perpendicular directions, or if light falls obliquely on a spherical surface, an astigmatic refractive power results which is equal to the difference between the refractive powers in the two main meridians.

If, in addition to this, the central ray 1 is deflected by an angle α, the test filter has, in addition to its spherical refractive power, a prismatic refractive power Δ, where:

$$\Delta = 100 \tan \alpha \text{ prism dioptre}$$

If the deflection of the light ray is measured in a plane at a distance *w* from the filter, then from Figure 10:

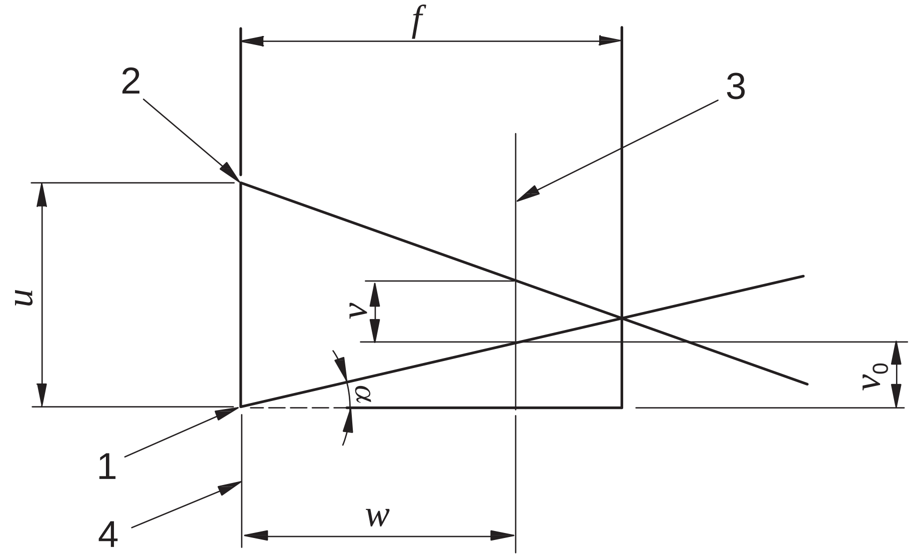
$$\frac{1}{f} = \frac{u-v}{u \times w}$$

where

u is the distance between the two parallel rays 1 and 2 in front of the sample;

v is the distance between the refracted rays in the measuring plane.

NOTE The recommendations specified are for reference. Alternative designs demonstrated to produce results that are equivalent to those obtained with the reference methods may also be used. For example, a focimeter can be used for the measurement of those local variations in refractive power for which equivalent results can be achieved to the reference method.



Key

1	ray 1
2	ray 2
3	measuring plane
4	test filter
f	focal length of filter
u	distance between the parallel rays 1 and 2
v	distance between the refracted rays 1 and 2 in the measuring plane
w	distance between the test filter and measuring plane
α	angle of deflection of the central ray 1
v_0	deflection of the central ray from the optical axis in the measuring plane

Figure 10 — Determination of the distance *f* of the focal plane from the test filter by means of two parallel rays 1 and 2

8.3.2 Apparatus

The apparatus for determining distance *f* comprises the following main elements (see Figure 11):

8.3.2.1 Laser, supplying a parallel light beam of wavelength (600 ± 70) nm.

8.3.2.2 Two lenses with a diaphragm at the common focal point to expand the laser beam to a nominal diameter of 5 mm (the average size of the eye-pupil).

8.3.2.3 Carriage to move the test filter continuously on a spiral path in a plane perpendicular to the direction of the laser beam. During measurement, the test filter should not turn in relation to the photodiode. The carriage runs on two guides perpendicular to each other, keeping the directions of the axes of the carriage and the test filter constant during measurement. A pivot guided by a spiral transmits the corresponding movement to the carriage. The pitch of the spiral is nominally 1,08 mm.

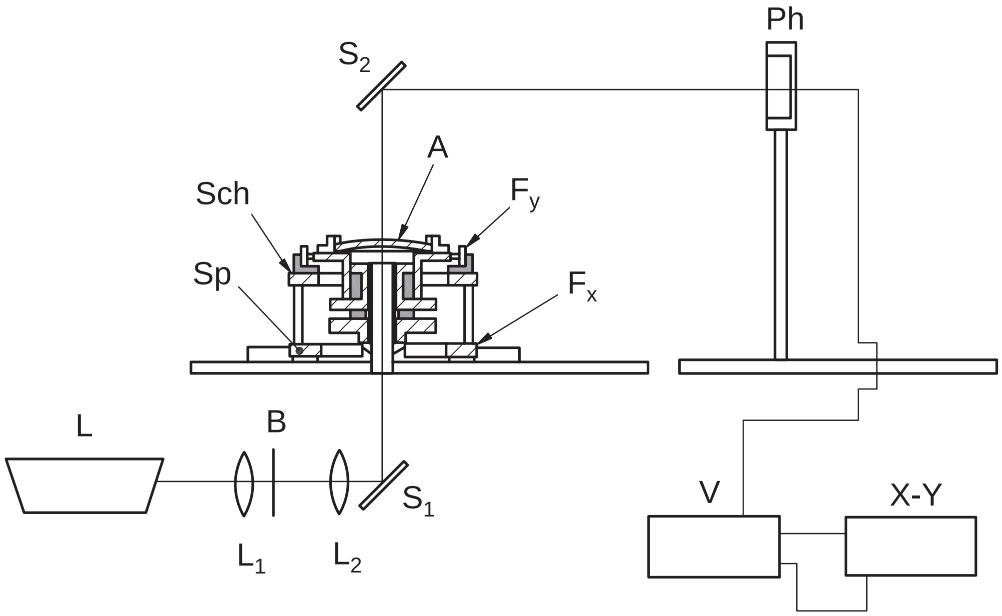
The 5 mm diameter laser beam continuously scans the area to be tested, centred on the reference point, or scans areas that have been identified as having local variations (see 6.2 in ISO 12312-1:2013). By appropriate markings, the position of the light beam on the filter and its deflection can be noted clearly. The entire measurement beam of 5 mm diameter shall lie within the measurement area of 20 mm diameter. A peripheral area 5 mm wide around the filter shall be excluded from the examination;

8.3.2.4 Position diode (see Figure 12), to measure the deflection of the laser beam (see Figure 11). On this photodiode (for example, PIN SC 25[2]) a rectangular system of coordinates is established by five electrical connections. When the centre connection, 5, is illuminated, the photocurrent of the remaining connections is equal. When the light spot moves over the sensitive surface, the photo-current of connections 1 to 4 changes according to the position of the light spot in relation to the centre.

The photocurrent of connection 5 remains constant and is directly proportional to the radiant flux.

The potential difference between the connections of one axis is proportional to the displacement on this axis as well as to the radiant flux. The photodiode has an active sensitive surface of 1,9 cm × 1,9 cm (minimum dimensions). In this apparatus, it can be positioned at distances between 50 cm and 250 cm from the test filter as required, so that, for a scanned area of 30 mm diameter, a refractive power up to a maximum of 2 m^{-1} can be measured.

8.3.2.5 Computer, to record the instantaneous position of the filter and corresponding position of the laser beam.



Key

L	laser, wavelength = (600 ± 70) nm
L_1, L_2	lenses
B	diaphragm, 0,1 mm nominal
S_1, S_2	deflection mirrors
Sp	spiral
Sch	carriage
F_x, F_y	guides in x and y directions
A	test sample
Ph	photo detector
V	preamplifier
X-Y	XY recorder

Figure 11 — Test apparatus for measuring spherical and astigmatic powers over small areas

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[2] PIN SC 25 is the trade name of a product supplied by UDT sensors Inc., Hawthorne, CA, USA. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

8.3.3 Test procedure

a) The filter is placed on the specimen carriage and the apparatus is started.

b) With a specimen having plane surfaces, the direction of the emergent light beam is independent of its position on the filter as the ray is not deflected when it passes through the filter. As a first approximation, the image on the recorder is therefore a point. With a curved afocal filter, the point can be slightly broadened because of light refraction at its surfaces. A filter with uniform refractive power (lens) has the same focal length at all points. Therefore the scanning path is reproduced either reduced or enlarged, depending on the refractive power (see Figure 13), without changing its form. The spiral scanning path is also drawn on the recorder as a spiral with constant distances between adjacent lines [see Figure 14 (a)].

c) Filters with astigmatic refractive power, i.e. different focal lengths in different meridians, give rise to an approximately elliptical curve, since the dimensions of the curve depend upon the refractive power which varies for the different meridians.

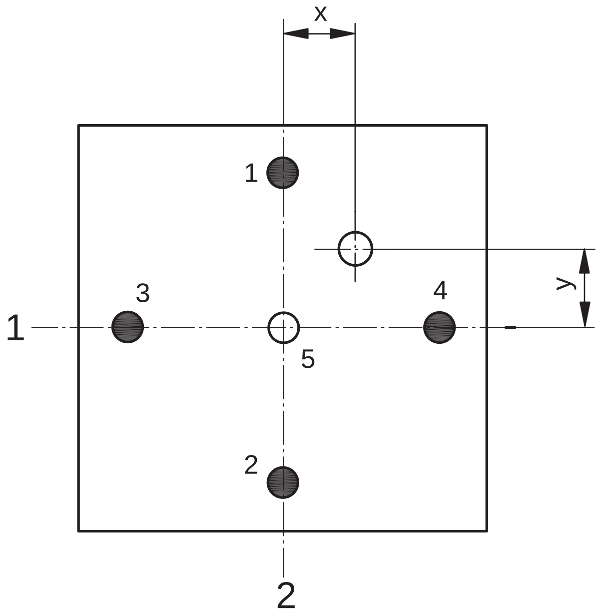
Since the dimensions of the curve depend on the refractive power, the distance from one line to the next is different for the different meridians and the spiral is therefore distorted [see Figure 14(b)].

Filters with irregularly varying focal lengths produce a deformed spiral path [see Figure 14 (c)]. From this distorted spiral the refractive powers at all points on the surface of the filter can be obtained by analysis.

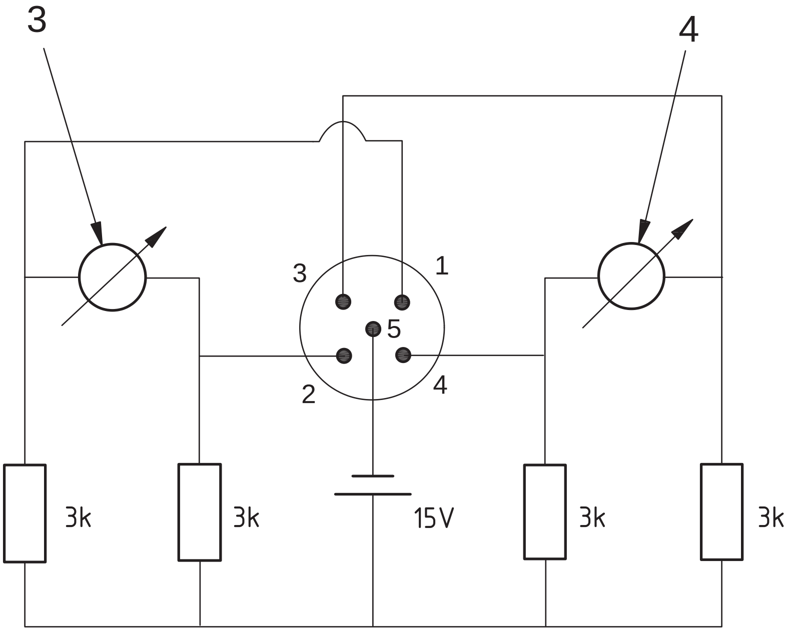
The apparatus can be calibrated using samples of known prismatic refractive power or by lateral displacement of the detector using a micrometer.

8.3.4 Verification and test report

The highest absolute values shall be determined of spherical and astigmatic power across the filter for a field of measurement of 20 mm in diameter, centred at the reference point of the filter. A marginal area 5 mm wide at the edge of the sunglass shall be disregarded. The measured quantities shall be given in the test report and compared with the limit values defined by ISO 12312 (all parts).



a) sketch of diode pin-layout

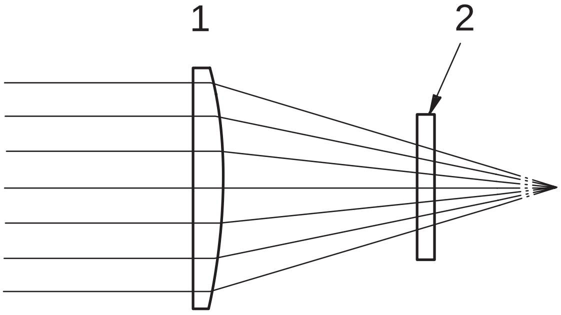


b) recording circuit

Key

1 x-axis
2 y-axis
3 xy recorder (y-axis)
4 xy recorder (x-axis)

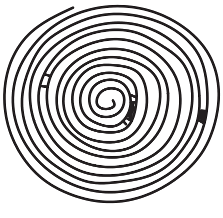
Figure 12 — Position sensing diode



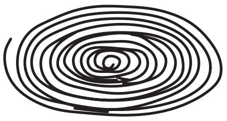
Key

1 test sample
2 measuring plane

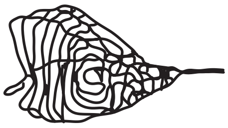
Figure 13 — Diagrammatic view of the image in the measuring plane



a) Refractive power without astigmatic refractive power



b) Refractive power with astigmatic power



c) Irregular refractive power

Figure 14 — Measuring curves for filters with different refractive properties

9 Test methods for mechanical properties

9.1 Test method for minimum robustness of filters

9.1.1 Principle

A static load (100 ± 2) N is applied on the test specimen.

9.1.2 Apparatus

9.1.2.1 Loading device

A steel ball of 22 mm nominal diameter is fastened to the lower end of a tube of 70 mm nominal length. This total loading mass is such that the force applied to the filter is (100 ± 2) N.

9.1.2.2 Specimen support

The support for the filter (see Figure 15) shall be a steel cylinder with an internal diameter of (35,0 ± 0,1) mm and an outside diameter of (41,0 ± 0,1) mm. The cylinder shall be inserted into, or be part of, a steel base.

The silicone gasket shall have a hardness of 40 ± 5 Shore A to IRHD per ISO 48, and shall be securely bonded to the support tube which shall be made of a rigid material.

If the specimen filter is of insufficient dimensions to enable its entire periphery to be adequately supported, suitable adaptor sleeves shall be used.

The pressure ring shall have a mass of (250 ± 5) g. By its weight, it presses the neoprene seating ring against the upper surface of the specimen.

A sheet of carbon paper on top of a sheet of white paper is placed on the supporting steel plate at the base of the 1,5 mm deep cavity.

9.1.3 Test procedure

Carry out the procedure as follows.

a) The central vertical axis of the loading tube shall be aligned with that of the specimen support.

b) The specimen shall be positioned on the support with the back surface downwards and the load ring shall be placed on the specimen. For curved filters with both surfaces being cylindrical or toroidal, the supporting plate may be curved to conform to the surface of the filter and the 3 mm thick seating ring may be flexed to match. The dimensions of 3,0 mm and 4,5 mm shall apply to the distance between the lowest point of the filter resting on the seating ring and the top of the supporting plate, i.e. the thickness of the seating ring, and the carbon paper respectively.

c) The position of the specimen shall be adjusted such that the load ring axis (9.1.2.1) passes through the boxed centre of the specimen.

d) The loading mass shall be lowered onto the filter at a speed not exceeding 400 mm/min. The force of (100 ± 2) N is maintained for (10 ± 2) s.

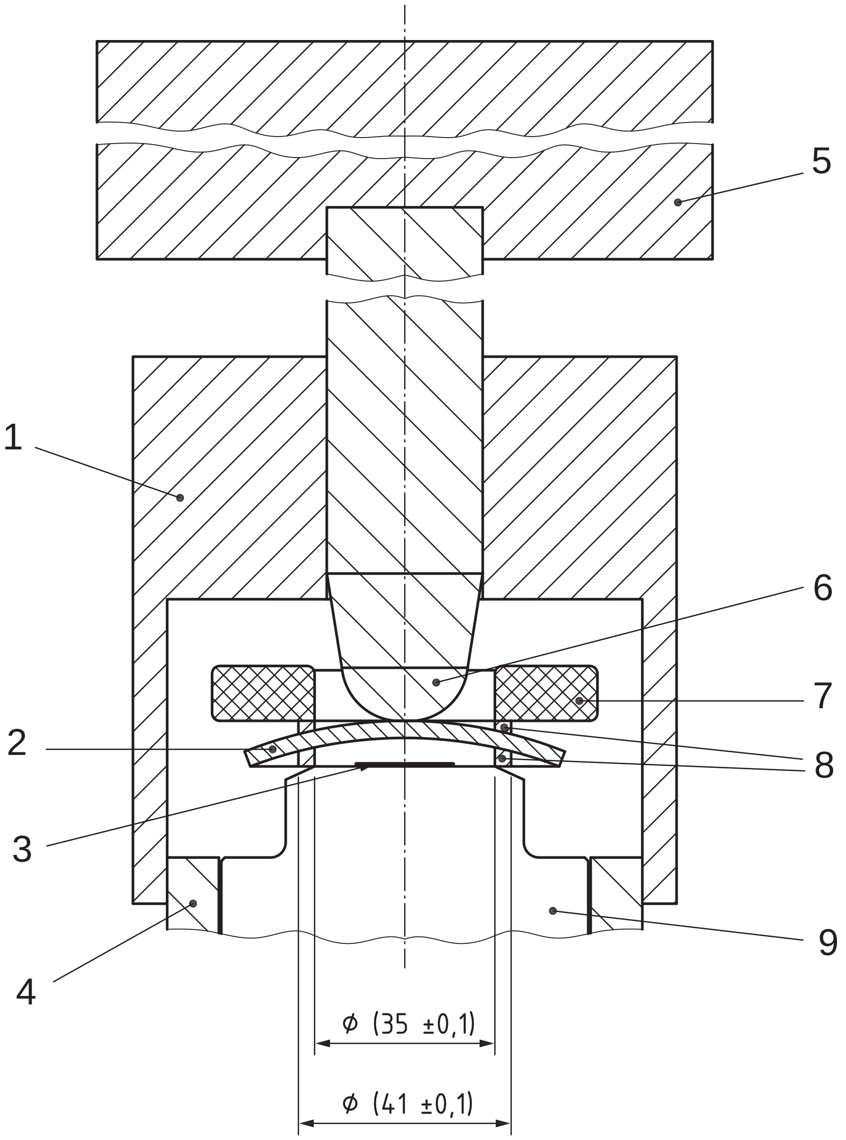
e) The loading mass is then removed.

Record whether the filter has fractured and/or the white paper is marked by the carbon paper.

9.1.4 Test report

Report whether filter fracture or white paper marking occurs.

Dimensions in millimetres



Key

1	guiding block
2	filter (can be curved)
3	carbon paper on white paper
4	centring ring
5	loading mass (100 ± 2) N
6	steel ball
7	pressure ring (250 ± 5) g
8	silicone seating rings (35×3×3)
9	support system

Figure 15 — Apparatus for minimum robustness (static deformation) test

9.2 Test method for impact resistance of filters, strength level 1

9.2.1 Principle

A 16 g steel ball is dropped through $\left(1{,}27^{+0{,}03}_{-0}\right)$ m onto a filter and the result is recorded.

9.2.2 Apparatus

9.2.2.1 Lens tube and test block (see Figure 16).

The test block shall be made of steel and is applicable to the majority of filters. However, if a diameter of the edged filter is less than 32 mm, a substitute support can be used whose outside diameter is equal to or less than the smallest diameter of the edged lens. The wall thickness of the support is a nominal 3 mm.

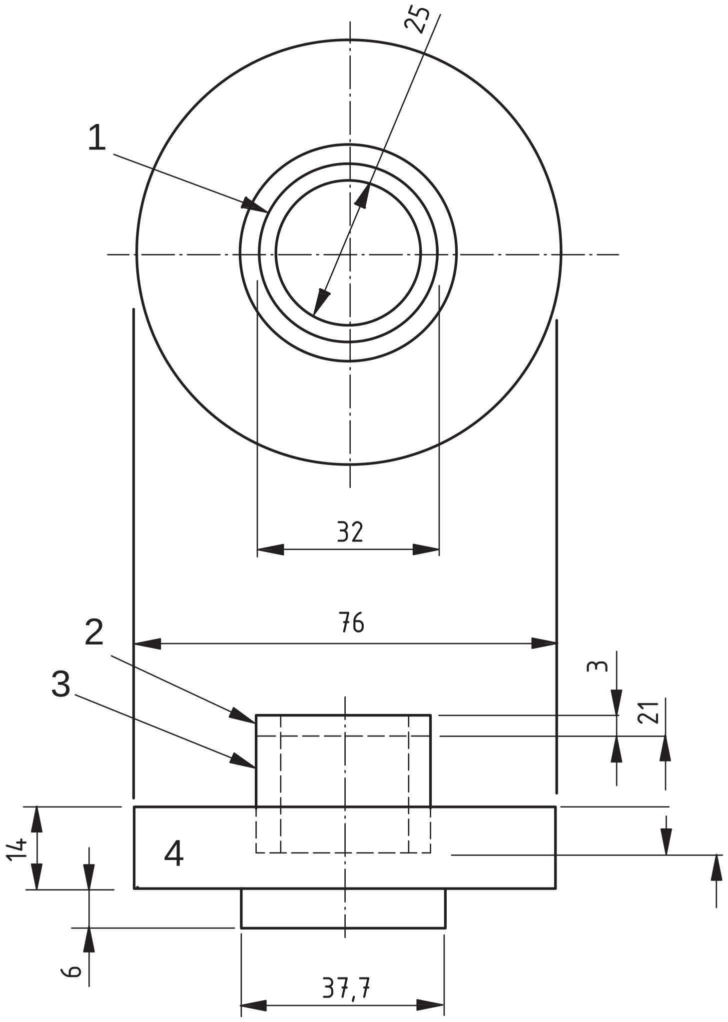
The neoprene gasket shall have a hardness of 40 ± 5 Shore A to IRHD, a minimum tensile strength of 8,274 kPa, and a minimum ultimate elongation of 400 %, and shall be securely bonded to the support tube which shall be made of a rigid material.

The test block is to be inserted in the base plate described in Figure 17.

9.2.2.2 Base plate, made of steel, as shown in Figure 17.

9.2.2.3 Steel test ball of nominal diameter 16 mm and mass not less than 16 g.

Dimensions in millimetres



Key

1	neoprene gasket
2	neoprene gasket
3	support tube
4	test block

NOTE Modification of the support tube may be made to accommodate non-spherical filter surfaces.

Figure 16 — Support tube and test block

Dimensions in millimetres

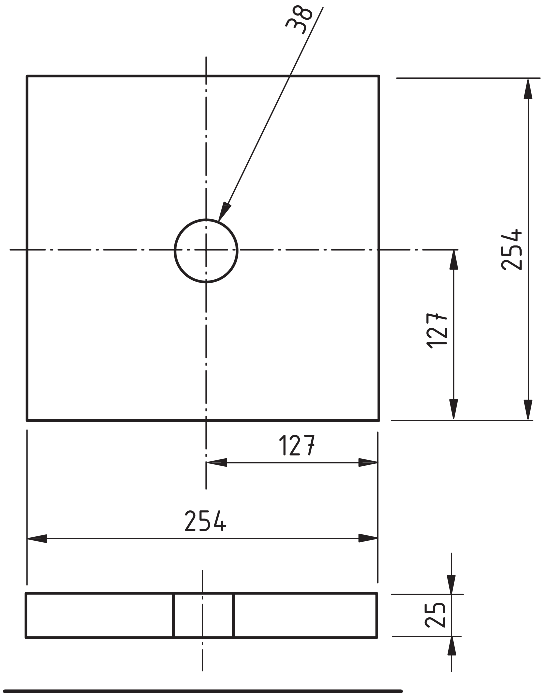


Figure 17 — Base plate

9.2.3 Test procedure

Carry out the procedure as follows.

- The filter shall be tested with its front surface uppermost and shall be supported by the method described in 9.2.1 to 9.2.2.
- A 16 mm diameter steel ball, weighing not less than 16 g shall be dropped in free fall from a height of $\left(1{,}27^{+0{,}03}_{-0}\right)$ m onto the front surface of the filter.
- The ball shall strike within a 16 mm diameter circle located at the boxed centre of the lens. The ball can be guided, but not restricted, in its fall by being dropped through a tube extending to within approximately 100 mm of the filter.

Record whether filter fracture occurs.

9.2.4 Test report

Report whether filter fracture occurs.

9.3 Test method for impact resistance of sunglasses, strength level 1

9.3.1 Principle

This procedure tests the ability of the sunglass, when mounted on a headform, to resist breakage or significant deformation under the impact of a 16 g steel ball dropped through $\left(1{,}27^{+0{,}03}_{-0}\right)$ m.

9.3.2 Apparatus

9.3.2.1 Headform, of a size appropriate to the specimen being tested and conforming to the description as indicated in Annex G. The headform shall be supported such that its central vertical (crown to neck) axis is horizontal and the face is uppermost. The headform shall be capable of being rotated continuously around its crown to neck axis, by not less than 90° either side of vertical (so that either side arm is uppermost).

NOTE If a justifiable reason exists, e.g. design for fitting a specific ethnicity or population group, the assessment should be carried out on an alternative headform designed to represent the specific target population.

9.3.2.2 **Steel ball**, of nominal diameter 16 mm and mass not less than 16 g.

9.3.2.3 **Pressure-sensitive material**, suitable for recording contact between the sunglass and the headform.

NOTE A combination of white paper and carbon paper may be suitable.

9.3.3 Test procedure

9.3.3.1 Position the headform face uppermost.

9.3.3.2 Apply the pressure-sensitive material to the headform to cover the area within the orbital rim of each eye.

NOTE Depending on the material used, it may be necessary to apply part of the material to the headform and part to the sunglass.

9.3.3.3 Place the specimen to be tested on the headform in the as-worn position and with the tension of the headband, if fitted, adjusted according to the manufacturer's instructions.

9.3.3.4 Allow the steel ball to fall from $(1{,}27\,^{+0{,}03}_{-0})$ m above the upper surface of the specimen so as to impact the specimen at the visual centre. If a guidance system is used, ensure that it does not touch the specimen or otherwise affect the results of the test.

9.3.3.5 Remove the specimen and note any damage as specified in ISO 12312-1.

9.3.3.6 Remove the pressure-sensitive material from the headform and inspect for evidence of impacts being transmitted to the eye area of the headform.

9.3.3.7 Repeat steps 9.3.3.2 to 9.3.3.6 for both eyes with the headform positioned appropriately.

9.3.4 Test report

Report the extent of any damage to the specimen as specified in ISO 12312-1 and whether or not there is evidence of impacts being transmitted to the eye area of the headform. Where the lens or filter contains several elements, the report shall refer to the rearmost element.

9.4 Test method for impact resistance of sunglasses, strength level 2

9.4.1 Principle

This procedure tests the ability of the sunglass, when mounted on a headform, to resist breakage or significant deformation under the impact of a 43 g steel ball dropped through $(1{,}27\,^{+0{,}03}_{-0})$ m.

9.4.2 Apparatus

9.4.2.1 **Headform**, of a size appropriate to the specimen being tested and conforming to the description given in Annex G. The headform shall be supported such that its central vertical (crown to neck) axis is horizontal and the face is uppermost. The headform shall be capable of being rotated continuously around its crown to neck axis, by not less than 90° either side of vertical (so that either side arm is uppermost).

NOTE If a justifiable reason exists, e.g. design for fitting a specific ethnicity or population group, the assessment should be carried out on an alternative headform designed to represent the specific target population.

9.4.2.2 Steel ball, of nominal diameter 22 mm and mass not less than 43 g.

9.4.2.3 Contact-indicative material, of a sufficient quantity for recording contact between the eye protector and the headform.

NOTE Suitable materials for recording contact may be contact indicator paste, pressure-sensitive media or a combination of white paper and carbon paper.

9.4.3 Test procedure

9.4.3.1 Position the headform face uppermost.

9.4.3.2 The contact-indicative material is applied to the headform to cover the area within the orbital rim of each eye.

9.4.3.3 Place the specimen to be tested on the headform in the as-worn position and with the tension of the headband, if fitted, adjusted according to the manufacturer's instructions.

9.4.3.4 Allow the steel ball to fall from $\left(1{,}27\,^{+0{,}03}_{-0}\right)$ m above the upper surface of the specimen so as to impact the specimen at the visual centre. If a guidance system is used, ensure that it does not touch the specimen or otherwise affect the results of the test.

9.4.3.5 Remove the specimen and note any damage as specified in ISO 12312-1.

9.4.3.6 Inspect the sunglass for evidence of contact (if using contact-indicative paste) or remove and inspect the pressure-sensitive media for evidence of impacts being transmitted to the eye area of the headform.

9.4.3.7 Repeat steps 9.4.3.2 to 9.4.3.6 for both eyes with the headform positioned appropriately.

9.4.4 Test report

Report the extent of any damage to the specimen as specified in ISO 12312-1 and whether or not there is evidence of impacts being transmitted to the eye area of the headform.

Where the lens or filter consist of several elements, the report shall refer to the rearmost element.

9.5 Test method for impact resistance of sunglasses, strength level 3

9.5.1 Principle

This procedure tests the ability of the sunglass, when mounted on a headform, to resist breakage or significant deformation under the impact of a steel ball of nominal diameter 6 mm travelling at a specified high speed.

9.5.2 Apparatus

9.5.2.1 Headform

The headform shall be of a size appropriate to the specimen being tested and conform to the description given in Annex G. The headform shall be supported such that its central vertical (crown to neck) axis is both vertical and normal to the barrel of the apparatus. The headform shall be capable of being rotated continuously around its vertical axis to not less than 90° either side of the axis of the barrel. The headform shall be capable of being raised and lowered vertically such that its upper and lower extremes can be aligned with the axis of the barrel and moved sideways.

NOTE If a justifiable reason exists, e.g. design for fitting a specific ethnicity or population group, the assessment should be carried out on an alternative headform designed to represent the specific target population.

9.5.2.2 Projectile propulsion

The apparatus consists of a horizontal barrel, with a breech or ball-loading mechanism, and a supply of compressed gas to propel the ball. The arrangement ensures that the ball impacts the specimen at the required position and speed $\left(45^{+1,5}_{-0}\right)\text{m/s}$. The projectile shall be a steel ball of 6 mm nominal diameter and 0,86 g mass. The barrel shall be of sufficient length to ensure a reproducible exit speed of the steel ball.

The end of the barrel or tube should be protected against ricochets.

The area surrounding the test specimen, the headform and the exit point from the barrel should be enclosed.

It is not possible to define precise requirements for the length of barrel and the bore diameter because these vary according to the design of each apparatus and the characteristics of the gas supply used for propulsion.

9.5.2.3 Projectile speed measurement

The apparatus shall include a means of measuring the speed of the ball to within an accuracy of ± 1,0 %, typically after it exits the barrel, and certainly no further than 250 mm from the point of impact. The timer shall record in multiples of not more than 10 µs.

A suitable method uses an electronic timer operated by signals from photodetectors as the ball passes by them. The distance between the photodetectors should be known accurately and not exceed 150 mm.

9.5.2.4 Pressure-sensitive material

The pressure-sensitive material shall be of a suitable quantity for recording contact between the sunglass and the headform.

NOTE A combination of white paper and carbon paper may be suitable.

9.5.3 Test procedure

9.5.3.1 The headform is positioned in front of the propulsion equipment such that the point of impact is as specified in ISO 12312-1.

9.5.3.2 The pressure-sensitive material is applied to the headform to cover the area within the orbital rim of each eye.

Depending on the material used, it might be necessary to apply part of the material to the headform and part to the sunglass.

The specimen to be tested is placed on the headform in the as-worn position and with the tension of the headband, if fitted, adjusted according to the manufacturer's instructions.

9.5.3.3 The steel ball is projected at the visual centre.

9.5.3.4 The specimen is removed and any damage as specified in ISO 12312-1 is noted.

9.5.3.5 Inspect the eye protector for evidence of contact (if using contact-indicative paste) or remove and inspect the pressure-sensitive media for evidence of impacts being transmitted to the eye area of the headform.

9.5.3.6 Repeat steps 9.5.3.2 to 9.5.3.6 for both eyes with the headform positioned accordingly.

9.5.4 Verification and test report

The extent of any damage to the specimen, and whether or not there is evidence of impacts being transmitted to the eye area of the headform, is reported.

Where the lens or filter contains several elements, the report shall refer to the rearmost element.

9.6 Test method for frame deformation and filter retention

9.6.1 Principle

This procedure tests the ability of the complete sunglass to resist deformation and to retain the filters.

9.6.2 Apparatus

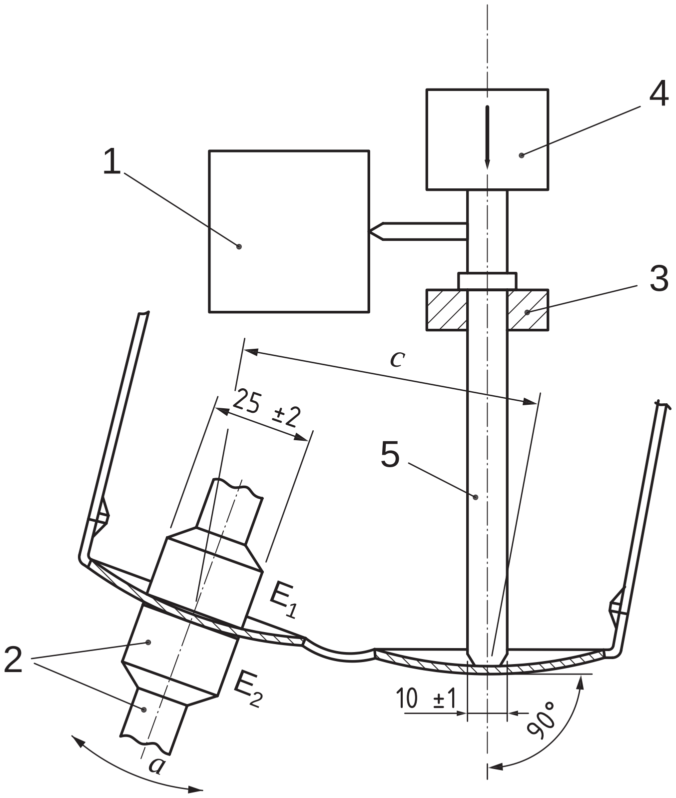
9.6.2.1 Vertically operating annular clamp, capable of holding the test sample without twist or slip and having a diameter of (25 ± 2) mm, with two contact surfaces, E_1 and E_2, made of a firm elastic material (e.g. polyamide).

9.6.2.2 Downward operating pressure peg (see 5 in Figure 18), having a diameter of (10 ± 1) mm with the contact surface an approximate hemisphere.

The clamping surfaces are capable of at least 10 mm separation equidistant either side of a horizontal line through the apparatus and the pressure peg is capable of travel from at least 10 mm above the horizontal line to not more than 8 mm below. To accept sunglasses with significant face form angle, the annular clamp shall also be capable of rotation about a horizontal axis so that the axis of the pressure peg remains perpendicular to the plane of the unclamped lens at its boxed centre. The distance between the clamp and pressure peg is adjustable.

9.6.2.3 Measuring device, having an accuracy better than 0,1 mm.

The test set-up is shown in Figure 18.



Key

1	measuring device
2	annular clamp
3	travelling ring
4	direction and point of application of force (maximum 5 N)
5	pressure peg D
E_1, E_2	contact surfaces
a	adjustment

Figure 18 — Illustration of frame deformation and filter retention test

9.6.3 Procedure

Mount the sunglass complete with its filters on the device with the sides of the test sample extended and with the front of the test sample downwards. Clamp the sample, if fitted with separate filters for each eye, within a tolerance of 2 mm at the boxed centre of one filter. For a sunglass fitted with a single filter covering both eyes, the clamping and reference points are positioned 64 mm apart, or as specified by the manufacturer (see Figure 19).

Lower the pressure peg so that it rests on the back surface of the unclamped filter within 2 mm of its boxed centre, ensuring that there is no movement of the lens. Record this as the starting position.

Then move the pressure peg downwards slowly and smoothly, applying an increasing force until the first of either of the following criteria is reached:

a) a maximum force of 5 N;

b) a distance equal to 10 % of the distance *c* between the reference points or, for single filters covering both eyes, a distance equal to 10 % of 64 mm or the distance specified by the manufacturer (see ISO 4007).

NOTE If the maximum force of 5 N is insufficient to displace the pressure peg by the distance specified in b), continue the test but record the displacement that was attained.

Retain the initial displacement for 5 s and then return the pressure peg to its starting position. After a relaxation period of 20 s, again lower the pressure peg until it just rests on the filter.

Determine, in millimetres, the movement, x, of the pressure peg from the starting position and calculate the percentage deformation using the following formula. Check that the sunglass frame shows no fracture.

$$f = \frac{x}{c} \times 100$$

where

f is the percentage deformation;

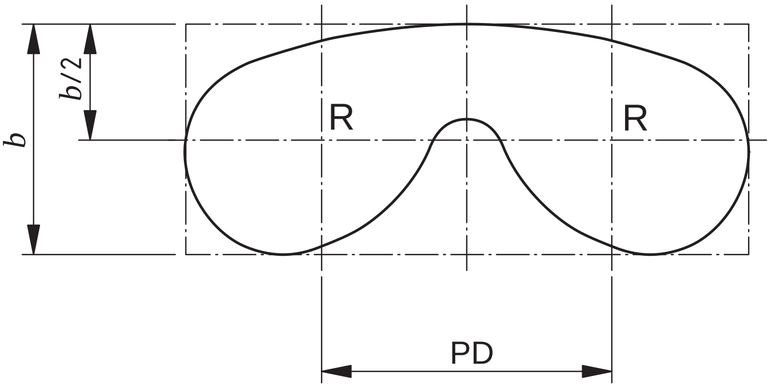
x is the movement of the pressure peg;

c is the distance between the reference points.

Sunglass frames shall be inspected without the aid of a magnifying lens by an observer with a visual acuity of at least 1,0, when tested using optotypes conforming to ISO 8596. Any visual correction required for the observation distance shall be worn.

During the examination, expose the test specimen to an illuminance of 1 000 lx to 2 000 lx and carry out the inspection against a matt black background.

Confirm that neither test lens has been dislodged wholly or partially from its original location in the groove or mount.



Key

R reference points

b distance between the tangents to the top and bottom of the filter

PD the specified interpupillary distance

Figure 19 — Determination of the reference points for filters

9.6.4 Verification and test report

Report whether the deformation of the sunglass exceeded 2 % of the distance between the reference points, whether the maximum load of 5 N achieved the distance specified in 9.6.3, whether the frame shows any fracture or crack and whether either filter has been dislodged wholly or partially from its original location in the groove or mount.

9.6.5 Uncertainty of measurement

An estimate of the uncertainty of measurement associated with this method of test shall be established in accordance with ISO/IEC Guide 98-3. The value of this estimate shall not exceed ± 10 %. See also Annex A.

NOTE The use of transfer standards may assist in establishing common uncertainties of measurement between laboratories.

9.7 Test method for increased endurance of sunglasses

9.7.1 Principle

The test aims to simulate the strains on the sunglass frame, particularly the joints, when putting the sunglasses on or off. The end of one side is clamped to restrain lateral, but not rotational movement, while the end of the other is rotated through a circle of diameter 60 mm. The bridge is supported, but not clamped, by an artificial nose to restrict movement of the frame.

9.7.2 Apparatus

9.7.2.1 Two clamping devices, mounted on universal joints, which are used to restrain the sides (see Figures 21 and 22).

9.7.2.2 Horizontal bar, forming a bridge support. The bridge support has a triangular cross section, enclosing an angle of (30 ± 2)°, having a thickness at the top of (12 ± 1) mm with the upper edge approximately radiused (see Figure 20).

The positions of the clamps and bridge support, relative to each other, are adjustable by at least 40 mm horizontally and vertically.

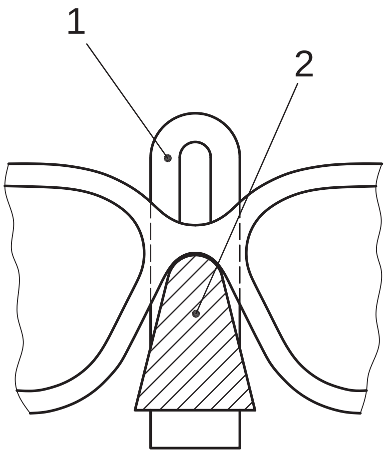
The universal joints shall not restrict the angular movement of the sides. The clamping point, defined as the edge of the clamp nearest the dowel screw centre, shall be (55 ± 1) mm from the centre of the pivot of the universal joint.

The apparatus is capable of continuously and smoothly imparting a cyclical motion to one of the universal joints of:

- down (30 ± 0,5) mm
- out (60 ± 1,0) mm
- up (30 ± 0,5) mm

at a rate of 40 cycles·min^{-1}, with the other clamped side remaining fixed, except for the flexure of the universal joint.

NOTE For testing in frame development, manufacturers may modify the test equipment so that either the right or the left side may be subject to the cyclical motion, the other remaining fixed.



Key

1 vertical support with slot to facilitate height adjustment

2 horizontal bar, located through a slot in the vertical support

Figure 20 — Detail of adjustable bridge support for endurance test rig

9.7.3 Procedure

9.7.3.1 Before mounting the test sample on the test apparatus, establish the clamping and measuring points.

For curl sides, ensure that the clamping points are (3 ± 1) mm nearer to the dowel screw than the join between curl and the rigid side. Each measuring point shall be (10 ± 1) mm nearer to the dowel screw than the clamping point.

9.7.3.2 Before testing, open the sides of the sunglass frame to the fullest extent, without tension, and measure the distance between the sides at the pre-determined measuring points. Record this distance, d_1.

Mount the sunglass frame on the test device, and ensure:

a) that the rotating clamp (5) is on the same plane as fixed clamp (4) and that it is positioned at the nearest point of its rotation towards fixed clamp (4) (see Figure 22);

b) that the bridge of the sunglass frame is freely supported on the bridge support (6) (see Figure 20);

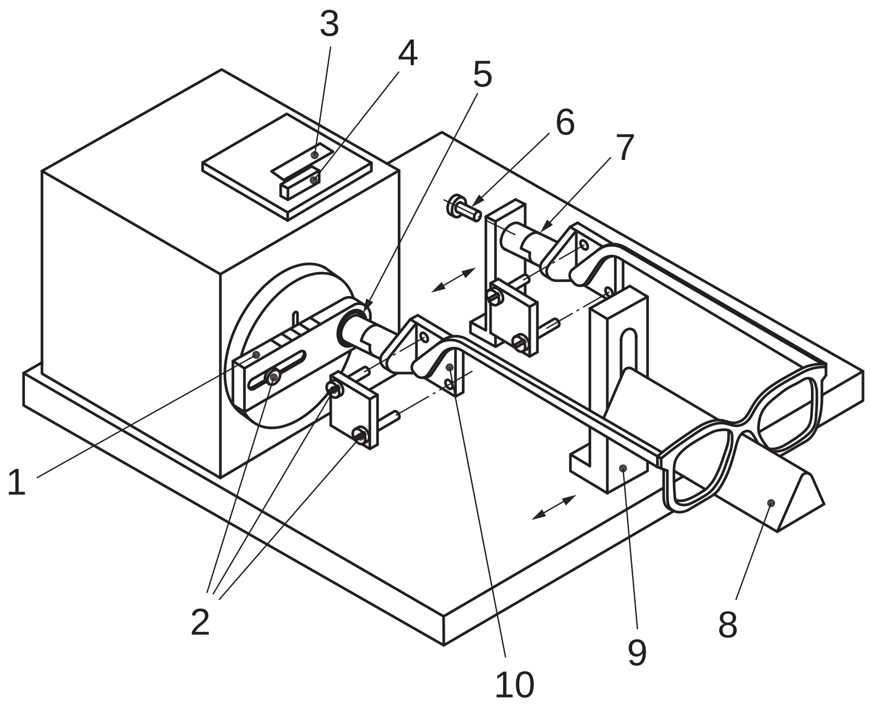
c) that the horizontal relationship between clamp (4), the bridge support (6) and clamp (5) are such that the sunglass frame can be mounted with sides fully open, but not under tension, and with the bridge support midway between the clamps (see Figure 22);

d) that the height of the bridge support is adjusted so as to ensure that the sides are in line with the axis of the clamps and parallel to the base of the device;

e) that the sides are clamped within 1 mm of the calculated clamping point;

f) that the lockscrew (6) is loosened to allow the fixed clamp to align with the inward angle of drop of the side, and then re-tightened (see Figure 21);

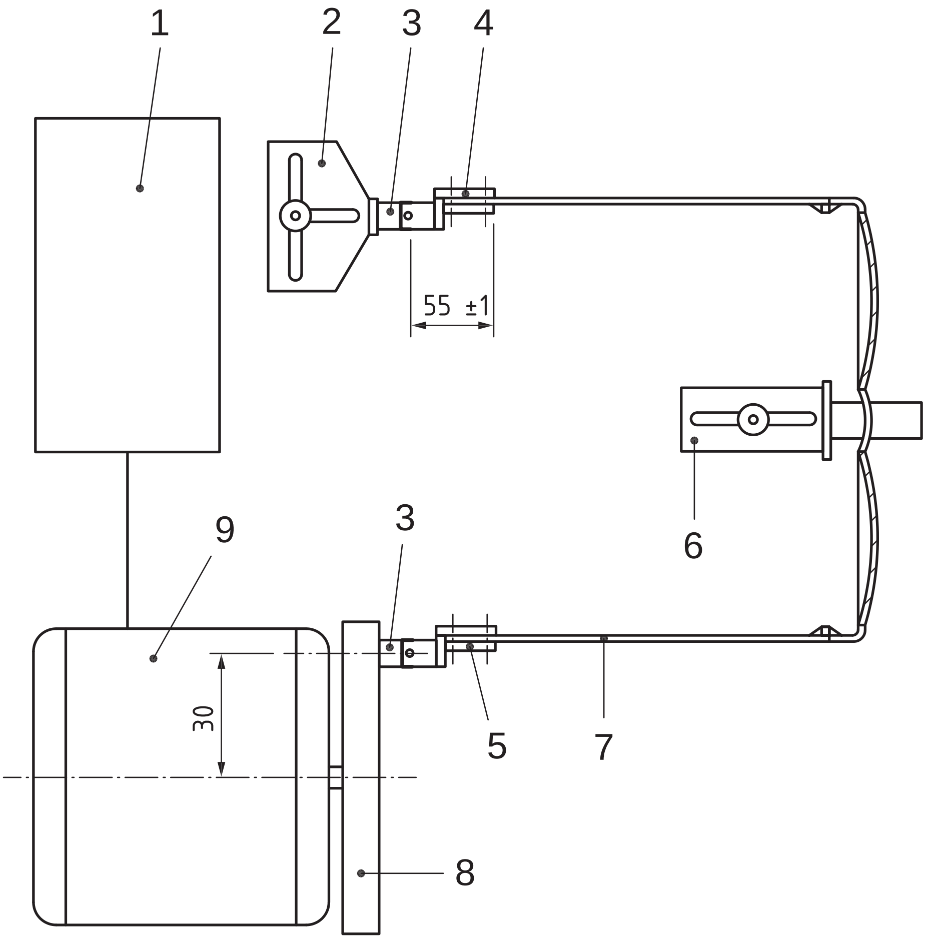
g) that the revolution counter is set to zero (see Figure 22).



Key

1	frame displacement amplitude scale
2	finger screws
3	counter window
4	control switch
5	ball bearing
6	lockscrew
7	universal joint
8	adjustable sunglass bridge support
9	adjustable bracket to match various sunglass frame sizes
10	clamping point

Figure 21 — General test arrangement showing clamping device



Key

1	control panel and counter
2	side clamp adjustment
3	universal joint
4	fixed clamp
5	rotating clamp
6	adjustable sunglass frame bridge support assembly
7	test sample
8	rotating disc
9	geared motor

Figure 22 — Diagram of typical test apparatus

9.7.3.3 With the test sample, complete with its filters, in position, set the apparatus in motion, subjecting the sample to the cyclical rotating movement described in 9.7.2.2 for a total of (500^{+1}_{0}) cycles.

After the 500 cycles have been completed, stop the motion and remove the sample from the apparatus. Measure the distance between the sides at the measuring point and record the distance, d_2, in millimetres.

The sunglass frames shall be inspected, without the aid of a magnifying lens, by an observer with a visual acuity of at least 1,0, when tested using optotypes conforming to ISO 8596. Any visual correction required for the observation distance shall be worn.

During the examination, expose the test specimen to an illuminance of 1 000 lx to 2 000 lx and carry out the inspection against a matt black background.

Record any fracture, cracks or change in side movement (see ISO 12312-1).

9.7.4 Verification and test report

Report on whether or not the difference between d_1 and d_2 exceeds 5 mm and whether the sunglass frame shows any fracture, cracks or change in side movement.

9.7.5 Uncertainty of measurement

An estimate of the uncertainty of measurement associated with this method of test shall be established, as described in ISO/IEC Guide 98-3. The value of this estimate shall not exceed ± 0,5 mm (see also Annex A).

NOTE The use of transfer standards may assist in establishing common uncertainties of measurement between laboratories.

9.8 Test method for resistance to solar radiation

9.8.1 Principle

Sunglass filters are exposed to irradiation from a specified source and distance for a specified amount of time. The transmittance and wide angle scatter of these filters are measured before and after exposure to determine their resistance to fading.

9.8.2 Apparatus

9.8.2.1 Fused-silica envelope high-pressure xenon ozone free lamp with power of (450 ± 50) W.

NOTE Suitable lamp references are XBO-450 OFR and CSX-450 OFR[3].

a) New lamps shall be burned in for at least 150 h.

b) The lamp shall not be used after 2 000 h of operation.

c) An irradiation time of (50 ± 0,1) h shall be used.

d) A cut-on filter shall be applied (e.g. a clear white crown glass, such as Schott B270[3], with a thickness of 4 mm) between the lamp and the sample. The spectral transmittance data for the cut-on filter are given in Annex J and illustrated in Figure 23. A shift of ± 5 nm is permitted as shown by the dotted and dashed lines in Figure 23.

e) The lamp current shall be stabilized at (25 ± 0,2) A.

f) The air temperature in the immediate area of the test specimen shall be (28 ± 5) °C.

NOTE Other power high-pressure xenon lamps may be used with the following limitations:

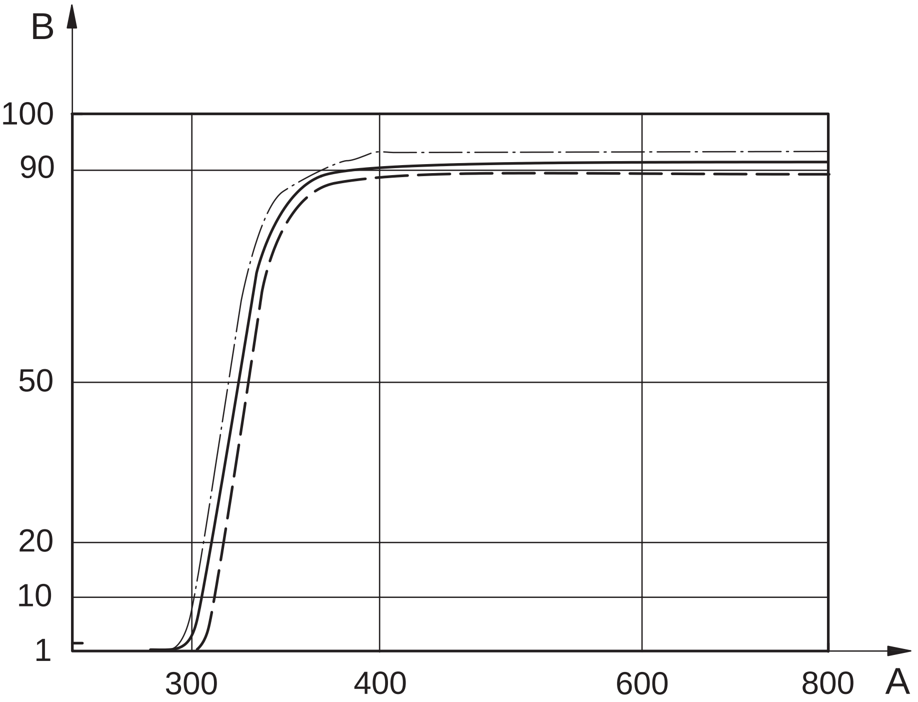
— irradiation time shall not be greater than 50 h or less than 10 h;

— there shall be no irradiation at wavelengths of less than 280 nm (use of cut-on filter);

— items a), b), d) and f) shall be respected.

---

[3] XBO-450 OFR is the trade name of a product supplied by OSRAM. CSX-450 OFR is the trade name of a product supplied by PHILLIPS. Schott B270 is the trade name of a product supplied by SCHOTT. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.



Key

solid line	nominal value
dotted line	upper limit
dashed line	lower limit
A	wavelength in nm
B	spectral transmittance in %

NOTE The cut-on λ_c = 320 nm is defined at the wavelength at which $\tau\lambda_c$ = 46 %. This point shall be (320 ± 5) nm.

Figure 23 — Spectral transmittance of cut-on filter

9.8.3 Test procedure

Carry out the procedure as follows.

a) Measure the luminous transmittance τ_v according to 7.1.2 (and other transmittances to be checked as described in 7.2 to 7.8) and wide angle scatter according to 7.9.

b) Expose the front surface of the filter to radiation from the lamp.

c) Ensure that the angle of incidence of the radiation on the specimen surface is essentially perpendicular.

d) The distance from the axis of the lamp to the nearest point on the sample shall be (300 ± 10) mm.

NOTE It is deemed that the required irradiation will be fulfilled, without calibration or further verification, provided that the specified apparatus and methods are applied. A variation of the irradiation of up to 30 % can be observed between various lamps, according to the age of lamps or of the supplier.

e) Measure the luminous transmittance τ_v according to 7.1.2 (and other transmittances to be checked as described in 7.2 to 7.8) and wide angle scatter according to 7.9, after exposure.

9.8.4 Verification and test report

In accordance with solar resistance requirements (ISO 12312-1:2013, Clause 8), report relative change in luminous transmittance, new wide angle scatter value, new UV-transmittances in accordance with the initial τ_V, and other additional transmittance(s) claimed by the manufacturer after solar radiation exposure. For photochromic filters, report the new value of the ratio τ_0/τ_1.

9.9 Test method for resistance to ignition

9.9.1 Principle

This procedure tests the ability of the sunglass to resist ignition.

9.9.2 Apparatus

9.9.2.1 Steel rod, (300 ± 3) mm long and 6 mm nominal diameter with end faces which are flat and perpendicular to its longitudinal axis.

9.9.2.2 Heat source.

9.9.2.3 Thermocouple and temperature indicating device.

9.9.2.4 Timer, capable of measuring an elapsed time of 10 s with a resolution of ± 0,1 s.

9.9.3 Test procedure

a) Heat at least 50 mm length of one end of the steel rod to a temperature of (650 ± 20) °C.

NOTE The temperature of the rod is measured by means of the thermocouple attached at a distance of (20 ± 1) mm from the heated end of the rod. Systematic measurement of the rod temperature before each contact with the test sample is not required as the cooling curve (temperature versus time) of the heated end of the rod is known.

b) Press the heated face of the rod (long axis vertical) against the surface of the test sample (the contact force being equal to the weight of the rod) for a period of not less than 5 s, and then remove it. Record during the test whether the specimens ignite or continue to glow.

c) Perform the test on all externally exposed parts of the sunglass except any elastic headband or textile edging.

9.9.4 Test report

Report whether or not the specimens ignite or continue to glow.

9.9.5 Uncertainty of measurement

This test method does not require a quantitative measurement to be reported. Consequently, an estimate of uncertainty of measurement is not given here.

9.10 Test for resistance to perspiration of the sunglass frame

9.10.1 Principle

Complete sunglasses are exposed to an artificial sweat and then inspected for flaws.

9.10.2 Apparatus and reagents

9.10.2.1 Oven, capable of producing the test temperature of (55 ± 5) °C.

9.10.2.2 Container, of glass or inert plastic of minimum dimensions 200 mm across and height of 90 mm, capable of being closed.

9.10.2.3 Volumetric flask, 1 l, gauged to class A of ISO 1042:1998

9.10.2.4 Water, conforming to Grade 3 of ISO 3696:1987.

9.10.2.5 Artificial sweat solution, comprising:

a) lactic acid, $\rho = 1{,}21$ g/ml, > 85 % purity;

b) sodium chloride (analytical reagent purity ≥ 99 %).

Impurities:

- Pb: ≤ 0,001 0 %
- Fe: ≤ 0,001 0 %
- Br: ≤ 0,020 0 %
- I: ≤ 0,010 0 %;

c) water, conforming to Grade 3 of ISO 3696:1987.

Using suitable containers, weigh an amount of lactic acid solution to have (50 ± 0,1) g of lactic acid [9.10.2.5 a)] and (100 ± 0,1) g of sodium chloride [9.10.2.5 b)] and dissolve in 900 ml of water (9.10.2.4). Using the flask (9.10.2.3), make up to 1 l with water.

9.10.2.6 Sunglasses frame supports, of glass or inert plastic, fitted in the container to enable the sample sunglasses to be held above the artificial sweat solution. The supports can be designed to hold several sample sunglasses stacked one above another, or side by side, or both, but without contact with each other.

9.10.3 Procedure

9.10.3.1 Cover the base of the container (9.10.2.2) with the artificial sweat solution (9.10.2.5) to a minimum depth of 10 mm so that the lowest part of the (lowest, if stacked) frame shall be not less than 12 mm above the solution.

Place the sunglass, complete with its filters, on the supports (9.10.2.6), with the sides open to the fullest extent (for frames with sprung hinges, opened to the fullest natural extent without activating the spring mechanism), and with the bottom edges of the sides resting on the supports (see Figure 24). Ensure that the sunglass frame does not touch other samples or the container walls.

Close the container, place it in the oven (9.10.2.1) and maintain at (55 ± 5) °C.

9.10.3.2 After (8,0 ± 0,5) h, remove each sample and immediately wash with water (9.10.2.4) and then dry without rubbing, using a soft cloth.

9.10.3.3 Within 30 min, examine each test sample using the inspection conditions described in 9.10.3.6. By comparison with an identical untested sunglass frame, check for and record any spots or change in colour (excluding a loss of gloss to the surface) anywhere on the frame, excluding joints and screws).

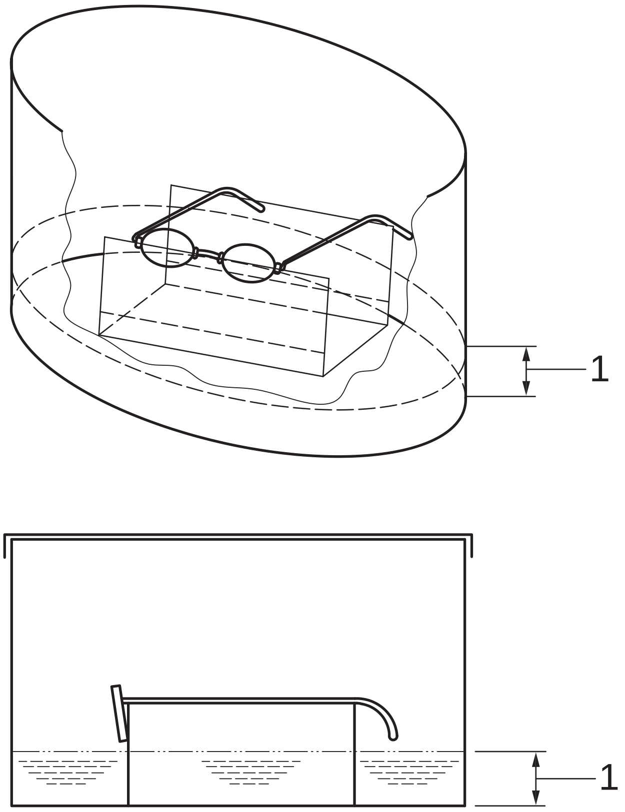
9.10.3.4 Replace the test samples on the supports, close the container and maintain the test temperature of (55 ± 5)°C for a further (16,0 ± 0.5) h. After completion of this second period, remove, clean and dry the samples as described in 9.10.3.2.

9.10.3.5 Within 30 min, examine those areas of each sample which are liable to come into prolonged contact with the skin of the wearer, using the inspection conditions described in 9.10.3.6. By comparison with an identical untested sunglass frame, check for and record any corrosion, surface degradation or separation of any coating layer on the parts liable to come into prolonged contact with the skin during wear, i.e. the insides of the sides, bottom and lower parts of the rim and the inside of the bridge.

NOTE If the sunglass frame is made from natural materials and the manufacturer recommends a cream or wax for its maintenance, then before testing, the sunglass frame(s) shall be prepared with this cream or wax according to the manufacturer's instructions. At the end of the test when the sunglass frame is checked for colour change or surface degradation, if the sunglass frame fails this requirement, use the cream or wax and wait for one day before checking again for colour change or surface degradation. If the frame has recovered its original appearance, the sunglass frame is considered to have passed the test; if the frame remains discoloured, the frame is considered to have failed the test.

9.10.3.6 The sunglass frames shall be inspected without the aid of a magnifying lens by an observer with a visual acuity of at least 1,0, when tested using optotypes conforming to ISO 8596. Any visual correction required for the observation distance shall be worn.

During the examination, expose the test specimen to an illuminance of 1 000 lx to 2 000 lx and carry out the inspection against a matt black background.



Key

1 artificial sweat

Figure 24 — Diagram of typical sunglasses frame support

9.10.4 Verification and test report

Report, regarding the sunglass frame only:

— any spots or change in colour (excluding a loss of gloss to the surface) anywhere on the frame, excluding joints and screws, after 8 h,

— any corrosion, surface degradation or separation of any coating layer on the parts liable to come into prolonged contact with the skin during wear, i.e. the insides of the sides, bottom and lower parts of the rim and the inside of the bridge, after 24 h,

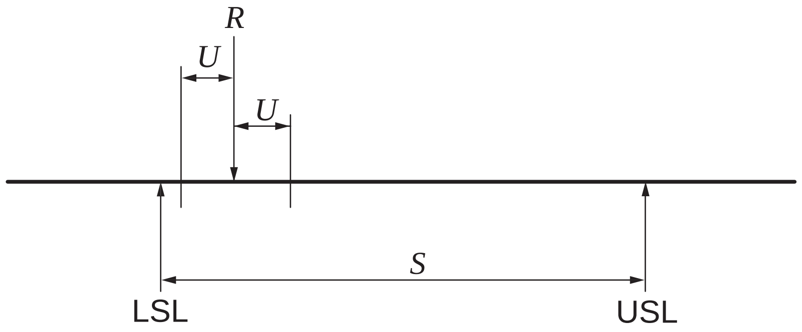
by comparison with an untested sunglass.

Annex A
(normative)

Application of uncertainty of measurement

In order to determine compliance or otherwise of the measurement made in accordance with the test methods when compared to the specification limits given in ISO 12312 (all parts), the following protocol shall be applied.

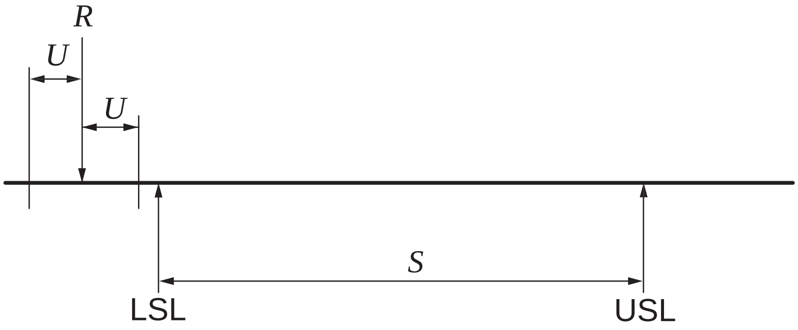
If the test result plus or minus the uncertainty of measurement, *U*, falls completely inside or outside the specification zone for the particular test given in the protective device standard, then the result shall be deemed to be a straightforward pass or fail (Figures A.1 and A.2).



Key

R	result of a measurement
S	specified performance guidelines
LSL	lower specified limit
USL	upper specified limit
U	uncertainty of measurement

Figure A.1 — Result pass

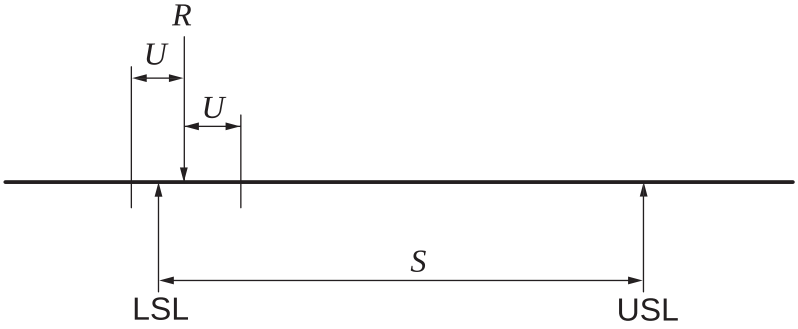


Key

R	result of a measurement
S	specified performance guidelines
LSL	lower specified limit
USL	upper specified limit
U	uncertainty of measurement

Figure A.2 — Result fail

If the test result plus or minus the uncertainty of measurement, *U*, overlaps a specification limit value (upper or lower) for the particular test given in the protective device standard, then the assessment of pass or fail shall be determined on the basis of safety for the wearer of the device; that is, the result shall be deemed to be a failure (Figures A.3).



Key

R	result of a measurement
S	specified performance guidelines
LSL	lower specified limit
USL	upper specified limit
U	uncertainty of measurement

Figure A.3 — Result fail

Annex B
(informative)

Sources of uncertainty in spectrophotometry and their estimation and control

B.1 General

There are many appropriate methods and instruments for measuring spectral transmittance of sunglasses and related eyewear. There is no instrument or technique which can be singled out as particularly superior. Accordingly, the approach in this International Standard is to specify maximum uncertainties of measurement acceptable in this context.

The methods of evaluating the components of uncertainty are set out in ISO/IEC Guide 98-3. This annex addresses the issues of sources of uncertainty in spectrophotometry, their minimization and evaluation.

The issues are the same regardless of the wavelength region used or the calculation that the spectral transmittance data are subsequently used in (e.g. to calculate luminous transmittance, ultraviolet transmittance, colour, Q_{signal}).

B.2 Principles of spectrophotometers

Spectrophotometers are generally described as:

a) one beam or two beam;

b) scanning or diode array;

c) ratio recording or null-point;

d) single or double monochromator;

e) monochromatic illumination or polychromatic illumination.

In a single-beam instrument there is only a single sample position. The measurement result is obtained from sequential comparison of the transmissions of the sample and an open beam. For greatest accuracy, the sample and open beam measurements should be made as close as possible to one another.

In a double-beam instrument, the measurement result is obtained from a simultaneous comparison of the sample transmission with the reference transmission; hence the sample is placed in one of two separate light paths. Measurement is effected either by simultaneous direction of the light through the two paths onto two detectors, or by alternate transmission of light from the two paths to a single detector, at a frequency sufficiently high to effectively simulate simultaneous comparison.

A scanning instrument makes measurements successively though the spectrum as the wavelength of the beam is altered.

A diode-array spectrophotometer disperses the beam onto an array of photodiodes to measure at selected wavelengths simultaneously. Diode array instruments are usually single beam and always use polychromatic illumination.

Ratio recording spectrophotometers measure the amplitude of the signal generated by the alternation between sample and open reference beam. The electronics of the amplifier determines the linearity of response.

Null-point spectrophotometers introduce a variable attenuator into the reference beam until the difference in signal with the sample beam is removed. The characteristics of the attenuator determine the linearity of response.

Double monochromator instruments use two diffraction gratings or a prism and grating combination. The stray light elimination characteristics of a double monochromator are markedly superior (typically 1/100th to 1/1000th of a single grating). This is particularly important at the short wavelength end of the ultraviolet spectrum or where there is rapid change of transmittance with wavelength.

The beam can pass through the monochromator before the sample so the sample is irradiated with monochromatic radiation, or after the sample so the sample is irradiated with polychromatic radiation. When dealing with ophthalmic products, this difference is probably insignificant. The difference can be very significant if some constituent of the sample is fluorescent.

In addition, spectrophotometers can be fitted with different detectors. For ultraviolet-visible (190 nm to 830 nm) measurements they are typically a photomultiplier or a silicon photodiode. The photomultiplier is a more sensitive detector and provides measurements for darker samples whereas the silicon photodiode is a robust and a less expensive option and provides measurement typically to 1 100 nm. If the instrument also provides near infrared measurements, another detector is required. Lead sulfide typically provides measurements to 3 000 nm and InGaAs currently to 1 800 nm.

B.3 Sources of uncertainty

B.3.1 General

Uncertainty in the measurement of spectral transmittance can usefully be considered to have three types of component:

- errors that result in a contribution that is independent of the transmittance of the sample and make a contribution to the uncertainty of a set absolute size (α);
- errors that result in a contribution to the uncertainty that is a proportion of the transmittance measured (β);
- errors that result from wavelength inaccuracies in the instrument (χ).

The combined uncertainty (u) of the transmittance ($\tau(\lambda)$) can be stated in the form:

$$u = \alpha + \beta \times \tau(\lambda) + \chi \times d\tau(\lambda) / d\lambda$$

B.3.2 Sources of uncertainty from calibration

B.3.2.1 Stray light

Stray light is typically caused by scattering in the optics of the instrument, particularly in the gratings. It is also caused by the partial overlap of higher order spectra with the first order that is used for measurement. It is particularly reduced in double monochromator instruments. In older instruments, deposits on the optics tend to increase stray light. This can be minimized by attention to the cleanliness of the environment. Cleaning the optics is a skilled job and should be carried out by people certified by the instrument supplier.

Stray light is particularly significant at shorter wavelengths and most spectrophotometers automatically insert a long short wavelength pass filter and use a deuterium discharge source for measurements below about 350 nm.

Stray light is assessed by the use of suitable aqueous solutions or glass filters with a long wavelength band pass.

Solutions used in the relevant wavelength range include those shown in Table B.1.

Table B.1 — Solutions for use in wavelength ranges

Compound	Typical concentration used	Wavelength range (absorbance > 3)
Potassium iodide	1 %	< 260 nm
Sodium iodide	1 %	< 260 nm
Lithium carbonate	Saturated	< 227 nm

Any measurable transmittance in the wavelength range nominated is to be taken to be stray light and minimized and accounted for under factor α.

B.3.2.2 0 % baseline

When the sample beam is covered with an opaque object there can be a consistent reading other than the expected zero. This should, preferably, be subtracted from any actual transmittance reading or, otherwise, accounted for under factor α. When the 0 % baseline is repeated, some variation in the values are recorded. This is most likely due to electrical noise in the system and there is little the user can do about this. An assessment of the magnitude of the error is made by repeated scans of the baseline and a calculation of the 95th percentile limits made. This is then factored into α.

B.3.2.3 100 % baseline

Much the same processes are used as in accounting for the 0 % baseline. Any discrepancy from 100 % should be eliminated by scaling the result to 100 % or accounted for in factor β. Repeats of the 100 % baseline also show variation and need to be assessed as in the 0 % baseline and factored into β. The sources of noise in the 100 % baseline are much more numerous.

The noise in the 100 % baseline is greater when the response of the detector is low. This can be because the amount of radiation reaching the detector is low. This occurs at the limits of the wavelength region where the energy from the source can be low and/or the efficiency of the grating is low. The response can also be low near the limits of the wavelength region because the detector spectral responsivity is low.

The magnitude and wavelength range of the problem vary depending on the instrument and are mainly beyond the control of the operator. Noise can be reduced by increasing the amount of radiation incident on the detector by increasing wavelength half band width, increasing the integration time (which can be linked to slowing the scan rate in some instruments) or increasing the amplifier gain in the instrument. Some instruments automatically vary the extra high tension (EHT) voltage to a photomultiplier in response to the total amount of light incident, some vary the amplifier gain and some automatically control the half bandwidth.

B.3.2.4 Wavelength accuracy

Wavelength accuracy is a function of the mechanics of the scanning mechanism or the location of the detectors in a diode array. It is not normally modifiable. It should be assessed and an estimate of χ made.

There are two principal methods. The first is the more accurate and involves introducing a line source (usually mercury discharge and neon discharge sources) in place of the built-in sources and monitoring the output of the detector in single beam mode. The mercury discharge spectrum has useful lines in the ultraviolet and visible to the yellow region while neon has many lines in the red region. Table B.2 lists the principal lines of the mercury spectrum and the neon spectrum. Some closely spaced lines cannot be individually resolved when the half bandwidth is not substantially smaller than the wavelength difference of the lines. In addition, many spectrophotometers have built-in deuterium sources for the UV region. This source produces a combination of a broad band distribution and some lines, most notably at 656,1 nm (but also at 486,0 nm, 434,0 nm and 410,1 nm). This line is often used as a one-point check of wavelength accuracy, possibly automatically on start up in some instruments. Once a full check has been carried out, this one-point check should be sufficient to ensure that no change has taken place. Set the wavelength 5 nm higher than the intended line and scan slowly across the line at the smallest wavelength interval possible. Identify the wavelength of maximum energy. Repeat for each available line. This method is necessary when wavelength accuracies ≤ 0,5 nm are being claimed. Wavelength accuracies < 0,1 nm can be validated if the FWHM (full width half maximum) is small enough.

The second method involves the use of solutions such as holmium perchlorate or glass filters containing holmium oxide or didymium. These have narrow and deep absorption bands with typical wavelengths of peak absorption. The typical wavelengths of peak absorption are set out in Table B.3. The actual wavelengths vary with the bandwidth and the thickness of the filter and should be obtained from a calibration laboratory for a particular solution or filter. Set the wavelength 5 nm higher than the intended absorption band and scan slowly across the band at the smallest wavelength interval possible. Identify the wavelength of minimum transmittance or maximum absorbance. The calibration uncertainty depends on the source of the calibration and the transfer calibration can be done typically ± 0,3 nm, resulting in a combined uncertainty of around 0,5 nm for small FWHM.

Table B.2 — Wavelengths (in air) of the line spectra from mercury and neon

Wavelength in air nm	Source	Wavelength in air nm	Source	Wavelength in air nm	Source
226,22	Hg	366,33	Hg	630,48	Ne
237,83	Hg	404,66	Hg	633,44	Ne
248,20	Hg	407,78	Hg	638,30	Ne
253,65	Hg	435,84	Hg	640,23	Ne
265,20	Hg	533,08	Ne	650,65	Ne
280,35	Hg	534,11	Ne	653,29	Ne
289,36	Hg	540,06	Ne	659,90	Ne
296,73	Hg	546,07	Hg	667,83	Ne
302,15	Hg	576,96	Hg	671,70	Ne
312,57	Hg	579,07	Hg	692,95	Ne
313,17	Hg	585,25	Ne	702,41	Ne
334,15	Hg	588,19	Ne	703,24	Ne
336,99	Ne	594,48	Ne	705,91	Ne
341,79	Ne	597,55	Ne	717,39	Ne
344,77	Ne	603,00	Ne	724,52	Ne
346,66	Ne	607,43	Ne	743,89	Ne
347,26	Ne	609,62	Ne	748,89	Ne
352,05	Ne	614,31	Ne	753,58	Ne
359,35	Ne	616,36	Ne	754,41	Ne
365,02	Hg	621,73	Ne	837,76	Ne
365,44	Hg	626,65	Ne		

Table B.3 — Main wavelengths (in air) of peak absorption

Reference	Wavelengths of peak absorption nm								
Holmium perchlorate solution	241,1 450,8	250,0 486,2	278,2 536,6	287,1 640,6	333,5	345,5	361,4	385,4	416,3
Holmium oxide filter	279,4	287,5	360,9	418,7	453,2	536,2	637,5		
Didymium filter	572,9	585,3	684,6	740,8	807,0				

For neutral coloured test lenses and samples, wavelength accuracy is not a large determinant of uncertainty in spectral transmittance; wavelength accuracies of 1 nm are perfectly adequate. On the other hand, the sharp cut-offs often seen in the UV region and rapid changes of transmittance with wavelength in highly coloured samples can lead to large uncertainties with wavelength. For instance, a change of 50 % transmittance (absolute) in 10 nm is not unusual in the UV region and a wavelength accuracy of 1 nm means an uncertainty of 5 %.

B.3.2.5 Precision (repeatability)

The assessments of noise in the baseline are measures of precision. Similar assessments can be carried out at different values of transmittance of a sample. Where a sample is not totally uniform, measures of repeatability can also involve removing and replacing the sample and repeating the measurements. In this case the repeatability is not just a function of the instrument but also the uniformity of the sample and the repeatability of the method of locating the sample in the instrument. Repeatability normally factors into β.

B.3.2.6 Photometric accuracy (linearity)

The assessment of photometric accuracy involves the measurement of a sample of known transmittance (values provided by a calibration laboratory) and the discrepancies either corrected out mathematically or incorporated into the uncertainty, usually β. Typically the reference samples are glass filters, but perforated metal gauzes can also be used; care needs to be exercised to ensure their uniformity.

B.3.3 Sources of uncertainty from methodology

B.3.3.1 Wavelength limits for specification and measurement

Spectral measurements should be made over the range specified in ISO 12312 (all parts) and this can vary with application.

In principle, the visible spectrum, as defined by the CIE data, extends from 360 nm to 830 nm. In practice, the sensitivity of the eye at the limits of the spectrum is so low that excluding those regions from the calculation makes no practical difference. In some applications, limits as low as 400 nm to 700 nm are accepted as adequate. However, comparisons of calculations made on the same sample for different limits show a variation and an accepted wavelength range for an application is normally set. For eye and face protection calculations, the wavelength limits for measurement and specification of eye and face protection have been generally set as 380 nm to 780 nm.

Similarly, there is variation in the regions accepted which is defined as the bands of ultraviolet and infrared limits for specification and measurement.

Since a standard wavelength range is adopted, any discrepancies from the full range are generally ignored and not factored into the uncertainties.

B.3.3.2 Wavelength step

In principle, the smaller the wavelength step, the more accurate the calculation. The CIE system is specified in 1 nm increments. Making the measurements and calculations at larger intervals has no consequence when the sample is neutral in colour and the spectral transmittances changes little with wavelength, but has a consequence where the spectral transmittance changes rapidly with wavelength. For this International Standard, the calculations and the measurements should be made at the same intervals as specified in ISO 12312-1. The wavelength step should be set as 5 nm and any discrepancies with measurements made at 1nm intervals ignored. Smaller wavelength steps (and a correspondingly smaller FWHM) can be necessary where weighting functions change rapidly with wavelength and this different wavelength step should be specified.

B.3.3.3 Bandwidth of the measuring device

The band width of the measuring device is normally described as the Full Width Half Maximum bandwidth (FWHM) Spectral half band width.

In principle, the smaller the spectral half bandwidth FWHM (bandwidth), the more accurate the measurement. Making the measurements and calculations at large FWHM bandwidths has no consequence when the sample is neutral in colour and the spectral transmittances changes little with wavelength. It has a consequence where the spectral transmittance changes rapidly with wavelength when transmittance peaks tend to be lower and troughs shallower with increasing FWHM bandwidth. On the other hand, smaller FWHM bandwidths reduce the amount of energy reaching the detector and increase the signal noise. Good measurement practice is to set the FWHM bandwidth no greater than the wavelength step (5 nm in this application). Two nm is a typical setting for fixed bandwidth instruments. When dealing with dark samples and reference beam attenuation (see B.3.4), it can be necessary to increase the bandwidth beyond 5 nm to minimize noise and this needs to be factored in to the uncertainty.

When using large bandwidths, the combined effects of detector sensitivity, source energy and grating efficiency can mean that energy is not uniformly or symmetrically distributed in the wavelength band and the wavelength with greatest energy can be some nanometres from the nominal centroid wavelength. In this case, wavelength accuracy needs to be re-evaluated.

B.3.4 Sources of uncertainty from sample characteristics

B.3.4.1 Beam displacement by sample

The beam in the spectrophotometer can be displaced when a sample is tilted or the sample includes even a small amount of prism (including “decentred” lenses). The beam can then fall partially outside the detector and an incorrectly lower transmittance is recorded. In some instruments, the beam is small compared with the detector (under filling) and a large amount of displacement is necessary for a spurious result to be recorded. This tends to be true more often of photomultiplier detectors that generally have large windows. Conversely, if the beam is large compared with the detector (over filling) it also takes a significant displacement for the beam to fail to fill the detector and, as long as the beam is uniform, displacement has relatively little effect. In practice many instruments just underfill the detector and a small displacement can have significant effects. The effects are most noticeable with curved, rather than flat, samples.

If the effect is significant, it can be identified by:

- tilting a sample and observing an apparent rise in transmittance (usually it should fall);
- rotating a (non-polarizing) sample and observing larger than expected changes in transmittance;
- moving a uniformly tinted sample laterally and observing larger than expected changes in transmittance;
- moving the sample from the front to the back of the sample chamber and observing a change in apparent transmittance (this can also be a sign of a sample with significant diffuse transmittance);
- checking with a curved sample of known transmittance.

The effect cannot be avoidable in many instruments. In order to minimize the problem, the sample should be placed as close to the detector as possible to minimize displacement of the beam. The use of an integrating sphere to collect the beam helps if the beam is small compared with the entrance port of the sphere (as it normally is). Otherwise the effect needs to be factored into β.

B.3.4.2 Fluorescence

For reasons described in B.3.4.1, fluorescence in samples contributes to errors. Visual examination under a UVA source should alert the operator to the presence of fluorescence. Appropriate filters placed in the test beam on the detector side of the sample permit valid measurements.

B.3.4.3 Sample tilt

The reference point for measurement is defined in ISO 4007 and ISO 12312-1 and the requirement is to measure with a normally incident beam. Tilting of the sample causes a greater path length to be traversed in the sample and displacement of the beam with respect to the detector. The method of locating the sample should ensure that normal incidence is maintained to within ± 2°.

B.3.4.4 Sample location

This is not particularly critical with uniformly tinted lenses, but with gradient tint lenses it is critical. The location of the sample should be repeatable to within ± 0,5 mm.

B.3.4.5 Sample beam size and shape

This is also not particularly critical with uniformly tinted lenses, but with gradient tint lenses it is critical. If the beam extends a significant distance in the direction of the gradient and the gradient is not a constant transmittance change, then it becomes difficult to know exactly what point is being measured. Along the direction of the gradient, the beam size should be as small as practicable. In instruments with a rectangular beam, the sample should be orientated so that the short dimension is along the gradient change. The dimension along the gradient should not exceed 5,0 mm.

B.3.4.6 Polarization

The process of monochromating the beam with a grating also introduces some partial polarization. The polarization efficiency and orientation of polarization varies through the spectrum. Some instruments have a depolarizer which can be used. In the absence of such an attachment, the measurement of spectral transmittance of linear polarizers should be made at two mutually perpendicular orientations of the sample. The absolute orientation is not important, but the mutual perpendicular requirement is. The spectral transmittance is the mean of the two measured spectral transmittances. The measurement of non-linear polarizers should be made with a depolarizer or made by a non-spectrophotometric method.

Annex C
(informative)

Definitions in summations form

C.1 Explanation

ISO 4007 defines the processes of convolving spectral data to an integrated value as an integral with the symbols ∫ and $d\lambda$. In an integral, the variables, such as $\tau(\lambda)$, $V(\lambda)$, $S(\lambda)$, are mathematical functions. While each of these variables may be fitted with a mathematical function, the more usual process in making this calculation is to carry out a summation at a given wavelength interval $\Delta\lambda$ within the defined wavelength range. ISO 12312-1 requires the use of a wavelength interval of 5 nm or less in the ultraviolet and visible regions and 10 nm in the infrared region. The calculations are therefore, in practice, represented as summations using the symbols Σ and $\Delta\lambda$.

The following are the definitions from ISO 4007, expressed in percentages and as summations, which are required in ISO 12312-1.

C.2 Definitions in summation form

C.2.1 Luminous transmittance

$$\tau_{\mathrm{V}} = 100 \times \frac{\sum\limits_{380}^{780} \tau(\lambda) \cdot S_{\mathrm{D65}}(\lambda) \cdot V(\lambda) \cdot \Delta\lambda}{\sum\limits_{380}^{780} S_{\mathrm{D65}}(\lambda) \cdot V(\lambda) \cdot \Delta\lambda} \tag{C.1}$$

where

λ is the wavelength in nanometres;

$\tau(\lambda)$ is the spectral transmittance;

$V(\lambda)$ is the relative sensitivity of the human eye as defined in ISO 11664-1;

$S_{\mathrm{D65}}(\lambda)$ is the spectral energy distribution of CIE Standard Illuminant D65 as defined in ISO 11664-2.

The weighting functions are given in Annex D.

C.2.2 Ultraviolet transmittance

C.2.2.1 Solar UV-transmittance, τ_{SUV}

$$\tau_{\mathrm{SUV}} = 100 \times \frac{\sum\limits_{280}^{380} \tau(\lambda) \cdot E_{\mathrm{s}}(\lambda) \cdot S(\lambda) \cdot \Delta\lambda}{\sum\limits_{280}^{380} E_{\mathrm{s}}(\lambda) \cdot S(\lambda) \cdot \Delta\lambda} = 100 \times \frac{\sum\limits_{280}^{380} \tau(\lambda) \cdot W(\lambda) \cdot \Delta\lambda}{\sum\limits_{280}^{380} W(\lambda) \cdot \Delta\lambda} \tag{C.2}$$

C.2.2.2 Solar UVA-transmittance, τ_{SUVA}

$$\tau_{\mathrm{SUVA}} = 100 \times \frac{\sum_{315}^{380} \tau(\lambda) \cdot E_{\mathrm{S}}(\lambda) \cdot S(\lambda) \cdot \Delta\lambda}{\sum_{315}^{380} E_{\mathrm{S}}(\lambda) \cdot S(\lambda) \cdot \Delta\lambda} = 100 \times \frac{\sum_{315}^{380} \tau(\lambda) \cdot W(\lambda) \cdot \Delta\lambda}{\sum_{315}^{380} W(\lambda) \cdot \Delta\lambda} \qquad \text{(C.3)}$$

C.2.2.3 Solar UVB-transmittance, τ_{SUVB}

$$\tau_{\mathrm{SUVB}} = 100 \times \frac{\sum_{280}^{315} \tau(\lambda) \cdot E_{\mathrm{S}}(\lambda) \cdot S(\lambda) \cdot \Delta\lambda}{\sum_{280}^{315} E_{\mathrm{S}}(\lambda) \cdot S(\lambda) \cdot \Delta\lambda} = 100 \times \frac{\sum_{280}^{315} \tau(\lambda) \cdot W(\lambda) \cdot \Delta\lambda}{\sum_{280}^{315} W(\lambda) \cdot \Delta\lambda} \qquad \text{(C.4)}$$

where, in the ultraviolet calculations:

λ is the wavelength in nanometres;

$\tau(\lambda)$ is the spectral transmittance;

$E_{\mathrm{S}}(\lambda)$ is the solar radiation at sea level for air mass 2;[7]

$S(\lambda)$ is the relative spectral effectiveness function for UV radiation;[8]

$W(\lambda)$ $= E_{\mathrm{S}}(\lambda) \cdot S(\lambda)$.

The weighting functions are given in Annex E.

C.2.3 Solar blue-light transmittance, τ_{sb}

$$\tau_{\mathrm{sb}} = 100 \times \frac{\sum_{380}^{500} \tau(\lambda) \cdot E_{\mathrm{s}}(\lambda) \cdot B(\lambda) \cdot \Delta\lambda}{\sum_{380}^{500} E_{\mathrm{s}}(\lambda) \cdot B(\lambda) \cdot \Delta\lambda} = 100 \times \frac{\sum_{380}^{500} \tau(\lambda) \cdot W_{\mathrm{B}}(\lambda) \cdot \Delta\lambda}{\sum_{380}^{500} W_{\mathrm{B}}(\lambda) \cdot \Delta\lambda} \qquad \text{(C.5)}$$

where

λ is the wavelength in nanometres;

$\tau(\lambda)$ is the spectral transmittance;

$E_{\mathrm{S}}(\lambda)$ is the solar radiation at sea level for air mass 2;[7]

$B(\lambda)$ is the blue-light hazard function;[9]

$W_{\mathrm{B}}(\lambda)$ $= E_{\mathrm{S}}(\lambda) \cdot B(\lambda)$.

The weighting functions are given in Annex E.

C.2.4 Solar infrared transmittance, τ_{SIR}

$$\tau_{\mathrm{SIR}} = 100 \times \frac{\sum_{780}^{2000} \tau(\lambda) \cdot E_{\mathrm{S}}(\lambda) \cdot \Delta\lambda}{\sum_{780}^{2000} E_{\mathrm{S}}(\lambda) \cdot \Delta\lambda} \tag{C.6}$$

where

λ is the wavelength in nanometres;

$\tau(\lambda)$ is the spectral transmittance;

$E_{\mathrm{S}}(\lambda)$ is the spectral distribution of solar radiation at sea level for air mass 2.[7]

The values of $E_{\mathrm{S}}(\lambda)$ are given in Annex E.

C.2.5 Luminous reflectance, ρ_{V}

$$\rho_{\mathrm{V}} = 100 \times \frac{\sum_{380}^{780} \rho(\lambda) \cdot V(\lambda) \cdot S_{\mathrm{D65}}(\lambda) \cdot \Delta\lambda}{\sum_{380}^{780} V(\lambda) \cdot S_{\mathrm{D65}}(\lambda) \cdot \Delta\lambda} \tag{C.7}$$

where

λ is the wavelength in nanometres;

$\rho(\lambda)$ is the spectral reflectance;

$V(\lambda)$ is the relative sensitivity of the human eye as defined in ISO 11664-1;

$S_{\mathrm{D65}}(\lambda)$ is the spectral energy distribution of CIE Standard Illuminant D65 as defined in ISO 11664-2.

C.2.6 Relative visual attenuation quotient for signal light detection, Q

$$Q = \frac{\tau_{\mathrm{Signal}}}{\tau_{\mathrm{V}}} \tag{C.8}$$

where

$$\tau_{\mathrm{V}} = 100 \times \frac{\sum_{380}^{780} \tau(\lambda) \cdot S_{\mathrm{D65}}(\lambda) \cdot V(\lambda) \cdot \Delta\lambda}{\sum_{380}^{780} S_{\mathrm{D65}}(\lambda) \cdot V(\lambda) \cdot \Delta\lambda} \tag{C.9}$$

and

$$\tau_{\mathrm{signal}} = 100 \times \frac{\sum_{380}^{780} \tau(\lambda) \cdot E_{\mathrm{signal}}(\lambda) \cdot V(\lambda) \cdot \Delta\lambda}{\sum_{380}^{780} E_{\mathrm{signal}}(\lambda) \cdot V(\lambda) \cdot \Delta\lambda} \tag{C.10}$$

where

λ	is the wavelength in nanometres;
$\tau(\lambda)$	is the spectral transmittance;
$V(\lambda)$	is the relative sensitivity of the human eye as defined in ISO 11664-1;
$S_{\mathrm{D65}}(\lambda)$	is the spectral energy distribution of CIE Standard Illuminant D65 as defined in ISO 11664-2;
$E_{\mathrm{signal}}(\lambda)$	is the spectral energy distribution of the red, yellow, green and blue traffic signals.

The values of $S_{\mathrm{D65}}(\lambda) \cdot V(\lambda)$ are given in Annex D and the values of $E_{\mathrm{signal}}(\lambda) \cdot V(\lambda)$ for incandescent signals are given in Annex H and for LED signals in Annex I.

Annex D
(normative)

Product of the energy distribution of Standard Illuminant D65 as specified in ISO 11664-2 and the spectral visibility function of the average human eye for daylight vision as specified in ISO 11664-1

Table D.1 — Product of the energy distribution of Standard Illuminant D65 and the spectral visibility function of the average human eye for daylight vision

Wavelength λ nm	$S_{\mathbf{D65}}(\lambda)\cdot V(\lambda)$	**Wavelength** λ nm	$S_{\mathbf{D65}}(\lambda)\cdot V(\lambda)$	**Wavelength** λ nm	$S_{\mathbf{D65}}(\lambda)\cdot V(\lambda)$
380	0,0001	515	3,0589	650	0,4052
385	0,0002	520	3,5203	655	0,3093
390	0,0003	525	3,9873	660	0,2315
395	0,0007	530	4,3922	665	0,1714
400	0,0016	535	4,5905	670	0,1246
405	0,0026	540	4,7128	675	0,0881
410	0,0052	545	4,8343	680	0,0630
415	0,0095	550	4,8981	685	0,0417
420	0,0177	555	4,8272	690	0,0271
425	0,0311	560	4,7078	695	0,0191
430	0,0476	565	4,5455	700	0,0139
435	0,0763	570	4,3393	705	0,0101
440	0,1141	575	4,1607	710	0,0074
445	0,1564	580	3,9431	715	0,0048
450	0,2104	585	3,5626	720	0,0031
455	0,2667	590	3,1766	725	0,0023
460	0,3345	595	2,9377	730	0,0017
465	0,4068	600	2,6873	735	0,0012
470	0,4945	605	2,4084	740	0,0009
475	0,6148	610	2,1324	745	0,0006
480	0,7625	615	1,8506	750	0,0004
485	0,9001	620	1,5810	755	0,0002
490	1,0710	625	1,2985	760	0,0001
495	1,3347	630	1,0443	765	0,0001
500	1,6713	635	0,8573	770	0,0001
505	2,0925	640	0,6931	775	0,0001
510	2,5657	645	0,5353	780	0,0000
				Sum	**100,0000**

Annex E
(normative)

Spectral functions for the calculation of solar UV and solar blue light transmittance values

This annex contains the spectral functions for the calculation of solar UV-transmittance values and blue-light transmittance (see Table E.1).

For the spectral distribution of solar radiation $E_S(\lambda)$ the values are taken from Reference.[7] These values extend to 295 nm and are interpolated where necessary. Between 280 nm and 290 nm the irradiance values are so low that they can be set to 0 for all practical purposes.

The spectral distribution of the relative spectral effectiveness function for UV radiation $S(\lambda)$ is taken from ICNIRP, Guidelines.[8] These data have been given at 5 nm intervals; where sources are narrow band, it can be necessary to work with specific wavelengths or at smaller wavelength intervals, in which case the data should be taken from the ICNIRP guidelines.

The complete weighting function for the calculation of the different UV-transmittance values is the product of the relative spectral effectiveness function for UV radiation $S(\lambda)$ and the spectral distribution of solar radiation $E_S(\lambda)$.

$$W(\lambda)=E_S(\lambda)\cdot S(\lambda) \tag{E.1}$$

The blue-light hazard function $B(\lambda)$ is taken from ACGIH[9]; below 400 nm the blue-light hazard function $B(\lambda)$ is extrapolated linearly on a logarithmic scale.

The complete weighting function for the calculation of the blue-light transmittance is the product of blue-light hazard function $B(\lambda)$ and the spectral distribution of solar radiation $E_S(\lambda)$.

$$W_B(\lambda)=E_S(\lambda)\cdot B(\lambda) \tag{E.2}$$

Table E.1 — Spectral functions for the calculation of solar UV and solar blue light transmittance values

Wavelength nm	**Solar spectral irradiance** $E_S(\lambda)$ mW/m^2/nm	**Relative spectral effectiveness function** $S(\lambda)$	**Weighting function** $W(\lambda)=E_S(\lambda)\cdot S(\lambda)$	**Blue-Light Hazard Function** $B(\lambda)$	**Weighting function** $W_B(\lambda) = E_S(\lambda)\cdot B(\lambda)$
280	0	0,88	0		
285	0	0,77	0		
290	0	0,64	0		
295	$2{,}09\cdot10^{-4}$	0,54	0,00011		
300	$8{,}10\cdot10^{-2}$	0,30	0,0243		
305	1,91	0,060	0,115		
310	11,0	0,015	0,165		
315	30,0	0,003	0,090		
320	54,0	0,0010	0,054		

Table E.1 *(continued)*

Wavelength nm	**Solar spectral irradiance** $E_S(\lambda)$ mW/m^2/nm	**Relative spectral effectiveness function** S(λ)	**Weighting function** $W(\lambda)=E_S(\lambda)\cdot S(\lambda)$	**Blue-Light Hazard Function** $B(\lambda)$	**Weighting function** $W_B(\lambda) = E_S(\lambda)\cdot B(\lambda)$
325	79,2	0,00050	0,040		
330	101	0,00041	0,041		
335	128	0,00034	0,044		
340	151	0,00028	0,042		
345	170	0,00024	0,041		
350	188	0,00020	0,038		
355	210	0,00016	0,034		
360	233	0,00013	0,030		
365	253	0,00011	0,028		
370	279	0,000093	0,026		
375	306	0,000077	0,024		
380	336	0,000064	0,022	0,006	2
385	365			0,012	4
390	397			0,025	10
395	432			0,05	22
400	470			0,10	47
405	562			0,20	112
410	672			0,40	269
415	705			0,80	564
420	733			0,90	660
425	760			0,95	722
430	787			0,98	771
435	849			1,00	849
440	911			1,00	911
445	959			0,97	930
450	1006			0,94	946
455	1037			0,90	933
460	1080			0,80	864
465	1109			0,70	776
470	1138			0,62	706
475	1161			0,55	639
480	1183			0,45	532
485	1197			0,40	479
490	1210			0,22	266
495	1213			0,16	194
500	1215			0,10	122

Annex F

(normative)

Spectral distribution of solar irradiance in the infrared spectrum for the calculation of the solar infrared transmittance[7]

Table F.1 — Spectral distribution of solar irradiance in the infrared spectrum for the calculation of the solar infrared transmittance

Wavelength λ nm	Spectral irradiance $E_S(\lambda)$ mW/m^2/nm	Wavelength λ nm	Spectral irradiance $E_S(\lambda)$ mW/m^2/nm	Wavelength λ nm	Spectral irradiance $E_S(\lambda)$ mW/m^2/nm
780	907	1190	344	1600	202
790	923	1200	373	1610	198
800	857	1210	402	1620	194
810	698	1220	431	1630	189
820	801	1230	420	1640	184
830	863	1240	387	1650	173
840	858	1250	328	1660	163
850	839	1260	311	1670	159
860	813	1270	381	1680	145
870	798	1280	382	1690	139
880	614	1290	346	1700	132
890	517	1300	264	1710	124
900	480	1310	208	1720	115
910	375	1320	168	1730	105
920	258	1330	115	1740	97,1
930	169	1340	58,1	1750	80,2
940	278	1350	18,1	1760	58,9
950	487	1360	0,660	1770	38,8
960	584	1370	0	1780	18,4
970	633	1380	0	1790	5,70
980	645	1390	0	1800	0,92
990	643	1400	0	1810	0
1000	630	1410	1,91	1820	0
1010	620	1420	3,72	1830	0
1020	610	1430	7,53	1840	0
1030	601	1440	13,7	1850	0
1040	592	1450	23,8	1860	0
1050	551	1460	30,5	1870	0
1060	526	1470	45,1	1880	0
1070	519	1480	83,7	1890	0

Table F.1 *(continued)*

Wavelength λ nm	**Spectral irradiance** $E_\mathrm{S}(\lambda)$ mW/m^2/nm	**Wavelength** λ nm	**Spectral irradiance** $E_\mathrm{S}(\lambda)$ mW/m^2/nm	**Wavelength** λ nm	**Spectral irradiance** $E_\mathrm{S}(\lambda)$ mW/m^2/nm
1080	512	1490	128	1900	0
1090	514	1500	157	1910	0,705
1100	252	1510	187	1920	2,34
1110	126	1520	209	1930	3,68
1120	69,9	1530	217	1940	5,30
1130	98,3	1540	226	1950	17,7
1140	164	1550	221	1960	31,7
1150	216	1560	217	1970	37,7
1160	271	1570	213	1980	22,6
1170	328	1580	209	1990	1,58
1180	346	1590	205	2000	2,66

Annex G
(normative)

Reference test headforms

There are two sizes of reference headform for the tests described in this International Standard. The medium headform approximates a 50th percentile European adult male. The small headform approximates a 60th percentile, 12 year old European child. The nominal dimensions are shown in Figure G.1; the constructional details are given below and in the notes to the figure.

Where reference is made in this International Standard to a headform specified in this annex, the size of headform (medium or small) to be used shall be that which is appropriate to the eye protector being assessed. Unless otherwise specified by the manufacturer of the eye protector, the medium size headform shall be used.

The appropriateness of the headform specified for the eye protector shall be confirmed by the test house.

All tests on the eye protector shall be performed using only the one size of headform selected.

Each headform is available constructed in three materials:

a) cast epoxy resin, inscribed with the areas to be protected;

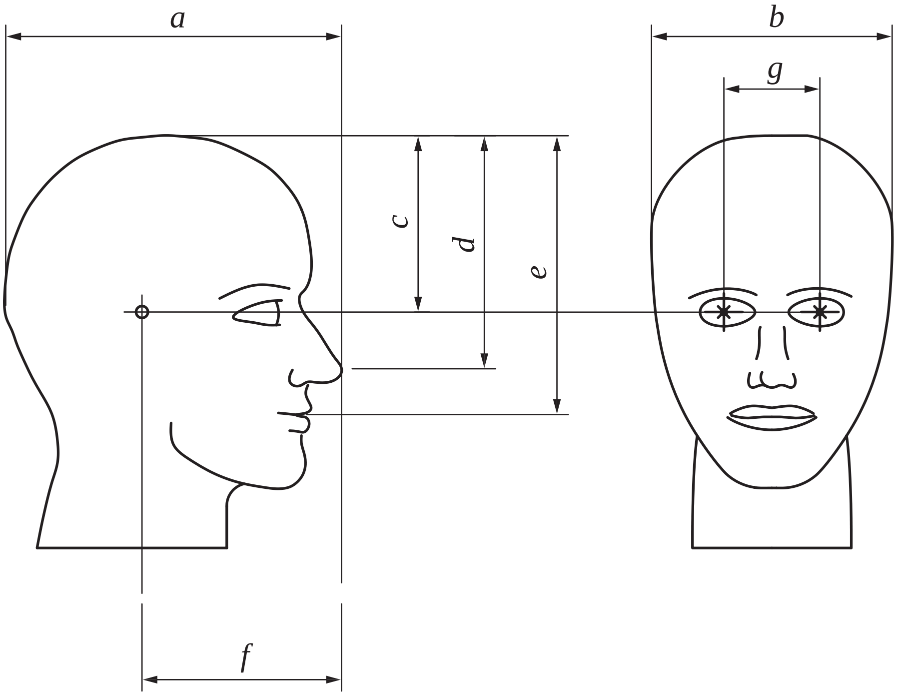
b) all aluminium;

c) an internal core covered by a nominal 12 mm thick layer of polyurethane of hardness (50 ± 5) IRHD.

The cast epoxy resin headform is best suited for use in assessing areas of protection and fields of vision.

For assessment of resistance to impacts (9.3.2.1, 9.4.2.1, 9.5.2.1) the polyurethane covered headform only shall be used.

The all aluminium headform shall be used for assessment of the requirements for non-radiation industrial use.



Dimension	Length (mm)	
	Small headform	Medium headform
a	206	218
b	146	156
c	110	111
d	131	144
e	166	178
f	113	123
g	54	64

Figure G.1 — Reference headforms

Annex H
(normative)

Spectral distribution of radiation in incandescent signal lights weighted by the sensitivity of the human eye $V(\lambda)$

Table H.1 — Spectral distribution of radiation in signal lights weighted by the sensitivity of the human eye $V(\lambda)$

Wavelength	**Red**	**Yellow**	**Green**	**Blue**
λ (nm)	$E_{\text{Red}}(\lambda)\cdot V(\lambda)$	$E_{\text{Yellow}}(\lambda)\cdot V(\lambda)$	$E_{\text{Green}}(\lambda)\cdot V(\lambda)$	$E_{\text{Blue}}(\lambda)\cdot V(\lambda)$
380	0,000	0,000	0,000	0,000
385	0,000	0,000	0,000	0,000
390	0,000	0,000	0,000	0,000
395	0,000	0,000	0,000	0,000
400	0,000	0,000	0,000	0,010
405	0,000	0,000	0,000	0,010
410	0,000	0,000	0,000	0,030
415	0,000	0,000	0,000	0,060
420	0,000	0,000	0,000	0,120
425	0,000	0,000	0,000	0,250
430	0,000	0,000	0,000	0,440
435	0,000	0,000	0,010	0,680
440	0,000	0,000	0,020	0,970
445	0,000	0,000	0,030	1,260
450	0,000	0,000	0,050	1,600
455	0,000	0,000	0,080	1,950
460	0,000	0,000	0,120	2,350
465	0,000	0,000	0,180	2,760
470	0,000	0,000	0,270	3,230
475	0,000	0,010	0,380	3,720
480	0,000	0,010	0,540	4,240
485	0,000	0,020	0,740	4,650
490	0,000	0,040	1,020	5,080
495	0,000	0,070	1,410	5,510
500	0,010	0,120	1,910	5,870
505	0,010	0,200	2,610	6,450
510	0,010	0,320	3,430	6,800
515	0,010	0,490	4,370	6,660
520	0,010	0,760	5,320	5,950
525	0,020	1,160	6,130	5,150

Table H.1 *(continued)*

Wavelength	Red	Yellow	Green	Blue
λ (nm)	$E_{Red}(\lambda) \cdot V(\lambda)$	$E_{\mathrm{Yellow}}(\lambda) \cdot V(\lambda)$	$E_{\mathrm{Green}}(\lambda) \cdot V(\lambda)$	$E_{\mathrm{Blue}}(\lambda) \cdot V(\lambda)$
530	0,020	1,700	6,860	3,960
535	0,020	2,350	7,370	3,370
540	0,020	3,060	7,700	2,650
545	0,020	3,710	7,750	2,320
550	0,020	4,260	7,340	1,940
555	0,020	4,730	6,460	1,460
560	0,030	5,050	5,480	0,970
565	0,040	5,270	4,790	0,660
570	0,080	5,440	4,340	0,360
575	0,230	5,470	3,770	0,280
580	0,670	5,430	3,040	0,200
585	1,640	5,320	2,400	0,220
590	3,320	5,160	1,790	0,240
595	5,400	4,940	1,050	0,230
600	7,320	4,670	0,400	0,230
605	8,750	4,380	0,120	0,180
610	9,350	4,040	0,050	0,130
615	9,320	3,640	0,060	0,100
620	8,950	3,270	0,090	0,060
625	8,080	2,840	0,110	0,070
630	7,070	2,420	0,100	0,070
635	6,100	2,030	0,070	0,160
640	5,150	1,700	0,040	0,210
645	4,230	1,390	0,020	0,430
650	3,410	1,110	0,020	0,540
655	2,690	0,870	0,010	0,420
660	2,090	0,670	0,000	0,320
665	1,570	0,510	0,000	0,210
670	1,150	0,370	0,000	0,140
675	0,850	0,280	0,000	0,260
680	0,640	0,210	0,000	0,300
685	0,470	0,150	0,000	0,320
690	0,330	0,100	0,000	0,300
695	0,240	0,070	0,000	0,230
700	0,180	0,060	0,010	0,180
705	0,130	0,040	0,020	0,130
710	0,090	0,030	0,020	0,100
715	0,070	0,020	0,020	0,070
720	0,050	0,010	0,020	0,050

Table H.1 *(continued)*

Wavelength	Red	Yellow	Green	Blue
λ (nm)	$E_{\text{Red}}(\lambda) \cdot V(\lambda)$	$E_{\text{Yellow}}(\lambda) \cdot V(\lambda)$	$E_{\text{Green}}(\lambda) \cdot V(\lambda)$	$E_{\text{Blue}}(\lambda) \cdot V(\lambda)$
725	0,030	0,010	0,020	0,030
730	0,020	0,010	0,010	0,030
735	0,020	0,010	0,010	0,020
740	0,010	0,000	0,010	0,010
745	0,010	0,000	0,010	0,010
750	0,010	0,000	0,000	0,010
755	0,010	0,000	0,000	0,010
760	0,010	0,000	0,000	0,010
765	0,000	0,000	0,000	0,000
770	0,000	0,000	0,000	0,000
775	0,000	0,000	0,000	0,000
780	0,000	0,000	0,000	0,000
Sum	100,000	100,000	100,000	100,000

Annex I
(informative)

Spectral distribution of radiation in LED signal lights weighted by the sensitivity of the human eye V(λ)

Table I.1 — - Spectral distribution of radiation in LED signal lights weighted by the sensitivity of the human eye $V(\lambda)$

Wavelength	Red LED	Yellow LED	Green LED	Blue LED
λ (nm)	$E'_{\text{Red}}(\lambda)$ $\cdot V(\lambda)$	$E'_{\text{Yellow}}(\lambda)$ $\cdot V(\lambda)$	$E'_{\text{Green}}(\lambda)$ $\cdot V(\lambda)$	$E'_{\text{Blue}}(\lambda)$ $\cdot V(\lambda)$
380	0,000	0,000	0,000	0,000
385	0,000	0,000	0,000	0,000
390	0,000	0,000	0,000	0,000
395	0,000	0,000	0,000	0,000
400	0,000	0,000	0,000	0,000
405	0,000	0,000	0,000	0,000
410	0,000	0,000	0,000	0,000
415	0,000	0,000	0,000	0,000
420	0,000	0,000	0,000	0,000
425	0,000	0,000	0,000	0,010
430	0,000	0,000	0,000	0,050
435	0,000	0,000	0,000	0,170
440	0,000	0,000	0,010	0,550
445	0,000	0,000	0,010	1,650
450	0,000	0,000	0,020	4,470
455	0,000	0,000	0,040	9,600
460	0,000	0,000	0,090	14,170
465	0,000	0,000	0,190	13,990
470	0,000	0,000	0,450	11,180
475	0,000	0,000	1,010	9,070
480	0,000	0,000	2,130	7,370
485	0,000	0,000	4,000	5,470
490	0,000	0,000	6,530	4,210
495	0,000	0,000	9,380	3,380
500	0,000	0,000	11,340	2,690
505	0,000	0,000	11,820	2,160
510	0,000	0,000	11,150	1,760
515	0,000	0,000	9,840	1,410
520	0,000	0,010	8,220	1,140

Table I.1 *(continued)*

Wavelength	**Red LED**	**Yellow LED**	**Green LED**	**Blue LED**
λ (nm)	$E'_{\text{Red}}(\lambda)$ $\cdot V(\lambda)$	$E'_{\text{Yellow}}(\lambda)$ $\cdot V(\lambda)$	$E'_{\text{Green}}(\lambda)$ $\cdot V(\lambda)$	$E'_{\text{Blue}}(\lambda)$ $\cdot V(\lambda)$
525	0,000	0,010	6,550	0,900
530	0,000	0,020	4,890	0,690
535	0,000	0,030	3,570	0,570
540	0,000	0,050	2,630	0,480
545	0,000	0,120	1,870	0,410
550	0,000	0,240	1,290	0,330
555	0,010	0,500	0,930	0,270
560	0,020	1,000	0,630	0,220
565	0,040	1,850	0,430	0,220
570	0,070	3,390	0,300	0,200
575	0,110	6,080	0,210	0,170
580	0,210	11,180	0,140	0,140
585	0,400	20,100	0,090	0,110
590	0,690	26,720	0,070	0,140
595	1,110	18,530	0,050	0,120
600	1,710	6,910	0,030	0,090
605	2,520	2,200	0,020	0,070
610	3,640	0,700	0,020	0,090
615	5,350	0,230	0,010	0,050
620	7,990	0,080	0,010	0,040
625	12,220	0,030	0,010	0,030
630	17,410	0,010	0,010	0,040
635	19,030	0,010	0,010	0,040
640	14,200	0,000	0,000	0,020
645	7,800	0,000	0,000	0,020
650	3,380	0,000	0,000	0,010
655	1,320	0,000	0,000	0,010
660	0,490	0,000	0,000	0,010
665	0,180	0,000	0,000	0,010
670	0,060	0,000	0,000	0,000
675	0,030	0,000	0,000	0,000
680	0,010	0,000	0,000	0,000
685	0,000	0,000	0,000	0,000
690	0,000	0,000	0,000	0,000
695	0,000	0,000	0,000	0,000
700	0,000	0,000	0,000	0,000
705	0,000	0,000	0,000	0,000
710	0,000	0,000	0,000	0,000

Table I.1 *(continued)*

Wavelength	**Red LED**	**Yellow LED**	**Green LED**	**Blue LED**
λ (nm)	$E'_{\text{Red}}(\lambda)\cdot V(\lambda)$	$E'_{\text{Yellow}}(\lambda)\cdot V(\lambda)$	$E'_{\text{Green}}(\lambda)\cdot V(\lambda)$	$E'_{\text{Blue}}(\lambda)\cdot V(\lambda)$
715	0,000	0,000	0,000	0,000
720	0,000	0,000	0,000	0,000
725	0,000	0,000	0,000	0,000
730	0,000	0,000	0,000	0,000
735	0,000	0,000	0,000	0,000
740	0,000	0,000	0,000	0,000
745	0,000	0,000	0,000	0,000
750	0,000	0,000	0,000	0,000
755	0,000	0,000	0,000	0,000
760	0,000	0,000	0,000	0,000
765	0,000	0,000	0,000	0,000
770	0,000	0,000	0,000	0,000
775	0,000	0,000	0,000	0,000
780	0,000	0,000	0,000	0,000
Sum	100,000	100,000	100,000	100,000

Annex J
(normative)

Long wavelength pass filter

The radiation emitted by the lamp used in 9.8 for the test of resistance to radiation shall be filtered by a cut-on filter with a transmittance curve lying in the wavelength band as specified by the upper and lower limit defined by Table J.1. The nominal position of the absorption edge of this filter is where $\tau_{46\ \%}$ is at (320 ± 5) nm. A suitable filter for this purpose is a 4 mm thick clear white crown glass B 270[4] Transmittance values for wavelengths with cells left blank and values between specified wavelength positions can be calculated by linear interpolation.

Table J.1 — Spectral characteristics for filtering the UV radiation for the test of resistance to radiation

Wavelength λ nm	Spectral lower limit	Nominal value %	Transmittance upper limit
280,0	< 0,1	< 0,1	< 0,1
287,0			< 0,1
288,0			0,1
289,0			0,2
290,0			0,3
291,0		< 0,1	0,5
292,0		0,1	0,7
293,0		0,2	1,0
294,0		0,3	1,5
295,0		0,5	2,1
296,0		0,7	2,8
297,0	< 0,1	1,1	3,7
298,0	0,1	1,5	4,9
299,0	0,2	2,1	6,1
300,0	0,3	2,8	7,6
301,0	0,5	3,6	9,3
302,0	0,8	4,7	11,2
303,0	1,1	5,9	13,4
304,0	1,6	7,3	15,6
305,0	2,2	8,9	18,0
306,0	3,0	10,7	20,5
307,0	4,0	12,7	23,2
308,0	5,2	14,9	26,0
309,0	6,6	17,2	28,8

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[4] Schott B270 is the trade name of a product supplied by SCHOTT. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

Table J.1 *(continued)*

Wavelength λ nm	Spectral lower limit	Nominal value %	Transmittance upper limit
310,0	8,1	19,6	31,7
311,0	9,9	22,1	34,5
312,0	11,9	24,7	37,4
313,0	14,0	27,4	40,2
314,0	16,3	30,1	42,9
315,0	18,7	32,8	45,7
316,0	21,3	35,5	48,2
317,0	24,0	38,2	50,8
318,0	26,7	41,0	53,3
319,0	29,5	43,5	55,6
320,0	32,3	46,2	57,9
321,0	35,1	48,7	60,0
322,0	37,9	51,1	62,1
323,0	40,8	53,5	64,1
324,0	43,5	55,7	65,9
325,0	46,1	57,8	67,7
326,0	48,7	60,0	69,3
327,0	51,3	61,9	70,9
328,0	53,7	63,7	72,4
329,0	55,9	65,5	73,7
330,0	58,1	67,2	74,9
331,0	60,3	68,7	76,1
332,0	62,3	70,2	77,1
333,0	64,1	71,6	78,2
334,0	65,9	72,9	79,1
335,0	67,6	74,1	79,9
336,0	69,3	75,2	80,8
337,0	70,7	76,3	81,6
338,0	72,1	77,4	82,3
339,0	73,4	78,2	82,9
340,0	74,7	79,1	83,5
341,0	75,8	79,9	84,1
342,0	76,9	80,5	84,6
343,0	77,9	81,3	85,1
344,0	78,9	82,0	85,6
345,0	79,7	82,6	85,9
346,0	80,4	83,2	86,3
347,0	81,3	83,6	86,7
348,0	81,9	84,1	87,0

Table J.1 *(continued)*

Wavelength λ nm	**Spectral lower limit**	**Nominal value** **%**	**Transmittance upper limit**
349,0	82,6	84,5	87,3
350,0	83,2	84,9	87,5
351,0	83,4	85,5	87,9
352,0	83,6	85,7	88,0
353,0	83,8	86,0	88,2
354,0	84,0	86,4	88,4
355,0	84,2	86,6	88,6
356,0	84,4	86,9	88,8
357,0	84,5	87,1	88,9
358,0	84,7	87,3	89,0
359,0	84,9	87,5	89,2
360,0	85,1	87,6	89,3
361,0	85,3	88,0	89,4
362,0	85,5	88,0	89,5
363,0	85,7	88,2	89,6
364,0	85,8	88,3	89,7
365,0	86,1	88,5	89,8
366,0	86,3	88,5	89,8
367,0	86,4	88,7	89,9
368,0	86,7	88,7	90,0
369,0	86,8	88,8	
370,0	87,0	88,9	
371,0		88,9	
372,0		88,9	
373,0		89,0	
374,0		88,8	
375,0		88,8	
376,0		88,8	
377,0		88,9	
378,0		88,8	
379,0		89,0	
380,0		89,0	
381,0		89,0	
382,0		89,1	
383,0		89,2	
384,0		89,2	91,0
385,0		89,4	
386,0		89,5	
387,0		89,5	

Table J.1 *(continued)*

Wavelength λ nm	**Spectral lower limit**	**Nominal value** **%**	**Transmittance upper limit**
388,0		89,7	
389,0		89,7	
390,0		89,7	
391,0		89,9	
392,0		89,9	
393,0		90,0	
394,0		90,0	
395,0		90,1	
396,0		90,1	
397,0		90,2	
398,0		90,2	
399,0		90,2	
400,0	89,0	90,3	93,0
600,0		91,2	
800,0	89,0	91,4	93,0

Annex K
(informative)

Method of variable distance for the calibration of the telescope

This annex relates to 8.1. The calibration of the apparatus can be achieved by a distance-dependent measurement of optical power. This technique takes into account the property that a variation in the distance between telescope and illuminated target results has the same effect as introducing a sample with defined optical power. For the telescope method the common lens (real is positive) formula:

$$\frac{1}{g}+\frac{1}{b}=\frac{1}{f} \qquad \text{(K.1)}$$

where

f is the focus length of the telescope objective;

b is the image distance;

g is the object distance between the telescope and the illuminated target.

If a sample having optical power *D* is placed immediately in front of the objective of the telescope, this optical power is added to the power $1/f$ of the telescope objective. The image seen in the telescope can be brought back into focus by changing the object distance *g* of the set-up changed by a distance *d.* Formula (K.1) has to be amended to

$$\frac{1}{g+d}+\frac{1}{b}=\frac{1}{f}-D \qquad \text{(K.2)}$$

From Formula (K.2) the measured value expressed in dioptres is given by Formula (K.3)

$$D=\frac{1}{g}-\frac{1}{g+d} \qquad \text{(K.3)}$$

Table K.1 shows the total distance ($g + d$) for a calibration in steps of 0,01 dpt, where for *g* the required value of 4,60 m is used.

Table K.1 — Functional dependence between measured optical power and distance between telescope and target for an initial object distance of 4,6 m

Optical power dioptres	Distance from telescope mm	Optical power dioptres	Distance from telescope mm
0	4 600,0	0	4 600,0
-0,01	4 397,7	0,01	4 821,8
-0,02	4 212,5	0,02	5 066,1
-0,03	4 042,2	0,03	5 336,4
-0,04	3 885,1	0,04	5 637,3
-0,05	3 739,8	0,05	5 974,0
-0,06	3 605,0	0,06	6 353,6
-0,07	3 479,6	0,07	6 784,7

Table K.1 *(continued)*

Optical power dioptres	**Distance from telescope** mm	**Optical power** dioptres	**Distance from telescope** mm
-0,08	3 362,6	0,08	7 278,5
-0,09	3 253,2	0,09	7 849,8
-0,1	3 150,7	0,1	8 518,5
-0,11	3 054,4	0,11	9 311,7
-0,12	2 963,9	0,12	10 267,9
-0,13	2 878,6	0,13	11 442,8
-0,14	2 798,1	0,14	12 921,3
-0,15	2 721,9	0,15	14 838,7
-0,16	2 649,8	0,16	17 424,2
-0,17	2 581,4	0,17	21 100,9
-0,18	2 516,4	0,18	26 744,2
-0,19	2 454,6	0,19	36 507,9
-0,2	2 395,8	0,2	57 500,0
-0,21	2 339,8		
-0,22	2 286,3		
-0,23	2 235,2		
-0,24	2 186,3		
-0,25	2 139,5		

Once a complete calibration has been made using these values, a check of the apparatus can be accomplished regularly by focusing the system to a target placed at a defined distance from the telescope.

Annex L
(normative)

Method to correct transmittance for variations in thickness of the filter

The following relation holds between the transmittance, τ, and the thickness, t, if multiple reflections within the sample are neglected and the sample is made from a material in which the tint is uniformly distributed throughout the material rather than being coated or imbibed into the surface:

$$\tau = (1-\rho_1)\cdot(1-\rho_2)e^{-kt} \tag{L.1}$$

where

ρ_1 is the reflectance at the front surface;

ρ_2 is the reflectance of the back surface;

t is the thickness measured by a calliper at the reference point of the filter;

k is the absorption coefficient.

The absorption coefficient k may be calculated from the transmittance, τ, for the reference thickness, t, as follows:

$$k = -\ln\left(\frac{\tau}{(1-\rho_1)\cdot(1-\rho_2)}\right) \Big/ t \tag{L.2}$$

The expected transmittance for a different thickness can than be calculated using Formula (L.1).

Where the refractive index n is known and there is no surface treatment, the reflectance ρ is given by the following formula:

$$\rho = \left((\mathrm{n}-1)/(\mathrm{n}+1)\right)^2 \tag{L.3}$$

For example, a filter having a refractive index $n = 1{,}5$, a thickness $t = 2$ mm at the centre and a transmittance at this point $\tau_\mathrm{v} = 30$ %, its reflectance (front surface or back surface without treatment) will be $\rho = 4$ %. Using this value for ρ_1 and ρ_2 in Formula (L.2), the absorption coefficient $k = 0{,}56$ mm^{-1}. Consequently, if transmittance measured at the edge of the filter, where the thickness is 1,8 mm, is 33,5 % then it could be assumed that variations of transmittance are only due to variations in thickness of the filter.

NOTE The reflectance of the front and/or back surface could also be measured directly using the method described in 7.7. This method is recommended when the surface of the filter has treatment.

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