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Ophthalmic optics — Uncut finished spectacle lenses —

Part 3:
Transmittance specifications and test methods

Optique ophtalmique — Verres de lunettes finis non détourés —

Partie 3: Spécifications relatives au facteur de transmission et méthodes d'essai

Reference number
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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: 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 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 7, *Ophthalmic optics and instruments*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 170, *Ophthalmic optics,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fourth edition cancels and replaces the third edition (ISO 8980-3:2013), which has been technically revised.

The main changes are as follows:

- terms and definitions, previously in Clause 3, have been referenced to ISO 13666;
- requirements regarding claimed transmittance properties have been added in 6.6;
- references have been updated as appropriate and needed;
- descriptions of requirements throughout the document have been updated and amended for clarification.

A list of all parts in the ISO 8980 series can be found on the ISO website.

Ophthalmic optics — Uncut finished spectacle lenses —

Part 3: Transmittance specifications and test methods

1 Scope

This document specifies requirements for the transmittance properties of uncut and unmounted finished spectacle lenses, including attenuation of solar radiation.

This document is not applicable to

- spectacle lenses having specific transmittance or absorption characteristics prescribed for medical reasons,
- products to which specific personal protective equipment transmittance standards apply, and
- products intended for direct observation of the sun, such as for solar-eclipse viewing.

NOTE 1 By reference to ISO 21987 and ISO 14889, this document also applies to lenses mounted in spectacles.

NOTE 2 Optical and geometric requirements are given for uncut finished spectacle lenses in ISO 8980-1 and ISO 8980-2, and for mounted lenses, in ISO 21987.

2 Normative references

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

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

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

ISO 13666:2019, *Ophthalmic optics — Spectacle lenses — Vocabulary*

ISO 14889, *Ophthalmic optics — Spectacle lenses — Fundamental requirements for uncut finished lenses*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13666 apply.

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

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at https://www.electropedia.org/

4 Symbols

The symbols for the characteristic luminous transmittances of photochromic lenses are given in Table 1.

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Table 1 — Symbols for the characteristic luminous transmittances of photochromic lenses

Symbols	Characteristic luminous transmittances
$\tau_{\mathrm{v}\,0}$	Luminous transmittance in the faded state as reached at (23 ± 2) °C after specified conditioning.
$\tau_{\mathrm{v}\,1}$	Luminous transmittance in the darkened state as reached at (23 ± 2) °C after specified irradiation simulating mean outdoor conditions.
$\tau_{\mathrm{v}\,\mathrm{W}}$	Luminous transmittance in the darkened state as reached at (5 ± 2) °C after specified irradiation simulating outdoor conditions at low temperatures.
$\tau_{\mathrm{v}\,\mathrm{S}}$	Luminous transmittance in the darkened state as reached at (35 ± 2) °C after specified irradiation simulating outdoor conditions at high temperatures.
$\tau_{\mathrm{v}\,\mathrm{R}}$	Luminous transmittance in the darkened state as reached at (23 ± 2) °C after specified irradiation simulating reduced light conditions.

NOTE 1 When describing a photochromic lens, the luminous transmittance refers to the faded state before exposure to optical radiation, and the darkened state after exposure to optical radiation.

NOTE 2 The symbol for the luminous transmittance in reduced light conditions, $\tau_{\mathrm{v}\,\mathrm{R}}$, has been changed from $\tau_{\mathrm{v}\,\mathrm{A}}$ which is in ISO 13666. This is to avoid possible confusion with the luminous transmittance measured in CIE standard illuminant A, which is also frequently given the symbol $\tau_{\mathrm{v}\,\mathrm{A}}$.

5 Classification

Spectacle lenses are classified with respect to transmittance as follows:

a) clear lenses, with no intended colour/tint in transmission;

b) uniformly tinted lenses;

c) gradient-tinted lenses;

d) photochromic lenses;

e) polarizing lenses.

NOTE b) or c) can be combined with d) and/or e).

6 Requirements

6.1 General

The fundamental requirements for uncut finished lenses, including reference to 6.3, are in ISO 14889. For other than photochromic lenses, the requirements shall apply at a temperature of (23 ± 5) °C, and shall apply at the design reference point unless specified otherwise. For photochromic lenses, the applicable temperatures are given in Table 1.

The results of all calculations of values to be assessed against the requirements of this document shall be rounded to the same precision as the statement of requirement.

NOTE For example, luminous transmittance is stated as an integer, UV transmittance to one decimal place, consistent with Table 1.

6.2 General transmittance requirements

6.2.1 Tint descriptions, categories, and UV transmittance requirements

Spectacle lenses shall be nominated to one of five tint descriptions or luminous transmittance categories as specified in Table 2. Lenses shall be tested as described in Clause 7.

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A spectacle lens nominated by the manufacturer as having a luminous transmittance, τ_v, that is in category 0, 1, 2 or 3 shall have a luminous transmittance at its design reference point that shall not lie outside the limits of the stated category by more than 2 % absolute.

A spectacle lens nominated by the manufacturer as having a luminous transmittance, τ_v, that is in category 4 shall have a luminous transmittance, τ_v, at its design reference point that shall not lie outside the limits of that category by more than 20 % relative to the stated luminous transmittance.

For gradient-tinted lenses, the overlap in luminous transmittance allowed between categories shall be double that for uniformly tinted lenses.

A lens nominated by the manufacturer as having a luminous transmittance, τ_v, that is in a particular category shall comply with the ultraviolet (UV) transmittance requirements of that category, regardless of the actual luminous transmittance. For example, a lens nominated to have a luminous transmittance in category 2 but actually having a luminous transmittance of 45 % (category 1, or category 2 allowing for the 2 % tolerance) shall comply with the UV transmittance requirements of a category 2 lens.

Any lens that does not meet the UV transmittance requirements in Table 2 shall include the warning indicated in 8 g).

6.2.2 Tolerances on luminous transmittance of tinted lenses

A tint should be ordered by reference to a manufacturer's sample. Such a tint should not be visibly different from the tint of the sample and its assessment is not restricted to its luminous transmittance, τ_v, measured by spectrophotometer.

A lens ordered by a specific luminous transmittance, τ_v, shall have a measured, τ_v, at the design reference point within ±8 % absolute of that ordered.

The tint of the two lenses of a pair should not be visibly different.

Table 2 — Categories for luminous transmittance and the related permissible transmittance in the ultraviolet solar spectral range

		Visible spectral range	**Ultraviolet spectral range**	
		380 nm to 780 nm	315 nm to 380 nm UV-A	280 nm to 315 nm UV-B
Tint description	**Luminous transmittance category**	Range of luminous transmittance τ_v	Maximum value of solar UV-A transmittance τ_{SUVA}	Maximum value of solar UV-B transmittance τ_{SUVB}
Clear or very light tint	0	$\tau_v > 80$ %	τ_v	0,05 τ_v
Light tint	1	80 % $\geq \tau_v >$ 43 %	τ_v	0,05 τ_v
Medium tint	2	43 % $\geq \tau_v >$ 18 %	0,5 τ_v	1,0 % absolute or 0,05 τ_v, whichever is greater
Dark tint	3	18 % $\geq \tau_v >$ 8 %	0,5 τ_v	1,0 % absolute
Very dark tint	4	8 % $\geq \tau_v >$ 3 %	1,0 % absolute or 0,25 τ_v, whichever is greater	1,0 % absolute

NOTE For the convenience of the reader, formulae are presented in Annex F in summation form.

6.3 Spectral transmittance requirements of spectacle lenses intended for driving and road use

6.3.1 General

Spectacle lenses having a luminous transmittance, τ_v, less than or equal to 8 % are not intended for driving and road use. Therefore, there are no requirements for such lenses in this clause.

6.3.2 Spectral transmittance

The spectral transmittance, $\tau(\lambda)$, at any wavelength in the range 475 nm to 650 nm shall be not less than 0,20 τ_v.

6.3.3 Daylight use

The luminous transmittance, τ_v, of spectacle lenses for driving and road use during daylight shall be greater than 8 % at the design reference point.

6.3.4 Driving in twilight or at night

Spectacle lenses with a luminous transmittance, τ_v, less than 75 % shall not be used for driving and road use in twilight or at night. In the case of photochromic spectacle lenses, this requirement applies when tested in accordance with 7.5.3.5.

6.3.5 Relative visual attenuation coefficient (quotient) for incandescent traffic signal light detection

Spectacle lenses for driving and road use shall have a relative visual attenuation coefficient (quotient), Q_{signal}, not less than:

a) 0,80 for Q_{red};

b) 0,60 for Q_{yellow};

c) 0,60 for Q_{green};

d) 0,40 for Q_{blue}.

The relative visual attenuation coefficients (quotients), Q_{signal}, shall be calculated according to ISO 13666:2019, 3.17.8, with the spectral data as specified in Annex A. An alternative calculation can be made in summation form according to E.6 with the spectral data as specified in Annex A.

6.4 Additional transmittance requirements for special types of spectacle lenses

6.4.1 Photochromic spectacle lenses

6.4.1.1 General

Two categories are typically used to characterize photochromic spectacle lenses, corresponding to the faded state and to the darkened state. Additional lens states may be specified under various temperatures (see 6.4.1.3) and moderate light levels (see 6.4.1.4). Transmittances shall be determined according to the method in 7.5. The UV transmittance in any state shall conform to the values specified for that category in Table 2.

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6.4.1.2 Photochromic response

When tested by the methods described in 7.5.3.1 to 7.5.3.3, the ratio of the luminous transmittance of a photochromic lens (see 7.5.1) in its faded state, $\tau_{\mathrm{v}\,0}$, to that in its darkened state, $\tau_{\mathrm{v}\,1}$, after 15 min irradiation, shall be at least 1,25, as given by Formula (1):

$$\frac{\tau_{\mathrm{v}\,0}}{\tau_{\mathrm{v}\,1}} \geq 1{,}25 \qquad (1)$$

6.4.1.3 Photochromic response at various temperatures

If the influence of temperature on photochromic response is stated, it shall be determined by measuring the luminous transmittance of the lens (see 7.5.1) in the darkened state using the procedure described in 7.5.3.6 at 5 °C ($\tau_{\mathrm{v\,W}}$), 23 °C ($\tau_{\mathrm{v}\,1}$) and 35 °C ($\tau_{\mathrm{v\,S}}$).

The manufacturer can use additional temperatures, provided this information is made available.

6.4.1.4 Photochromic response at moderate light levels

If the photochromic response at moderate light levels is stated, it shall be determined by measuring the luminous transmittance of the lens (see 7.5.1) in the darkened state, $\tau_{\mathrm{v\,R}}$, using the procedure described in 7.5.3.4.

6.4.2 Polarizing spectacle lenses

6.4.2.1 Polarizing efficiency

When tested according to the method in 7.6, the polarizing efficiency shall be >78 % for luminous transmittance categories 2, 3, 4 and >60 % for luminous transmittance category 1.

6.4.2.2 Orientation

When tested according to the method in 7.6, the actual plane of transmittance shall be at (90 ± 5)° from the horizontal reference.

This reference is constituted by

- the permanent alignment reference markings for power-variation lenses and position-specific single-vision lenses,
- the dividing line for straight-top and E-line multifocal lenses, and to the tangent to the mid-point of the dividing line of curved-top multifocal lenses in their intended orientation,
- the marking according to 6.4.2.3 for single-vision and multifocal lenses with no other geometric orientation properties, and
- for finished lenses, the horizontal line joining the boxed centres of the lenses when fitted to the intended frame.

6.4.2.3 Marking

Polarizing finished single-vision and multifocal lenses with no other geometric orientation properties shall include permanent or non-permanent marking on the horizontal meridian to identify clearly the intended horizontal orientation.

Alternatively, if manufacturers or suppliers choose to include marking on the vertical meridian of the finished lenses to indicate the plane of transmission, this alternative method of marking shall be clearly identified. In this case, the same tolerance as stated in 6.4.2.2 (±5°) applies for the difference between the marking and the actual plane of transmittance.

6.4.3 Gradient-tinted spectacle lenses

The requirements for gradient-tinted spectacle lenses shall be determined at the design reference point of the spectacle lens. It is recommended that gradient tints be ordered by reference to a manufacturer's sample lens, identification code, name or reference number.

6.5 Resistance to ultraviolet radiation

Following irradiation as specified in 7.7, the absolute change in the luminous transmittance ($\tau_v' - \tau_v$) of the lenses shall be less than or equal to 5 % absolute, where τ_v' is the luminous transmittance after irradiation. This tolerance shall also apply to photochromic lenses in the faded state when measured after conditioning according to 7.5.3.1, following testing according to 7.7.

In addition, the following shall be met:

a) for photochromic filters $\frac{\tau_{v\,0}}{\tau_{v\,1}}$ shall be ≥1,25;

b) the UV requirements for the initial τ_v shall continue to be satisfied;

c) if originally intended for driving and road use, the requirements of 6.3 shall continue to be satisfied.

6.6 Claimed UV absorption/transmittance properties

6.6.1 General

In cases where it is claimed that a lens reaches a certain percentage of UV absorption or UV transmittance better than the requirement in Table 2, the relevant requirement(s) below shall apply. For reference, Annex B shall be used.

6.6.2 Solar UV absorption

In the case where it is claimed that a lens has x % solar UV absorption, the solar UV transmittance of the lens, τ_{SUV}, shall not exceed (100,5 - x) %.

6.6.3 Solar UV transmittance

In the case where it is claimed that a lens has less than x % solar UV transmittance, the solar UV transmittance of the lens, τ_{SUV}, shall not exceed (x + 0,5) %.

6.6.4 Solar UV-A absorption

In the case where it is claimed that a lens has x % solar UV-A absorption, the solar UV-A transmittance of the lens, τ_{SUVA}, shall not exceed (100,5 - x) %.

6.6.5 Solar UV-A transmittance

In the case where it is claimed that a lens has less than x % solar UV-A transmittance, the solar UV-A transmittance of the lens, τ_{SUVA}, shall not exceed (x + 0,5) %.

6.6.6 Solar UV-B absorption

In the case where it is claimed that a lens has x % solar UV-B absorption, the solar UV-B transmittance of the lens, τ_{SUVB}, shall not exceed (100,5 - x) %.

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6.6.7 Solar UV-B transmittance

In the case where it is claimed that a lens has less than x % solar UV-B transmittance, the solar UV-B transmittance of the lens, τ_{SUVB}, shall not exceed (x + 0,5) %.

7 Test methods

7.1 General

This clause specifies reference methods for transmittance properties of spectacle lenses.

For purposes of quality control, etc., alternative test methods can be used provided they have been shown to be equivalent and include uncertainties of measurement no greater than those required of the reference method.

7.2 Spectral transmittance

The uncertainties of the test methods determining transmittance values shall be not greater than:

- 2 % absolute, for transmittance >20 %;
- 1 % absolute, for luminous transmittance ≤20 %;
- 10 % relative, for UV transmittance of lenses with luminous transmittance ≤20 %.

These measurement uncertainties shall be based on a confidence level of 95 %.

NOTE Guidelines for evaluating uncertainty can be found in ISO/IEC Guide 98-3. Advice on the specific issues in evaluating uncertainty of measurement in lenses can be found in ISO 18526-2:2020, Annex B. The user can refer to operating manuals and other information provided by manufacturers of specific instruments for additional information.

7.3 Luminous transmittance and relative visual attenuation coefficient (quotient)

7.3.1 The spectral distribution of standard illuminant D65 as specified in ISO 11664-2 and the luminous efficiency of the average human eye for photopic vision (2° observer) as specified in ISO 11664-1 shall be used to determine the luminous transmittance, τ_{v}. When calculating the luminous transmittance, τ_{v}, from the spectral transmittance $\tau(\lambda)$, the step width (wavelength interval) shall not exceed 10 nm.

7.3.2 When calculating the relative visual attenuation coefficient (quotient), Q_{signal}, for incandescent signal lights from the spectral transmittance $\tau(\lambda)$, the step width shall not exceed 5 nm. The relevant formula, from ISO 13666, is as given by Formula (2):

$$Q_{\mathrm{signal}} = \frac{\tau_{\mathrm{signal}}}{\tau_{\mathrm{v}}} \tag{2}$$

where

τ_{v} is given in E.5;

τ_{signal} is given in E.6;.

NOTE Calculations are currently based on the measured values of $E_{\mathrm{signal}}(\lambda)$ for traffic signal lights using incandescent quartz-halogen lamps given in Table A.1. Calculations using values for LED signals will give different results than those using the values for quartz-halogen lamps.

7.4 Ultraviolet transmittance

7.4.1 Principle

The ultraviolet transmittance in the spectral range from 280 nm to 380 nm of the finished spectacle lens shall be determined using a spectrophotometer.

7.4.2 Apparatus

The spectrophotometer shall

a) operate over the wavelength range from 280 nm to 380 nm,

b) have a spectral bandwidth (full width at half maximum, FWHM) not exceeding 5 nm, and

c) be capable of measuring spectral data at wavelength intervals of 5 nm or less.

7.4.3 Calculation

In the calculation of solar UV-B transmittance, τ_{SUVB}, solar UV-A transmittance, τ_{SUVA}, and total solar UV transmittance, τ_{SUV}, the wavelength interval shall be no greater than 5 nm. The wavelength interval should be nominally equal to the spectral bandwidth. For data recorded with varying spectral bandwidth or for bandwidths that do not equal the wavelength interval, the effects of this mismatch shall be accounted for in the reported values of spectral transmittance.

The relevant formulae for the solar ultraviolet transmittance values, τ_{SUV}, τ_{SUVA}, and τ_{SUVB}, are defined in ISO 13666:2019, 3.17.4 and 3.17.5, and given, in summation form, in E.2 to E.4. The weighting data are given in ISO 13666:2019, Table A.1 and Table B.1. Linear interpolation of these values for wavelength intervals smaller than 5 nm is permitted.

7.5 Transmittance properties of photochromic spectacle lenses and photochromic specimens

7.5.1 Test lenses

Lenses used for testing shall be plano power, normally with a reference thickness of (2,0 ± 0,1) mm. If a thickness outside this range is used, the thickness shall be stated. After having undergone careful cleaning, each lens shall be conditioned as described in 7.5.3.1.

The base curve is not specified but should be recorded.

7.5.2 Apparatus

7.5.2.1 Irradiation source, used to darken photochromic spectacle lens

The irradiation source (solar simulator) shall approximate as closely as practical the spectral power distribution of solar radiation defined as air mass (AM) $m = 2$ (see Reference [7] or Reference [15]) at an illuminance of (50 000 ± 5 000) lx, or, when the luminous transmittance for night driving shall be measured, at the illuminance specified in 7.5.3.4.

Testing shall be done with a source (e.g. a high pressure xenon arc lamp with filters) that provides an illuminance of (50 000 ± 5 000) lx and the irradiance values at the position of the lens given in Table 3. The irradiation source should be monitored to correct for drifts in its output.

Where testing at (15 000 ± 1 500) lx is specified, the irradiances and tolerances in Table 3 shall be multiplied by 0,30.

See Annex D for details of risks associated with solar radiation and solar simulators.

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Care should be taken to ensure that irradiation from the source does not interfere with the transmittance measurements.

NOTE To attenuate the intensity of the irradiation source (solar simulator) for the measurement of the transmittance properties of a photochromic lens at moderate light levels (see 6.4.1.4), a neutral density filter can be used, suitably positioned in the irradiation beam.

Table 3 — Irradiance for testing photochromic lenses

Wavelength range nm	**Irradiance** W/m^2	**Irradiance tolerance** W/m^2
300 to 340	<2,5	—
340 to 380	5,6	±1,5
380 to 420	12	±3,0
420 to 460	20	±3,0
460 to 500	26	±2,6

7.5.2.1.1 Radiation source using one lamp

Use a high-pressure xenon arc lamp, a filter or filter combination (e.g. heat absorbing filter and cut-on filter) with a nominal spectral transmittance as specified in Figure 1.

If the lamp is not an ozone free type (OFR), it can be vented to prevent exposure of the operator to ozone generated by the lamp.

NOTE Figure 1 is an idealized plot. Spectral irradiances according to Table 3 can be achieved, for example, by combination of a KG2 filter1) with a nominal thickness of 3 mm and an appropriate cut-on filter.

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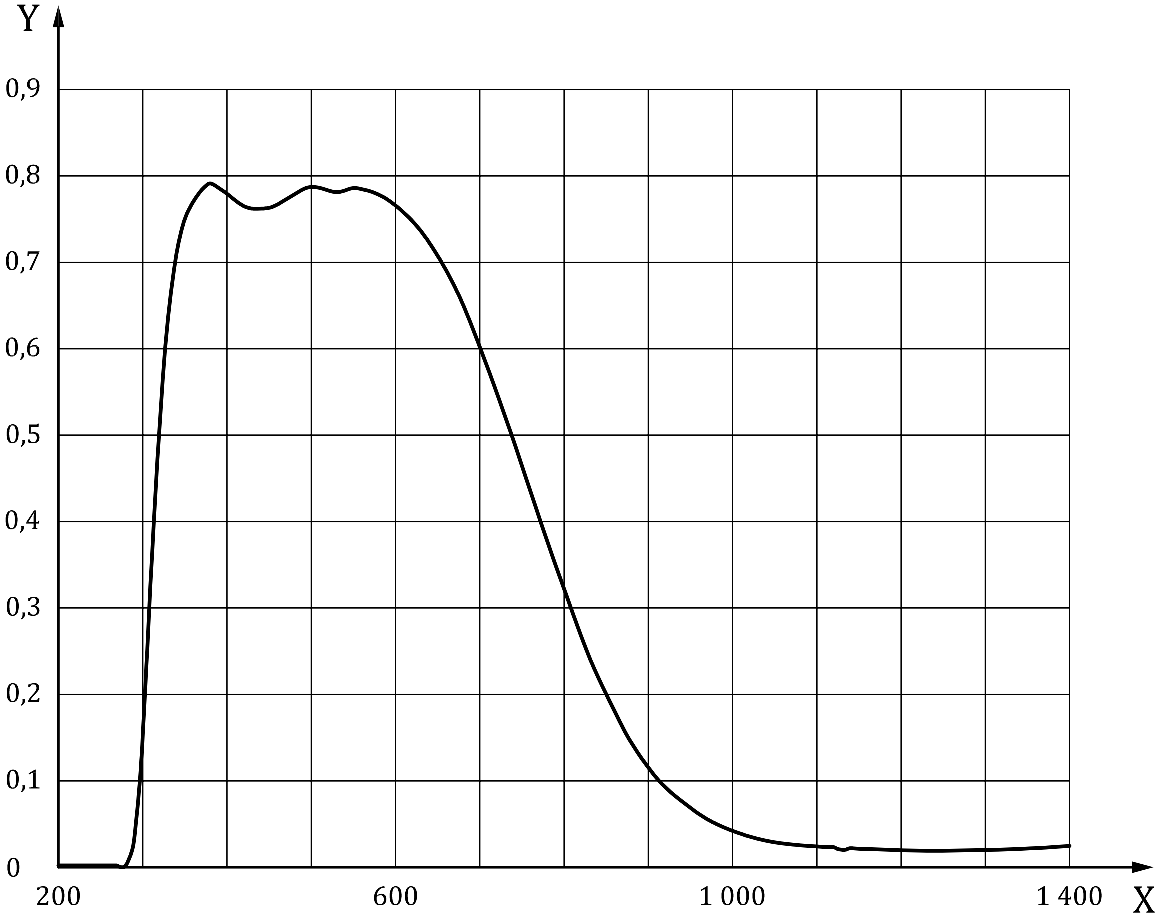
1) Schott KG2 is the trade name of a product supplied by SCHOTT AG. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.



Key

X wavelength (nm)

Y transmittance (decimal value)

Figure 1 — Spectral transmittance of the combination of the heat absorbing filter and the cut-on filter for the irradiation of photochromic lenses

7.5.2.1.2 Radiation source using two lamps

The solar spectrum can be approximated more closely than with one lamp by using two high-pressure xenon arc lamps with different filtering in front of them. The radiation from the two lamps is then combined by means of a semi-transparent mirror.

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

If any lamp is not an ozone free type (OFR), it should be vented to prevent exposure of the operator to ozone generated by the lamp.

7.5.2.2 Specimen chamber, to maintain the lens at the required temperature, 5 °C, 23 °C or 35 °C, to within ±2 °C during exposure to the solar simulator.

NOTE A water bath can be used to achieve temperature control. Since immersion of the lens(es) in water reduces the reflectivity of the surfaces, the transmittance values determined using water immersion will require correction to yield the equivalent “air” values. In order to avoid modifying the photochromic performance due to water absorption into the lens, do not immerse lenses longer than necessary. Calibration of the equipment can be checked using a non-photochromic lens with refractive index within ±0,01 of the refractive index of the photochromic lens.

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7.5.2.3 Spectrophotometer, capable of recording spectral transmittance data from 280 nm to 780 nm within a time span that does not affect the results. Alternatively, the 280 nm to 380 nm range may be measured immediately after removal from the irradiation source to ensure the performance measurement is not affected by the measuring beam.

For determining transmittance properties in the darkened state, the spectrophotometer shall

a) have a spectral bandwidth not greater than 5 nm, and

b) be capable of measuring spectral data at wavelength intervals of 5 nm or less.

7.5.3 Determination of transmittance

7.5.3.1 Conditioning

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

a) store lenses in the dark at (65 ± 5) °C for (2,0 ± 0,2) h, then,

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

7.5.3.2 Luminous and UV transmittance in the faded state

After conditioning and before exposing the lens to any irradiation source, determine the luminous transmittance, $\tau_{\mathrm{v}\,0}$, and the solar UV transmittance values of the lens, τ_{SUVA} and τ_{SUVB}, in its faded state, using the apparatus described in 7.5.2 with the lens at a temperature of (23 ± 2) °C.

7.5.3.3 Luminous and UV transmittance in the darkened state

While maintaining the lens temperature of (23 ± 2) °C, irradiate it with the irradiation source for (15,0 ± 0,1) min and determine the luminous transmittance, $\tau_{\mathrm{v}\,1}$, and the solar UV transmittance values of the lens, τ_{SUVA} and τ_{SUVB}, in the darkened state using the apparatus described in 7.5.2.

7.5.3.4 Luminous transmittance at moderate light levels

When determining the photochromic response at moderate light levels, repeat the procedure described in 7.5.3.1 to 7.5.3.3 at (23 ± 2) °C at an illuminance of (15 000 ± 1 500) lx and maintain the same relative spectral power distribution with the solar simulator specified in 7.5.2.1.

7.5.3.5 Luminous transmittance for driving in twilight or at night

After conditioning as described in 7.5.3.1 and while maintaining the lens at a temperature of (23 ± 2) °C, irradiate it under the conditions described in 7.5.3.4 for (15,0 ± 0,1) min. Afterwards, store the lens at (23 ± 2) °C for (60 ± 1) min either in the dark or under reduced illumination, depending on the manufacturer’s instructions. Then determine the luminous transmittance, τ_{v}, using the apparatus described in 7.5.2.

7.5.3.6 Luminous and UV transmittance at various temperatures

If the luminous transmittance or photochromic response at a temperature different from 23 °C is stated, it shall be determined by the procedure described in 7.5.3.1 to 7.5.3.3 at (5 ± 2) °C and (35 ± 2) °C.

If additional temperatures are stated by the manufacturer, testing shall be performed at the stated temperatures ±2 °C.

7.6 Test methods for polarizing spectacle lenses

7.6.1 Mean luminous transmittance

The transmittance value of polarizing lenses shall be determined using unpolarized light or shall be calculated as a mean value of the transmittance values determined for two mutually perpendicular orientations of the plane of transmission of the lens.

7.6.2 Polarizing efficiency

7.6.2.1 Principle

The polarizing efficiency of a polarizing lens is determined with radiation polarized firstly parallel and secondly perpendicular to the plane of transmission. Before measuring the sample lens, the incident beam should be essentially 100 % linearly polarized by the introduction of a suitable polarizing medium and calibrating to 100 %. Insert the lens, then rotate the lens or the linear polarizer to the point of maximum transmittance. At this orientation, the luminous transmittance, $\tau_{\mathrm{P\,max}}$, is recorded. The lens or linear polarizer is then rotated 90° and the luminous transmittance, $\tau_{\mathrm{P\,min}}$, is recorded. The polarizing efficiency shall then be calculated according to E.8.

7.6.2.2 Spectrophotometer method

For the measurements, a spectrophotometer shall be used in combination with a polarizing medium of known plane of polarization in the light path. The spectral transmittance shall be determined in accordance with 7.2 and 7.3.

7.6.2.3 Broadband method

Select a combination of source of light and filter to give a correlated colour temperature of (6 500 ± 1 000) K (approximating CIE Standard Illuminant D65 in the visible region). Select a detector with approximately the spectral sensitivity of the CIE 2° Standard Observer (ISO 11664-1) in the visible spectral range that is linear to within ±0,5 %. Collimate the beam of light from the source and insert the linear polarizer and the spectacle lens under test between the collimator and detector.

7.6.3 Plane of transmission

7.6.3.1 General

For the determination of the plane of transmission, a polarizer of known plane of polarization in the light path shall be used, e.g., by the method given in 7.6.3.2 and 7.6.3.3.

7.6.3.2 Apparatus

See Figure 2.

A pair of polarizers are cut to give planes of transmission at a +3° and a −3° angle about the horizontal. The top and bottom halves of the polarizers shall then be joined together and glass mounted, with the line of the join horizontal to form a split field polarizer. The split-field polarizer 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.

7.6.3.3 Procedure for an uncut lens

Mount the lens on the apparatus between the two register bars with the indicating marks aligned along 180° (horizontal) and with its front surface towards the split-field polarizer. Ensure that the split-field appears in the centre of the lens by means of vertical adjusters.

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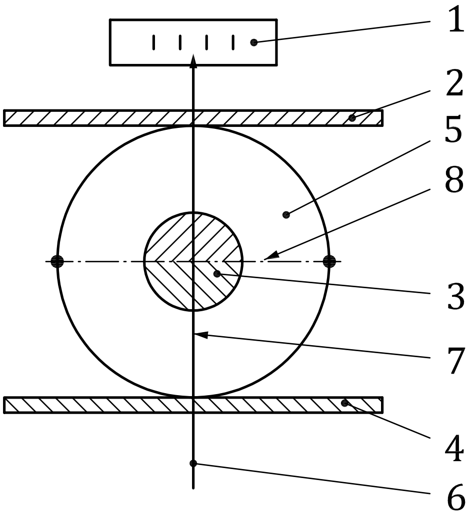
Move the lever from side to side until the top and bottom halves of the illuminated split-field appear of equal luminance when viewed through the lens.

Read off the pointer position to give the deviation in degrees (plus or minus) of the plane of transmission of the lens from the vertical.

NOTE For a lens marked with the plane of transmission (see 6.4.2.3), mount the lens with these marks aligned along 90° (vertical).



Key

1	scale
2	top register bar
3	split field polarizer
4	bottom register bar
5	polarizing lens
6	split field rotation lever
7	plane of transmission
8	intended horizontal orientation of lens

Figure 2 — Principle of an apparatus for the determination of the plane of transmission

7.7 Determination of resistance to ultraviolet radiation

7.7.1 Principle

This procedure exposes lenses to a minimum of 1,4 MJ/m^2 of UV radiation with a spectral distribution simulating sun light from 300 nm to 400 nm. The transmittance of lenses shall be measured according to 7.3 before and after exposure to determine their resistance to radiation.

7.7.2 Reference apparatus

Fused-silica envelope high-pressure xenon arc lamp. The power of the lamp shall be between 400 W and 500 W, with a preferred value of 450 W.

NOTE 1 Suitable lamp references are XBO-450 W, USHIO UXL 451-O 450W, and XBO-450 W/4[2].

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[2] XBO-450 W, USHIO UXL 451-O 450W, and XBO-450 W/4 are examples of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

NOTE 2 If the lamp is not an ozone free type (OFR), it can be vented to prevent exposure of the operator to ozone generated by the lamp.

For the operation of the lamp, adhere to the following requirements:

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) apply a cut-on filter, between the lamp and the sample, with the spectral transmittance data specified in Annex C. An example of such a filter is Schott B270i[3] with a nominal thickness of 4 mm;

d) stabilize the lamp current at (25,0 ± 0,2) A;

e) the air temperature in the immediate area of the test lens shall be (28 ± 5) °C.

7.7.3 Procedure using reference apparatus

Expose the front surface of the lens to radiation from the lamp using an irradiation time of (50,0 ± 0,1) h. The angle of incidence of the radiation on the lens surface shall be essentially perpendicular. The distance from the axis of the lamp to the nearest point on the sample shall be (300 ± 10) mm. The exposure time shall be (50,0 ± 0,1) h at a lamp power of 450 W. The samples shall be allowed to thermally stabilize before measurement of their transmittance properties.

WARNING — Precautions should be taken against potential generation and build-up of ozone.

Apparatus using other power high pressure xenon lamps having different power may be used with the following conditions:

- lenses shall be exposed to the radiation as specified in 7.7.1;
- irradiation time shall not be greater than 50 h and not less than 10 h;
- lenses shall not be exposed to radiation with wavelengths less than 280 nm;
- air temperature in the immediate area of the test lens shall be (28 ± 5) °C;
- lenses shall be allowed to stabilize thermally prior to measurement of their transmittance properties.

8 Identification

The following information shall be supplied by the manufacturer or supplier on the package of the lens or in an accompanying document:

a) identification of the finished lens;

b) classification(s) in accordance with Clause 5;

c) tint description or category(ies) in accordance with Table 2;

d) any claimed absorption or transmittance properties in accordance with 6.6;

e) when the lens is nominated as category 4 or does not meet the requirements of 6.3.5, the following warning: “Not suitable for driving and road use” in the form of either of the symbols shown in Figure 3 and/or in writing. The minimum height of the symbol shall be 5 mm;

f) when the lens has a luminous transmittance of less than 75 % and higher than 8 %, the following warning: “Not suitable for driving in twilight or at night” or “Not suitable for driving at night or

---

[3] Schott B270i is the trade name of a product supplied by SCHOTT. This filter differs slightly from the original suggestion, Schott B270, but satisfies the requirements in Annex C; Schott B270 may still be used if it is available. 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.

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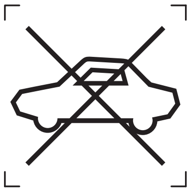
under condition of dull light.” The same warning applies to photochromic filters for which luminous transmittance in the faded condition is less than 75 %;

g) when the lens does not meet the specified requirements for UV transmittance, the following warning: “Not suitable for outdoor daytime use";

h) reference to this document, i.e. ISO 8980-3:2022, either on the package or in available literature (documents), if the manufacturer or supplier claims conformity with this document.

ISO 7000-2952A



ISO 7000-2952B

Figure 3 — Symbol option for: “Not suitable for driving and road use”

Annex A
(normative)

Spectral data for calculating relative visual attenuation quotients for incandescent signal lights

Table A.1 — Relative spectral distribution of radiation emitted by incandescent signal lights, $E_{\mathrm{signal}}(\lambda)$, weighted by the spectral luminous efficiency function of the average human eye for daylight vision, $V(\lambda)$, as specified in ISO 11664-1

Wavelength λ nm	**Red** $E_{\mathrm{red}}(\lambda)\cdot V(\lambda)$	**Yellow** $E_{\mathrm{yellow}}(\lambda)\cdot V(\lambda)$	**Green** $E_{\mathrm{green}}(\lambda)\cdot V(\lambda)$	**Blue** $E_{\mathrm{blue}}(\lambda)\cdot V(\lambda)$
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
530	0,020	1,700	6,860	3,960
535	0,020	2,350	7,370	3,370

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Table A.1 *(continued)*

Wavelength λ nm	**Red** $E_{\text{red}}(\lambda)\cdot V(\lambda)$	**Yellow** $E_{\text{yellow}}(\lambda)\cdot V(\lambda)$	**Green** $E_{\text{green}}(\lambda)\cdot V(\lambda)$	**Blue** $E_{\text{blue}}(\lambda)\cdot V(\lambda)$
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
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

Table A.1 *(continued)*

Wavelength λ nm	**Red** $E_{\text{red}}(\lambda)\cdot V(\lambda)$	**Yellow** $E_{\text{yellow}}(\lambda)\cdot V(\lambda)$	**Green** $E_{\text{green}}(\lambda)\cdot V(\lambda)$	**Blue** $E_{\text{blue}}(\lambda)\cdot V(\lambda)$
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

Table A.2 — Product, $S_{\text{D65}}(\lambda)\cdot V(\lambda)$, of the spectral distribution of radiation of CIE standard illuminant D65, $S_{\text{D65}}(\lambda)$, as specified in ISO 11664-2 and the spectral luminous efficiency function of the average human eye for daylight vision, $V(\lambda)$, as specified in ISO 11664-1

Wavelength λ nm	$S_{\text{D65}}(\lambda)\cdot V(\lambda)$
380	0,000 1
385	0,000 2
390	0,000 3
395	0,000 7
400	0,001 6
405	0,002 6
410	0,005 2
415	0,009 5
420	0,017 7
425	0,031 1
430	0,047 6
435	0,076 3
440	0,114 1
445	0,156 4
450	0,210 4
455	0,266 7
460	0,334 5
465	0,406 8
470	0,494 5
475	0,614 8
480	0,762 5
485	0,900 1
490	1,071 0
495	1,334 7
500	1,671 3
505	2,092 5
510	2,565 7
515	3,058 9

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Table A.2 *(continued)*

Wavelength λ nm	$S_{\mathrm{D65}}(\lambda)\cdot V(\lambda)$
520	3,520 3
525	3,987 3
530	4,392 2
535	4,590 5
540	4,712 8
545	4,834 3
550	4,898 1
555	4,827 2
560	4,707 8
565	4,545 5
570	4,339 3
575	4,160 7
580	3,943 1
585	3,562 6
590	3,176 6
595	2,937 7
600	2,687 3
605	2,408 4
610	2,132 4
615	1,850 6
620	1,581 0
625	1,298 5
630	1,044 3
635	0,857 3
640	0,693 1
645	0,535 3
650	0,405 2
655	0,309 3
660	0,231 5
665	0,171 4
670	0,124 6
675	0,088 1
680	0,063 0
685	0,041 7
690	0,027 1
695	0,019 1
700	0,013 9
705	0,010 1
710	0,007 4
715	0,004 8
720	0,003 1
725	0,002 3

Table A.2 *(continued)*

Wavelength λ nm	$S_{\mathrm{D65}}(\lambda)\cdot V(\lambda)$
730	0,001 7
735	0,001 2
740	0,000 9
745	0,000 6
750	0,000 4
755	0,000 2
760	0,000 1
765	0,000 1
770	0,000 1
775	0,000 1
780	0,000 0
Sum	100,000 0

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Annex B
(normative)

Calculation of solar UV and blue-light transmittance values

This annex contains the spectral functions for the calculation of solar UV transmittance values.

For the spectral distribution of solar radiation $E_S(\lambda)$, the values are from Reference [15].

These values extend to 280 nm and are interpolated linearly where necessary. Between 280 nm and 290 nm the irradiation 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 Reference [16].

The complete weighting function for the calculation of the different UV-transmittance values $W(\lambda)$ is the product of the relative spectral effectiveness function for UV radiation $S(\lambda)$ and the spectral distribution of solar radiation $E_S(\lambda)$ as given by Formula (B.1):

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

This weighting function is also given in Table B.1.

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

Wavelength λ nm	**Solar spectral irradiance** $E_S(\lambda)$ $\mathrm{mW \cdot m^{-2}\ nm^{-1}}$	**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	$2{,}09 \times 10^{-4}$	0,54	0,000 11		
300	$8{,}10 \times 10^{-2}$	0,30	0,024 3		
305	1,91	0,060	0,115		
310	11,0	0,015	0,165		
315	30,0	0,003	0,090		
320	54,0	0,001 0	0,054		
325	79,2	0,000 50	0,040		
330	101	0,000 41	0,041		
335	128	0,000 34	0,044		
340	151	0,000 28	0,042		
345	170	0,000 24	0,041		
350	188	0,000 20	0,038		
355	210	0,000 16	0,034		
360	233	0,000 13	0,030		
365	253	0,000 11	0,028		

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Table B.1 *(continued)*

Wavelength λ nm	**Solar spectral irradiance** $E_S(\lambda)$ $\text{mW·m}^{-2}\ \text{nm}^{-1}$	**Relative spectral effectiveness function** $S(\lambda)$	**Weighting function** $W(\lambda) = E_S(\lambda) \cdot S(\lambda)$	**Blue-light hazard function** $B(\lambda)$	**Weighting function** $W_B(\lambda) = E_S(\lambda) \cdot B(\lambda)$
370	279	0,000 093	0,026		
375	306	0,000 077	0,024		
380	336	0,000 064	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	1 006			0,94	946
455	1 037			0,90	933
460	1 080			0,80	864
465	1 109			0,70	776
470	1 138			0,62	706
475	1 161			0,55	639
480	1 183			0,45	532
485	1 197			0,40	479
490	1 210			0,22	266
495	1 213			0,16	194
500	1 215			0,10	122

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Annex C
(normative)

Cut-on filter for UV filtering

The radiation emitted by the lamp used in 7.7.3 for the test of resistance to ultraviolet 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 C.1. Transmittance values for wavelengths with cells left blank and values between specified wavelength positions should be calculated by linear interpolation if necessary. The nominal position of the absorption edge of this filter is $\tau_{46\,\%}$ = 320 nm. A suitable filter for this purpose is a 4 mm thick clear white crown glass B270i (see note for 7.7.2 c)).

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

Wavelength λ nm	**Spectral transmittance** $\tau(\lambda)$ %		
	lower limit	**nominal value**	**upper limit**
280	<0,1	<0,1	<0,1
287	<0,1	<0,1	<0,1
288	<0,1	<0,1	0,1
289	<0,1	<0,1	0,2
290	<0,1	<0,1	0,3
291	<0,1	<0,1	0,5
292	<0,1	0,1	0,7
293	<0,1	0,2	1,0
294	<0,1	0,3	1,5
295	<0,1	0,5	2,1
296	<0,1	0,7	2,8
297	<0,1	1,1	3,7
298	0,1	1,5	4,9
299	0,2	2,1	6,1
300	0,3	2,8	7,6
301	0,5	3,6	9,3
302	0,8	4,7	11,2
303	1,1	5,9	13,4
304	1,6	7,3	15,6
305	2,2	8,9	18,0
306	3,0	10,7	20,5
307	4,0	12,7	23,2
308	5,2	14,9	26,0
309	6,6	17,2	28,8
310	8,1	19,6	31,7
311	9,9	22,1	34,5
312	11,9	24,7	37,4

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Table C.1 *(continued)*

Wavelength λ nm	Spectral transmittance $\tau(\lambda)$ %		
	lower limit	**nominal value**	**upper limit**
313	14,0	27,4	40,2
314	16,3	30,1	42,9
315	18,7	32,8	45,7
316	21,3	35,5	48,2
317	24,0	38,2	50,8
318	26,7	41,0	53,3
319	29,5	43,5	55,6
320	32,3	46,2	57,9
321	35,1	48,7	60,0
322	37,9	51,1	62,1
323	40,8	53,5	64,1
324	43,5	55,7	65,9
325	46,1	57,8	67,7
326	48,7	60,0	69,3
327	51,3	61,9	70,9
328	53,7	63,7	72,4
329	55,9	65,5	73,7
330	58,1	67,2	74,9
331	60,3	68,7	76,1
332	62,3	70,2	77,1
333	64,1	71,6	78,2
334	65,9	72,9	79,1
335	67,6	74,1	79,9
336	69,3	75,2	80,8
337	70,7	76,3	81,6
338	72,1	77,4	82,3
339	73,4	78,2	82,9
340	74,7	79,1	83,5
341	75,8	79,9	84,1
342	76,9	80,5	84,6
343	77,9	81,3	85,1
344	78,9	82,0	85,6
345	79,8	82,6	85,9
346	80,6	83,2	86,3
347	81,3	83,6	86,7
348	81,9	84,1	87,0
349	82,3	84,5	87,1
350	82,7	84,9	87,5
351	83,3	85,5	87,9
352	83,6	85,7	88,0
353	83,8	86,0	88,2

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Table C.1 *(continued)*

Wavelength λ nm	Spectral transmittance $\tau(\lambda)$ %		
	lower limit	**nominal value**	**upper limit**
354	83,9	86,4	88,4
355	84,2	86,6	88,6
356	84,3	86,9	88,8
357	84,5	87,1	88,9
358	84,7	87,3	89,0
359	84,9	87,5	89,2
360	85,1	87,6	89,3
361	85,2	88,0	89,4
362	85,6	88,0	89,5
363	85,6	88,2	89,7
364	85,8	88,3	89,8
365	86,1	88,5	89,9
366	86,3	88,5	89,9
367	86,4	88,5	89,9
368	86,6	88,6	90,0
369	86,7	88,7	90,1
370	86,9	88,8	90,2
371	87,0	88,9	90,3
372	87,1	88,9	90,4
373	87,1	89,0	90,5
374	87,4	89,0	90,7
375	87,5	89,0	90,7
376	87,5	89,0	90,7
377	87,5	89,0	90,7
378	87,7	89,0	90,7
379	87,5	89,0	90,7
380	87,6	89,0	90,7
381	87,7	89,0	90,7
382	87,7	89,1	90,8
383	87,8	89,2	90,9
384	87,9	89,2	90,9
385	87,9	89,4	91,1
386	88,0	89,5	91,2
387	88,0	89,5	91,2
388	88,2	89,7	91,3
389	88,2	89,7	91,3
390	88,2	89,7	91,3
391	88,4	89,9	91,4
392	88,4	89,9	91,4
393	88,5	90,0	91,4
394	88,5	90,0	91,4

Table C.1 *(continued)*

Wavelength λ nm	Spectral transmittance $\tau(\lambda)$ %		
	lower limit	**nominal value**	**upper limit**
395	88,6	90,1	91,4
396	88,7	90,1	91,4
397	88,8	90,2	91,4
398	88,8	90,2	91,4
399	88,9	90,2	91,4
400	89,0	90,3	91,4
600	90,9	91,2	91,5
800	91,0	91,4	91,8

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Annex D
(informative)

Spectral radiation risks

D.1 Blue-light risk

If solar radiation on the ground is evaluated with currently used limit values[16], even under extreme illuminance conditions (e.g. snow surfaces), a risk from the blue part of the radiation is not to be expected. Therefore this part of ISO 8980 contains no specification in this respect but opinion is divided whether there could be a risk. However, in order to allow a correct description of the blue-light attenuation, a definition of the blue-light transmittance is included.

The blue-light hazard function $B(\lambda)$ is taken from Reference [16]. 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 $E_S(\lambda)$ as given by Formula (D.1):

$$W_B(\lambda) = E_s(\lambda) \cdot B(\lambda) \qquad \text{(D.1)}$$

This weighting function is given in Table B.1.

D.2 Infrared risk

If solar radiation on the ground is evaluated with the currently used limit values[16], even under extreme illuminance conditions (e.g. snow surfaces), no risk by the infrared part of radiation is to be expected. Therefore, this document contains no specification in this respect.

D.3 Ultraviolet risk

Equations for the analytic characterization of ultraviolet skylight[8] as adapted for calculating corneal irradiance[9], show that the largest influence on lens exposure in temperate regions is the seasonal variation of solar irradiance; this is followed by ground reflectance, and then by time from solar noon[10]. Diffuse sky radiation decreases with increasing altitude[11][12], and corneal irradiation is nearly constant[10]. Calculated biologically-weighted exposure doses and the corresponding ultraviolet transmittance limits for spectacle lenses that would keep those doses below a recognized safe limit, for exceptional (greater than plausibly realizable) daily exposure experiences[10][13], are the bases of the adopted transmittance limits. Further margins of safety, in addition to those implicit in the exceptional exposure experiences, are incorporated.

Annex E
(informative)

Transmittance equations in summation form

E.1 General

In ISO 13666, the equations for the various transmittances are expressed as integrals. In practice, spectral transmittance is sampled at discrete wavelength intervals, typically 1 nm, 5 nm, or 10 nm, and then calculated as a summation. Hence this annex gives these equations in summation form.

In this document, transmittance is expressed as a percentage between 0 % and 100 %. The formulae in this annex are written in this form and on the basis that the spectral values, $\tau(\lambda)$, are also expressed as percentages.

NOTE Formulae in ISO 13666 express $\tau(\lambda)$ as decimal values between 0,0 and 1,0. Hence the 100 × multiplier that is in the formulae in ISO 13666 has been omitted in this annex.

E.2 Solar UV transmittance, τ_{SUV}

Normalized value of the spectral transmittance averaged between 280 nm and 380 nm, weighted by the solar spectral power distribution at sea level for air mass 2 and the relative spectral effectiveness function for ultraviolet radiation as given by Formula (E.1):

$$\tau_{\mathrm{SUV}}(\%)=\frac{\sum_{280\ \mathrm{nm}}^{380\ \mathrm{nm}}\tau(\lambda)\cdot E_{\mathrm{S}}(\lambda)\cdot S(\lambda)\cdot\Delta\lambda}{\sum_{280\ \mathrm{nm}}^{380\ \mathrm{nm}}E_{\mathrm{S}}(\lambda)\cdot S(\lambda)\cdot\Delta\lambda}=\frac{\sum_{280\ \mathrm{nm}}^{380\ \mathrm{nm}}\tau(\lambda)\cdot W(\lambda)\cdot\Delta\lambda}{\sum_{280\ \mathrm{nm}}^{380\ \mathrm{nm}}W(\lambda)\cdot\Delta\lambda} \tag{E.1}$$

where

λ is the wavelength of the ultraviolet radiation, expressed in nanometres;

$\tau(\lambda)$ is the spectral transmittance, as a percentage;

$E_{\mathrm{S}}(\lambda)$ is the solar spectral power distribution at sea level for air mass 2;

$S(\lambda)$ is the relative spectral effectiveness function for ultraviolet radiation;

$W(\lambda)$ is the complete weighting function: $W(\lambda)=E_{\mathrm{S}}(\lambda)\cdot S(\lambda)$, and is given in Table B.1.

E.3 Solar UV-A transmittance, τ_{SUVA}

Normalized value of the spectral transmittance averaged between 315 nm and 380 nm, weighted by the solar spectral power distribution at sea level for air mass 2 and the relative spectral effectiveness function for UV radiation as given by Formula (E.2):

$$\tau_{\mathrm{SUVA}}(\%)=\frac{\sum_{315\ \mathrm{nm}}^{380\ \mathrm{nm}}\tau(\lambda)\cdot E_{\mathrm{S}}(\lambda)\cdot S(\lambda)\cdot\Delta\lambda}{\sum_{315\ \mathrm{nm}}^{380\ \mathrm{nm}}E_{\mathrm{S}}(\lambda)\cdot S(\lambda)\cdot\Delta\lambda}=\frac{\sum_{315\ \mathrm{nm}}^{380\ \mathrm{nm}}\tau(\lambda)\cdot W(\lambda)\cdot\Delta\lambda}{\sum_{315\ \mathrm{nm}}^{380\ \mathrm{nm}}W(\lambda)\cdot\Delta\lambda} \tag{E.2}$$

where

λ is the wavelength of the ultraviolet radiation in nanometres;

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$\tau(\lambda)$ is the spectral transmittance, as a percentage;

$E_S(\lambda)$ is the solar spectral power distribution at sea level for air mass 2;

$S(\lambda)$ is the relative spectral effectiveness function for ultraviolet radiation;

$W(\lambda)$ is the complete weighting function: $W(\lambda)=E_S(\lambda)\cdot S(\lambda)$, and is given in Table B.1.

E.4 Solar UV-B transmittance, τ_{SUVB}

Normalized value of the spectral transmittance averaged between 280 nm and 315 nm, weighted by the solar spectral power distribution at sea level for air mass 2 and the relative spectral effectiveness function for ultraviolet radiation as given by Formula (E.3):

$$\tau_{\text{SUVB}}(\%)=\frac{\sum_{280\text{ nm}}^{315\text{ nm}}\tau(\lambda)\cdot E_s(\lambda)\cdot S(\lambda)\cdot\Delta\lambda}{\sum_{280\text{ nm}}^{315\text{ nm}}E_s(\lambda)\cdot S(\lambda)\cdot\Delta\lambda}=\frac{\sum_{280\text{ nm}}^{315\text{ nm}}\tau(\lambda)\cdot W(\lambda)\cdot\Delta\lambda}{\sum_{280\text{ nm}}^{315\text{ nm}}W(\lambda)\cdot\Delta\lambda} \tag{E.3}$$

where

λ is the wavelength of the ultraviolet radiation, in nanometres;

$\tau(\lambda)$ is the spectral transmittance, as a percentage;

$E_S(\lambda)$ is the solar spectral power distribution at sea level for air mass 2;

$S(\lambda)$ is the relative spectral effectiveness function for ultraviolet radiation;

$W(\lambda)$ is the complete weighting function: $W(\lambda)=E_S(\lambda)\cdot S(\lambda)$, and is given in Table B.1.

E.5 Luminous transmittance, τ_v

Ratio of the luminous flux transmitted by the lens or filter to the incident luminous flux for a specified illuminant and photopic vision as given by Formula (E.4):

$$\tau_v(\%)=\frac{\sum_{380\text{ nm}}^{780\text{ nm}}\tau(\lambda)\cdot S_{D65}(\lambda)\cdot V(\lambda)\cdot\Delta\lambda}{\sum_{380\text{ nm}}^{780\text{ nm}}S_{D65}(\lambda)\cdot V(\lambda)\cdot\Delta\lambda} \tag{E.4}$$

where

λ is the wavelength of the light in nanometres;

$\tau(\lambda)$ is the spectral transmittance, as a percentage;

$S_{D65}(\lambda)$ is the spectral distribution of the incident radiation of CIE standard illuminant D65;

$V(\lambda)$ is the CIE 2° spectral luminous efficiency function for photopic vision.

NOTE The spectral values of the product $S_{D65}(\lambda)\cdot V(\lambda)$ are given in Table A.2.

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E.6 Relative visual attenuation coefficient (quotient) for traffic signal light detection, Q_{signal}

Quotient of the luminous transmittance of a lens for the spectral radiant power distribution of the light emitted by a traffic signal light to the luminous transmittance of the same lens as given by Formula (E.5):

$$Q_{\text{signal}} = \frac{\tau_{\text{signal}}}{\tau_{\text{V}}} \tag{E.5}$$

where

$$\tau_{\text{signal}}\ (\%) = \frac{\sum_{380\ \text{nm}}^{780\ \text{nm}} \tau(\lambda) \cdot E_{\text{signal}}(\lambda) \cdot V(\lambda) \cdot \Delta\lambda}{\sum_{380\ \text{nm}}^{780\ \text{nm}} E_{\text{signal}}(\lambda) \cdot V(\lambda) \cdot \Delta\lambda}$$

and where

λ is the wavelength of the light in nanometres;

$\tau(\lambda)$ is the spectral transmittance, as a percentage;

τ_{V} is the luminous transmittance of the lens – see E.5;

$E_{\text{signal}}(\lambda)$ is the accepted measured value of the relative spectral distribution of luminance of the traffic signal;

$V(\lambda)$ is the spectral visibility function for photopic vision.

NOTE The spectral values of the product $E_{\text{signal}}(\lambda) \cdot V(\lambda)$ are given in Table A.1.

E.7 Solar blue-light transmittance, τ_{SB}

normalized value of the spectral transmittance averaged between 380 nm and 500 nm, weighted by the solar spectral power distribution, at sea level for air mass 2 and the blue-light hazard function as given by Formula (E.6):

$$\tau_{\text{SB}}\ (\%) = \frac{\sum_{380\ \text{nm}}^{500\ \text{nm}} \tau(\lambda) \cdot E_{\text{S}}(\lambda) \cdot B(\lambda) \cdot \Delta\lambda}{\sum_{380\ \text{nm}}^{500\ \text{nm}} E_{\text{S}}(\lambda) \cdot B(\lambda) \cdot \Delta\lambda} = \frac{\sum_{380\ \text{nm}}^{500\ \text{nm}} \tau(\lambda) \cdot W_{\text{B}}(\lambda) \cdot \Delta\lambda}{\sum_{380\ \text{nm}}^{500\ \text{nm}} W_{\text{B}}(\lambda) \cdot \Delta\lambda} \tag{E.6}$$

where

λ is the wavelength of the light in nanometres;

$\tau(\lambda)$ is the spectral transmittance, as a percentage;

$E_{\text{S}}(\lambda)$ is the solar spectral power distribution at sea level for air mass 2;

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

$W_{\text{B}}(\lambda)$ is the complete weighting function: $W_{\text{B}}(\lambda) = E_{\text{S}}(\lambda) \cdot B(\lambda)$, and is given in Table B.1.

E.8 Polarizing efficiency, P

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Parameter describing the performance of a polarizing lens determined from the maximum and minimum transmittance in 100 % linearly polarized radiation as given by Formula (E.7):

$$P = 100 \times \frac{\tau_{\mathrm{P\,max}} - \tau_{\mathrm{P\,min}}}{\tau_{\mathrm{P\,max}} + \tau_{\mathrm{P\,min}}} \tag{E.7}$$

where

$\tau_{\mathrm{P\,max}}$	is the maximum value of luminous transmittance as determined with 100 % linearly polarized radiation;
$\tau_{\mathrm{P\,min}}$	is the minimum value of luminous transmittance as determined with 100 % linearly polarized radiation.

NOTE Polarizing efficiency can also be determined by measuring the luminous transmittance of two polarizing lenses of the same type in series in unpolarized light as:

$$P = \sqrt{\frac{h(0)-h(\pi/2)}{h(0)+h(\pi/2)}}$$

where

$h(0)$	is the transmittance of two polarizing lenses of the same type when they are orientated with their planes of transmission in alignment, and equals $0{,}5 \cdot (\tau_{\mathrm{P\,max}}{}^2 + \tau_{\mathrm{P\,min}}{}^2)$;
$h(\pi/2)$	is the transmittance of two polarizing lenses of the same type when they are orientated with their planes of transmission perpendicular to each other, and equals $(\tau_{\mathrm{P\,max}} \cdot \tau_{\mathrm{P\,min}})$.

Annex F
(informative)

Example of the calculation of luminous transmittance, τ_V

This annex provides information on how to perform the summation calculations defined by Formulae (E.1) to (E.6), using luminous transmittance, $\tau_{v,}$ in E.5, as an example, see Formula (F.1):

$$\tau_v\ (\%)=\frac{\sum_{380\text{ nm}}^{780\text{ nm}}\tau(\lambda)\cdot S_{D65}(\lambda)\cdot V(\lambda)}{\sum_{380\text{ nm}}^{780\text{ nm}}S_{D65}(\lambda)\cdot V(\lambda)} \tag{F.1}$$

A similar method is used for the solar UV, IR, and blue-light transmittances, and for the relative visual attenuation coefficients (quotients) for signal light detection.

In order to calculate τ_v, tabulate, as shown in Table F.1:

- in column 1, wavelengths from 380 nm to 780 nm at 5 nm steps (for greater accuracy, 1 nm steps may be used, for lower accuracy, 10 nm steps);
- in column 2, the product of the relative spectral power of CIE Standard illuminant D65, $S_{D65}(\lambda)$, and the CIE 2° spectral luminous efficiency function for photopic vision, $V(\lambda)$ from Table A.2; and
- in column 3, the spectral transmittance values of the lens, $\tau(\lambda)$, as percentages.

Multiply the values in columns 2 and 3 together, and enter the result for each wavelength in column 4.

Sum the values in columns 2 and 4 [for $V(\lambda)\cdot S_{D65}(\lambda)$ and for $\tau(\lambda)\cdot V(\lambda)\cdot S_{D65}(\lambda)$, respectively]. Divide the total of column 4 [$\tau(\lambda)\ V(\lambda)\cdot S_{D65}(\lambda)$] by the total of column 2 [$V(\lambda)\cdot S_{D65}(\lambda)$] to give τ_v. In this case, the total of column 4 is 91,995 while the values in column 2 have been adjusted or "normalized" so that the total is 100,0.

Table F.1 — Tabulation of the values needed in the calculation of luminous transmittance, τ_V

Wavelength nm	$V(\lambda)\cdot S_{D65}(\lambda)$	$\tau(\lambda)$	$\tau(\lambda)\cdot V(\lambda)\cdot S_{D65}(\lambda)$
380	0,000 1	58	0,005 8
385	0,000 2	72	0,014 4
390	0,000 3	81	0,024 3
395	0,000 7	89	0,062 3
400	0,001 6	90	0,144 0
etc.	etc.	etc.	etc.
755	0,000 2	92	0,018 4
760	0,000 1	92	0,009 2
765	0,000 1	92	0,009 2
770	0,000 1	92	0,009 2
775	0,000 1	92	0,009 2
780	0,000 0	92	0,000
Total	**100,00**		**9 199,50**

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Hence

$$\tau_\text{v} = \frac{9\ 199{,}5}{100{,}0}\ \% = 91{,}995\ \% \approx 92\,\%$$

The example here uses 5 nm steps; if 1 nm steps are used, then the values for $V(\lambda) \cdot S_{\text{D65}}(\lambda)$ will need to be interpolated linearly. If 10 nm steps are used, the total for column 2 sums to 50,0, but the total for column 4 sums to 4 600,1, such that the final result will still be approximately 92 %.

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