
Textiles — Solar UV protective properties —

Part 1: Method of test for apparel
fabrics

The European Standard EN 13758-1:2001 has the status of a
British Standard

ICS 59.080.30

National foreword

This British Standard is the official English language version of EN 13758-1:2001. It supersedes BS 7914:1998 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee TCI/66, Apparel, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
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Summary of pages

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English version

**Textiles — Solar UV protective properties — Part 1: Method of
test for apparel fabrics**

Textiles — Propriétés de protection contre le rayonnement
UV solaire — Partie 1: Méthode d'essai pour étoffes
destinées à l'habillement

Textilien — Schutzeigenschaften gegen ultraviolette
Sonnenstrahlung — Teil 1: Prüfverfahren für
Bekleidungstextilien

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 248, Textiles and textile products, the Secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2002, and conflicting national standards shall be withdrawn at the latest by May 2002.

This standard includes a normative annex A and informative annexes B and C.

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1 Scope

This European Standard specifies a method for the determination of the erythemally weighted ultraviolet (UV) radiation transmittance of standard conditioned apparel fabrics to assess their solar UV protective properties.

This method is not suitable for fabrics which offer protection at a distance such as umbrellas, shade structures or artificial sources.

NOTE This standard may not be appropriate for fabrics with small colour and construction variations.

2 Normative references

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate place in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 20139:1992, *Textiles — Standard atmospheres for conditioning and testing (ISO 139:1973)*.

3 Terms, definitions and abbreviations

For the purposes of this European Standard the following terms and definitions apply.

3.1.1

wavelength (λ)

spatial period of radiation expressed in nanometres

3.1.2

ultraviolet radiation (UVR)

electromagnetic radiation with wavelength between 180 nm and 400 nm

UVA: ultraviolet radiation with wavelength between 315 nm and 400 nm

UVB: ultraviolet radiation with wavelength between 280 nm and 315 nm

3.1.3

solar irradiance $E(\lambda)$

quantity of energy emitted by the sun received at the surface of the earth per unit wavelength and per unit area. It is expressed as $W \cdot m^{-2} \cdot nm^{-1}$. The solar UVR spectrum as measured at the earth's surface extends between 290 nm and 400 nm

3.1.4

erythema

reddening of the skin caused by various physical or chemical agents

3.1.5

erythema action spectrum ($S(\lambda)$)

relative erythema effectiveness of radiation with wavelength

3.1.6

spectral transmittance $T(\lambda)$

ratio of transmitted radiation and incident radiation at a wavelength

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3.1.7

integrating sphere

hollow sphere whose internal surface is a non-selective diffuse reflector

3.1.8

fluorescence

absorption of radiation of a particular wavelength and its re-emission within a short time as optical radiation of greater wavelength

3.1.9

spectral bandwidth

width in nanometres at half peak intensity of optical radiation emerging from a monochromator

3.1.10

sample recess error

error introduced when the sample is recessed from the port of the integrating sphere (e.g. by using a filter between the port and the sample). In this case part of the diffused transmitted radiation is intercepted and will not enter the sphere. The sample recess error depends on sample construction, distance of sample from port and ratio of port and illumination patch dimensions

3.1.11

shade

particular hue, depth or lightness of colour

3.1.12

construction

set of parameters such as materials, interlacing and pattern which describe the fabric

3.1.13

Ultraviolet Protection Factor (UPF)

expression of the level of protection as attained by the method described in this standard

4 Principle

The UPF of a textile material is determined from the total spectral transmittance $T(\lambda)$ as follows:

$$UPF = \frac{E(\lambda) \int_{290}^{400} \epsilon(\lambda) d\lambda}{E(\lambda) T(\lambda) \int_{290}^{400} \epsilon(\lambda) d\lambda}$$

with:

$E(\lambda)$: the solar irradiance (see annex A);

$\epsilon(\lambda)$: the erythema action spectrum (see annex A);

$\Delta\lambda$: the wavelength interval of the measurements;

$T(\lambda)$: the spectral transmittance at wavelength λ .

The total spectral transmittance is measured by irradiating the sample with monochromatic or polychromatic UV radiation and collecting the total (diffuse and direct) transmitted radiation. In the case of polychromatic incident radiation, the transmitted radiation is collected monochromatically. The apparatus shall either irradiate the sample with a parallel beam and collect all transmitted radiation with an integrating sphere or irradiate the sample hemispherically and collect a parallel beam of transmitted radiation.

5 Apparatus

The measurement device consists of the following:

5.1 A UV source, providing UV radiation throughout the wavelength range 290 nm to 400 nm. Suitable UV sources include Xenon arc lamps, Deuterium lamps and Solar simulators.

5.2 An integrating sphere, having total openings representing not more than 10 % of the internal spherical surface. The internal surface shall be lined with a highly reflective matt surface, e.g. barium sulfate paint. It shall be fitted with baffles to shield the inner detector or the inner source from the specimen port and, if applicable, the sphere wall where the incident flux is measured.

5.3 A monochromator, suited for measurements with a spectral bandwidth of 5 nm or less in the wavelength region 290 nm to 400 nm.

5.4 UV transmitting filter, which transmits significantly only at wavelengths less than approximately 400 nm and which does not fluoresce.

5.5 A specimen holder to hold a specimen in a flat, tensionless or in a predefined stretched state. This device shall not obstruct the entrance port of the integrating sphere and shall ideally position the fabric in the plane of the integrating sphere port.

In the case where a parallel incident beam is used, the surface of the beam should be at least 25 mm² and should cover at least 3 times the repeat fabric construction. Moreover, in the case of a monochromatic incident beam and for reducing the sample recess error, the ratio of the smallest dimension of the port of the integrating sphere to the largest dimension of the illumination patch shall also be larger than 1,5. The beam should be normal to the fabric to within ± 5 degrees. The angular divergence of the beam should be less than 5 degrees about the beam axis. These conditions should apply to the collected beam if diffuse illumination is used.

A suitable UV transmitting filter shall be positioned between the sample and the detector if the instrument monochromates before the sample. When this is not practical the filter shall be placed at the specimen port between the specimen and the sphere. The thickness of the UV transmitting filter shall be between 1 mm and 3 mm.

6 Preparation and conditioning of test specimens

6.1 Preparation

For uniform materials, at least 4 specimens shall be prepared. These specimens shall be as widely spaced as possible across the fabric width. The first 5 cm from each selvedge shall be discarded and samples shall not be taken closer than 1 m from the beginning or the end of the fabric piece.

For materials with areas of various shades and/or construction at least two specimens of each colour and of each texture area shall be tested.

The specimen dimensions shall be sufficient to cover the specimen aperture of the instrument.

6.2 Conditions for testing

The conditioning and testing shall be done in accordance with EN 20139:1992. If the testing instrument is not cited in these standard atmospheric conditions transportation and testing of the conditioned test specimen shall be finished within 10 min.

7 Procedure

7.1 Place the specimen to be tested before the entrance port of the integrating sphere such that the face of the fabric intended to be worn away from the skin is exposed to the UV source.

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7.2 In instruments that monochromate before the sample, check for fluorescence. If a fluorescent agent is present use a UV transmitting filter and verify its effectiveness.

7.3 Record the transmittance between 290 nm and 400 nm and record the data at least every 5 nm.

8 Calculation and expression of the results

8.1 General

Calculate the arithmetic mean of the UVA transmittance (UVA_i) for each specimen i as follows:

$$UVA_i = \frac{1}{m} \int_{315}^{400} T_i(\lambda) d\lambda$$

Calculate the arithmetic mean of the UVB transmittance (UVB_i) for each specimen i as follows:

$$UVB_i = \frac{1}{k} \int_{290}^{315} T_i(\lambda) d\lambda$$

where:

Z T_i(λ) is the spectral transmittance of specimen i at wavelength ;

Z m and k are the number of measurement points between 315 nm and 400 nm and between 290 nm and 315 nm respectively.

These definitions are applicable only when the wavelength interval, Δλ, is fixed, e.g. 5 nm, during the measurements.

Calculate the Ultraviolet Protection Factor for each specimen i as follows:

$$UPF_i = \frac{\int_{290}^{400} E(\lambda) \epsilon(\lambda) d\lambda}{\int_{290}^{400} E(\lambda) T_i(\lambda) d\lambda}$$

where:

E(λ) = solar spectral irradiance in W·m⁻² nm⁻¹ (see annex A, Table 1)

ε(λ) = relative erythemal effectiveness (see annex A, Table 2)

$T(\lambda)$ = spectral transmittance of specimen i at wavelength λ

$\Delta\lambda$ = wavelength step in nm

8.1.1 Uniform sample

In the case of a uniform sample, calculate the mean UPF of the sample as follows:

$$\text{UPF}_{\text{average}} = \frac{1}{n} \sum_{i=1}^n \text{UPF}_i$$

The standard deviation (s) of the mean UPF is given as follows:

$$s = \sqrt{\frac{\sum_{i=1}^n (\text{UPF}_i - \text{UPF}_{\text{average}})^2}{n-1}}$$

with n the number of specimens.

The sample UPF is given as:

$$\text{UPF}_{\text{sample}} = \text{UPF}_{\text{average}} + t_{\alpha/2, n-1} \frac{s}{\sqrt{n}}$$

with $t_{\alpha/2, n-1}$ as specified in Table 1:

Table 1 — Determination of $t_{\alpha/2, n-1}$ for $\alpha = 0,05$

Number of specimen	n-1	t _{α/2, n-1}
4	3	3,18
5	4	2,77
6	5	2,57
7	6	2,44
8	7	2,36
9	8	2,30
10	9	2,26

When UPF is less than the lowest positive UPF measured for a particular specimen, then the UPF of that specimen shall be reported.

When the sample UPF is greater than 50, only “UPF > 50” need be reported.

8.1.2 Non-uniform sample either in shade and/or construction

For materials with areas of various shades and/or construction the lowest positive UPF value measured shall be reported as the sample UPF. When the sample UPF is larger than 50 only “UPF > 50” need be reported.

8.2 Accuracy of measurements

The repeatability and reproducibility standard deviation, s_r and s_R , has been determined by means of an interlaboratory trial using 14 materials tested in 8 laboratories. The $\text{UPF}_{\text{average}}$ range of the samples was between 10 and 65. Statistical analysis based on ISO 5725:1994 showed that the repeatability standard deviation (s_r) was $\text{UPF}_{\text{average}}$ independent and equal to 1,36. The reproducibility standard deviation, s_R , satisfied the following equation: $s_R = 0,37 + 0,11 P \text{UPF}_{\text{average}}$.

9 Test report

The test report shall contain the following information:

- a) a reference to this standard;
- b) a complete definition of the product tested, including type, source, colour and manufacturer's reference numbers;
- c) method of sampling and by which organization;
- d) a complete description of the stretching and the state of the fabric, if required;
- e) temperature and relative humidity;
- f) the number of samples tested and if necessary a description of the sample;
- g) in the case of a uniform sample the UVA_{average} and UVB_{average} together with their standard deviations;
- h) the solar spectrum used in the calculation of the UPF;
- i) the UPF for each specimen tested and in the case of a uniform sample the standard deviation of the mean UPF of the sample;
- j) the UPF of the sample;
- k) any deviation from this standard.

Annex A
(normative)

Solar spectral irradiance and erythral effectiveness

A.1 Solar spectral irradiance

Table A.1 — Spectral irradiance in $W \cdot m^{-2} \cdot nm^{-1}$ of the solar summer spectrum measured at Albuquerque

E()		E()		E()		E() P 10 ⁻¹	
290	3,090 P 10 ⁻⁶	318	2,790 P 10 ⁻¹	346	5,340 P 10 ⁻¹	374	6,610 P 10 ⁻¹
291	1,579 P 10 ⁻⁵	319	2,965 P 10 ⁻¹	347	5,355 P 10 ⁻¹	375	6,635 P 10 ⁻¹
292	2,850 P 10 ⁻⁵	320	3,140 P 10 ⁻¹	348	5,370 P 10 ⁻¹	376	6,660 P 10 ⁻¹
293	1,602 P 10 ⁻⁴	321	3,230 P 10 ⁻¹	349	5,480 P 10 ⁻¹	377	7,060 P 10 ⁻¹
294	2,920 P 10 ⁻⁴	322	3,320 P 10 ⁻¹	350	5,590 P 10 ⁻¹	378	7,460 P 10 ⁻¹
295	7,860 P 10 ⁻⁴	323	3,465 P 10 ⁻¹	351	5,740 P 10 ⁻¹	379	7,500 P 10 ⁻¹
296	1,280 P 10 ⁻³	324	3,610 P 10 ⁻¹	352	5,890 P 10 ⁻¹	380	7,540 P 10 ⁻¹
297	2,325 P 10 ⁻³	325	4,030 P 10 ⁻¹	353	6,010 P 10 ⁻¹	381	6,980 P 10 ⁻¹
298	3,370 P 10 ⁻³	326	4,450 P 10 ⁻¹	354	6,130 P 10 ⁻¹	382	6,420 P 10 ⁻¹
299	6,005 P 10 ⁻³	327	4,730 P 10 ⁻¹	355	6,080 P 10 ⁻¹	383	6,135 P 10 ⁻¹
300	8,640 P 10 ⁻³	328	5,010 P 10 ⁻¹	356	6,030 P 10 ⁻¹	384	5,850 P 10 ⁻¹
301	1,612 P 10 ⁻²	329	5,165 P 10 ⁻¹	357	5,705 P 10 ⁻¹	385	6,055 P 10 ⁻¹
302	2,360 P 10 ⁻²	330	5,320 P 10 ⁻¹	358	5,380 P 10 ⁻¹	386	6,260 P 10 ⁻¹
303	3,355 P 10 ⁻²	331	5,325 P 10 ⁻¹	359	5,510 P 10 ⁻¹	387	6,490 P 10 ⁻¹
304	4,350 P 10 ⁻²	332	5,330 P 10 ⁻¹	360	5,640 P 10 ⁻¹	388	6,720 P 10 ⁻¹
305	5,770 P 10 ⁻²	333	5,280 P 10 ⁻¹	361	5,820 P 10 ⁻¹	389	7,145 P 10 ⁻¹
306	7,190 P 10 ⁻²	334	5,230 P 10 ⁻¹	362	6,000 P 10 ⁻¹	390	7,570 P 10 ⁻¹
307	8,435 P 10 ⁻²	335	5,135 P 10 ⁻¹	363	6,240 P 10 ⁻¹	391	7,365 P 10 ⁻¹
308	9,680 P 10 ⁻²	336	5,040 P 10 ⁻¹	364	6,480 P 10 ⁻¹	392	7,160 P 10 ⁻¹
309	1,154 P 10 ⁻¹	337	5,015 P 10 ⁻¹	365	6,830 P 10 ⁻¹	393	6,855 P 10 ⁻¹
310	1,340 P 10 ⁻¹	338	4,990 P 10 ⁻¹	366	7,180 P 10 ⁻¹	394	6,550 P 10 ⁻¹
311	1,545 P 10 ⁻¹	339	5,190 P 10 ⁻¹	367	7,400 P 10 ⁻¹	395	6,680 P 10 ⁻¹
312	1,750 P 10 ⁻¹	340	5,390 P 10 ⁻¹	368	7,620 P 10 ⁻¹	396	6,810 P 10 ⁻¹
313	1,940 P 10 ⁻¹	341	5,490 P 10 ⁻¹	369	7,640 P 10 ⁻¹	397	7,410 P 10 ⁻¹
314	2,130 P 10 ⁻¹	342	5,590 P 10 ⁻¹	370	7,660 P 10 ⁻¹	398	8,010 P 10 ⁻¹
315	2,280 P 10 ⁻¹	343	5,470 P 10 ⁻¹	371	7,580 P 10 ⁻¹	399	9,055
316	2,430 P 10 ⁻¹	344	5,350 P 10 ⁻¹	372	7,500 P 10 ⁻¹	400	1,010
317	2,610 P 10 ⁻¹	345	5,345 P 10 ⁻¹	373	7,055 P 10 ⁻¹		

NOTE Although other solar irradiance spectra are known (e.g. at Melbourne, Garmisch) the spectrum obtained at Albuquerque is well known and frequently used by European Dermatologists. Moreover UPF values calculated with a spectrum other than the spectrum obtained at Albuquerque do not differ substantially.

A.2 Erythematous effectiveness

Functional representation:

$$\begin{aligned}
 &() = 1,0 && \text{if } 290 \text{ nm} < \lambda < 298 \text{ nm} \\
 &() = 10^{0,094(298-\lambda)} && \text{if } 298 \text{ nm} < \lambda < 328 \text{ nm} \\
 &() = 10^{0,015(139-\lambda)} && \text{if } 328 \text{ nm} < \lambda < 400 \text{ nm}
 \end{aligned}$$

Table A.2 — Relative erythematous effectiveness ¹⁾	
Wavelength (nm)	()
290	1,000
295	1,000
300	0,649
305	0,220
310	0,745 P 10 ⁻¹
315	0,252 P 10 ⁻¹
320	0,855 P 10 ⁻²
325	0,290 P 10 ⁻²
330	0,136 P 10 ⁻²
335	0,115 P 10 ⁻²
340	0,966 P 10 ⁻³
345	0,810 P 10 ⁻³
350	0,684 P 10 ⁻³
355	0,575 P 10 ⁻³
360	0,484 P 10 ⁻³
365	0,407 P 10 ⁻³
370	0,343 P 10 ⁻³
375	0,288 P 10 ⁻³
380	0,243 P 10 ⁻³
385	0,204 P 10 ⁻³
390	0,172 P 10 ⁻³
395	0,145 P 10 ⁻³
400	0,122 P 10 ⁻³

¹⁾ CIE research note: "A reference action spectrum for ultraviolet induced erythema in human skin", A.F. McKinlay, B.L. Diffey, CIE, vol. 6, no. 1, p. 17 - 22 (1987).

Annex B

(informative)

Reference samples

Reference materials are an excellent help in checking the calibration of the instrument and the calculations. It is unfortunately very difficult to define reference textile materials because textile materials are generally not very stable with time. It is therefore recommended to select non-textile materials, such as neutral density glass filters.

Annex C
(informative)

Measurements under stretched and wet conditions

Textile materials are often worn under stretched and/or wet conditions. Under these conditions materials will offer different protection than textile materials worn under relaxed conditions. When textile materials are measured under stretched conditions the following should be kept in mind:

- i) How the textile material is stretched should be clearly defined. Stretching can be obtained by applying a constant force or by applying a specified elongation. It is clear that UPF will depend on the magnitude of the force or the amount of elongation.
- ii) Textile materials generally exhibit anisotropy in the elasticity. By consequence UPF measurements on materials stretched in one direction will not necessarily yield identical results in comparison with UPF measurements on the material stretched in another direction.
- iii) Some textile materials will exhibit necking when stretched. The sample holder should be constructed such that this is prevented.
- iv) Some textile materials will exhibit relaxation over a short or long period of time. By consequence it should be clearly mentioned in the report when the measurements were taken.

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