International Standard 7589

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Photography — Illuminants for sensitometry — Specifications for daylight and incandescent tungsten

Photographie — Illuminants sensitométriques — Spécifications pour la lumière du jour et la lumière artificielle

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Foreword

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

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 7589 was prepared by Technical Committee ISO/TC 42, *Photography*.

It cancels and replaces International Standards ISO 2239-1972, ISO 2241-1972 and ISO 2242-1972 of which it constitutes a technical revision.

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Photography — Illuminants for sensitometry — Specifications for daylight and incandescent tungsten

0 Introduction

Colour and black-and-white camera films are most commonly designed for use with three light sources — daylight, studio tungsten (type B), and photoflood (type A). This International Standard specifies three corresponding illuminants for sensitometry, since most meaningful results are obtained when exposing conditions match those of actual film use. Two other important photographic light sources — electronic flashtube and blue photoflash lamps — give light of a colour that approximates daylight so the sensitometric daylight illuminant serves for films used with them as well. Other aspects of sensitometric exposure and testing form the subjects of International Standards more closely related to specific classes of sensitized products.

This International Standard constitutes a revision of ISO 2239-1972, ISO 2241-1972 and ISO 2242-1972.

It differs in the following respects:

a) a new spectral power distribution, designated studio tungsten, is used to represent illumination supplied by lamps operated at 3 200 K. This is based on spectroradiometric measurements taken in several professional photographic studios. It recognizes the fact that lamp ageing, reflectors, diffusers, and general studio conditions reduce the effective distribution temperature from 3 200 to about 3 050 K. This does not mean there is a change in the lamps themselves or in the balance of type B colour films;

b) the spectral transmittance values have been changed to coincide with those of the ISO standard camera lens (see ISO 6728). For this reason, transmittance values are slightly lower in the blue and red portions of the spectrum compared to those previously used;

c) a new criterion has been adopted for judging the acceptability of illuminants for sensitometry, which generally are lamp-filter combinations. Unlike the old criterion which gave equal weighting to all wavelength regions, the new criterion emphasizes the spectral bands to which typical colour films are most sensitive. The result is significantly greater flexibility in finding lamp-filter combinations that provide the aim spectral power distributions required.

The illuminants described in this International Standard are used in ISO 3028 and other International Standards which describe methods for determining the speed of various types of sensitized products exposed in cameras.

1 Scope and field of application

This International Standard specifies the spectral characteristics of illuminants for sensitometry appropriate for evaluating camera films used for pictorial photography in natural daylight, studio tungsten, and photoflood, including colour and black-and-white films, both reversal and negative types. It also describes a method for evaluating the acceptability of illuminants for sensitometry and specifies tolerances.

2 References

ISO 3028, *Photography — Camera flash sources — Determination of ISO spectral distribution index (ISO/SDI).*

ISO 6728, *Photography — Camera lenses — Determination of ISO colour contribution index (ISO/CCI).*

CIE Publication No. 15 (E-1.3.1), *Colorimetry, Official Recommendations of the International Commission on Illumination.*

CIE Publication No. 17 (E-1-1), *International Lighting Vocabulary.*

3 Definitions

For the purpose of this International Standard, the following definitions apply.

3.1 source: A physical emitter of energy such as a lamp or the sun and sky.

3.2 illuminant: Light having a specific spectral power distribution not necessarily provided directly by a source and not necessarily realizable by a source.

3.3 relative spectral power distribution: A description of the spectral character of radiation by the relative spectral distribution of some radiometric quantity (radiant flux, radiant intensity).

3.4 distribution temperature: The thermodynamic temperature of the full radiator for which the ordinates of the spectral distribution curve of its radiance are proportional, in the visible region, to those of the distribution curve of the radiation considered.

3.5 photographic daylight: The relative spectral power distribution of typical daylight having a correlated colour temperature of 5 500 K. This describes the combination of skylight and sunlight when the sun is about 40° above the horizon with a clear atmosphere, and is designated as D_{55}.

3.6 spectral distribution index; SDI: A three number designation which describes the degree to which a light source is expected to change the overall colour of a photograph relative to that obtained with a specified illuminant.

4 ISO sensitometric illuminants

The colour quality of a photographic illuminant is a description of the relative spectral power distribution used to illuminate the subject matter photographed. This would be the same as that incident on the camera lens from a non-selective neutral absorber. This International Standard is concerned with the quality of radiation incident on the film (not the camera) after it has been modulated by the ISO standard camera lens (see ISO 6728). This is representative of lenses found in medium and high priced cameras used for reversal colour films which are the most critically sensitive to spectral conditions.

The relative spectral power distributions of the three ISO sensitometric illuminants described in this International Standard are normally obtained by operating a lamp at a specified condition and modulating the flux with selectively absorbing filters of suitable spectral transmittance. It should be emphasized that this International Standard specifies the spectral distribution of power incident on the exposure plane at 10 nm intervals, i.e. the spectral power emitted by a source and its modulation by all elements in the sensitometer that affect the spectral quality, for example filters, mirrors, and step tablet.

4.1 ISO sensitometric daylight illuminant

This is suitable for the sensitometry of "daylight balanced" colour films and is also normally used for black-and-white camera films. These films are designed to be exposed in photographic daylight (see 3.5), or with flash. The spectral power distribution used to represent photographic daylight was taken from the data of Judd *et al*[1] who give typical spectral irradiance data for five different conditions of daylight (skylight, and sunlight plus skylight). Data corresponding to a correlated colour temperature of 5 500 K were selected as the most appropriate for photography and designated as D_{55}. This is the prevailing condition in temperate zones during the daylight hours recommended for colour photography.

The ISO sensitometric daylight illuminant, is defined as the product of the spectral power distribution of photographic daylight (D_{55}) and the spectral transmittance of the International Standard camera lens $\bar{\tau}(\lambda)$. The aim values, S_λ, for the relative spectral power distribution for this illuminant are given in table 1. An illuminant complying with these values within the tolerances specified in clause 6 may be designated "ISO sensitometric daylight illuminant".

4.2 ISO sensitometric studio tungsten illuminant

This is suitable for the sensitometry of type B colour films which are normally exposed with lamps described as 3 200 K lamps. However, the effect of lamp age, reflectors, and diffusers is to reduce the average effective distribution temperature to about 3 050 K. The spectral power distribution used to represent studio tungsten was obtained by spectroradiometric measurements in several photographic studios. The aim values, S_λ, for the relative spectral power distribution for this source after modulation by the ISO standard lens are given in table 2. An illuminant complying with these values within the tolerances specified in clause 6 may be designated "ISO sensitometric studio tungsten illuminant".

4.3 ISO sensitometric photoflood illuminant

This illuminant is suitable for the sensitometry of type A colour films. The spectral power distribution used to represent photoflood lamps is that of a black body at 3 400 K. The aim values, S_λ, for the relative spectral power distribution of this source after modulation by the ISO standard lens are given in table 3. An illuminant complying with these values within the tolerances specified in clause 6 may be designated "ISO sensitometric photoflood illuminant".

5 Spectral distribution index (ISO/SDI)

Spectral distribution index is a three number designation which describes how well an illuminant matches a specified spectral power distribution in terms of the total photographic responses of the three component emulsions of average colour film. In this International Standard, three different distributions are involved. Refer to ISO 3028 for a more complete description of SDI.

5.1 Weighted spectral sensitivity values

Weighted spectral sensitivity values for use in evaluating candidate illuminants for acceptability are given in tables 1, 2, and 3. These values have been weighted so that the aim relative spectral power values for the ISO illuminant in the same table will yield an ISO/SDI of 0/0/0.

5.2 Calculation of the ISO/SDI

The relative spectral power values of a candidate illuminant need to be determined at 10 nm intervals. These values, S_λ, are multiplied by the appropriate blue, green, and red, weighted spectral sensitivity values $W(\lambda)$. For example, to determine if the illuminant is satisfactory for sensitometric daylight, the weighted spectral sensitivity values in table 1 would be used. The total photographic responses, R_B, R_G, and R_R are obtained by summation $R = \Sigma W(\lambda) S_\lambda$. Logarithms to the base 10 of the total response values are determined to two decimal places. The smallest element of this three number designation is made equal to zero by subtracting it from all three $\log_{10}$ values. The decimal is eliminated by multiplying by 100. The resultant three numbers are the ISO/SDI for the candidate illuminant. The above calculations are illustrated in table 4 of annex A for a candidate ISO sensitometric daylight illuminant.

1) JUDD, D.B., MACADAM, D.L., WYSZECKI, G. Spectral distribution of typical daylight as a function of correlated color temperature. *Journal of the Optical Society of America.* **54** (8) 1964: 1031-1040.

6 Tolerances

To meet the requirements of this International Standard, the red index shall not differ from the green index by more than ± 3, and the blue index shall not differ from the green index by more than ± 4. These tolerances are depicted in parenthesis in the figure.

To determine whether an illuminant meets these tolerances, it is recommended the blue, green, and red SDI values be plotted on a trilinear diagram on similar axes to those indicated in the figure. This portrays the colour balance of the photographic image obtained with a candidate illuminant compared to that obtained with the illuminant used as a standard.

Calculations for a typical sensitometer set-up that meets the acceptance criterion are illustrated in table 4. This table shows how to calculate spectral distribution index. The resultant ISO/SDI 4/1/0 is plotted in the figure.

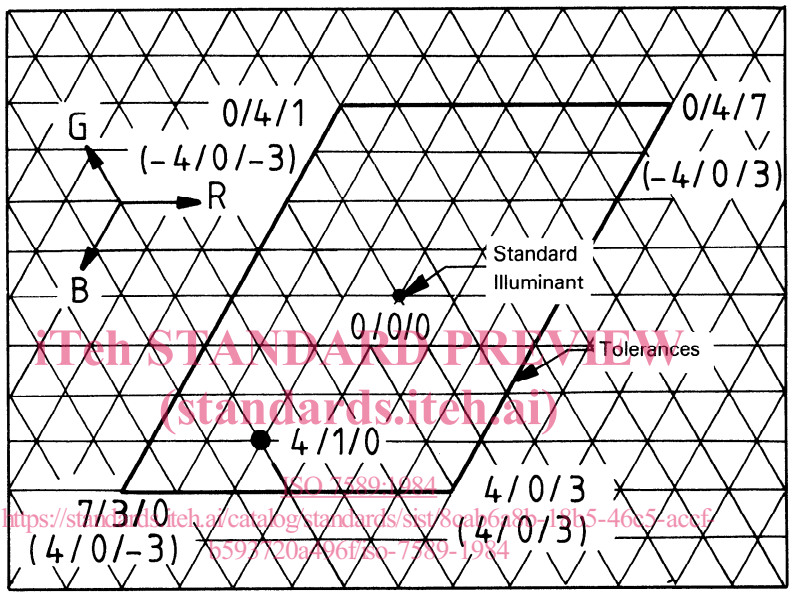

Figure — Trilinear graph

Table 1 — Relative spectral power distribution, S_λ, of ISO sensitometric daylight illuminant

Wavelength, λ	Photographic daylight[1] relative power,	Relative spectral transmittance of the ISO standard lens	ISO sensitometric daylight illuminant (daylight transmited by lens),	Weighted spectral sensitivities for calculating ISO/SDI of daylight illuminant		
				Blue	Green	Red
nm	D_{55}	$\bar{\tau}(\lambda)$	$S_\lambda = D_{55}\bar{\tau}(\lambda)$	$W_B(\lambda)$	$W_G(\lambda)$	$W_R(\lambda)$
350	28	0,00	0			
360	31	0,07	2	1		
370	34	0,23	8	2		
380	33	0,42	14	5		
390	38	0,60	23	9		
400	61	0,74	45	14		
410	69	0,83	57	17		
420	72	0,88	63	19		
430	68	0,91	62	19		
440	86	0,94	81	17		
450	98	0,95	93	15		
460	100	0,97	97	13		
470	100	0,98	98	9	1	
480	103	0,98	101	5	1	
490	98	0,99	97	2	1	
500	101	0,99	100	1	2	
510	101	1,00	101		3	
520	100	1,00	100		5	
530	104	1,00	104		8	
540	102	1,00	102		15	
550	103	1,00	103		24	1
560	100	1,00	100		12	1
570	97	1,00	97		13	1
580	98	1,00	98		10	2
590	91	0,99	90		3	3
600	94	0,99	93		1	5
610	95	0,99	94			7
620	94	0,98	92			9
630	90	0,98	88			14
640	92	0,97	89			21
650	89	0,97	86			26
660	90	0,96	86			18
670	94	0,95	89			4
680	90	0,94	85			1
690	80	0,94	75			

1) Data for D_{55} daylight from CIE Publication No. 15 (E-1.3.1), table 1.1.4.

Table 2 — Relative spectral power distribution, S_λ, of ISO sensitometric studio tungsten illuminant

Wavelength, λ nm	Studio tungsten relative power	Relative spectral transmittance of the ISO standard lens $\bar{\tau}(\lambda)$	ISO sensitometric studio tungsten illuminant (studio tungsten transmited by lens), S_λ	Weighted spectral sensitivities for calculating ISO/SDI of studio tungsten illuminant		
				Blue	Green	Red
				$W_B(\lambda)$	$W_G(\lambda)$	$W_R(\lambda)$
350	1	0,00	0	1		
360	3	0,07	0	2		
370	5	0,23	1	5		
380	8	0,42	3	12		
390	12	0,60	7	22		
400	16	0,74	12	32		
410	20	0,83	17	40		
420	24	0,88	21	44		
430	29	0,91	26	45		
440	34	0,94	32	40		
450	38	0,95	36	36		
460	43	0,97	42	31		
470	48	0,98	47	21	1	
480	53	0,98	52	11	1	
490	59	0,99	58	5	1	
500	64	0,99	63	2	2	
510	70	1,00	70	1	3	
520	76	1,00	76		5	
530	81	1,00	81		8	
540	88	1,00	88		15	
550	94	1,00	94		24	1
560	100	1,00	100		12	1
570	105	1,00	105		13	1
580	111	1,00	111		10	1
590	116	0,99	115		3	2
600	122	0,99	121		1	3
610	127	0,99	126			4
620	132	0,98	129			5
630	138	0,98	135			8
640	143	0,97	139			13
650	148	0,97	144			15
660	153	0,96	147			11
670	157	0,95	149			3
680	162	0,94	152			0
690	167	0,94	157			

Table 3 — Relative spectral power distribution, S_λ, of ISO sensitometric photoflood illuminant

Wavelength, λ nm	Photoflood relative power[1]	Relative spectral transmittance of the ISO standard lens $\bar{\tau}(\lambda)$	ISO sensitometric photoflood illuminant (photoflood transmited by lens), S_λ	Weighted spectral sensitivities for calculating ISO/SDI for photoflood illuminant		
				Blue $W_B(\lambda)$	Green $W_G(\lambda)$	Red $W_R(\lambda)$
350	11	0,00				
360	14	0,07	1	2		
370	16	0,23	4	4		
380	19	0,42	8	9		
390	23	0,60	14	17		
400	26	0,74	19	25		
410	30	0,83	25	31		
420	34	0,88	30	34		
430	38	0,91	35	35		
440	42	0,94	39	31		
450	47	0,95	45	28		
460	52	0,97	50	24		
470	56	0,98	55	17	1	
480	61	0,98	60	9	1	
490	66	0,99	65	4	1	
500	71	0,99	70	1	2	
510	76	1,00	76	1	3	
520	81	1,00	81		5	
530	86	1,00	86		8	
540	91	1,00	91		15	
550	95	1,00	95		24	1
560	100	1,00	100		12	1
570	104	1,00	104		13	1
580	109	1,00	109		10	1
590	113	0,99	112		3	2
600	117	0,99	116		1	3
610	121	0,99	120			4
620	125	0,98	123			5
630	129	0,98	126			9
640	132	0,97	128			14
650	135	0,97	131			17
660	138	0,96	132			12
670	141	0,95	134			3
680	144	0,94	135			1
690	146	0,94	137			

1) Calculated from Planck's equation using $T = 3\,400$ K and $c_2 = 1{,}438\,8 \times 10^{-2}$ m·K, the value recommended in CIE Publication No. 15 (E-1.3.1).

Annex A

Example sources

(This annex does not form part of the standard.)

CAUTION — Manufacturers of selectively absorbing filters warn that a small variability in spectral properties is unavoidable. Therefore, it is necessary to have spectral transmittance data measured for the individual filter under consideration. Filters should be checked spectroradiometrically at regular intervals.

A.0 Introduction

Actual lamp-filter combinations that meet the acceptance criterion are listed below. It is important to note that the standard illuminants are the spectral distributions, S_λ, given in tables 1 to 3; the example illuminants given here are included as a convenience to users of this International Standard. These examples are not represented as the only combinations that meet the acceptable criterion, or that they are necessarily the best of those available.

A.1 Daylight source

An incandescent tungsten lamp operating at a distribution temperature of 2 856 K in conjunction with a Corning type 5 900 glass filter or equivalent, of suitable thickness, mirror and glass on which a non-selective neutral step tablet is mounted. Table 4 illustrates how the spectral power distribution is determined, and shows how SDI is calculated to determine whether it meets the specification for ISO sensitometric daylight.

A.2 Studio tungsten source

An incandescent tungsten lamp operating at a distribution temperature of 2 856 K in combination with Corning Type 5 900 and Hoya 39 glass filters (or equivalent) of appropriate thicknesses.

A.3 Photoflood source

An incandescent tungsten lamp operating at a distribution temperature of 2 856 K in conjunction with a Kodak Wratten gelatin filter No. 82C (or equivalent).