International Standard 3028

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Photography — Camera flash illuminants — Determination of ISO spectral distribution index (ISO/SDI)

Photographie — Illuminant type «lampe éclair» pour photographie — Détermination de l'indice de distribution spectrale ISO (ISO/SDI)

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Foreword

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

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 3028 was prepared by Technical Committee ISO/TC 42, *Photography*.

ISO 3028 was first published in 1974. This second edition cancels and replaces the first edition, of which it constitutes a fundamental revision.

Photography — Camera flash illuminants — Determination of ISO spectral distribution index (ISO/SDI)

0 Introduction

This International Standard specifies a method for evaluating the colour quality of flash illuminants used in photography. This revision of ISO 3028 was considered necessary in order to recognize the spectral sensitivity of colour films as they are presently manufactured. It also utilizes the recently approved spectral transmittance values of the ISO standard camera lens (see ISO 6728). For these reasons, spectral distribution indexes (SDI) determined according to this edition of ISO 3028 shall not be compared with those of the previous edition.

Camera flash units are generally used indoors for exposing film which has been specifically designed to provide optimum results outdoors in daylight. Therefore, flash units should give results with an overall colour balance equivalent to that obtained in daylight (see ISO 7589). The ISO/SDI of a flash source, determined according to this International Standard, is a numerical expression of the colour balance shift expected in flash pictures compared with those taken in natural daylight. It is expected that this International Standard will be used by manufacturers in the design and control of photographic light illuminants.

This International Standard is intended primarily to evaluate electronic flash units and expendable sources such as flash bulbs. However, it may also be used to evaluate any illuminant under which daylight-type colour films are exposed.

1 Scope and field of application

This International Standard specifies a method for calculating a spectral distribution index (SDI) to evaluate the ability of expendable flash and electronic flash units to produce photographic colour results comparable to those obtained with daylight-type films exposed to daylight illumination.

2 References

ISO 5/1, *Photography — Density measurements — Part 1: Terms, symbols, and notations.*

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

ISO 7589, *Photography, — Illuminants for sensitometry — Specifications for daylight and incandescent tungsten.*

CIE Publication No. 15, *Colorimetry, Official Recommendations of the International Commission on Illumination.*

3 Definitions

For the purpose of this International Standard, the terms listed in ISO 5/1 and the following apply:

3.1 source: A physical emitter of energy.

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 distribution of some radiometric quantity (radiant flux, radiant intensity).

3.4 photographic response R**:** The effective response of a sensitized photographic material to radiant flux.

This can be represented by the equation

$$R = \int_{\lambda_1}^{\lambda_2} S_\lambda \, s(\lambda) \, \tau(\lambda) \, \mathrm{d}\lambda \qquad \ldots (1)$$

where

R is the photographic response;

S_λ is the relative spectral power distribution of the radiant flux;

$s(\lambda)$ is the relative spectral sensitivity of the camera film or paper;

$\tau(\lambda)$ is the axial relative spectral transmittance of the camera lens (or optical system);

λ is the wavelength;

λ_1 to λ_2 is the range of wavelengths over which the photographic material is sensitive.

3.5 spectral sensitivity of film: The reciprocal of the amount of power required at each wavelength to produce a specified density in the final image.

3.6 weighted spectral sensitivity values: Obtained by combining the relative spectral sensitivity of the material and relative spectral transmittance values for the ISO standard camera lens to simplify the determination of spectral distribution index values.

3.7 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. In this International Standard, photographic daylight is used as the reference.

3.8 photographic daylight: The relative spectral power distribution of typical daylight having a correlated colour temperature of approximately 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}.

4 Method of test

4.1 Principle

The SDI of a flash illuminant is calculated from its relative spectral power distribution values and the weighted spectral sensitivity values provided in this International Standard.

4.2 Illuminants

4.2.1 Photographic daylight: Most camera colour films are designed to produce optimum results with photographic daylight illumination. The spectral power distribution of daylight varies with time of day, geographical location, and the orientation of the illuminated surface.

Extensive radiometric measurements were made for five different conditions of daylight normally encountered. Data corresponding to a correlated colour temperature of about 5 500 K were selected as the most appropriate for photography and designated D_{55}[1]. This is the prevailing condition in temperate zones during the daylight hours recommended for colour photography. The relative spectral power distribution for D_{55} is given in table 1 and used as a reference in this International Standard.

Table 1 — Spectral data

Wavelength, λ	Relative spectral transmittance of the ISO standard lens	Relative spectral power distribution of daylight[2] D_{55}
nm	$\overline{\tau}(\lambda)$	
350	0,00	28
360	0,07	31
370	0,23	34
380	0,42	33
390	0,60	38
400	0,74	61
410	0,83	69
420	0,88	72
430	0,91	68
440	0,94	86
450	0,95	98
460	0,97	100
470	0,98	100
480	0,98	103
490	0,99	98
500	0,99	101
510	1,00	101
520	1,00	100
530	1,00	104
540	1,00	102
550	1,00	103
560	1,00	100
570	1,00	97
580	1,00	98
590	0,99	91
600	0,99	94
610	0,99	95
620	0,98	94
630	0,98	90
640	0,97	92
650	0,97	89
660	0,96	90
670	0,95	94
680	0,94	90
690	0,94	80

4.2.2 Flash illuminants

The ideal flash source for exposing colour films balanced for daylight would have the same relative spectral power distributions as daylight illumination D_{55} at all wavelengths. While this is not achievable in practice, even when filters are employed in combination with a basic flash source, illuminants can be designed to produce the same general photographic effect as obtained from D_{55}. An evaluation of any divergence in photographic effect must consider the spectral sensitivity of films and the spectral transmittance of camera lenses.

Flash illuminants are usually designed to produce the same result as daylight using a non-selective neutral test object. This will generally produce excellent pictures. However, the greater the flash spectrum deviates from that of D_{55}, the greater is the potential for error in the colour reproduction for spectrally selective objects. Also, even though a flash source is balanced to give the same result as daylight for non-selective neutral objects on average daylight film according to this International Standard, specific film products may show significant colour balance shifts if their spectral sensitivities differ significantly from the average values used in this International Standard.

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.

2) CIE Publication No. 15 (E-3.1.3).

4.2.2.1 Temporal considerations. The spectral quality of a flash source is a function of time. The time interval over which the film is exposed may be limited either by closing the shutter or quenching the electronic flash when sufficient radiant energy has been detected by a photocell. In some cases, exposure time duration can be significantly shorter than the duration of the flash, particularly when taking close-up pictures. This makes it necessary to consider the temporal aspects of the flash spectrum to characterize its spectral power distribution properly for use in this International Standard.

4.2.2.2 Spectroradiometric measurements. Measurement of the relative spectral power distribution of a flash source shall be accurately made at bandwidths of 10 nm or less from 360 to 680 nm. The values determined and used shall be for the wavelengths specified in this International Standard.

4.3 Weighted spectral sensitivity values

4.3.1 Lens transmittance

The spectral transmittance of a camera's optical system, including such elements as lenses, mirrors and filters over the wavelength interval to which daylight-type film has significant sensitivity must be considered in evaluating illuminants. Since a lens is the only element in the optical taking system of most cameras, its characteristics are of primary interest in standardization. However, if additional items such as mirrors are used in the optical path of the imaging system, their spectral selectivity must be considered together with that of the lens.

The average axial relative spectral transmittance characteristics of 57 typical lenses as found in medium and high priced cameras were determined by a survey in 1979 and are referred to as those of an ISO standard camera lens. The spectral transmittance values for this lens are given in table 1 and used as a basis for this International Standard.

4.3.2 Spectral sensitivity of colour film

Colour films consist of layers, each with its own spectral sensitivity. Some layers will be primarily sensitive to blue light, while others will have primary sensitivity in the green or red regions. Since colour films differ in their relative spectral sensitivity, the effective colour of an illuminant depends on the film used for evaluation.

During 1977, manufacturers worldwide were requested to supply average spectral sensitivity data for their daylight type camera colour sensitized materials used in pictorial photography. Data from four manufacturers were received and averaged. These average values are used as references in this International Standard. Average relative spectral sensitivity values, $\bar{s}(\lambda)$, for the blue, green, and red sensitive layers, each normalized to a peak of 100, are given in table 2.

Table 2 — Average colour-film relative spectral sensitivity $\bar{s}(\lambda)$
(The sensitivity of each layer is normalized to a peak of 100.)

Wavelength, λ nm	Blue $\bar{s}_B(\lambda)$	Green $\bar{s}_G(\lambda)$	Red $\bar{s}_R(\lambda)$
350	2		
360	5		
370	12		
380	26		
390	49	1	
400	71	1	
410	87	1	
420	97	1	
430	100	1	
440	87	1	
450	80	1	
460	68	1	
470	47	2	
480	25	3	
490	11	6	
500	4	9	
510	3	14	
520	1	20	
530		31	1
540		60	1
550		100	2
560		51	3
570		54	5
580		39	7
590		11	12
600		2	19
610			26
620			34
630			54
640			83
650			100
660			70
670			17
680			2

NOTE — Reciprocity law failure of a film can be responsible for shifts in colour balance and speed as exposure time is changed. An attempt is made on the part of film manufacturers to minimize such effects. There is no satisfactory method for accomodating this variable for an average film, but it should be recognized as a factor when extremely short exposure times are involved, i.e. close-up pictures with self-quenching electronic flash or when long exposure times are used.

4.3.3 Determination of weighted spectral sensitivity values

The spectral quality of an illuminant can be evaluated in terms of its total effect on the image forming layers of an average colour film. The effect on the blue sensitive layers is referred to as the blue photographic response to the illuminant. The blue photographic response, R_B, of the average colour film to D_{55} illumination in combination with the ISO standard camera lens is given by the equation

$$R_B = \int_{\lambda_1}^{\lambda_2} D_{55}\,\overline{\tau}(\lambda)\,\overline{s}_B(\lambda)\,d\lambda \qquad \ldots (2)$$

where

D_{55} is the relative spectral power distribution for D_{55};

$\overline{s}_B(\lambda)$ is the relative spectral sensitivity of the blue sensitive layers of average daylight-type colour film;

$\overline{\tau}(\lambda)$ is the axial relative spectral transmittance of the ISO standard camera lens;

λ_1 to λ_2 is the range of wavelengths over which the blue layers are sensitive.

Multiply the integrand by a constant, K_B, to make the blue response to daylight equal to 10 000, i.e.

$$R_B = \int_{\lambda_1}^{\lambda_2} K_B D_{55}\,\overline{\tau}(\lambda)\,\overline{s}_B(\lambda)\,d\lambda = 10\,000 \qquad \ldots (3)$$

Equation (3) may be written

$$R_B = \int_{\lambda_1}^{\lambda_2} W_B(\lambda)\,D_{55}\,d\lambda \qquad \ldots (4)$$

where

$$W_B(\lambda) = K_B\,\overline{s}_B(\lambda)\,\overline{\tau}(\lambda)$$

The values of $W_B(\lambda)$ are called weighted spectral sensitivity values of the blue sensitive layers. Likewise, weighted values for the green $W_G(\lambda)$ and red $W_R(\lambda)$ sensitive layers can also be calculated by equating their photographic responses to daylight to 10 000. In other words, the weighting factors have been derived so that the red, green, and blue responses are equal for D_{55}. The values for W_B, W_G, W_R are given in table 3.

4.4 Photographic response to an illuminant

The photographic blue response of average camera colour material to flash illumination can be determined from the general equation

$$R_B = \int_{\lambda_1}^{\lambda_2} W_B(\lambda)\,S_\lambda\,d\lambda \qquad \ldots (5)$$

where S_λ is the average relative spectral power distribution of the flash illuminant, over the duration of the exposure of the sensitized material. For discrete values of $W_B(\lambda)$ and S_λ, the blue response becomes

$$R_B = \sum W_B(\lambda)\,S_\lambda$$

R_G and R_R are determined likewise.

Table 3 — Weighted spectral sensitivity values[1] $W(\lambda)$
(To be used with relative spectral power distribution values)

Wavelength, λ nm	Blue $W_B(\lambda)$	Green $W_G(\lambda)$	Red $W_R(\lambda)$
350			
360			
370	1		
380	2		
390	6		
400	10		
410	14		
420	16		
430	17		
440	16		
450	14		
460	13		
470	9	1	
480	4	1	
490	2	1	
500	1	2	
510	1	3	
520		5	
530		8	
540		15	
550		24	1
560		12	1
570		13	1
580		10	2
590		3	3
600		1	5
610			7
620			8
630			14
640			21
650			25
660			17
670			4

1) If the rounded weighted values are used with D_{55}, the red, green and blue responses found by summation would each be equal to 10 000 (rounded) and yield an ISO/SDI of 0/0/0.

4.5 Calculation of the ISO/SDI

The relative spectral power values of the flash illuminant shall be determined at 10 nm intervals. These values are multiplied by the appropriate blue, green and red weighted spectral sensitivity values. The total photographic responses, R_B, R_G, and R_R are obtained by summation. Logarithms to base 10 of the total response values are determined to two decimal places. The smallest logarithm 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 particular illuminant evaluated. The above calculations are illustrated in the annex.

5 Marking and labelling

The ISO/SDI of a flash illuminant determined using the method specified in this International Standard is designated the "ISO spectral distribution index" and may be denoted in the form

ISO/SDI 11/0/2

Because of the changes in film sensitivity and camera lens transmittance, SDI as determined according to this edition of ISO 3028 shall not be compared with SDI following the procedure outlined in the previous edition of this International Standard (ISO 3028-1974). From the latter, SDIs generally were designated in the form 11-0-2 rather than 11/0/2.

Annex

Calculation of the ISO spectral distribution index for a flash illuminant which produces pictures with a blue colour balance compared to those obtained with photographic daylight

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

Wavelength, λ nm	S_λ	Blue $W_B(\lambda)$	$W_B(\lambda)S_\lambda$	Green $W_G(\lambda)$	$W_G(\lambda)S_\lambda$	Red $W_R(\lambda)$	$W_R(\lambda)S_\lambda$
360	18						
370	35	1	35				
380	49	2	98				
390	61	6	366				
400	73	10	730				
410	86	14	1 204				
420	97	16	1 552				
430	106	17	1 802				
440	114	16	1 824				
450	122	14	1 708				
460	129	13	1 677				
470	128	9	1 152	1	128		
480	123	4	492	1	123		
490	121	2	242	1	121		
500	120	1	120	2	240		
510	117	1	117	3	351		
520	113			5	565		
530	108			8	864		
540	102			15	1 530		
550	100			24	2 400	1	100
560	99			12	1 188	1	99
570	99			13	1 287	1	99
580	100			10	1 000	2	200
590	103			3	309	3	309
600	106			1	106	5	530
610	110					7	770
620	113					8	904
630	108					14	1 512
640	97					21	2 037
650	91					25	2 275
660	86					17	1 462
670	86					4	344
680	88						
Total photographic responses $R = \sum W(\lambda)S_\lambda$			13 119		10 212		10 641
$\log_{10}$ responses ($\log_{10} R$)			4,12		4,01		4,03
Subtract $\log_{10} R_G$ (smallest value)			0,11		0,00		0,02
Multiply by 100			11		0		2
The ISO/SDI is 11/0/2							

This means the average colour film sees the flash as providing more blue (by 0,11 $\log_{10}R$) and red (by 0,02 $\log_{10}R$) exposure relative to the green than that obtained with D_{55} illumination when using the ISO standard camera lens. In other words, the flash source would produce pictures which were primarily blue when compared to those obtained under D_{55} illumination. To compensate for this, a filter is needed with the flash to decrease the log response of the blue layer by 0,11 and the red layer by 0,02.

A trilinear diagram (see the figure) may be used to portray the colour balance of pictures expected from a flash source with a particular SDI compared to those obtained with D_{55} illumination. The colour of a flash source is determined by plotting the blue, green, and red values of the SDI in the directions indicated. The above example is plotted for illustration. The effect is comparable to the colour change obtained by placing an 11 blue colour correction filter in combination with a 2 red filter over a D_{55} illuminant.

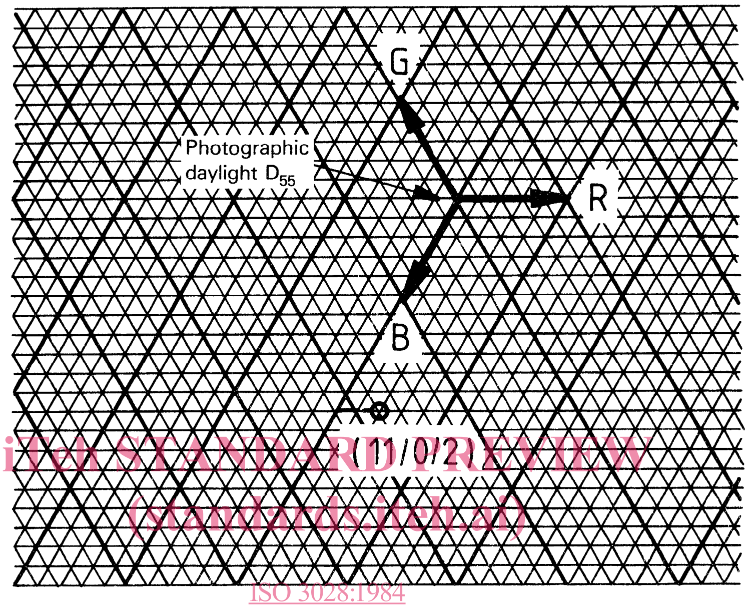

Figure — Trilinear graph