International Standard ISO 6728

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Photography — Camera lenses — Determination of ISO colour contribution index (ISO/CCI)

Photographie — Objectifs photographiques — Détermination de l'indice ISO de contribution à la couleur des images (ISO/CCI)

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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 developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been authorized 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.

International Standard ISO 6728 was developed by Technical Committee ISO/TC 42, *Photography*, and was circulated to the member bodies in June 1981.

It has been approved by the member bodies of the following countries :

Australia	Italy	Spain
Belgium	Japan	United Kingdom
Canada	Mexico	USA
France	Netherlands	USSR
Germany, F.R.	South Africa, Rep. of	

No member body expressed disapproval of the document.

Photography — Camera lenses — Determination of ISO colour contribution index (ISO/CCI)

0 Introduction

The overall colour balance of a photographic film camera image depends on the spectral characteristics of the film/process combination, the illuminant, and the optical system. These three elements are made by a large number of manufacturers throughout the world, but are expected to work interchangeably with one another to produce satisfactory pictures either in the form of transparencies or prints. For this reason common standards or aims have to be established for products and variability has to be tightly controlled.

This International Standard is concerned with the optical component of the photographic system which, in most cases, is the lens. It describes the spectral characteristics of an ISO standard camera lens and a method for determining the contribution of spectrally selective lenses to the colour of the final camera film image. The method is based on the assumption that the film will have the spectral sensitivity of an average colour film and be exposed to "photographic daylight" illumination. Spectral transmittance values of an ISO standard camera lens are suggested aims for lens manufacturers.

Previous to this International Standard, the colour contribution of lenses was determined using the procedure based on density, while the procedure in this International Standard is based on log transmittance. This International Standard also updates the average spectral sensitivity values for the latest colour films. For the above reasons, the colour contribution index (CCI) values obtained through the use of this International Standard cannot be compared to those obtained with other methods prior to 1980. The use of the notation 0/5/4 rather than 5-0-1 should indicate the values are obtained by using this International Standard.

The annexes provide additional information on this subject.

1 Scope and field of application

This International Standard describes a method for determining and specifiying the contribution of camera lenses to the colour of a photograph. The procedure can also be applied to other optical elements in the camera.

2 References

ISO 5/1, *Photography — Density measurements — Part 1: Terms, symbols and notations for reflection and transmission density.* [1)]

ISO 2239, *Photography — Light sources for use in sensitometric exposure — Simulation of the spectral distribution of daylight.*

ISO 3028, *Photography — Camera flash — Determination of ISO spectral distribution index.* [2)]

1) At present at the stage of draft.

2) At present at the stage of draft. (Revision of ISO 3028-1974.)

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

3 Definitions

3.1 photographic response: The effective response of a photographic film or paper to radiant flux. This can be represented by the equation

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

where

R is the photographic response;

S_λ is the spectral power distribution of the light source;

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

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

λ is the wavelength;

λ_1 to λ_2 is the wavelength region over which the photographic film or paper is sensitive.

3.2 spectral sensitivity (of a film) : The reciprocal of the amount of radiant energy required at each wavelength to produce a specified density in the final image.

3.3 weighted spectral sensitivity values : Values obtained by combining the relative film sensitivity and relative spectral power values for daylight to simplify the determination of colour contribution index values.

3.4 colour contribution index (CCI) : A three number system which describes the degree to which a lens is expected to change the overall colour of a photograph relative to that obtained with no lens in the system.

4 Method of test

4.1 Principle

The colour contribution index of a camera lens is calculated from its spectral transmittance values and the weighted spectral sensitivity values provided in this International Standard.

4.2 Lens transmittance values

The spectral transmittance of a camera's imaging system, including such elements as lenses, mirrors and filters, has to be considered in evaluating its colour contribution to the photographic result. This International Standard has been developed on the assumption that the lens is the only element in the optical system, since this is the case for most types of cameras. If additional elements are used, the combined spectral effect of all components has to be considered.

The spectral transmittance of the lens over the wavelength interval to which the film involved has significant sensitivity has to be determined. Monochromators providing bandwidths of 10 nm are required as well as an integrating sphere collector or its equivalent to measure the spectral transmittance of a lens.

4.2.1 ISO standard camera lens

The spectral transmittance characteristics of 57 typical camera lenses found in medium- and high-priced cameras were determined in a survey in 1979. The average relative spectral transmittance values are given in table 1 and designated as being those of the ISO standard camera lens.

4.3 Weighted spectral sensitivity values

4.3.1 Illuminants

4.3.1.1 Photographic daylight

Most camera colour films are designed to produce optimum results with "photographic daylight" illumination. The spectral power distribution of daylight varies with the 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 5 500 K were selected as the most appropriate for photography and designated as D_{55}. This is the prevailing condition when the sun is 40° above the horizon in a cloudless atmosphere (see ISO 2239). The relative power distribution values for D_{55} are given in table 1 and used as a reference in this International Standard.

4.3.1.2 Artifical illuminants

Blue flashbulbs and electronic flash units are normally designed to produce the same photographic results as daylight even though their relative power distribution may be different.

4.3.2 Spectral sensitivity of colour film

Some layers of colour film are primarily sensitive to blue light, while others will have primary sensitivity in the green and red regions. Since colour films differ in their relative spectral sensitivity, the effective colour of a lens 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 films used in pictorial photography. Data from four manufacturers were received and averaged. The average values are used as references in this International Standard. Average spectral sensitivity values,

Table 1 — Spectral data

Wavelength	Relative spectral transmittance of the ISO standard lens	Relative spectral power distribution of daylight[1)]
(λ) nm	$\overline{\tau}$ (λ)	D_{55}
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

1) CIE Publication No. 15 (E-1.3.1).

$\bar{s}(\lambda)$, for the blue, green and red sensitive layers, each normalized to a peak of 100, are given in table 2.

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

Wavelength	Blue	Green	Red
(λ) nm	$\bar{s}_B(\lambda)$	$\bar{s}_G(\lambda)$	$\bar{s}_R(\lambda)$
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

4.3.3 Determination of weighted spectral sensitivity value

The spectral characteristics of a lens can be evaluated in terms of its total effect on the various layers of an average colour film. The effect on the blue sensitive layers is referred to as the blue photographic response to the lens. The relative blue photographic response of the average colour film to D_{55} illumination with no camera lens in the system, can be denoted as :

$$\text{Blue photographic response : } R_B = \int_{\lambda_1}^{\lambda_2} D_{55}\,\bar{s}_B(\lambda)\,d\lambda \qquad \ldots (2)$$

where

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

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

λ_1 to λ_2 is the wavelength region over which the blue layers are sensitive.

Multiply the integrand by a constant K_B to make the blue response equal to 100, i.e.;

$$R_B = \int_{\lambda_1}^{\lambda_2} K_B\,D_{55}\,\bar{s}_B(\lambda)\,d\lambda = 100 \qquad \ldots (3)$$

equation (3) may be written :

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

where $W_B(\lambda) = K_B\,D_{55}\,\bar{s}_B(\lambda)$

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 100. In other words, the weighting factors have been derived so that the red, green, and blue responses are equal when no lens is in the system. The values for W_B, W_G, and W_R, are given in table 3.

4.4 Photographic response using a lens

The photographic blue response of average colour film using D_{55}, when a lens is included in the system, can be determined from the general equation :

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

where $\tau(\lambda)$ is the relative spectral transmittance of the lens. For discrete values of $W_B(\lambda)$ and $\tau(\lambda)$, the blue response becomes :

$$R_B = \Sigma\,W_B(\lambda)\,\tau(\lambda) \qquad \ldots (6)$$

Likewise, R_G and R_R are determined.

NOTE — If a lens is to be used with a specific film or group of films, the spectral sensitivities of those products can, of course, be used to determine the photographic response of a lens in that application. Since camera lenses vary primarily in transmittance of shorter wavelengths, differences in the spectral sensitivity of film in this region are generally the most important in evaluating the effect of various lenses on the colour of the resultant photograph.

4.5 Calculation of ISO colour contribution index (ISO/CCI)

The relative spectral transmittance values of a lens are multiplied by the weighted spectral sensitivity values for the blue, green, and red sensitive layers in table 3. The total photographic responses, R_B, R_G, and R_R are obtained by summation. Log_{10} response values are determined to two decimal places. To simplify, make the smallest element of this three-number designation equal to zero by subtracting it from all three log values.

Table 3 — Weighted spectral sensitivity values $W(\lambda)$
(to be used with transmittance values)

Wavelength (λ) nm	$W_B(\lambda)$	$W_G(\lambda)$	$W_R(\lambda)$
370	1		
380	1		
390	3		
400	7		
410	10		
420	12		
430	12		
440	13		
450	13		
460	12		
470	8	1	
480	4	1	
490	2	1	
500	1	2	
510	1	4	
520		5	
530		8	
540		15	
550		25	1
560		13	1
570		13	1
580		9	2
590		2	3
600		1	4
610			6
620			8
630			12
640			19
650			22
660			16
670			4
680			1

A further simplification occurs if the decimal is eliminated by multiplying by 100. The final reduction of the three-numbers is called the "Colour Contribution Index" for the particular lens evaluated. These calculations are illustrated in the example below :

$R_B = 89$	$\log_{10} R_B = 1{,}95$	subtracting	0,00	multiplying	0
$R_G = 99$	$\log_{10} R_G = 2{,}00$	1,95 from each value	0,05	each value by 100	5
$R_R = 97$	$\log_{10} R_R = 1{,}99$	gives	0,04	gives	4

Colour Contribution Index = 0/5/4

This means the average colour film in D_{55} illumination sees the lens as providing more green (by 0,05 log R) and red layer (by 0,04 log R) response relative to the blue than that obtained with no lens in the system. In other words, the lens would produce pictures which were primarily yellow when compared to those obtained with no lens present. An example showing all the calculations is given in annex A.

5 Tolerances for CCI

When the weighted factors in table 3 are used with the transmittance values of the ISO standard camera lens, the colour contribution index is 0/5/4 (see annex A for calculations).

Film manufacturers generally establish aims for daylight-type colour products based on the D_{55} illuminant and a camera lens having the spectral transmittance values given in table 1. If a lens has characteristics significantly different from the ISO standard camera lens, the average picture produced from it would be expected to be biased for colour balance. Such a lens would also produce colour shifts if it were used interchangeably with lenses which are close to the standard lens for spectral transmittance. For this reason, it is recommended 0/5/4 be used as an aim for the colour contribution index of camera lenses (or optical imaging system). Suggested tolerances for CCI are given in annex B.

6 Marking and labelling

The ISO colour contribution index of a camera lens determined using the method specified in this International Standard may be denoted in the form "ISO/CCI 0/5/4".

Annex A

Example of the method used for calculating the colour contribution index of a lens from transmittance measurements

(Relative spectral transmittance values of the ISO standard camera lens are used in this example)

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

Wavelength	Relative transmittance	W_B	$W_B\tau$	W_G	$W_G\tau$	W_R	$W_R\tau$
(λ) nm	τ						
350	0,00						
360	0,07						
370	0,23	1	0,23				
380	0,42	1	0,42				
390	0,60	3	1,80				
400	0,74	7	5,18				
410	0,83	10	8,30				
420	0,88	12	10,56				
430	0,91	12	10,92				
440	0,94	13	12,22				
450	0,95	13	12,35				
460	0,97	12	11,64				
470	0,98	8	7,84	1	0,98		
480	0,98	4	3,92	1	0,98		
490	0,99	2	1,98	1	0,99		
500	0,99	1	0,99	2	1,98		
510	1,00	1	1,00	4	4,00		
520	1,00			5	5,00		
530	1,00			8	8,00		
540	1,00			15	15,00		
550	1,00			25	25,00	1	1,00
560	1,00			13	13,00	1	1,00
570	1,00			13	13,00	1	1,00
580	1,00			9	9,00	2	2,00
590	0,99			2	1,98	3	2,97
600	0,99			1	0,99	4	3,96
610	0,99					6	5,94
620	0,98					8	7,84
630	0,98					12	11,76
640	0,97					19	18,43
650	0,97					22	21,34
660	0,96					16	15,36
670	0,95					4	3,80
680	0,94					1	0,94
$\Sigma W\tau$			89,35		99,90		97,34
$\log_{10} (\Sigma W\tau)$			1,95		2,00		1,99
Subtract 1,95			0,00		0,05		0,04
Multiplying by 100			0		5		4
Colour contribution index = 0/5/4							

Annex B

Recommended values for colour contribution index of camera lenses

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

The colour contribution index for an average ISO standard camera lens is 0/5/4. Ideally, all manufacturers should use this as an aim point. As a guide, the following tolerances, for each value, are recommended :

Blue :	0	$^{+3}_{-4}$
Green :	5	$^{0}_{-2}$
Red :	4	$^{+1}_{-2}$

A trilinear graph is a useful method for portraying CCI values. Plotting the above tolerances yields a hexagon within which CCI values of lenses should fall (dotted lines in the figure). Index values should be plotted moving in the blue, green, and red directions indicated in the figure (for example, for CCI 0/2/3, starting at the origin 0/0/0, move 0 unit in the blue direction, then 2 units in the green direction, and from there, 3 units in the red direction).

Because the procedure for deriving CCI equates the smallest value to 0, it is not readily apparent whether a CCI is acceptable by comparing the values directly to the above tolerances. For example, in the case of 0/2/3, the green and red values do not seem to comply when compared directly to the tolerances. However, the plotted values indicate it falls within the hexagon. This is because indexes 0/2/3 and −2/0/1 (all values meet the tolerances) are equivalent and plot in the same location since they only differ because of a neutral shift (−2/−2/−2). Therefore, it is recommended that CCI indexes be plotted on a trilinear graph to determine if they comply with the tolerances.

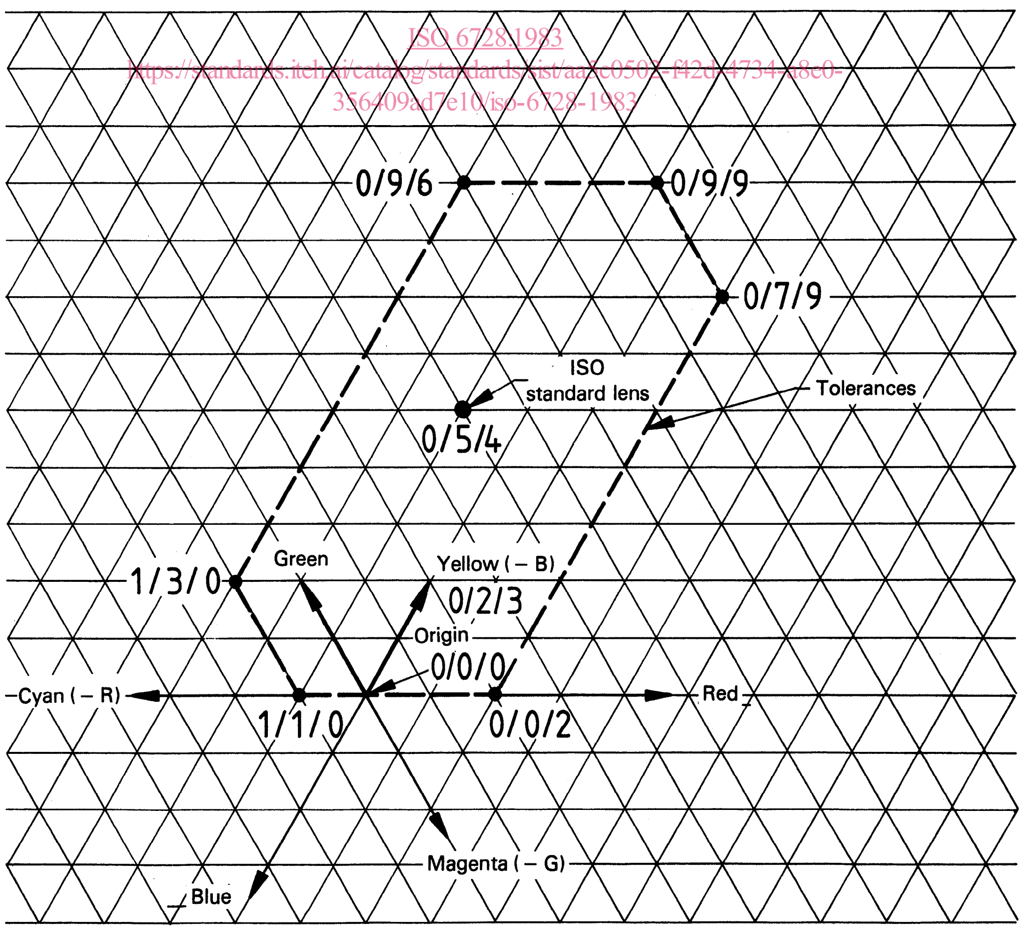

Figure — Trilinear graph