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British Standard

Photographic density measurements

Part 3. Specification for spectral conditions

[ISO title: Photography — Density measurements — Part 3: Spectral conditions]

Densité photographique
Partie 3. Conditions spectrales — Spécifications

Optische Dichte
Teil 3. Spektrale Bedingungen

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National foreword

This British Standard is one of a series of Parts which together constitute a revision of BS 1384, first published in 1947 and confirmed in 1962, and has been prepared under the direction of the Cinematography and Photography Standards Committee. This Part is identical with ISO 5/3-1984 'Photography – Density measurements – Part 3 : Spectral Conditions' published by the International Organization for Standardization (ISO).

BS 1384 : 1974 defines terms and symbols and provides a method for measuring photographic transmission density only. The complete revision of this standard in four Parts will in addition cover reflection density.

Terminology and conventions. The text of the international standard has been approved as suitable for publication as a British Standard without deviation. Some terminology and certain conventions are not identical with those used in British Standards; attention is drawn especially to the following.

The comma has been used as a decimal marker. In British Standards it is current practice to use a full point on the baseline as the decimal marker.

Wherever the words 'International Standard' appear, referring to this standard, they should be read as 'British Standard'.

Cross-references

International standards	Corresponding British Standards
ISO 5/1-1984	BS 1384 Photographic density measurements Part 1 : 1985 Guide for terms, symbols and notations (Identical)
ISO 5/4-1983	Part 4 : 1985 Specification for geometric conditions for reflection density (Identical)

ISO 5/2 and the identical corresponding Part of BS 1384 are in course of preparation.

CIE Publication No. 15, referred to in the text, is published by the International Commission on Illumination (Commission Internationale de l'Eclairage).

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British Standard

Photographic density measurements

Part 3. Specification for spectral conditions

0 Introduction

This International Standard is one of a series which specifies the spectral conditions for optical densitometry as practiced in black-and-white and colour photography.

To define a density value fully, it is necessary to specify both the geometric and spectral conditions of the measuring system. Geometric conditions are described in ISO 5/2 for transmission density, and in ISO 5/4 for reflection density. This part of ISO 5 specifies the spectral conditions for both transmission and reflection. It represents a revision of the spectral conditions described in the first edition of ISO 5, but has been expanded to include additional spectral types commonly used in photography.

In photography, optical density is a measure of the modulation of light or other radiant flux by a given area of photographic film or a photographic print. The measurement of density may be of interest for various reasons. It may be necessary to assess the lightness or darkness of an image, to predict how a film will perform in a photographic printing operation, or to determine some measure of the amounts of coloured dyes in the image for the purpose of controlling a colour process. If the visual effect is of interest, the spectral conditions of measurement must simulate some appropriate illumination and the spectral sensitivity of the eye. For photographic printing operations, the spectral power distribution of the irradiator to be used in the printing operation and the spectral sensitivity of the print material must be simulated. In evaluating original material for colour separation, the illuminant, the sensitivity of the separation film, and the spectral transmittance of the tricolour separation filters must be simulated.

Certain types of density measurements are often made to generate sensitometric curves which are used to characterize the photographic properties of films and paper. Densities can also be used to monitor various photographic operations such as processing.

The specified spectral power distribution of the incident flux for transmission measurements differs from that for reflection measurements. For reflection measurements, incandescent tungsten illumination of the type known as CIE standard illuminant A, adopted by the International Commission on Illumination in 1931 is specified. This illuminant is used throughout the world as the standard incandescent source for measurements of colour. Its use in densitometry is preferred because national standardizing laboratories are generally prepared to make spectrophotometric measurements and perform colorimetric computations of visual reflection factors on the basis of CIE standard illuminant A. This usage facilitates the procurement of physical standards for reflection densitometry.

For transmission measurements, the spectral distribution of the influx is CIE standard illuminant A as modified by a typical infrared filter to protect the specimen and optical system from heat.

The definition of visual density adopted in this International Standard differs slightly from that in the previous edition. Previously specified were an influx spectrum having a distribution temperature of 3 000 K and a receiver sensitivity in accordance with the CIE photopic luminous efficiency function, which defines the standard observer for photometry. CIE standard illuminant A has now been adopted for the actual influx in reflection measurements and for the definition of the spectral product in both reflection and transmission measurements. Thus, for the first time the spectral conditions of measurement of visual density are in essential accord with the spectral conditions internationally adopted in all fields of photometry and colorimetry for the measurement of luminous reflectance factors or luminous transmittances. However, it should be emphasized that most colour-measuring equipment does not have the geometric conditions specified for standard densitometry. Although the adoption of a distribution temperature of 2 856 K instead of 3 000 K may require the assignment of new values that are spectrally selective to laboratory standards of visual density, the new temperature is more representative of the illumination in the practical densitometers in general use.

Many standards for reflection density specify the use of barium sulphate as the reference standard. However, pressed barium sulphate is fragile, variable from lot to lot of powder, variable from pressing to pressing, and the reflectance drifts appreciably in the first few days after pressing.

In 1969, the International Commission on Illumination recommended that all reflectance factors and, by inference, the corresponding reflection densities be reported relative to a perfectly reflecting and perfectly diffusing material. Reflection densitometers are almost always calibrated with enamelled metal working standards. These working standards are calibrated with respect to primary standards that are calibrated by absolute methods in national standards laboratories.

1 Scope and field of application

This part of ISO 5 specifies spectral conditions for the measurement of several types of densities used in photography, to evaluate processed black-and-white or coloured images of films, papers and plates.

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2 References

ISO 5, *Photography — Density measurements —*

Part 1: Terms, symbols and notations.

Part 2: Geometric conditions for transmission density. [1)]

Part 4: Geometric conditions for reflection density.

CIE Publication No. 15 — *Colorimetry,* 1971.

3 Definition

CIE standard illuminant A: The radiant flux from a gas-filled coil tungsten filament lamp operating at a distribution temperature of 2 856 K based on Planck's second constant (c_2 = 1,438 8 × 10^{-2} m·K).

4 Influx spectrum, S

To completely define a type of density spectrally, it is necessary to specify the light source, optics, and spectral response of the measuring system. The influx spectrum is the radiant flux incident on the specimen surface or sampling aperture. It is a function of the energy source and the optical system.

The basic light source for densitometry is CIE standard illuminant A (see clause 3).

In some reflection and almost all transmission densitometers, it is necessary to add a heat-absorbing filter to the influx side to protect the specimen and optical elements. If the absorber does not change the relative power distribution of CIE A below 550 nm, no significant fluorescence effect should be observed or be of concern.

4.1 Reflection densitometry (S_A)

For reflection density measurements, the relative spectral power distribution of the incident flux shall be CIE standard illuminant A which is given in table 1 under the heading S_A, which is the symbol used in functional notation.

4.2 Transmission densitometry (S_H)

For transmission density measurements, the relative spectral power distribution of the incident flux shall be that given in table 1 under the heading S_H, which is the symbol used in functional notation. This is based on the spectral power distribution of the CIE standard illuminant A modified in the infrared region to protect the sample and optical elements from excessive heat which is typical for most transmission densitometers.

4.3 Sample conditions

Some materials change density with variations in temperature and relative humidity. Therefore, to avoid ambiguity, specimens shall be at 23 ± 2 °C and 50 ± 5 % relative humidity when determining ISO density.

1) At present at the stage of draft. (Revision of ISO 5-1974.)

Table 1 — ISO densitometer illuminants (influx spectra)
(Relative spectral power distributions normalized to 100 at 560 nm)

Wavelength nm	Transmission densitometer illuminant S_H	Reflection densitometer illuminant S_A
340	4	4
350	5	5
360	6	6
370	8	8
380	10	10
390	12	12
400	15	15
410	18	18
420	21	21
430	25	25
440	29	29
450	33	33
460	38	38
470	43	43
480	48	48
490	54	54
500	60	60
510	66	66
520	72	72
530	79	79
540	86	86
550	93	93
560	100	100
570	107	107
580	111	114
590	115	122
600	116	129
610	119	136
620	117	144
630	113	151
640	107	158
650	102	165
660	94	172
670	89	179
680	80	185
690	72	192
700	62	198
710	53	204
720	45	210
730	37	216
740	31	222
750	24	227
760	19	232
770	15	237

5 Spectral response, s

The spectral response of a densitometer is a function of the spectral sensitivity of the photodetector, and the spectral transmittance of the optics and filters associated with it. Theoretically, it is desirable for the spectral response to match the spectral sensitivity of the receiver (eye, photographic paper, etc.) used in the practical applications of the product.

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6 Spectral products

If the spectral power of the influx spectrum, S, is multiplied by the spectral response, s, of the receiver, wavelength by wavelength, spectral products are obtained. If there is no fluorescence in the optical elements or the specimen, it is not necessary to specify the spectral characteristics of the influx and receiver separately as long as the correct spectral products are obtained. The spectral products for a densitometer may be denoted as

$$\Pi = Ss$$

where

S is the relative spectral power of the influx;

s is the relative spectral response of the receiver.

7 Notation

ISO 5/1 specifies functional notation of the form $D(G\,;\,S:g\,;\,s)$, where G and g symbolize the influx geometry and efflux geometry respectively. Since this part of ISO 5 is only concerned with spectral conditions, the notation is abbreviated to $D(S:s)$. To distinguish between reflection density (D_R) and transmission density (D_T), a subscript may be used.

8 Types of density

Several spectral types of densitometry are used to evaluate photographic materials. These are defined in terms of logarithmic spectral product values specified at 10 nanometre (nm) intervals. Spectral product, Π, values are obtained by multiplying the relative spectral energy values of the densitometer illuminant, S, at 10 nm intervals by the relative spectral response values, s, of the receiver of the pertinent wavelength region. The resultant products are normalized to yield a peak value of 100,000. The logarithms to the base 10 of these values are used in this International Standard to define the various spectral types.

8.1 ISO visual density, $D_T(S_H : V_T)$, $D_R(S_A : V)$

To evaluate the darkness of an image which is to be viewed directly or by projection, visual density is measured. Such measurements are most often made on black-and-white images, but can be made on other types of images.

For the reflection density, the combined spectral sensitivity of the receiver and the spectral characteristics of the components on the efflux section of the densitometer shall match the spectral luminous efficiency in photopic vision, $V(\lambda)$[1]. The product of $V(\lambda)$ and S_A, wavelength by wavelength, defines the spectral products the whole densitometer shall have to provide ISO visual densities. The logarithms of the products are given in table 2.

The spectral products required for visual transmission densitometry are the same as those used for reflection. However, since the influx is different, the spectral response of the receiver, V_T, must compensate so that $S_H V_T = S_A V$ at every 10 nm interval.

Table 2 — $\log_{10}$ spectral products for ISO visual type 1 and type 2 densities
(Normalized to 5,000 peak)

Wavelength nm	Π_v (Visual)	Π_1 (Type 1)	Π_2 (Type 2)
340			< 1,000
350			2,708
360		< 1,000	4,280
370		1,640	4,583
380		2,860	4,760
390		4,460	4,851
400	< 1,000	5,000	4,916
410	1,322	4,460	4,956
420	1,914	2,860	4,988
430	2,447	1,640	5,000
440	2,811	< 1,000	4,990
450	3,090		4,951
460	3,346		4,864
470	3,582		4,743
480	3,818		4,582
490	4,041		4,351
500	4,276		3,993
510	4,513		3,402
520	4,702		2,805
530	4,825		2,211
540	4,905		< 1,000
550	4,957		
560	4,989		
570	5,000		
580	4,989		
590	4,956		
600	4,902		
610	4,827		
620	4,731		
630	4,593		
640	4,433		
650	4,238		
660	4,013		
670	3,749		
680	3,490		
690	3,188		
700	2,901		
710	2,622		
720	2,334		
730	2,041		
740	1,732		
750	1,431		
760	1,146		
770	< 1,000		

1) See CIE Publication No. 15. The values for $V(\lambda)$ are those adopted in 1933 by the *International Committee of Weights and Measures*.

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