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American National Standard

for Photography –

Density Measurements – Part 3: Spectral Conditions

ANSI/ISO 5-3-1995,
ANSI/NAPM IT2.18-1996

ANSI American National Standards Institute
11 West 42nd Street
New York, New York
10036

American National Standard

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American National Standard
for Photography –

Density Measurements – Part 3: Spectral Conditions

Secretariat

National Association of Photographic Manufacturers, Inc.

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American National Standards Institute, Inc.

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Foreword

(This foreword is not part of American National Standard ANSI/ISO 5-3-1995, ANSI/NAPM IT2.18-1996. This document is identical to ISO 5-3: 1995 and the following five paragraphs are the original foreword as it appeared in that document.)

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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote.

International Standard ISO 5-3 was prepared by Technical Committee ISO/TC 42, *Photography*.

This second edition cancels and replaces the first edition (ISO 5-3:1984), which has been technically revised. It has also been expanded to include additional spectral types commonly used in consumer, professional, and graphic arts photographic applications. Status E and status I responses have been included in view of their relevance to graphic technology.

Annexes A to D of this part of ISO 5 are for information only.

Suggestions for improvement of this standard will be welcome. They should be sent to the National Association of Photographic Manufacturers, Inc., 550 Mamaroneck Avenue, Suite 307, Harrison, NY 10528-1612

This standard was processed and approved for submittal to ANSI by NAPM Technical Committee IT2 on Image Evaluation. Committee approval of the standard does not necessarily imply that all committee members voted for its approval. At the time this standard was approved, the IT2 Committee had the following members:

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Introduction

This part of ISO 5 is one of a series which specifies the spectral conditions for optical densitometry as practised in black-and-white and colour photographic applications.

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 density measurements.

In the early years of densitometry, the spectral responses of instruments were specified only in terms of the colour filters used in the construction. Although it was seldom the case, it was assumed that the spectral responses of the photoreceivers and the illuminant spectral energy distributions as well as all intervening optical components were the same in all instruments. In more recent times densitometry standards have specified that the product of all these components must equal some given set of published "documentary" values. Such a specification allows flexibility to the manufacturer while providing for improved accuracy and precision. It also allows for standard reference materials to be manufactured and certified based on fundamental measurements.

In photographic image reproduction, optical density is a measure of the modulation of light or other radiant flux by a given area of the recording medium. 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 or paper will perform in a printing operation, or to determine some measure of the amounts of colorants 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 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 spectral sensitivity of the separation medium, 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 papers. Densities can also be used for tone-reproduction analysis and to monitor various operations such as photoprocessing, lithography, gravure, screen printing processes, etc.

The specified spectral power distribution of the incident flux for transmission density measurements differs from that for reflection density measurements. For reflection density measurements, incandescent tungsten illumination of the type known as CIE (Commission internationale de l'éclairage) standard illuminant A, adopted by the International Commission on Illumination in 1931 is specified. 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 density measurements, the spectral distribution of the influx is CIE standard illuminant A, as modified by a typical heat-absorbing filter to protect the specimen and optical system from heat.

Many standards for reflection density specify the use of barium sulfate as the reference standard. However, pressed barium sulfate 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 (CIE) recommended that all reflectance factors and, by inference, the corresponding reflection densities be reported relative to a perfectly reflecting and perfectly diffusing material.

In day-to-day operation reflection densitometers are usually calibrated with standard reference materials available from a number of sources. These working standards are calibrated with respect to primary standards that are calibrated by absolute methods in national standards laboratories.

American National Standard for Photography –

Density Measurements – Part 3: Spectral Conditions

1 Scope

This part of ISO 5 specifies spectral conditions for the measurement of several types of densities used in photographic image reproduction. Photographic image reproduction as used throughout this part of ISO 5 encompasses the broad definition of photography as the art or process of producing images on a sensitized surface by the action of radiant energy.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 5. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 5 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 5-1:1984, *Photography — Density measurements — Part 1: Terms, symbols and notations.*

CIE Publication 17.4:1987, *International lighting vocabulary.*

CIE Publication 18.2:1983, *The basis of physical photometry.*

3 Definitions

For the purposes of this part of ISO 5, the definitions given in ISO 5-1 and the following definitions apply.

3.1 CIE standard illuminant A: Planckian radiation at a temperature of about 2 856 K.[1)]

NOTES

1 Based on the International Practical Temperature Scale, 1968, using Planck's second constant
$c_2 = 1{,}438\,8 \times 10^{-2}$ m·K

2 The radiation of a gas-filled coil tungsten filament lamp operated at a distribution temperature of 2 856 K will approximate this spectral distribution and thus can serve as a practical realization of this standard illuminant.

3.2 sideband rejection: The degree that radiation outside a desired passband is blocked or suppressed. It is usually expressed as the ratio of the integrated energy within the desired passband to the integrated energy outside the passband.

3.3 peak wavelength: That wavelength at which the system response is a maximum.

3.4 spectral bandwidth: Width, in wavelength units, of the response band measured between the points where the response has fallen to designated percentages of the peak response.

3.5 influx spectrum: Spectrum of the radiant flux incident on the specimen surface or sampling aperture. It is a function of the energy source and the optical system on the source side of the specimen.

4 Density measurements

To define completely a type of density spectrally, it is necessary to specify the light source, optics and spectral response of the measuring system.

The basic light source for densitometry is CIE standard illuminant A (see 3.1). 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 ab-

1) As defined in CIE Publication 17.4.

sorber 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

For reflection density measurements, if either the densitometer manufacturer or the user is not sure of the absence of fluorescence in the sample to be measured, 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

For transmission density measurements, if either the densitometer manufacturer or the user is not sure of the absence of fluorescence in the sample to be measured, 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 °C ± 2 °C and (50 ± 5) % relative humidity when determining ISO density.

5 Spectral response, s

The spectral response of a densitometer is a function of the spectral sensitivity of the photodetector and the spectral modifications by any of the optics and filters between the plane of the specimen and the photodetector. 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.

6 Spectral products, Π

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. Since significant fluorescence from a number of sources is often encountered, it is desirable to conform to the influx spectra specified in this part of ISO 5. However, in those cases where there is no fluorescence in the specimen or in the optical elements, 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, which includes the photodetector and all intervening components between it and the plane of the specimen.

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 recording media. These are defined in terms of logarithmic spectral product values specified at 10 nm (nanometre) intervals. Spectral product, Π, values are obtained by multiplying the relative spectral power values of the densitometer influx spectrum, S, at 10 nm intervals by the relative spectral response values, s, of the receiver in 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 part of ISO 5 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 reflection density, the combined spectral sensitivity of the receiver and the spectral characteristics of the components of the efflux section of the densitometer shall match the spectral luminous efficiency function for photopic vision, $V(\lambda)$.[2] The product of $V(\lambda)$ and S_A, wavelength by wavelength, defines the spectral products the whole densitometer must have in order to provide ISO visual densities. The logarithms of the products are given in table 2.

2) See CIE Publication 18.2.

Table 1 — ISO densitometer influx spectra

Wavelength λ, nm	**Transmission densitometer influx spectrum** S_H	**Reflection densitometer influx spectrum** 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	96	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

NOTE — Relative spectral power distributions are normalized to 100 at 560 nm.

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

Wavelength λ, nm	**Visual** $\log_{10} \Pi_v$	**Type 1** $\log_{10} \Pi_1$ (Printing: diazo and vesicular)	**Type 2** $\log_{10} \Pi_2$ (Printing: silver halide)
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		

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.

8.2 Printing density [3]

Printing continuous-tone images onto light-sensitive materials requires a special metric called printing density. The spectral conditions required for measuring the printing density are a function of the spectral power distribution of the illuminant, the spectral characteristics of the optical system, and the spectral sensitivity of the print material. The contact-printing density of a film sample is equal to the transmission density of a spectrally non-selective modulator when they both produce the same response on the print material when contact-printed together.

In the case of projection-printing density, the film sample shall be projection-printed onto the print material. The spectrally non-selective modulator, however, shall be contact-printed onto the print material using the same projector, the same exposure time and same lamp operating at the same voltage.

The spectral characteristics of a densitometer may be designed to provide printing densities directly for a particular print material through the proper selection of light source, attenuators and photodetectors. However, in most cases it is possible to correlate density readings from a commercially available densitometer to printing densities using equations derived by regression analysis.

8.2.1 ISO type 1 printing density, $D_T(S_H : s_1)$

Diazo and vesicular films are used extensively in the microfilm industry for making prints from camera-original images or later generations. These print films normally have sensitivity in the blue and ultraviolet regions. They are generally exposed on printers equipped with additive high-pressure mercury vapour lamps. It has been determined that under these film-light source conditions, density measurements from the original image, using a densitometer with a narrow band filter having peak transmission at 400 nm, provide ISO type 1 printing density values. The effective spectral sensitivity of the print materials is denoted as s_1. For ease of reference, densities determined from a densitometer which has the log spectral product values ($\log_{10} \Pi_1$) given in table 2 are designated type 1. However, the extent to which such a densitometer will measure printing densities depends on the sensitivity of the print film and the spectral and geometrical characteristics of the printing system.

8.2.2 ISO type 2 printing density, $D_T(S_H : s_2)$

When printing is done onto non-colour-sensitized silver halide photographic material (e.g. a black-and-white paper or film), the log spectral products found useful are indicated as $\log_{10} \Pi_2$ in table 2. These have been derived by using the average spectral sensitivity of a print material as modified by the transmission of an ultraviolet absorbing filter with a sharp cut-off at 360 nm. The resultant sensitivity is designated s_2. The filter is included to minimize effects caused by variations in the optics of printing systems, and the absorption band of silver deposits at 320 nm. Multiplying the spectral sensitivity values by the relative spectral power distribution of the illuminant yields the spectral product values required in order for a densitometer to provide printing density values directly from the material being printed.

8.3 ISO status A density

By transmission:

$D_T(S_H : A_B)$, $D_T(S_H : A_G)$ and $D_T(S_H : A_R)$

By reflection:

$D_R(S_A : A'_B)$, $D_R(S_A : A'_G)$ and $D_R(S_A : A'_R)$

The log spectral products for the whole instrument shall conform to the values listed in table 3. The symbols A_B, A_G and A_R shall be used to designate the transmission status A blue, green and red spectral responses, respectively, in the functional notation. Similarly, A'_B, A'_G and A'_R are designated the spectral responses for reflection status A densitometry.

NOTE 3 The status A responses were defined to match closely the responses historically used in evaluating transparency films and later applied to similar colorants on reflective supports.

8.4 ISO status M density

By transmission:

$D_T(S_H : M_B)$, $D_T(S_H : M_G)$ and $D_T(S_H : M_R)$

The log spectral products shall conform to the values listed in table 4. The symbols M_B, M_G and M_R shall be used to designate status M blue, green and red transmission spectral responses, respectively, in the functional notation.

NOTE 4 The status M responses were defined to match closely the responses historically used in evaluating colour negative films.

3) For further details, see reference [4] in annex D.

8.5 ISO status T density

By transmission:

$D_T(S_H : T_B)$, $D_T(S_H : T_G)$ and $D_T(S_H : T_R)$

By reflection:

$D_R(S_A : T'_B)$, $D_R(S_A : T'_G)$ and $D_R(S_A : T'_R)$

The log spectral products shall conform to the values listed in table 5. The symbols T_B, T_G and T_R shall be used to designate the transmission status T blue, green and red spectral responses, respectively, in the functional notation. Similarly T'_B, T'_G and T'_R are designated the spectral responses for reflection status T densitometry.

NOTE 5 The status T responses were defined to match closely the responses historically used in evaluating original art to be colour separated. In extension, status T responses have also been applied, notably in the USA, to graphic arts materials such as ink-on-paper printed sheets, and off-press proofs.

8.6 ISO status E density

By reflection:

$D_R(S_A : E'_B)$, $D_R(S_A : E'_G)$ and $D_R(S_A : E'_R)$

The log spectral products shall conform to the values listed in table 6. The symbols E'_B, E'_G and E'_R shall be used to designate the reflection status E blue, green and red spectral responses, respectively, in the functional notation.

NOTES

6 *Status E responses are intended to match the responses used in the graphic arts trade in Europe.*

7 Status E response evolved from the wider of the two passband filter specifications of DIN 16536-2 (see annex D), taking into account the influx spectrum and the spectral response of the receiver.

8 Some users wish to use polarizers when determining "status E" densities. It should be noted that polarizers are not neutral and a "standard" polarizer does not exist. Please refer to clause 9 for further discussion on this subject.

9 Application of status E blue spectral products requires further studies and these spectral products are expected to be revised in the next edition of this part of ISO 5.

8.7 ISO narrow-band density

By transmission:

$D_{T \cdot r}(S_H : N_\lambda)$

By reflection:

$D_{R \cdot r}(S_A : N_\lambda)$

The subscript r identifies the exponent of the power of ten sideband rejection, and the subscript λ identifies the peak wavelength, in nanometres.

EXAMPLE

$D_{T \cdot 5}(S_H : N_{480})$ equals 10^5 sideband rejection, with a peak wavelength of 480 nm, and

$D_{R \cdot 4}(S_A : N_{590})$ equals 10^4 sideband rejection, with a peak wavelength of 590 nm.

Narrow-band densitometry is designed to approximate spectral or monochromatic densitometry. It is defined by three basic characteristics as follows.

a) **Peak wavelength**

Any wavelengths appropriate to the application may be chosen.

b) **Spectral bandwidth**

Spectral bandwidth is defined as the width, in wavelength units, of the spectral products measured between the points where the spectral product has fallen to the indicated percentage of the peak.

50 %: not more than 20 nm

0,1 %: not more than 40 nm

NOTE 10 A three-cavity Fabry Perot interference filter with a nominal 15 nm bandwidth (50 % points) would easily meet the above requirements.

c) **Sideband rejection**

The total integration of the spectral products outside the 0,01 % points should not exceed a given fraction of the integration of the spectral products within the 0,01 % points. That fraction should not be more than 1/10 000 (10^4 rejection) if 3,0 is the highest density to be measured, and not more than 1/100 000 (10^5 rejection) if 4,0 is the highest density to be measured. (See annex C.)

8.8 ISO status I density

Status I is a special case of the previous narrow-band densitometry with spectral bandwidth and sideband rejection as defined in 8.7, and peak wavelengths as follows.

Peak wavelengths:

blue: 430 nm (± 5 nm)

green: 535 nm (± 5 nm)

red: 625 nm (± 5 nm)

This particular set has been found to be particularly useful for evaluating graphic arts materials such as process ink on paper.

Refer to clause 9 for a discussion of the use of polarizers.

Table 3 — Status A — $\log_{10}$ spectral products Π_A
(Normalized to 5,000 peak)

Wavelength λ, nm	Blue	Green	Red
	▲	▲	▲
400	slope = 0,380/nm		
410			
420	3,602		
430	4,819	slope = 0,220/nm	
440	5,000		slope = 0,270/nm
450	4,912		
460	4,620		
470	4,040		
480	2,989		
490	1,566		
500	0,165	1,650	
510		3,822	
520		4,782	
530		5,000	
540		4,906	
550		4,644	
560	slope = −0,140/nm	4,221	
570		3,609	
580		2,766	
590		1,579	
600			2,568
610			4,638
620		slope = −0,170/nm	5,000
630			4,871
640			4,604
650			4,286
660			3,900
670			3,551
680			3,165
690			2,776
700			2,383
710			1,970
720			1,551
730			1,141
740			0,741
750			0,341
	▼	▼	slope = −0,040/nm ▼

Table 4 — Status M — $\log_{10}$ spectral products Π_M
(Normalized to 5,000 peak)

Wavelength λ, nm	Blue	Green	Red
	▲	▲	▲
400	slope = 0,250/nm		
410	2,103		
420	4,111		
430	4,632	slope = 0,106/nm	
440	4,871		
450	5,000		
460	4,955		
470	4,743	1,152	
480	4,343	2,207	
490	3,743	3,156	
500	2,990	3,804	slope = 0,260/nm
510	1,852	4,272	
520		4,626	
530		4,872	
540		5,000	
550	slope = −0,220/nm	4,995	
560		4,818	
570		4,458	
580		3,915	
590		3,172	
600		2,239	
610		1,070	
620			2,109
630			4,479
640			5,000
650			4,899
660			4,578
670		slope = −0,120/nm	4,252
680			3,875
690			3,491
700			3,099
710			2,687
720			2,269
730			1,859
740			1,449
750			1,054
760			0,654
770			0,254
	▼	▼	slope = −0,040/nm ▼

Table 5 — Status T — $\log_{10}$ spectral products Π_T
(Normalized to 5,000 peak)

Wavelength λ, nm	Blue	Green	Red
340	< 1,000		
350	1,000		
360	1,301		
370	2,000		
380	2,477		
390	3,176		
400	3,778		
410	4,230		
420	4,602		
430	4,778		
440	4,914		
450	4,973		
460	5,000		
470	4,987	< 1,000	
480	4,929	3,000	
490	4,813	3,699	
500	4,602	4,447	
510	4,255	4,833	
520	3,699	4,964	
530	2,301	5,000	
540	1,602	4,944	
550	< 1,000	4,820	
560		4,623	< 1,000
570		4,342	1,778
580		3,954	2,653
590		3,398	4,477
600		2,845	5,000
610		1,954	4,929
620		1,000	4,740
630		< 1,000	4,398
640			4,000
650			3,699
660			3,176
670			2,699
680			2,477
690			2,176
700			1,699
710			1,000
720			< 1,000

Table 6 — Status E — $\log_{10}$ spectral products Π_E
(Normalized to 5,000 peak)

Wavelength λ, nm	Blue	Green	Red
370	1,000		
380	2,431		
390	3,431		
400	4,114		
410	4,477		
420	4,778		
430	4,914		
440	5,000		
450	4,959		
460	4,881		
470	4,672	< 1,000	
480	4,255	3,000	
490	3,778	3,699	
500	2,903	4,477	
510	1,699	4,833	
520	1,000	4,964	
530	< 1,000	5,000	
540		4,944	
550		4,820	
560		4,623	< 1,000
570		4,342	1,778
580		3,954	2,653
590		3,398	4,477
600		2,845	5,000
610		1,954	4,929
620		1,000	4,740
630		< 1,000	4,398
640			4,000
650			3,699
660			3,176
670			2,699
680			2,477
690			2,176
700			1,699
710			1,000
720			< 1,000

8.9 ISO type 3 density, $D_T(S_H : s_3)$

Optical sound records on three-component subtractive colour films made up of dye images plus silver or a metallic salt are often used in sound reproduction systems employing an S-1 photosurface or a silicon photodetector response. A densitometer using a narrow-band filter with a peak transmission of 800 nm has been found useful in monitoring this type of sound record. The "effective" spectral sensitivity for this system is designated s_3. This part of ISO 5, therefore, identifies density values as type 3 when they are obtained from a densitometer having an overall response bandwidth of 20 nm peaking at 800 nm ± 5 nm with at least 80 % of the overall response of the instrument falling within the 20 nm bandwidth. The bandwidth shall be considered to lie between those wavelengths at which the spectral product is one-half the maximum value.

9 Spectral tolerances

The deviations from specified spectral conditions that may be tolerated in a densitometer depend on the spectral nature of the application and the materials to be measured. For completely non-selective (i.e. "neutral") non-fluorescent materials, variations in spectral conditions have no effect. Highly selective materials or those that fluoresce may demand close conformance to specified conditions. Given some specimens of the materials to be measured, a basic standards laboratory can measure the spectral modulation (spectral reflectance factor or spectral transmittance factor) of the specimens and compute the densities that would be indicated by a densitometer with specified spectral conditions. The geometry of the spectrophotometric system used for such calibrations shall match that of the densitometry and the influx spectrum and shall be specified to avoid errors due to fluorescence effects. If a densitometer indicates values within 0,03 or 3 % (whichever is the greater) of the calibrated values of such specimens, the spectral specifications of this part of ISO 5 shall be considered adequately satisfied. In this case, the measurement may be designated as ISO visual, ISO status A, M, T, E or I, or ISO type 1, 2 or 3.

Under certain circumstances, some users wish to have polarizers in their densitometers. It shall be noted that polarizers are not neutral and no "standard" polarizer exists. If a manufacturer supplies an instrument containing polarizers and claims conformance to any particular status, he must ensure that the spectral product, including polarizers, meets the specification. It follows, therefore, that the addition of a polarizer to an instrument that has been made to conform with the spectral products specified in the relevant table will result in an instrument that no longer conforms.

10 Absolute reference standard (white)

Reflectance factors and corresponding reflection densities are measured relative to some reference standard, which may be real or ideal. Unless otherwise stated, the reference standard for determining ISO reflection density shall be an ideal perfectly reflecting and perfectly diffusing material. Working standards are customarily calibrated relative to an ideal perfectly white diffuser by a basic standards laboratory.

In many applications, the reference standard is the base on which an image may be placed, such as unexposed but processed photographic printing paper. In such cases, the measured density is called "relative reflection density" and the reference standard shall be stated.

Annex A
(informative)
Calibration of densitometer

A.1 General

It is expected that manufacturers of sensitized products and densitometers maintain facilities to calibrate densitometers (including the signal-processing component). Once a densitometer has been calibrated, a system is necessary to maintain short- and long-term control. Three methods described below may be used to calibrate or evaluate the performance of a densitometer.

A.2 Calculation method

Measure the spectral contribution of each component of the densitometer and calculate the spectral products, Π, and compare with the spectral products desired.

A.3 Reference filter method

A.3.1 A series of narrow-band filters at 20 nm ± 2 nm intervals is required to encompass the spectral region to be calibrated. Their peak transmission should be at least 30 % and their half-transmission bandwidth should be no greater than 10 nm. Beyond 50 nm of the peak, their transmission should be less than 0,01 %.

Six of the reference filters shall be non-selective density filters. The variation throughout the spectral range of interest shall not exceed ± 5 % of the average density or ± 0,02 density, whichever is the greater.

Required transmissions are 63 %, 32 %, 10 %, 1,0 %, 0,1 % and 0,01 %, corresponding to densities of 0,2, 0,5, 1,0, 2,0, 3,0 and 4,0.

A.3.2 The spectral density or transmission of the above filters is measured on a spectrophotometer with an accuracy of a least 0,1 % transmission. In the case of the narrow-band filters, precautions are necessary to restrict the bandwidth adequately to obtain spectral transmission values.

A.3.3 Calculate the density of each filter using the desired spectral products of the densitometer system. Then measure these filters on the densitometer under test using geometrical conditions similar to the spectrophotometer. A densitometer reading of the reference filters within ± 2 % of the calculated value is considered reasonable compliance to status densitometry for critical work.

NOTE 11 A densitometer has a source aperture from which light is projected to a collection aperture. When a reference filter or sample is being measured, a sampling aperture is used in place of the source aperture. This aperture ensures that the reference filters are measured at the same aperture as is used in the spectrophotometer in which they are calibrated. This precaution is necessary because of the sensitivity of interference filters to angular spread of the light beam incident on them. It also eliminates problems associated with the light-scattering tendency of some filters.

This method will work well for broad spectral products such as visual, but density values for the narrow-band filters will generally be too high when used to evaluate status A and status M densitometry. Therefore, it is suggested that the unfiltered spectral products for the densitometer be determined first using the reference filter set. These results are then combined with the spectrophotometer readings of the filters to be used, to obtain status A or status M densitometry. The final spectral products are checked with the values given in tables 3 to 6.

A.4 Sample method

This method is for determining if the spectral products of a densitometer are within acceptable tolerances.

A.4.1 Select exposed and processed film or paper samples containing uniform density areas of the product to be measured. This should represent the range of colour and density which will be encountered.

A.4.2 Determine spectral transmittance (or reflectance) values for the samples.

A.4.3 Calculate densities using the ideal spectral product values given in tables 3 to 6.

A.4.4 Read the densities of the samples on the densitometer.

A.4.5 Compare values obtained in A.4.4 with those calculated. For critical densitometry, the values should agree within ± 0,02 or ± 2 % whichever is the larger.

Annex B
(informative)

Spectral products for ISO density and relative spectral power distributions for influxes

Figures B.1 to B.5 show the spectral products for various types of ISO densities specified in this part of ISO 5 and the relative spectral power distribution for the influxes specified for transmission and reflection densitometry. Since (except for status E) the values are based on values at 10 nm intervals which have been normalized, the peak wavelength may fall between these intervals (e.g. status M, green).

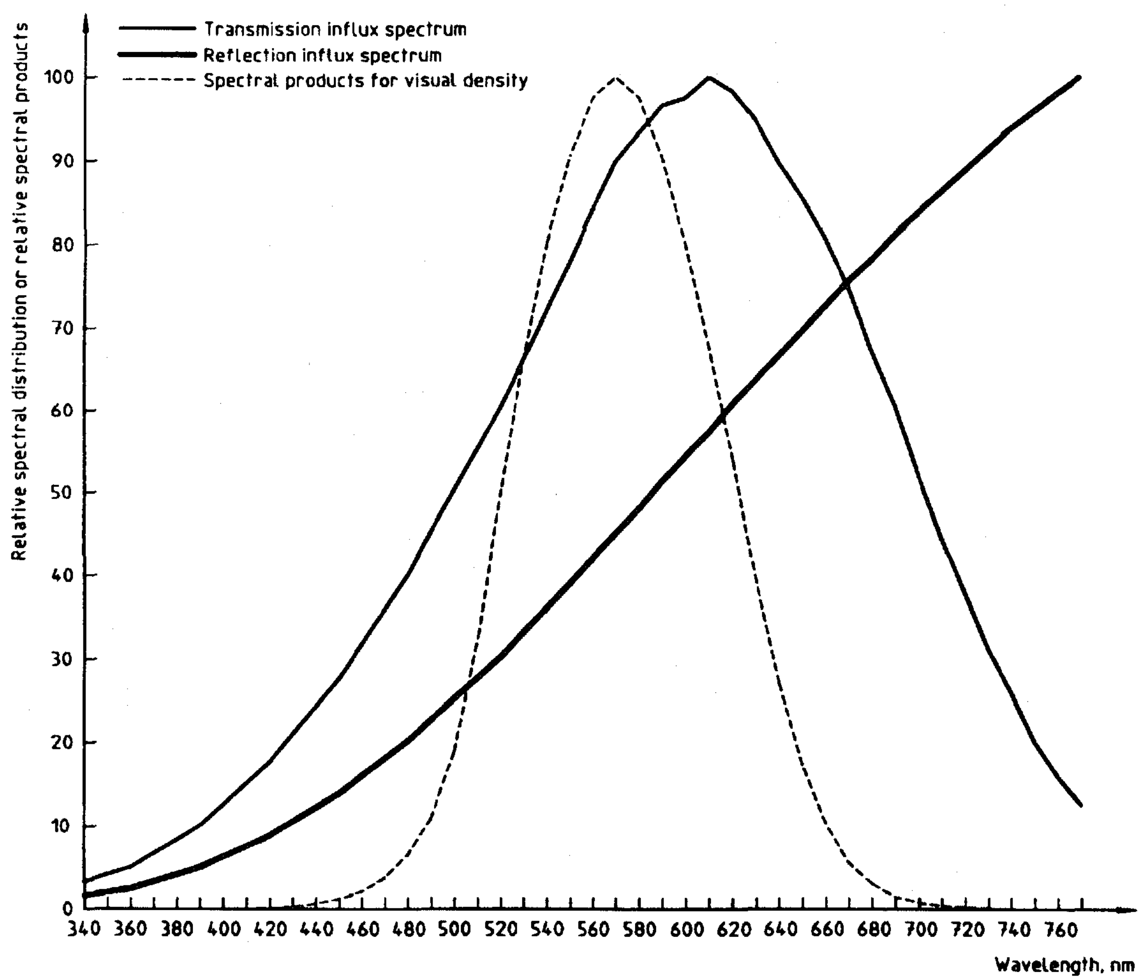

Figure B.1 — Influx distributions and spectral products for visual density

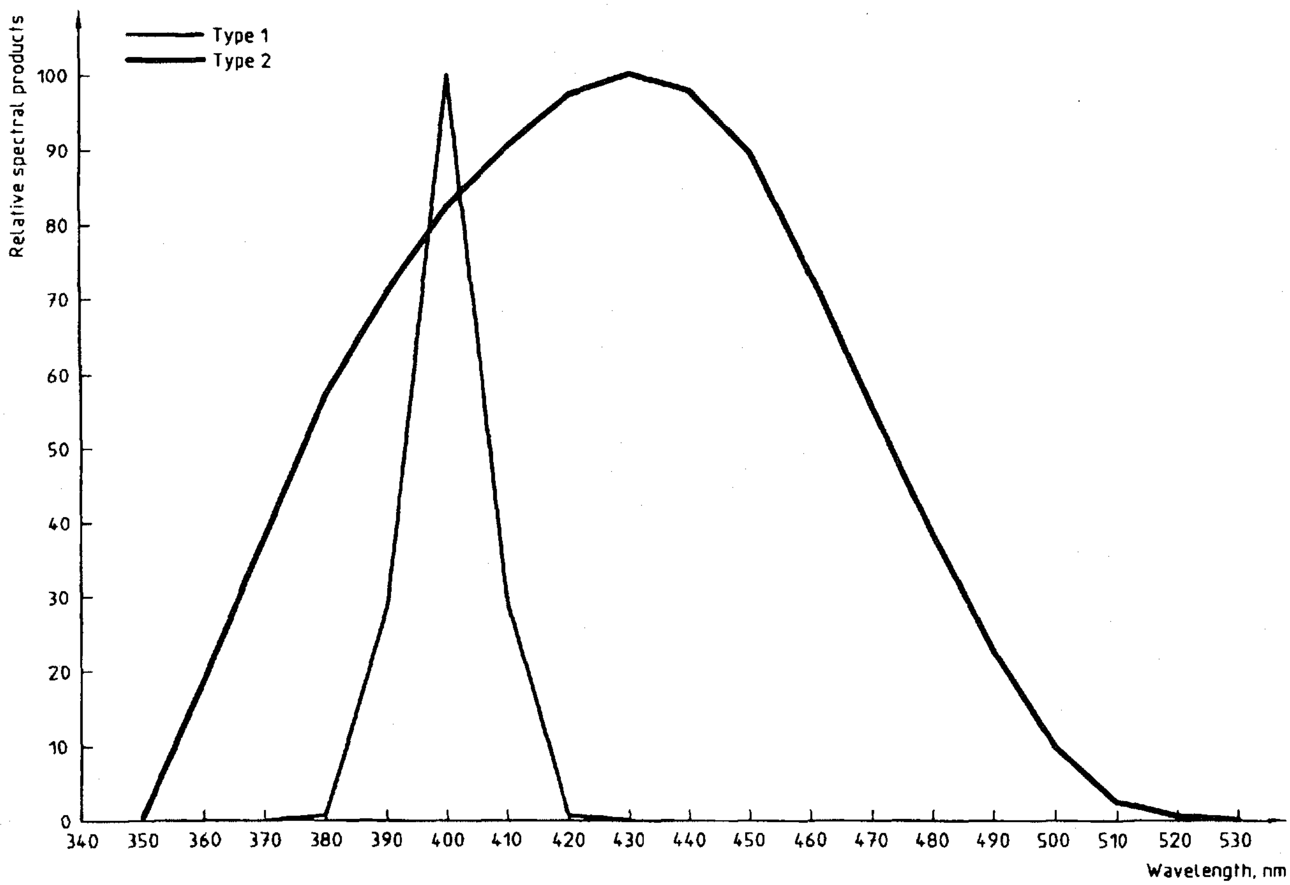

Figure B.2 — Spectral products for type 1 and type 2 densities

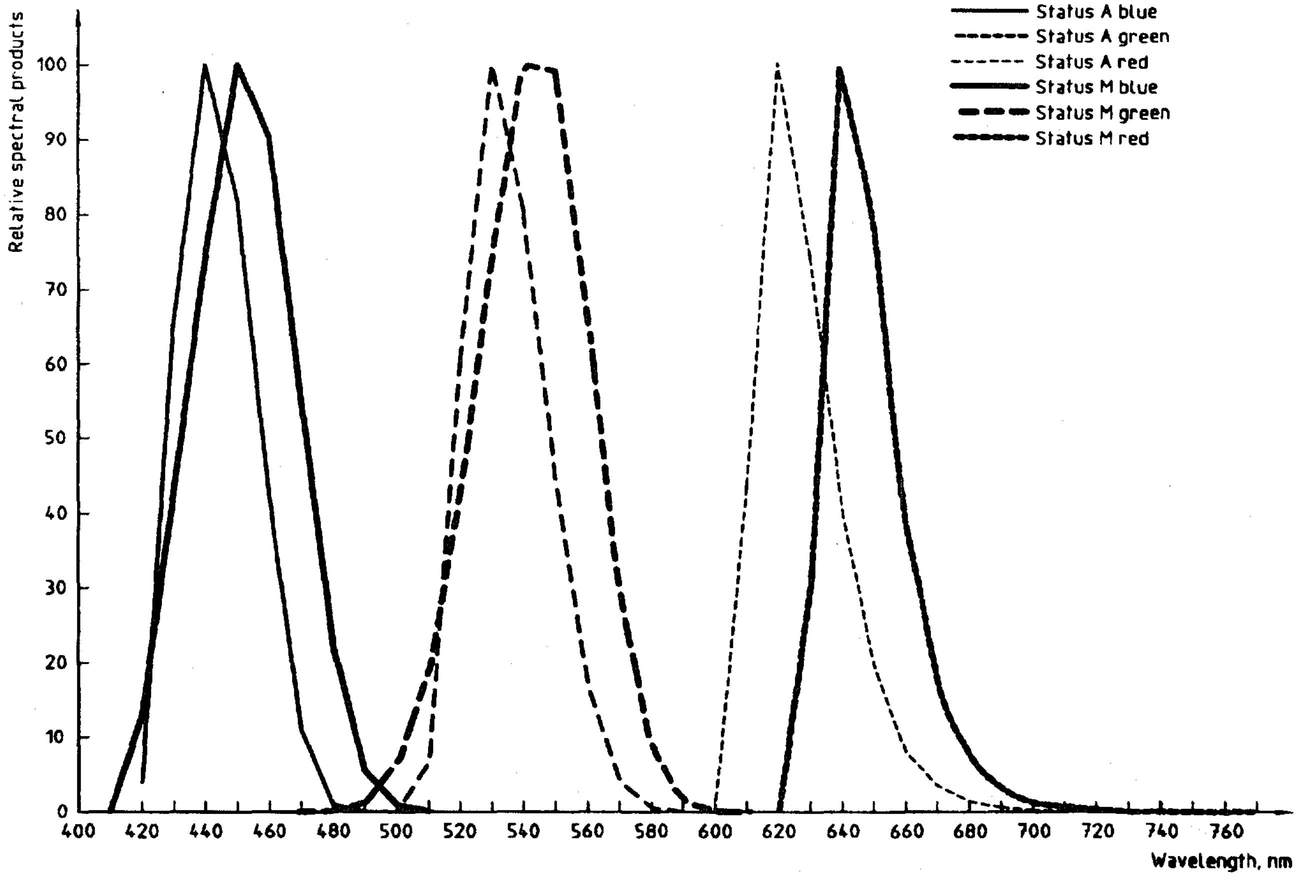

Figure B.3 — Spectral products for status A and M densities

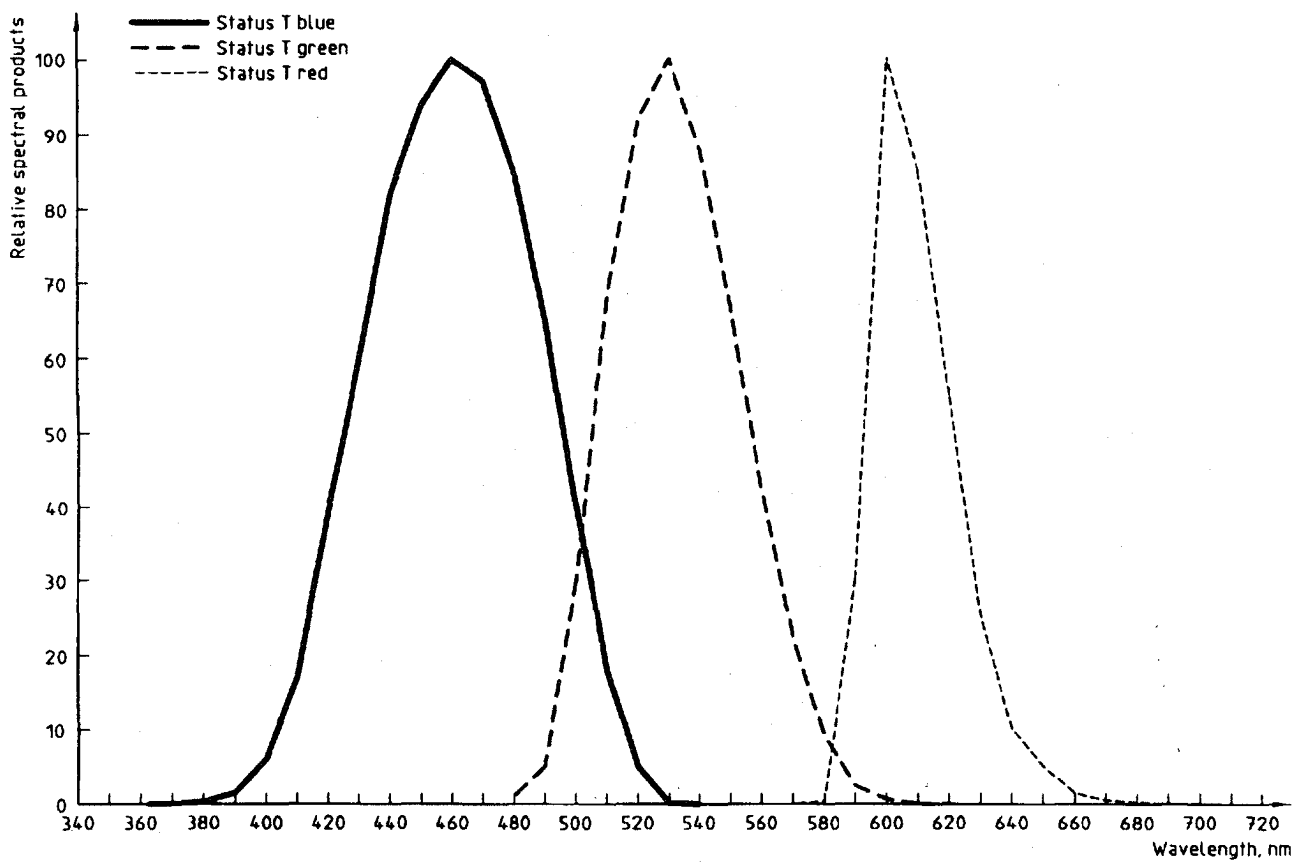

Figure B.4 — Spectral products for status T densities

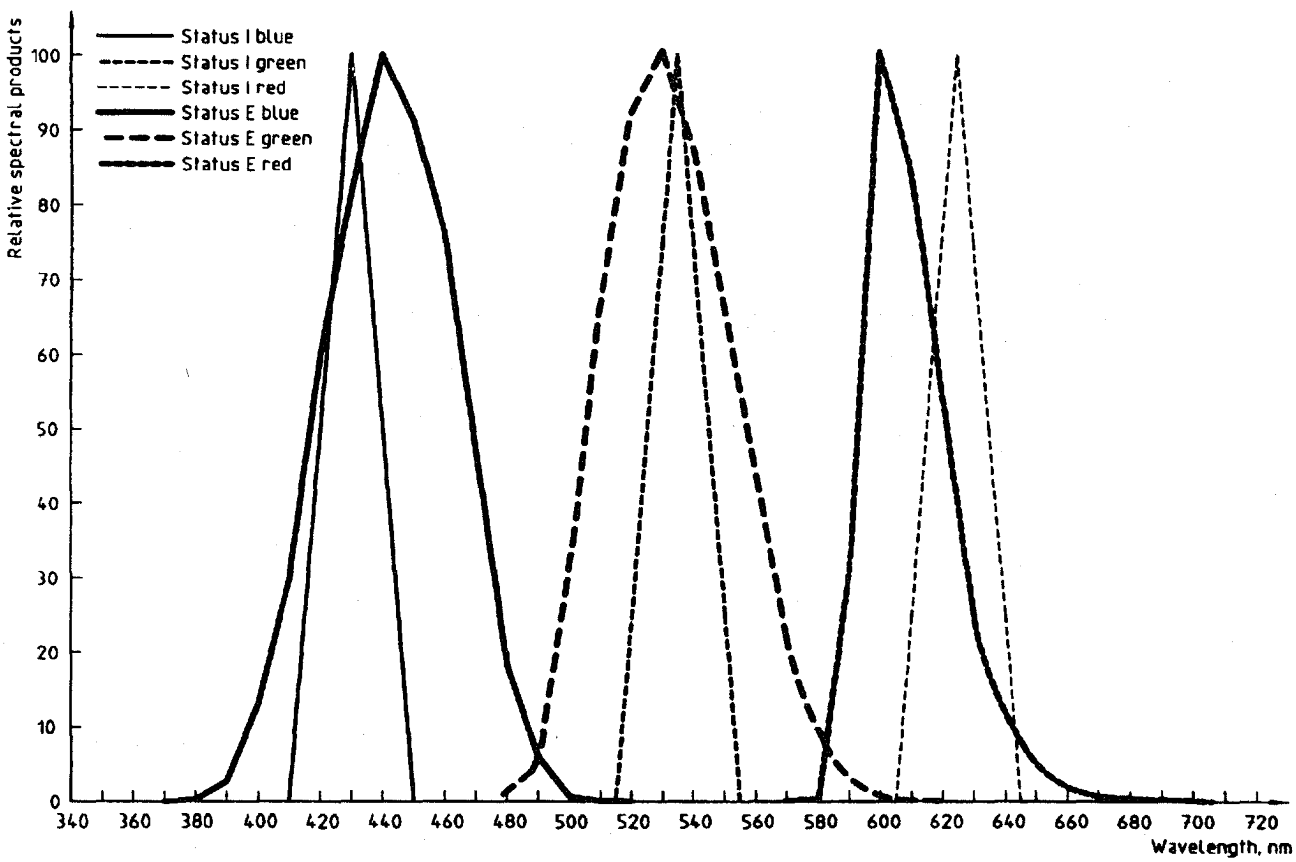

Figure B.5 — Spectral products for status E and I densities

Annex C
(informative)

Sideband rejection

Sideband rejection is very important to the accuracy of measurements. This may be seen from table C.1 which shows deviations from actual density under four different levels of sideband rejection. The data are based on a rather unsophisticated model which assumes that the sample has no density outside the passband, that the spectral sensitivity of the receiver is flat, and that the spectral energy distribution of the illuminant is flat.

Table C.1 — Deviations from actual density

Actual density (∝ rejection)	**Deviations**			
	10^6 rejection	**10^5 rejection**	**10^4 rejection**	**10^3 rejection**
5,0	4,9586	4,6990	3,959	2,996
4,0	3,9957	3,9586	3,699	2,959
3,0	2,9996	2,9957	2,959	2,699
2,0	2,0000	1,9996	1,996	1,959
1,0	1,0000	1,0000	0,999	0,996

Annex D
(informative)

Bibliography

[1] ISO 5-2:1991, *Photography — Density measurements — Part 2: Geometric conditions for transmission density.*

[2] ISO 5-4:1995, *Photography — Density measurements — Part 4: Geometric conditions for reflection density.*

[3] DIN 16536-2:1986, *Colour density measurement on prints — Part 2: Requirements on measuring apparatus for reflection densitometers.*

[4] Mees and James, *The theory of the photographic process*. MacMillan, 3rd edn., 1971, p. 453.