INTERNATIONAL STANDARD

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Graphic technology — Process control — Optical, geometrical and metrological requirements for reflection densitometers for graphic arts use

Technologie graphique — Contrôle du processus — Exigences optiques, géométriques et métrologiques relatives aux densitomètres par réflexion utilisés dans l'industrie graphique

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 14981 was prepared by Technical Committee ISO/TC 130, *Graphic technology.*

Annexes A and B form a normative part of this International Standard.

Introduction

Densitometers used in the graphic arts for process control possess a number of features which are specific to the graphic arts. Whereas the photography standards ISO 5-1 [1], ISO 5-3 and ISO 5-4 [2] are considered to be the basis, the measuring instruments used in graphic technology require specific requirements and tolerances.

In principle, reflection densitometers and reflection colorimeters (of photoelectric or spectrophotometric type) are both reflectometers measuring the reflectance factor of reflection copy materials. Densitometers conforming to ISO 5 and colorimeters conforming to ISO 13655 possess a common geometry type, namely either 45/0 or 0/45. It is also noted that reflectometers of the spectrophotometer type can, in principle, be used both as a densitometer and as a colorimeter. The definition of the colorimeter used in this International Standard follows CIE 17.4, the International Lighting Vocabulary. In graphic arts, the geometry 45/0 (influx at 45° and efflux at 0°), or the geometry 0/45 are preferred over that with an integrating sphere because they correspond to the usual geometry under which glossy graphic products are being viewed to minimize the effect of gloss typically seen by the human observer, see also ISO 13655:1996, annex E. The introduction of polarizing means is an additional measure to remove first-surface reflection; for matt surfaces this is the only possibility.

Notwithstanding the similarities between instruments for densitometry and colorimetry, there are fundamental differences between them: Firstly, the illuminant used in densitometry is CIE standard illuminant A whereas ISO 13655 specifies CIE standard illuminant D_{50} for colorimetry in the graphic arts. Secondly, for the chromatic colours the weighting of the reflectance factors is different between densitometry and colorimetry. Only the "visual" weighting function, used for the densitometry of achromatic colours (such as black), is the same as that for the tristimulus value *Y* in colorimetry.

The aim of colorimetry is to provide a measuring instrument response which simulates, as well as possible, the visual characteristics of a sample as seen by the standard observer. In graphic arts, colorimetry serves mainly for colour matching and the establishment of colour standards. The availability of inexpensive, hand held colorimeters of the spectrophotometric or photoelectric type, with small sampling apertures, has also permitted the use of colorimetry in process control as a complement to densitometry. This should eliminate the use of densitometers for colour matching.

The aims of densitometry in graphic arts are the control of the ink film thickness or, more general, the control of the amount of colorant per area, and the determination of tone values or other quantities. A distinctly different task is the evaluation of the density ranges of colour separation input material; this type of densitometry is not covered by this International Standard.

The concept of this International Standard is based on the general principles specified for photography in the ISO 5 series of International Standards; for the spectral products it refers to certain tables of ISO 5-3. Just as the ISO 5 series it does not directly address the end user but the densitometer manufacturer or a suitably equipped laboratory. Directions for the end user are to be provided by ISO 13656, which will also give an overview on the various types of densitometers.

Graphic technology — Process control — Optical, geometrical and metrological requirements for reflection densitometers for graphic arts use

1 Scope

This International Standard specifies requirements for measuring instruments to be used for the measurement of the reflection densities and the tone values on half-tone or continuous-tone multi-colour graphic arts reflection-copy material.

This International Standard is applicable equally to measuring instruments that measure status density directly using filter/bandpass limiting techniques and to measuring instruments which measure spectrally and compute status density. This International Standard is not applicable to measuring instruments used for continuous-tone original art.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 5-3:1995, *Photography — Density measurements — Part 3: Spectral conditions*.

ISO 2846-1:1997, *Graphic technology — Colour and transparency of ink sets for four-colour-printing — Part 1: Sheet-fed and heat-set web offset lithographic printing*.

ISO 13655:1996, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*.

ISO 13656:2000, *Graphic technology — Application of reflection densitometry and colorimetry to process control or evaluation of prints and proofs*.

ISO 14807:—[1)], *Photography — Method for the determination of densitometer performance specifications*.

ISO 15790:—[1)], *Graphic technology and photography — Reflection and transmission metrology — Certified reference materials — Documentation and procedures for use, including determination of combined standard uncertainty.*

1) To be published.

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

NOTE For quantities, the preferred unit is given together with the definition. By definition, the unit of formerly so-called “dimensionless” quantities is 1.

3.1
achromatic (perceived) colour
colour devoid of hue, such as black and grey. For transmitting objects, the descriptions colourless or neutral are also used [CIE 17.4, 845-2-26], [6]

NOTE In printing practice, achromatic colours can be produced either by a single ink or three chromatic inks suitably balanced.

3.2
calibration
set of operations that establish, under specified conditions, the relationship between quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or reference material, and the corresponding values realized by the standards [5]

NOTE Contrary to a common misconception, calibration is not the process of adjusting a measurement system such that it produces values that are believed to be correct but may be the cause for such an action.

3.3
certified reference material
CRM
reference material, accompanied by a certificate, one or more of whose property values are certified by a procedure which establishes traceability to an accurate realization of the unit in which the property values are expressed, and for which each certified value is accompanied by an uncertainty at a stated level of confidence [ISO 15790]

3.4
chromatic (perceived) colour
opposite of achromatic colour [CIE 17.4, 845-02-27], [6]

NOTE The process inks cyan, magenta and yellow are the chromatic primary colour inks.

3.5
gloss suppression factor
factor by which the reflectance factor of a polarization test object is reduced by installing polarization means into the measuring instrument

Unit: 1

3.6
illuminated area
part of the surface of the specimen that is illuminated by the illumination source

3.7
mechanical aperture
aperture created by an opaque mask used to position the measuring instrument on the specimen

3.8
process colours (for four-colour printing)
yellow, magenta, cyan and black [3]

3.9
receiver
detection means for radiation

3.10
reflectance factor
R
ratio of the radiant or luminous flux reflected in the directions delimited by the given cone to that reflected in the same directions by a perfect reflecting diffuser identically illuminated [CIE 17.4, 845-04-64], [6]

Unit: 1

3.11
sampling aperture
part of the sample surface determined by the angular field of sensitivity of the receiver

3.12
screen ruling; screen frequency:
number of image elements, such as dots or lines, per length in the direction which produces the highest value [3]

Unit: cm^{-1}

3.13
screen width
reciprocal of screen ruling [3]

Unit: µm

3.14
spectral products
Π
products of the spectral power of the influx spectrum and the spectral response of the receiver, wavelength by wavelength

Unit: 1

NOTE The spectral response of the receiver includes the photodetector and all intervening components between it and the sampling aperture.

4 Requirements

4.1 Influx and efflux geometry

4.1.1 General

Measurement shall be made either

— with an annular (ring-shaped) illuminator and with a directional receiver which senses in the direction normal to the sampling aperture (annular influx mode); or

— with the illumination normal to the sampling aperture and an annular receiver (annular efflux mode).

4.1.2 Annular influx mode

The illumination shall be uniform around the annulus. If the reflection characteristics of the specimen do not change as it is rotated in its own plane, the illumination need not be uniform around the annulus.

NOTE For applications where graphic arts materials have been shown to have a slight sensitivity to directional effects the following are suggested compromises to the requirement of annular uniformity: The influx should be coming either from two illumination sources positioned at azimuth angles which are 90° apart, or, preferably, from more than two illumination sources, with equally spaced azimuth angles. A directional dependence is considered to be slight, if the averages over five repeated density measurements differ by no more than 0,03 over the directions 0°, 45° and 90°.

At the centre of the sampling aperture, the angular distribution of the illumination shall be at its maximum at 45° ± 2° to the sampling aperture and shall be negligible at angles that differ by more than 5° from the angle of the maximum, see Figure 1.

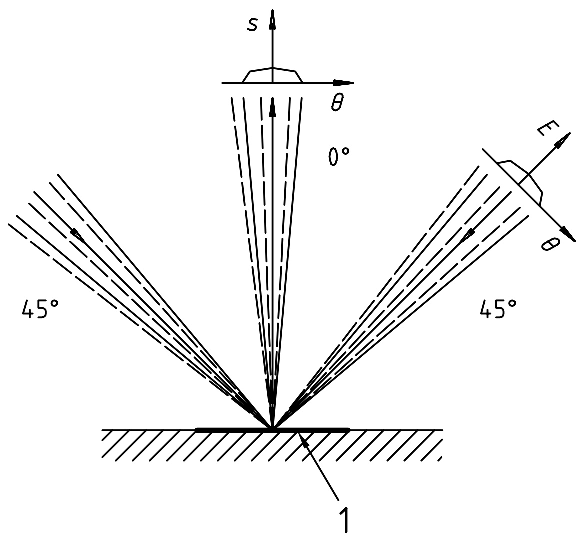
The receiver shall sense in the direction normal to the sampling aperture. At the centre of the sampling aperture, the angular distribution of the receiver sensitivity shall be at its maximum no further than 2° from the normal to the sampling aperture and shall be negligible at angles that differ by more than 5° from the angle of the maximum, see Figure 1.

4.1.3 Annular efflux mode

The sensing by the receiver shall be annular, its sensitivity shall be uniform around the annulus. If the reflection characteristics of the specimen do not change as it is rotated in its own plane, the sensing distribution of the receiver need not be uniform around the annulus.

NOTE For applications where graphic arts materials have been shown to have a slight sensitivity to directional effects the following are suggested compromises to the requirement of annular uniformity: The efflux should be detected either by two receivers positioned at azimuth angles which are 90° apart or by more than two receivers with equally spaced azimuth angles. A directional dependence is considered to be slight, if the averages over 5 repeated density measurements differ by no more than 0,03 over the directions 0°, 45° and 90°.

At the centre of the sampling aperture, the angular distribution of the receiver sensitivity shall be at its maximum at 45° ± 2° to the sample aperture and shall be negligible at angles that differ by more than 5° from the angle of the maximum.



Key

1 Sampling aperture

Continuous lines: nominal angles of the maximum and associated tolerances

Broken lines: example for 2° deviations of the angles of the maximum.

Also shown are example distributions of the irradiance E and the detector sensitivity s, both versus the colatitude angle θ.

Figure 1 — Annular influx mode — Cross-section showing the radiation cones at the centre of the sampling aperture

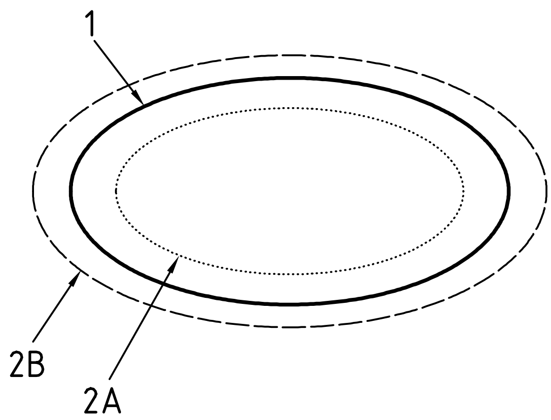
The illumination source shall illuminate the sampling aperture in the direction normal to this plane. At the centre of the sampling aperture, the angular distribution of the illumination shall be at its maximum no further than 2° from the normal to the sampling aperture and shall be negligible at angles that differ by more than 5° from the angle of the maximum.

4.2 Mechanical aperture and sampling aperture

The inner boundary of a mechanical aperture, if present at all, shall lie at least 0,5 mm outside of the boundary of the sampling aperture.

The diameter of a circular sampling aperture should be not less than 15 times the screen width; it shall be not less than 10 times the screen width that corresponds to the lower limit for the screen ruling stated by the vendor, see 4.7. The area of non-circular sampling apertures shall not be smaller than that required for circular sampling apertures.

NOTE The relationship between the minimum size of the sampling aperture and the screen width is identical to that contained in ISO 12647-1 [3] and ISO 13656.



Key

1 Sampling aperture

2A Smaller illuminated area

2B Larger illuminated area

Figure 2 — Schematic representation of the boundaries of the sampling aperture and the two possibilities for the illuminated area

4.3 Illuminated area

The full length of the boundary of the illuminated area shall lie either inside or outside of the boundary of the sampling aperture by at least 0,5 mm, see Figure 2.

NOTE 1 This requirement reduces the lateral translucency error, which is the error in the measured reflectance factor when light is scattered laterally from points inside to points outside the sampling aperture of the instruments receiver. The reflectance factor will then normally be lower than in a situation where all of the reflected light were collected.

NOTE 2 In practice, it is preferred to make the illuminated area smaller than the sampling aperture.

NOTE 3 There is no requirement for the uniformity because in graphic arts, densitometric measurements are usually made with very small sampling apertures in control patches of even tone value.

4.4 Spectral conditions

4.4.1 Influx spectrum

The spectral energy distribution of the flux incident on the specimen surface shall conform to CIE standard illuminant A, corresponding to a distribution temperature of 2 856 K. A tolerance of ± 100 K shall apply.

NOTE This requirement is particularly important because graphic arts materials, especially print substrates, are often not free of fluorescence effects. If fluorescence is not an issue, the same spectral reflectance factor data may be used for calculating both colorimetric quantities and status density.

4.4.2 Spectral products

For the measurement of achromatic colours such as black and grey, the spectral products shall conform to those given in ISO 5-3 for ISO visual reflection density.

For the measurement of the chromatic colours cyan, magenta and yellow, the spectral products of all three chromatic-colour channels of the measuring instrument shall conform to the same spectral condition specified in ISO 5-3 for status T, I or E density. In particular, the cyan channel shall correspond to the spectral data labelled "red", the magenta channel shall correspond to data labelled "green" and the yellow channel shall correspond to data labelled "blue" in ISO 5-3.

4.5 Calculation of reflection density from spectral data

Status density may be determined either by

— a measuring instrument which uses optical filters in combination with the spectral sensitivity of the receiver for the spectral weighting of the reflected distribution; or

— a measuring instrument which measures spectrally and computes the status density.

The second procedure shall be used for the verification of spectral conformance, see 4.6.3.

The determination of density by calculation shall be carried out in the following way: The spectral reflectance factors shall be based on 10 nm intervals where the spectral response function is triangular with a 10 nm halfwidth at half power. If the measured data is at intervals and bandpass smaller than 10 nm, the method given in annex A of ISO 13655 shall be used to widen the bandpass of the data. The reflectance factor data shall be measured from at least 400 nm, inclusive, to at least 700 nm, inclusive. The spectral reflectance factors shall be measured with a measuring instrument that conforms to either 4.1.2 or 4.1.3 and to the following: 4.2, 4.3, 4.4.1.

The following formula shall be used to calculate the reflection density:

$$D = -\lg \frac{\sum R(\lambda) \cdot \Pi(\lambda)}{\sum \Pi(\lambda)} \qquad \text{... (1)}$$

where

D is the reflection density;

$R(\lambda)$ is the reflectance factor at wavelength λ;

$\Pi(\lambda)$ is the appropriate spectral product at wavelength λ, taken from ISO 5-3;

lg is the logarithm to base 10.

Summation shall be carried out over the defined range of the spectral product data.

If the reflectance factor data begin at a wavelength greater than the lowest wavelength of the spectral product data, then all spectral products below the former wavelength shall be summed and added to the spectral product for that wavelength.

If the reflectance factor data end at a wavelength lower than the highest wavelength of the spectral product data, then all spectral products greater than the former wavelength shall be summed and added to the spectral product for that wavelength.

NOTE 1 This procedure is analogous to that specified in ISO 13655 for colorimetric computation.

NOTE 2 If the spectral reflectance factor changes rapidly with wavelength the use of 10 nm data may not be adequate and the status density computed may differ from those measured using a continuous response function.

4.6 Conformance

4.6.1 General

A measuring instrument conforms to this International Standard if it meets the requirements of 4.6.2 and 4.6.3. In case the measuring instrument uses polarizing means, the additional requirement of 4.6.4 shall be met.

4.6.2 Linearity

After adjustment of all four colour channels according to 5.2, the reflection densities of a CRM set conforming to ISO 15790 shall be measured with the measuring instrument. On at least three CRMs with nominal reflection densities comprising 0,0 to 0,2; 1,0 ± 0,2; 2,0 ± 0,5 the measured density for each spectral condition of the instrument shall agree within 0,02 or 2 %, whichever is the greater, to the density reported for the appropriate spectral condition in the documentation accompanying the CRM. For measuring instruments with polarizing means, the CRMs used shall, in addition, conform to the requirements of the normative annex A.

NOTE The CRMs conforming to the normative annex A may also be used for measuring instruments without polarizing means.

4.6.3 Spectral conformance

The following refers to a measuring instrument which has been prepared according to 5.2 and which conforms to 4.6.2. In this condition, and without further adjustment, the measuring instrument shall meet the following requirements: The reflection densities determined in 5.3.2 and 5.3.4 shall differ by no more than 0,03 or 3 %, whichever is the greater, for the process colour solids cyan, magenta, yellow and black. The same shall apply to the reflection densities determined in 5.3.2 and 5.3.5.

NOTE This combined linearity and spectral requirement reflects the use of such measuring instruments in practice. The combined requirement of this subclause is more stringent than requiring the measuring instrument to conform to independent tests of linearity and spectral conditions, where individual adjustments are permitted before each test.

4.6.4 Polarization

For measuring instruments with polarization means, the gloss suppression factor shall not be less than 50 for every colour channel using the test method described in 5.4.

4.7 Documentation

For measuring instruments claiming conformance to this International Standard, the vendor shall provide the following information with the measuring instrument:

- the status densities yielded by the measuring instrument;
- whether polarization means are incorporated in the measuring instrument;
- the size of the sampling aperture and the degree of over-/under-illumination, both in mm;

— the lower limit for the screen ruling of half-tones to be measured with the measuring instrument, see 4.2;

— instructions and means to allow the instrument to be calibrated and, if necessary, adjusted.

The vendor should provide performance specifications of the measuring instrument using the methods specified in ISO 14807. The documentation provided should alert the end user to the fact that status reflection densities refer to the perfectly reflecting and perfectly diffusing surface and that if another reference is used the adjective relative shall be inserted before the word reflection.

5 Test methods

5.1 General

The measurement of reflection density shall be carried out in accordance with ISO 13656, that means the backing material shall be diffuse-reflecting, spectrally non-selective and possess an ISO visual reflection density of 1,50 ± 0,20. Where measurements by a national standardizing laboratory are reported, the geometry and spectral status of the measuring instrument should be stated.

NOTE The test methods specified in the following are intended to be used by the manufacturer or suitably equipped laboratories, not by the end user.

5.2 Adjustment

Calibrate and, if necessary, adjust the measuring instrument for optimum performance. The adjustment process includes hardware and/or software manipulations.

5.3 Spectral conditions

5.3.1 Take a set of CRMs whose spectral characteristics reasonably match those of annex C of ISO 2846-1:1997 and whose colours conform to Table 1 of this International Standard to within a tolerance of ± 5, applicable to each of the quantities *L**, *a**, *b**. In the absence of an appropriate set of CRMs, take a set of offset process inks that conform to ISO 2846-1 and print the process colour solids cyan, magenta, yellow and black on glossy substrates such that the CIELAB colour co-ordinates given in Table 1 are approximated with a tolerance of ± 5, applicable to each of the quantities *L**, *a**, *b**.

5.3.2 Place the prints on a black backing in accordance with 5.1 and measure the four process colour solids with the measuring instrument.

5.3.3 Take a precision spectrophotometer

— of not more than 10 nm bandwidth;

— that conforms to ISO 13655 except for the geometry;

— whose geometry conforms to this International Standard;

— the performance of which has been verified by CRMs traceable to a national standards institution and to a level of uncertainty that is compatible with the measurement task (the latter being characterized by the tolerance stated in 4.6.3).

For measuring instruments with polarizing means the spectrophotometer shall be equipped with polarizing means as well. Measure the spectral reflectance factors of the four process colour solids on a black backing in accordance with 5.1, from at least 400 nm to 700 nm, both inclusive. Average the spectral reflectance factors of 5 to 10 measurements per wavelength.

5.3.4 Using the formula (1) and procedures given in 4.5, calculate the reflection densities from the averaged reflectance factors of 5.3.3.

5.3.5 Repeat steps 5.3.1 to 5.3.4 using any other ink set or colorant set typical of the intended application of the measuring instrument.

NOTE Step 5.3.5 is particularly important when densitometric measurements are to be used for process control of off-press proofing with photographic paper, thermal dye sublimation or ink jet materials.

Table 1 — CIELAB co-ordinates of the CRMs to be used for spectral conformance tests

unit: 1

Colour	L^* [a]	a^* [a]	b^* [a]
Cyan	54	– 37	– 50
Magenta	47	75	– 6
Yellow	88	– 6	95
Black	18	0	– 1

[a] Measured according to ISO 13656 (Black backing, 2° standard observer, D_{50}, geometry 0/45 or 45/0)

5.4 Polarization efficiency

5.4.1 Use a polarization test object as described in the normative annex B. For every colour channel of the measuring instrument, carry out the following steps 5.4.2 to 5.4.9.

5.4.2 Remove the polarization means from the measuring instrument and set it to zero on a white substrate.

5.4.3 Mount the polarization test object horizontally and place the measuring instrument on it.

5.4.4 Adjust the horizontal position of the measuring instrument such that the reflection density reaches a minimum.

5.4.5 Adjust the vertical position of the pointed cylinder such that the reflection density reaches again a minimum value, D_1; this may be as low as – 0,8. Make sure that the electronic circuit can handle such high photo current levels within its linear range. Otherwise insert attenuating means into the light path and make sure they do not disturb the geometry. An example is the insertion of a thin spectrally non-selective density filter.

5.4.6 Reinstall the polarization means into the measuring instrument and set it to zero as in 5.4.2.

5.4.7 Place the measuring instrument back on the polarization test object within 0,1 mm of the location at which the minimum density was achieved in 5.4.4.

5.4.8 Read the new reflection density, D_2.

5.4.9 Calculate

$$P = 10^{D_2 - D_1} \qquad \text{... (2)}$$

where

P is the gloss suppression factor;

D_1 is the density determined in 5.4.5;

D_2 is the density determined in 5.4.8.

6 Reporting

Reflection densities obtained observing the requirements specified in this International Standard shall be referred to as "visual reflection density", "status T reflection density", "status I reflection density", "status E reflection density" depending on which set of spectral products of ISO 5-3 was used. If an instrument with polarizing means was used, or if a backing other than that specified in ISO 13656 was used, these facts shall be reported with the data. If the reflection density data is not referred to the perfectly reflecting and perfectly diffusing surface the adjective relative shall be inserted before the word reflection.

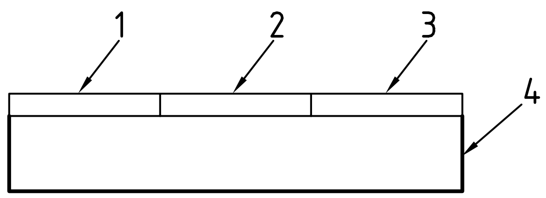
Annex A
(normative)

Certified reference materials (CRM) for measuring instruments with polarizing means

A set of CRMs for linearity testing shall consist of a plane matt white ceramic baseplate onto which at least three optically polished and plane spectrally non-selective ("neutral density") glass filters have been cemented with an spectrally non-selective cement, see Figure A.1. The size of each spectrally non-selective glass filter shall not be smaller than 1 cm × 1 cm, the thickness shall not exceed 0,2 mm. The filters shall be selected such that the following ISO visual reflection densities are realised by the finished CRM set: 0,0 to 0,2; 1,0 ± 0,2; 2,0 ± 0,5. In the documentation accompanying the CRM, the (absolute) reflection densities and their uncertainties at a stated level of confidence (coverage factor) shall be reported for the spectral conditions including ISO visual and at least one of the following sets ISO status T, ISO status I, or ISO status E.

NOTE 1 This construction of a CRM set provides an opportunity for calibration of measuring instruments with and without polarization means on the same set since the first surface reflection is highly directional here, it is therefore effectively suppressed by the geometry, irrespective of whether polarization means are used or not.

NOTE 2 For further information see reference [4] of the bibliography.



Key

1, 2, 3 Spectrally non-selective glass filters

4 Ceramic base plate

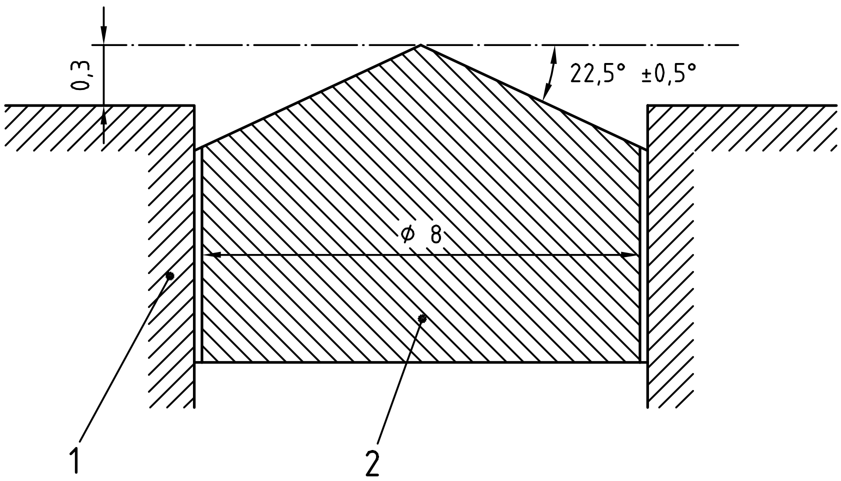
Figure A.1 — Cross-section of the test object for measuring instruments with a polarizing means

Annex B
(normative)

Polarization test object

The test object shall consist of a plate with a central, vertical and circular hole from which a snug-fitting metal cylinder, with a 135° conical point, shall protrude partly, see Figure B.1. The diameter of the cylinder shall be suitably chosen in view of the size of the sampling aperture, (such as 8 mm for a sampling aperture of 3,5 mm). The conical point shall be spherically blunted at its very top; the cone shall be chrome plated and highly polished. The vertical position of the pointed cylinder shall be adjustable from below by small increments.

NOTE For further information see reference [4] of the bibliography.



Key

1 Base plate

2 Circular cylinder with conical point

Figure B.1 — Cross-section of polarization test object; example for a sampling aperture of approximately 3,5 mm diameter

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