INTERNATIONAL STANDARD

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Photography — Density measurements —

Part 2: Geometric conditions for transmission density

Photographie — Mesurage des densités —

Partie 2: Conditions géométriques pour la densité instrumentale par transmission

Reference number
ISO 5-2:2001(E)

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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 part of ISO 5 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 5-2 was prepared by Technical Committee ISO/TC 42, *Photography*.

This fourth edition cancels and replaces the third edition (ISO 5-2:1991), which has been technically revised.

The changes from the third edition are as follows.

a) The diffusion coefficient describing the diffusivity of the irradiating or the detecting system has been redefined. The definition in the third edition was inappropriate and did not describe the practice. In particular, the determination of the diffusion coefficient now takes into account that the distribution of the radiation of the radiating source or the sensitivity of the detector is three-dimensional.

b) A new value, needed for the diffusion coefficient, is specified. The tolerances allowed have been tightened.

c) The position of the diaphragm, which determines the sampling aperture, in relation to the front or back side of the diffuse irradiating or receiving opal glass has been defined, since neither the opal glass nor the sample are infinitely thin but have a finite thickness.

ISO 5 consists of the following parts, under the general title *Photography — Density measurements*:

— *Part 1: Terms, symbols and notations*

— *Part 2: Geometric conditions for transmission density*

— *Part 3: Spectral conditions*

— *Part 4: Geometric conditions for reflection density*

Annex A forms a normative part of this part of ISO 5. Annexes B, C and D are for information only.

Introduction

This part of ISO 5 is one of a series which specifies the geometric conditions for transmission densitometry, primarily but not exclusively, as practised in black-and-white and colour photography. The primary change from the first edition (1974) to the second edition (1985) was the replacement of the integrating sphere method with the “opal glass” method as the basis for specifying ISO standard diffuse transmission density. Although any means of diffusion which meets the specifications of this part of ISO 5 may be used, the method is often denoted simply by the words “opal glass” to differentiate it from the integrating sphere method. Slightly smaller density values are generally obtained compared to those based on the integrating sphere method because of inter-reflections between the opal glass and the specimen. The effect is dependent on the reflectance characteristics of the opal glass and the surface of the specimen facing the diffuser.

The “philosophy” of this part of ISO 5 is to specify geometrical conditions for the measurement of optical densities which are close to those used in practice. Diffuse transmission densities are, among other things, relevant for contact printing and rating films on viewing boxes. Viewing films on light boxes is one of the most important applications where diffuse transmission densities are relevant. Therefore, the specified conditions for the measurement of diffuse transmission densities consider the properties of viewing boxes concerning diffusivity and spectral reflectance factor.

This part of ISO 5 also describes the geometric conditions for two types of projection density. The spectral conditions described are specified in ISO 5-3.

Diffuse transmission density is a measure of the modulation of light by a film that is diffusely irradiated on one side and viewed from the other, as when a film is viewed on a diffuse transparency radiation source (illuminator). The geometric conditions of projection with diffuse irradiation are nearly equivalent to the conditions of viewing a film on a diffuse illuminator, the projection lens taking the place of the eye. When film is on a diffuse radiation source (illuminator) or in contact with a print material, light is inter-reflected between the film and the nearby surface. This inter-reflection affects the density and is best taken into account in a measuring instrument by the use of an opal glass diffuser or integrator, rather than an integrating sphere. Apart from this fundamental reason for using densitometers employing opal glass diffusers, such instruments are preferred because they are more durable and more convenient to manufacture and use.

Projection density is a measure of the modulation of light by a film that is specularly irradiated on one side and is projected by way of a specular collection system. Equipment employing optical condensers is used to view microfilm, motion pictures, and slides, and to make projection prints. The conditions defined in this part of ISO 5 for projection density simulate the geometric conditions affecting the transmitting characteristics of a small area on a negative or transparency at the centre of the frame of a typical projection system employing condensers. The area under consideration may be defined by a small opening, known as the sampling aperture, in an otherwise opaque sheet in the frame.

The ratio of the total flux transmitted by a specimen to the total flux incident on the sampling aperture is defined as transmittance and is of little practical use. However, the flux transmitted by the sampled area and collected by the projection lens to form the projected image is of interest. The ratio of this flux to the flux collected when there is no film in the sampling aperture is designated as transmittance factor, and is used as a basis for calculating projection density.

The measured density depends on the half-angle of the cone of incident rays and the half-angle subtended by the projection lens at the sampling aperture. These half-angles may be indicated either in degrees or by *f*-numbers. Since the *f*-number is usually marked on projection lenses, the two types of projection density specified in this part of ISO 5 are identified by *f*-numbers, namely *f*/4,5 and *f*/1,6. The *f*/4,5 type is frequently used since it is representative of microfilm readers. The *f*/1,6 type is considered representative of motion-picture projectors.

Photography — Density measurements —

Part 2:
Geometric conditions for transmission density

1 Scope

This part of ISO 5 specifies the geometric conditions for measuring ISO diffuse and *f*/4,5 and *f*/1,6 projection transmission densities.

Diffuse density is primarily applicable to measurements of photographic images to be viewed on a transparency illuminator (viewing box), to be contact printed, or to be projected with a system employing diffuse irradiation.

Projection density is primarily applicable to measurements of photographic images to be projected with systems employing optical condensers.

Although primarily intended for the measurement of photographic images, the densitometric methods specified in this part of ISO 5 are often applied to optical filters and other transparent materials.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 5. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 5 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 5-1:1984, *Photography — Density measurements — Part 1: Terms, symbols and notations.*

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

ISO 7724-1:—[1)], *Paints and varnishes — Colorimetry — Part 1: Principles.*

1) To be published. (Revision of ISO 7724-1:1984)

3 Terms and definitions

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

3.1
transmittance factor
T
ratio of the measured flux transmitted by a specimen to the measured flux when the specimen is removed from the sampling aperture of the measuring device

$$T = \frac{\phi_\tau}{\phi_j}$$

where

ϕ_τ is the transmitted flux;

ϕ_j is the aperture flux.

3.2
transmission density
D_T
logarithm to the base 10 of the reciprocal of the transmittance factor

$$D_T = \log_{10} \frac{1}{T} = \log_{10} \frac{\phi_j}{\phi_\tau}$$

3.3
diffusion coefficient
β_{dc}
measure of the diffusivity of the irradiating or receiving system

NOTE See normative annex A.

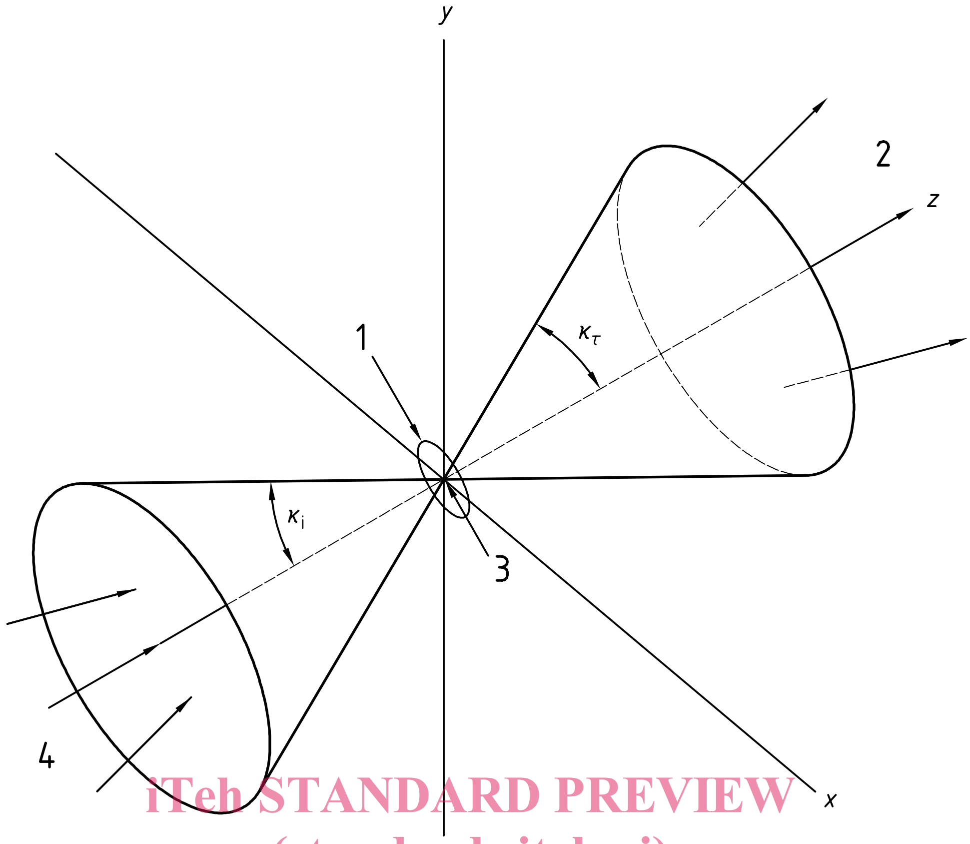
4 Coordinate system, terminology and symbols

The coordinate system, terminology and symbols described in ISO 5-1 are used herein as a basis for specifying the geometric conditions for measurement of transmission density.

5 ISO standard diffuse density

5.1 Geometric modes

Diffuse transmission measurements may be made with a diffuse irradiation source (illuminator) and a directional receiver, this arrangement being known as the “diffuse influx mode”. Alternatively, measurements may be made with a directional irradiation source and a diffuse receiver, this arrangement being known as the “diffuse efflux mode”. The diffuse modes are shown in Figure 1. These modes can be described in terms of a specified diffuse distribution and a specified directional distribution, the distributions being distributions of radiance or distributions of sensitivity, depending on the mode.



Key

1 Sampling aperture
2 Efflux geometry
3 Point O
4 Influx geometry

Diffuse density measurement
(for diffuse influx $\kappa_i = 90°$, $\kappa_\tau \leqslant 10°$)[a]
(for diffuse efflux $\kappa_i \leqslant 10°$, $\kappa_\tau = 90°$)[a]

Projection density measurement
(for *f* /4,5 $\kappa_i = \kappa_\tau = 6{,}4°$)[b]
(for *f* /1,6 $\kappa_i = \kappa_\tau = 18{,}2°$)[b]

[a] The 90° specification implies physical contact between the specimen and the diffuse irradiating system.

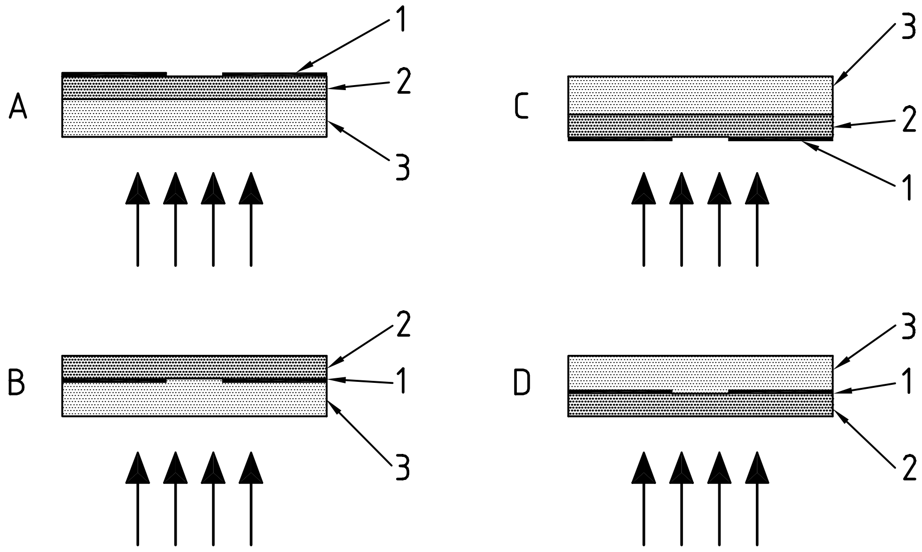
[b] The values of the half-angle κ are calculated using the formula contained in the note of 6.2.

Figure 1 — Geometry for density measurements

5.2 Sampling aperture

The extent and shape of the area on which density is measured is known as the sampling aperture. Physically, the sampling aperture is realized by a diaphragm which has to be in contact with the sample to be measured. Figure 2 shows the four combinations which may be applied: two for the influx mode and two for the efflux mode. Other combinations are excluded.

NOTE Figure 2 shows, for the combinations B and D, that the opaque material of the diaphragm constitutes a smooth surface with the diffusing material. This may be gained by grinding the opal glass and filling the step with an appropriate opaque material. Since these combinations are rather costly, combinations A and C will be preferred in practice.



A, B: Diffuse influx mode **C, D: Diffuse efflux mode**

Key

1 Diaphragm

2 Specimen

3 Opal glass

Figure 2 — Geometrical arrangement of the diaphragm for the diffuse influx mode (A, B) and the diffuse efflux mode (C, D)

The size and shape of the sampling aperture is not critical if no dimension is so large that the influx and efflux geometric conditions vary materially over the sampling aperture or so small that the granularity of the film, specimen thickness, or diffraction effects are significant. Measurements on areas less than 0,5 mm in diameter border on or involve micro-densitometry and are subject to special considerations not dealt with in this part of ISO 5. The relative sizes of the sampling aperture and the optical components limiting the directional distribution are related by the specified tolerances on the angular subtense of the directional distribution.

Ideally, the influx and efflux distribution should be uniform over the sampling aperture. When the sampling aperture is scanned laterally with a geometrically similar aperture, similarly oriented and having dimensions no more than one-quarter of those of the corresponding dimensions of the sampling aperture, the radiance at any place on the sampling aperture shall be within 10 % of the maximum value. Lack of uniformity is immaterial when uniform images are measured, but can be an important source of error in measurements on non-uniform images.

The size of the diffuser relative to the sampling aperture shall be large enough to prevent its rim or support from affecting density measurement. The specimen to be measured shall be placed in contact with the diffuser. In the case of photographic films and plates, the emulsion surface shall face the diffuser.

5.3 Diffuse distribution

The angular distribution of radiance or the angular distribution of sensitivity in the diffuse distribution, at the centre of the sampling aperture, should ideally be uniform throughout the hemisphere bounded by the plane of the sampling aperture. For the purposes of this part of ISO 5, the degree of uniformity shall be such that the diffusion coefficient is 0,92 ± 0,02. The determination of the diffusion coefficient is specified in annex A.

For the spectral range specified in ISO 5-3, the spectral reflectance factor $R_{d/8}$ (as defined in ISO 7724-1) of the diffuse irradiating (receiving) system shall be 0,55 ± 0,05, and the face shall be polished.

Such a distribution has often been produced by the use of a plate of opal glass. The use of opal glass is not required if the specified optical conditions are met.

NOTE 1 If a densitometer has a diffusion coefficient and a reflectance factor within the tolerances specified above, uncertainties in the density measurement introduced by deviations from the exact values of the diffusion coefficient and reflectance factor are generally small when compared to the overall uncertainty.

NOTE 2 The surface polishing and the reflectance of the diffusing system influence the density readings because of the effects on the inter-reflections which occur between the diffusing system and the specimen. The reflectance, which is defined as "ratio of the reflected or luminous flux to the incident flux in the given conditions" (CIE Publ. 17.4), is characterized by the reflectance factor R, which is defined as "ratio of radiant or luminous flux reflected in the directions by the given cone to that reflected in the same directions by a perfect reflecting diffuser identically irradiated or illuminated" (CIE Publ. 17.4). If the solid angle of the cone approaches 2π sr, the reflectance factor approaches the reflectance. Generally, the (spectral) reflectance factor is measured, for instance by using an integrating sphere, when specifying the reflectance of the diffusing system. Therefore, the value of the (spectral) reflectance factor is specified in this part of ISO 5 but the term "reflectance" is generally used in the text, when discussing physical phenomena.

5.4 Directional distribution

The angular distribution of radiance or the angular distribution of sensitivity, for the directional distribution, shall be at its maximum on the normal to the sampling aperture at the centre of the sampling aperture, and shall be negligible at angles more than 10° from the normal to the sampling aperture plane, at any point on the sampling aperture.

5.5 Designation

The density values obtained using the specifications given in 5.1 to 5.4 shall be referred to as "ISO standard diffuse transmission density". In functional notation, this shall be denoted as

D_T (90° opal; S_H: $\leqslant$ 10°; s) for the diffuse influx mode, or

D_T ($\leqslant$ 10°; S_H: 90° opal; s) for the diffuse efflux mode,

where S_H is defined as the influx spectrum for transmission density (see ISO 5-3:1995, clause 4), and s as the spectral sensitivity of the receiver.

6 ISO standard projection density

6.1 Sampling aperture

The sampling aperture shall be small compared with the remainder of the optical system in order to limit the variation of geometric conditions across it. Its diameter shall not exceed one-sixth of that of the aperture simulating the entrance pupil of the projection lens. The diameter of the sampling aperture shall not be less than 0,5 mm.

Ideally, the incident flux should be uniformly distributed over the area of the sampling aperture. When the sampling aperture is scanned laterally with a radiometer having a uniform angular response throughout an acceptance angle of at least 20°, and a uniform response over a circular sensing area with a diameter one-quarter of that of the sampling aperture, the flux measured at any point on the aperture shall be within 10 % of the maximum value.

6.2 *f*/4,5 type

The angular distribution of incident radiance and the angular distribution of the sensitivity of the receiver (including the effects of any filters, lenses, or other optical components), shall be uniform to within ± 10 % at all angles to the optical axis from 0° to 6,4° ± 0,2°.