INTERNATIONAL STANDARD

ISO 5-2

Third edition
1991-12-15

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 5-2:1991(E)

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.

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

This third edition cancels and replaces the second edition (ISO 5-2:1985), which has been technically revised.

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*

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

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Case Postale 56 • CH-1211 Genève 20 • Switzerland
Printed in Switzerland

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.) By that change it was recognized that transmission density measurements of photographic products are almost exclusively made by using diffusers. Slightly smaller density values are obtained compared to those based on the integrating sphere method because of inter-reflections between the opal-glass and the specimen. The effect is greatest at low densities and dependent on the reflectance characteristics of the opal-glass and the surface of the specimen facing the diffuser.

The changes from the second edition are as follows:

a) The Halbertsma method for measuring diffusion coefficient has been replaced by a general method intended to describe the illumination distribution incident on the film or receiver. That distribution is influenced by the system not just by the "opal" as "illuminated by normally incident light", which is prescribed by the Halbertsma method. In other words, a diffuser having a diffusion coefficient of 0,9, measured by the Halbertsma method, may have an entirely different distribution when placed in a system not having normally incident light.

b) The diffusion coefficient of an entire system has been defined along with the method of measurement.

c) The system for which the reflectance factor is to be measured has been defined and the method of measurement has been prescribed to achieve consistency of results.

d) Since inter-reflections and surface finish play such an important role in the determination of density with this geometry, the condition that the diffusing system surface be polished was placed in the body of the text instead of in a footnote.

e) Wording which fostered inconsistency in interpretation regarding the separation between sample and diffuser has been altered.

f) The figure describing geometry for density measurements was clarified and made more general in order to accommodate both diffuse and projection density.

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 illuminated on one side and viewed from the other, as when a film is viewed on a diffuse transparency illuminator. The geometric conditions of projection with diffuse illumination 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 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 illuminated 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 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 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, to be contact printed, or to be projected with a system employing diffuse illumination.

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

Though 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 sheet materials.

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.*

ISO 5-3:1984, *Photography — Density measurements — Part 3: Spectral conditions.*

CIE Publication 15-2:1978, *Recommendations on uniform color spaces — Color difference equations — Psychometric color terms.*

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 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

T is the transmittance factor;

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:

$$D_T = \log_{10} \frac{1}{T} = \log_{10} \frac{\Phi_j}{\Phi_\tau}$$

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 transmission density measurements.

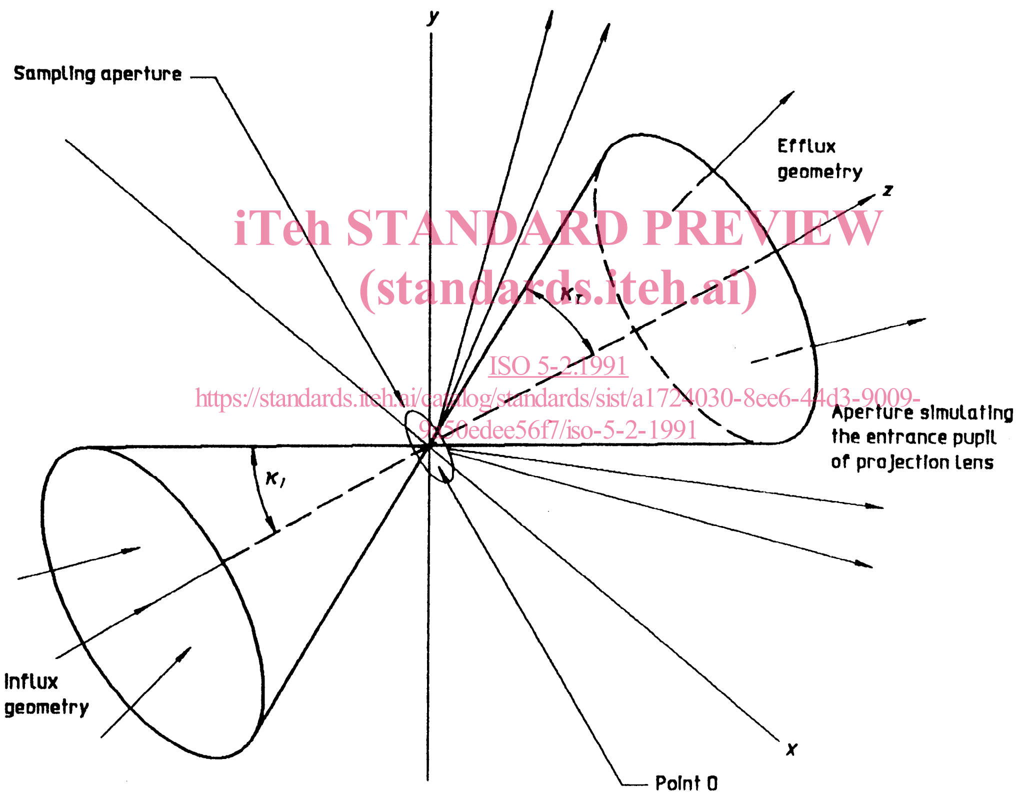
5 ISO standard diffuse density

5.1 Geometric modes

Diffuse transmission measurements may be made with a diffuse illuminator and a directional receiver, this arrangement being known as the "diffuse influx mode". Use of directional illumination and a diffuse receiver is 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.

5.2 Sampling aperture

The extent and shape of the area on which density is measured is known as the sampling aperture. 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 diameter border on or involve microdensitometry 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.



Diffuse density measurement

(for diffuse influx $K_I = 90°$, $K_T \leq 10°$)[1]
(for diffuse efflux $K_I \leq 10°$, $K_T = 90°$)[1]

Projection density measurement

(for $f/4{,}5$ $K_I = K_T = 6{,}4° \pm 0{,}2°$)
(for $f/1{,}6$ $K_I = K_T = 18{,}2° \pm 1°$)

1) The 90° specification implies physical contact between the specimen and the diffuse illuminating/receiving system.

Figure 1 — Geometry for density measurements

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 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 shall fall between 0,90 and 1,00 as defined below.[1)]

For the spectral range specified in ISO 5-3, the reflectance factor (as defined by CIE diffuse/normal geometry)[2)] of the diffuse illuminating (receiving) system shall be 0,55 ± 0,05, and the face shall be polished.[3)] Such a distribution has often been produced by the use of a plate of opal-glass to diffuse the incident flux or integrate the transmitted flux, but the use of opal-glass is not required if the specified optical conditions are met.

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

Density values obtained using specifications given above shall be referred to as "ISO standard diffuse transmission density". In functional notation this shall be denoted as

D_T (90° *opal*; S_H: ≤ 10°; s) for the diffuse influx mode, or

D_T (≤ 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, 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 photometer 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 place 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

1) **diffusion coefficient** (see also annex C): The luminous intensity (sensitivity) of the diffuse illuminating (receiving) system relative to the normal at different angles of view, θ, are plotted in polar coordinate form. For a Lambertian illuminating (cosine corrected receiving) system the resulting curve is a circle. The ratio of the area circumscribed by the values obtained with any diffuse illuminating (receiving) system to the area obtained with a Lambertian illuminating (cosine corrected receiving) system is termed the diffusion coefficient of the diffuse illuminating (receiving) system. The field of measurement for determining the diffusion coefficient shall not exceed 10°.

2) **CIE Publication 15-2:1978, section 1.4:** "The specimen is illuminated diffusely by an integrating sphere. The angle between the normal to the specimen and the axis of the viewing beam should not exceed 10 degrees. The integrating sphere may be of any diameter provided the total area of the ports does not exceed 10 per cent of the internal reflecting sphere area. The angle between the axis and any ray of the viewing beam should not exceed 5 degrees." The reflectance factor is the ratio of the light reflected by the sample to the light reflected by a perfect reflecting diffuser.

3) Low density readings are sensitive to variations in the reflectance factor and surface polish of the diffusing system because of the effects on the inter-reflections which occur between it and the specimen.

± 10 % at all angles to the optical axis from 0° to 6,4° ± 0,2°.[4] This angular distribution simulates an ideal *f*/4,5 projection system.

6.3 *f*/1,6 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 18,2° ± 1,0°. This angular distribution simulates an ideal *f*/1,6 projection system.

6.4 Uniformity of influx geometry

When the angular distribution of incident radiance is scanned with a photometer having uniform angular response (within ± 10 %) over a conic distribution with a half-angle of 2°, the radiance in any direction within the specified influx cone shall be within 10 % of the maximum. Outside the specified influx cone, the flux shall be less than 2 % of the maximum within the cone.

6.5 Uniformity of efflux geometry

When the angular distribution of sensitivity of the receiver is scanned by a small beam with a conic distribution having a half-angle of 2°, the sensitivity shall be within 10 % of the maximum, for any direction within the specified cone. Outside the specified efflux cone, the flux shall be less than 2 % of the maximum within the cone.

6.6 Designation

Density values obtained using the specifications for the *f*/4,5 type given in 6.2 shall be referred to as "ISO standard *f*/4,5 projection transmission density". In functional notation this is denoted as D_T (6,4°; S_H: 6,4°; s).

Density values obtained using the specifications for the *f*/1,6 type given in 6.3 shall be referred to as "ISO standard *f*/1,6 projection transmission density". In functional notation this is denoted as D_T (18,2°; S_H: 18,2°; s).

4) The relationship between *f*-number and half-angle (κ) of the cone of rays forming the axial image point is

$$f\text{-number} = \frac{1}{2n \sin \kappa}$$

where n is the refractive index of the image space.

Annex A
(informative)

Sphere diffuse density

For many years the use of an integrating sphere was specified for measuring ISO standard density. A major disadvantage of that method of measurement was that the densities obtained with the integrating sphere did not correlate satisfactorily with the densities obtained in practical photographic applications. At low density levels the integrating sphere method yields densities that are approximately 0,03 higher than those obtained with the opal-glass diffuser. The primary reason for the difference is the re-reflection by the opal-glass diffuser of the flux that is reflected by the test sample.

This situation also occurs when negative films are contact printed on photographic paper that has a reflectance factor similar to that of the opal-glass diffuser. Similarly, when the transparencies are viewed on an illuminator, light which is reflected by the transparency is re-reflected by the diffusing surface of the illuminator.

Another important reason for adoption of the "opal-glass" method in 1985 was the fact that almost all densitometers use a diffuser close to the sampling aperture.

Annex B
(informative)

Unmatched influx and efflux angles

Although projection density is a function of both influx and efflux geometries, represented in this part of ISO 5 by half-angles, the measured value varies markedly with changes in the larger of the two, but very little with changes in the smaller. For this reason, either of the half-angles can be reduced by a small amount without affecting the measured density. Instrument designers may take advantage of this fact and avoid the problem of aligning aperture with identical coverage. If this technique is used, the large half-angle shall meet the requirements of clause 6.