TC 42

International Standard ISO 5/2

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Photography — Density measurements — Part 2: Geometric conditions for transmission density

Photographie — Mesurage des densités — Partie 2: Conditions géométriques pour la densité instrumentale par transmission

Second edition — 1985-06-15

UDC 771.534.531.5 **Ref. No. ISO 5/2-1985 (E)**

Descriptors : photography, density measurement, flux density, radiant flux density, transmission, geometric.

Price based on 5 pages

ISO 5/2-1985 (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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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

The present edition constitutes a partial revision of International Standard ISO 5-1974.

Printed in Switzerland

Photography — Density measurements — Part 2: Geometric conditions for transmission density

0 Introduction

This part of ISO 5 is a partial revision of the first edition of ISO 5 *Photography — Determination of diffuse transmission density*, published in 1974. The primary change is the replacing of the integrating sphere method with the "opal"[1] glass method as the basis for specifying ISO standard diffuse transmission density. By this it is 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 and the specimen. The effect is greatest at low densities and dependent on the reflectance characteristics of the surface of the specimen facing the diffuser.

This part of ISO 5 also describes the geometric conditions for two types of projection density. The spectral conditions described in ISO 5-1974 are specified in ISO 5/3.

Transmission density is a measure of the ability of a film image to transmit light or other radiant flux. The measured value depends on the geometric and spectral conditions of measurement. This part of ISO 5 treats the geometric conditions only.

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, or is contact printed. 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.

Doubly diffuse transmission density is a measure of the modulation of light by a specimen that is diffusely illuminated to expose an underlying sensitive surface, as is done in some contact printers. Since this type of density is closely related to diffuse density and since very few instruments are available for its measurement, the geometric conditions for doubly diffuse density are not described in this part of ISO 5.

Equipment employing optical condensers is used to view microfilm, motion pictures, and slides, and to make projection prints. When a condenser system is used, a given area of a transparency reduces the amount of light passing from the lamp to the viewing screen or print material in a different manner from that in diffuse illumination or collection applications. 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 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*-number, 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.

1 Scope and field of application

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

1) Although any diffusing material meeting the specifications contained in this International Standard may be used, the method is often denoted simply by the word "opal" to differentiate it from the integrating sphere method.

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 References

ISO 5, *Photography — Density measurements —*

Part 1: Terms, symbols and notations.

Part 3: Spectral conditions.

Part 4: Geometric conditions for reflection density.

3 Definitions

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

For the purpose 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: 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 ISO standard diffuse density

4.1 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." Diagrams of the diffuse modes are shown in the figure. 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.

4.2 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.

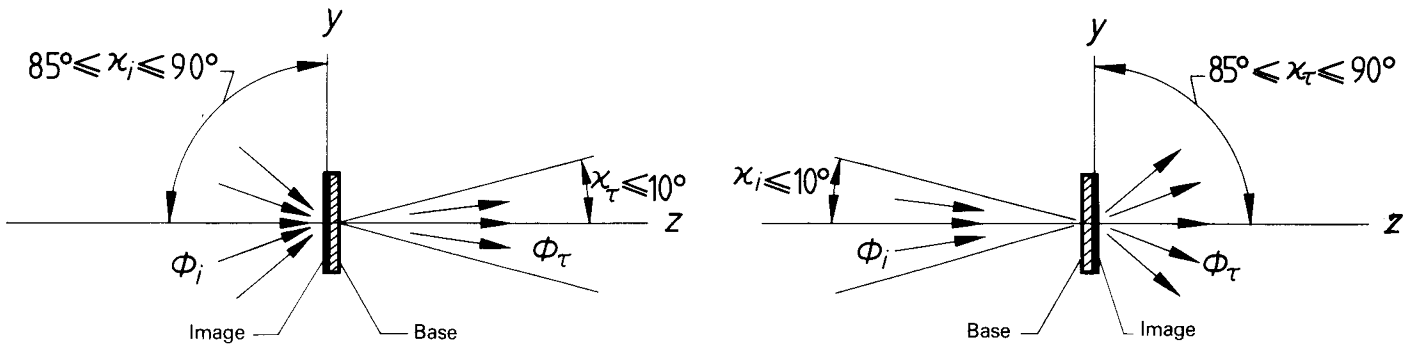
Ideally, the influx and efflux distribution should be uniform over the sampling aperture. When the sampling aperture is scanned laterally with a geometrically similar aperture, similarly oriented and having dimensions no more than a quarter of those of the corresponding dimensions of the sampling aperture, 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.

4.3 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. The degree of uniformity shall be such that the diffusion coefficient for transmitted flux shall be 0,90 to 0,94 as measured by the Halbertsma[1)] method.

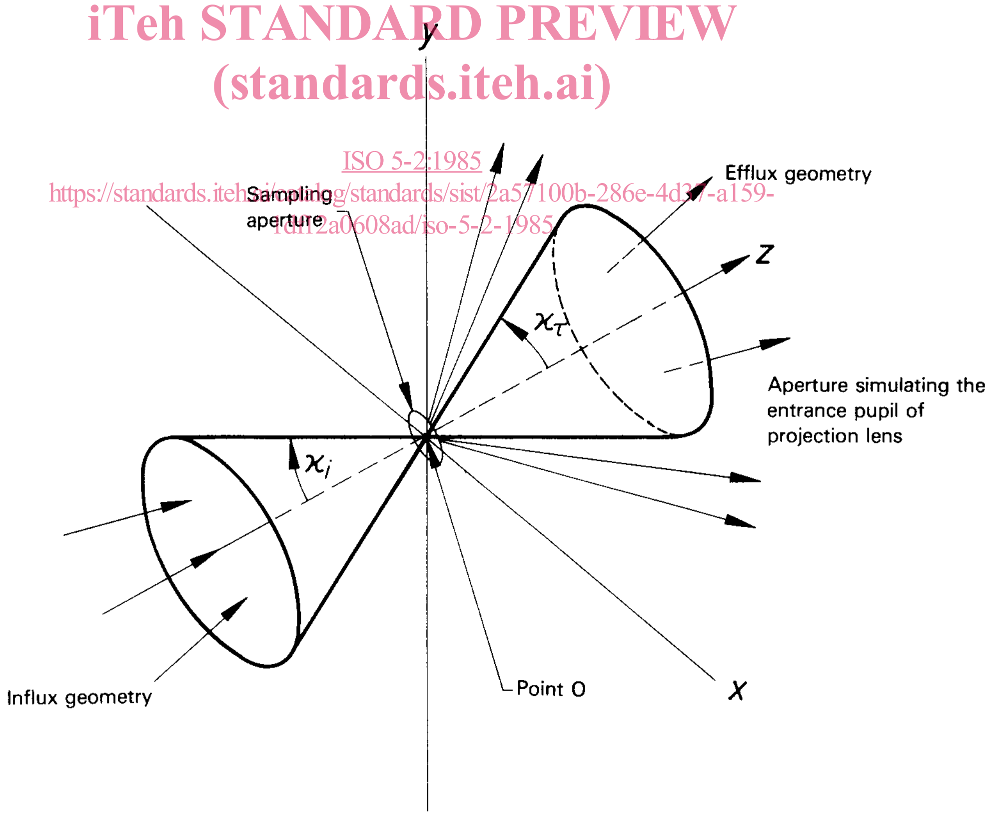
1) Halbertsma method: With light incident normally on the surface, the luminous intensities (relative to normal, in percent) at different angles of view, θ, are plotted as abscissae, the corresponding ordinates being proportional to $(1 - \cos \theta)$. For a perfectly diffusing material the resulting curve is a straight line. The ratio of the area enclosed by the axes of co-ordinates and the representative curve for any material to the area for a perfectly diffusing material is termed the "diffusion coefficient" of the material.



a) Diffuse influx mode

b) Diffuse efflux mode

Diffuse density measurement



Projection density measurement

(for $f/4,5$ $\kappa = 6,4° \pm 0,2°$)
(for $f/1,6$ $\kappa = 18,2° \pm 1,0°$)

Figure — Geometry for density measurements

The half angle of the distribution shall be between 85° and 90°. For the specified spectral conditions, the absolute reflectance factor of the face of the diffuse illuminator or diffuse collector, as the case may be, shall be 0,55 to 0,60.[1] 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.

4.4 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 specimen plane, at any point on the sampling aperture.

4.5 Designation

Density values obtained using specifications given above may be referred to as "ISO standard diffuse transmission density" or simply as "ISO diffuse density." In functional notation, they may be denoted as D_T(90° *opal*; S: $\leqslant$ 10°; s) or D_T($\leqslant$ 10°; S: 90° *opal*; s) where S and s are defined as the influx spectrum and the spectral sensitivity of the receiver. As the previous International Standard (ISO 5-1974) for specifying diffuse density was based on the use of an integrating sphere, it may be desirable to indicate the method on which densities are based. The use of "sphere" or "opal" in describing the diffuse reading is suggested for this purpose (i.e., standard sphere diffuse density). Materials other than opal may be used provided their diffusing characteristics meet the requirements of this International Standard.

5 ISO standard projection density

5.1 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 a quarter of that of the sampling aperture, the flux measured at any place on the aperture shall be within 10 % of the maximum value.

5.2 *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°.[2] This angular distribution simulates an ideal *f*/4,5 projection system.

5.3 *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.

5.4 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 for 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.

5.5 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.

5.6 Designation

Density values obtained using the specifications for the *f*/4,5 type given above may be referred to as "ISO standard *f*/4,5 projection transmission density" or "ISO *f*/4,5 density." In functional notation this is denoted as D_T (6,4°; S_H: 6,4°; s). Projection densities of the *f*/1,6 would be designated D_T (18,2°; S_H: 18,2°; s).

6 Bibliography

Walsh, J.W.T. *Photometry*. New York: Dover Publications, 1965, 3rd ed. (London: Constable and Co., 1958, 3rd ed.)

1) Low density readings are very sensitive to variations in the absolute reflectance factor of the diffuser because of its effect on the inter-reflection which occurs between it and the specimen. It is recommended the surface of the opal be polished on the side adjacent to the sample to permit cleaning. The other surface should be ground.

2) The relationship between *f*-number and half-angle (κ) of the cone of rays forming the axial image point is *f*-number $= \dfrac{1}{2\,n \sin \kappa}$ where n is the refractive index of the image space.

Annex A

Sphere diffuse density

(This annex does not form part of the standard.)

For many years, the use of an integrating sphere has been specified for measuring ISO Standard Density. A major disadvantage of this method of measurement is that the densities obtained with the integrating sphere do 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 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 adopting the "opal" method is because almost all densitometers use a diffuser close to the sampling aperture.

Annex B

Unmatched influx and efflux angles

(This annex does not form part of the standard.)

Although projection density is a function of both influx and efflux geometries, represented in this International Standard 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 larger half-angle shall meet the requirements of clause 5.