INTERNATIONAL STANDARD

ISO 5-1

Second edition
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Photography and graphic technology — Density measurements —

Part 1: Geometry and functional notation

Photographie et technologie graphique — Mesurages de la densité —

Partie 1: Géométrie et notation fonctionnelle

Reference number
ISO 5-1:2009(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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 5-1 was prepared by ISO/TC 42, *Photography*, and ISO/TC 130, *Graphic technology*, in a Joint Working Group.

This second edition cancels and replaces the first edition (ISO 5-1:1984), which has been technically revised. In the course of this technical revision, all parts of ISO 5 have been reviewed together, and the terminology, nomenclature and technical requirements have been made consistent across all parts.

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

— *Part 1: Geometry and functional notation*

— *Part 2: Geometric conditions for transmittance density*

— *Part 3: Spectral conditions*

— *Part 4: Geometric conditions for reflection density*

Introduction

The measurement of the transmission and reflection characteristics of objects is essential to the science of photography and graphic arts. When light, or other radiant energy, is incident upon an object, it is either absorbed or propagated. Propagation can involve reflection, transmission, refraction, diffraction, scattering, fluorescence, and polarization. The propagated light is distributed in various directions about the object. In most practical applications it is neither necessary nor desirable to consider the light distributed in every direction, but only that which leaves the object in the direction for which there is response by a receiver, such as the eye.

The object modulates the flow of radiant energy from the illuminator to the receiver. The time rate of flow of radiant energy is called radiant flux, or simply flux. This part of ISO 5 provides methods to describe the measurements of the flux modulation in any system. To specify such a system accurately, geometric characteristics of the system, the spectral distribution of the flux incident on the object to be measured, and the spectral responsivity of the receiver need to be given. If the reflection characteristics of the illuminator or receiver affect the measurement, as they do in transmission measurements by the opal glass method, they need to be specified.

The area under consideration is defined by a sampling aperture, the dimensions of which can be important in some applications and need to be specified if the object has appreciable non-uniformity. If the measurement is to quantify the way the object would modulate flux in a given practical application, such as viewing or contact printing, the geometric and spectral conditions of measurement need to simulate those conditions in the practical application.

Modulation is measured and expressed as a dimensionless ratio of fluxes; that is, the flux propagated in the direction of the receiver and that part of the spectrum of interest divided by some reference flux. The reference flux can be the incident flux or the flux propagated through the system when the object is replaced by an ideal object. For some purposes, a logarithmically scaled measure of modulation is more useful than the measured arithmetic ratio. In such cases, it is customary to use optical density defined as the negative logarithm to base 10 of the ratio.

Most geometric arrangements used in photographic and graphic arts optical systems can be conveniently and adequately described in terms of uniform rays of flux bounded by right circular cones. A point on the object is often illuminated by such a conic distribution, and the geometric form of the pencil of rays reaching the receiver is generally conic. The pupil of the eye, for example, subtends a conic solid angle at an object point. In projection systems, the projection lens subtends a conic solid angle at the specimen point. This part of ISO 5 specifies a conic distribution by the half-angle of the cone and the direction of its axis.

A working knowledge of radiometry is generally required to obtain primary standard measurements of transmittance and reflectance. In good radiometric practice, for example, the effects of stray light are minimized by the use of appropriate baffles and proper blackening of certain surfaces. Because the principles and practice of radiometry are well known and are fully described in the *Handbook of Applied Photometry*[10], it is considered unnecessary to provide a detailed specification of radiometric procedures in this part of ISO 5.

Photography and graphic technology — Density measurements —

Part 1: Geometry and functional notation

1 Scope

This part of ISO 5 establishes terms, symbols, functional notations and a coordinate system to describe geometric and spectral conditions for the measurement of the degree to which a specimen modulates radiant flux for applications in photography, graphic technology, and radiometry.

This part of ISO 5 primarily provides a system for describing methods of measuring or specifying the transmission and reflection properties of photographic and graphic arts materials. The geometric and spectral conditions associated with such measurement are specified in ISO 5-2, ISO 5-3 and ISO 5-4.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5-2, *Photography and graphic technology — Density measurements — Part 2: Geometric conditions for transmittance density*

ISO 5-3, *Photography and graphic technology — Density measurements — Part 3: Spectral conditions*

ISO 5-4, *Photography and graphic technology — Density measurements — Part 4: Geometric conditions for reflection density*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply[1)].

3.1
absolute reference reflected flux
Φ_{rA}
radiant flux that would be reflected by a perfect reflecting diffuser

1) For the convenience of the user, Annex A lists those terms and definitions used in other parts of ISO 5 that are not used in this part of ISO 5.

3.2
absolute reference transmitted flux
Φ_{tA}
radiant flux that would be transmitted by a perfect transmitting diffuser

3.3
anormal angle
θ
angle between the normal of the reference plane and a direction

NOTE Adapted from ASTM E1767.

3.4
azimuthal angle
η
angle between the x-axis of the reference plane and the projection of a direction onto the reference plane

NOTE Adapted from ASTM E284.

3.5
cone half-angle
κ
angle between the central axis and the edge of the pupil with the apex at the centre of the sampling aperture

3.6
efflux
radiant flux collected by the receiver from the reference plane

NOTE Adapted from ASTM E1767.

3.7
illuminator axis
central axis of the illuminator, usually the optical axis

3.8
illuminator region
intersection of the illuminator beam with the reference plane

3.9
incident flux
Φ_i
radiant flux incident upon the sampling aperture

3.10
influx
radiant flux projected by the illuminator onto the reference plane

NOTE Adapted from ASTM E1767.

3.11
influx spectrum
S
spectral distribution of the radiometric quantity, such as radiance, irradiance or radiant flux, incident upon the sampling aperture

NOTE This is a function of the source and optics used for the illumination.

3.12
ISO 5 standard density
density value obtained using an instrument conforming to one of the geometries specified in ISO 5-2 or ISO 5-4, and one of the spectral definitions in ISO 5-3

3.13
receiver axis
central axis of the receiver, usually the optical axis

3.14
receiver region
intersection of the receiver beam with the reference plane

3.15
reflectance
ρ
ratio of the reflected flux to the incident flux under specified geometrical and spectral conditions of measurement

NOTE Adapted from ASTM E284.

3.16
reflectance density
D_ρ
negative logarithm to the base 10 of the reflectance

3.17
reflectance factor
R
ratio of the reflected flux to the absolute reference reflected flux under the same geometrical and spectral conditions of measurement

3.18
reflected flux
Φ_r
radiant flux that emerges from the specimen surface on which the incident flux falls

3.19
reflection density
D_R
negative logarithm to the base 10 of the reflectance factor

NOTE The International Commission on Illumination (CIE) designates the measurement referred to as “reflection density” in ISO 5 as “reflectance factor density”. (See IEC 60050-845:1987 | CIE 17.4:1987.)

3.20
spectral responsivity
s
output signal of a receiver per unit input of radiant flux as a function of wavelength

NOTE Adapted from ASTM E284.

3.21
transmission density
D_T
negative logarithm to the base 10 of the transmittance factor

3.22
transmittance
τ
ratio of the transmitted flux to the incident flux under specified geometrical and spectral conditions of measurement

NOTE 1 In practical instruments for transmittance measurements, the incident flux is defined by the combination of all of the components that are placed before the reference plane (influx), so the incident flux is provided by the surface of the opal diffuser for diffuse transmittance and by the film gate for projection density.

NOTE 2 Adapted from ASTM E284.

3.23
transmittance density
D_τ
negative logarithm to the base 10 of the transmittance

NOTE The subscript is the lower case Greek letter tau.

3.24
transmittance factor
T
ratio of the transmitted flux to the absolute reference transmitted flux under the same geometrical and spectral conditions of measurement

NOTE Adapted from ASTM E284.

3.25
transmitted flux
Φ_t
radiant flux that passes through the specimen and emerges from a surface other than that on which the incident flux falls

4 Equations

The terms and equations applicable to density measurements are given in Table 1.

Table 1 — Terms and equations for density measurements

Term	Equation	Term	Equation
Transmittance	$\tau = \frac{\Phi_\text{t}}{\Phi_\text{i}}$	Transmittance density	$D_\tau = -\log_{10} \tau$
Reflectance	$\rho = \frac{\Phi_\text{r}}{\Phi_\text{i}}$	Reflectance density	$D_\rho = -\log_{10} \rho$
Transmittance factor	$T = \frac{\Phi_\text{t}}{\Phi_\text{tA}}$	Transmission density	$D_T = -\log_{10} T$
Reflectance factor	$R = \frac{\Phi_\text{r}}{\Phi_\text{rA}}$	Reflection density	$D_R = -\log_{10} R$

5 Instrument representation

Every instrument used to perform optical density measurements of a specimen typically has three components:

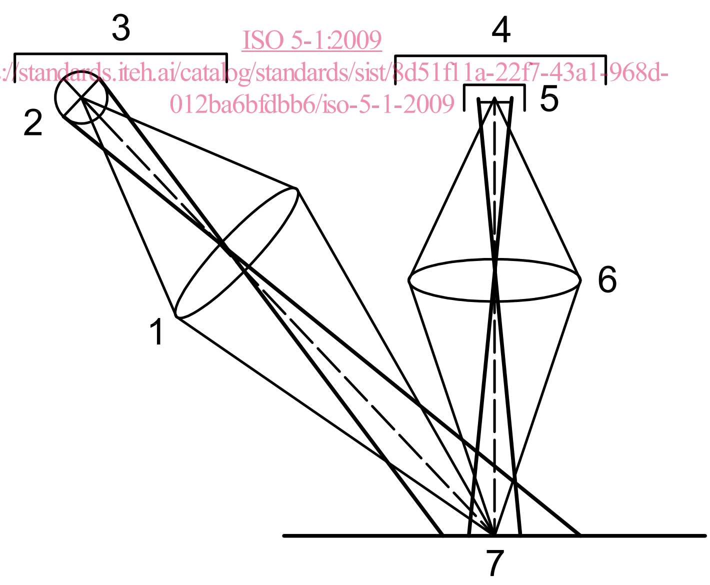
— an illuminator to project radiant flux onto the specimen,

— a reference plane at which the specimen is placed, and

— a receiver to measure the radiant flux from the specimen.

These components are shown schematically in Figure 1 for a general instrument. The illuminator consists of a source for providing radiant flux, and a director, which directs the radiant flux from the source onto the reference plane. Likewise, the receiver consists of a collector, which guides the radiant flux from the reference plane to the detector, which is a device that converts radiant flux into a measurable signal. Examples of sources are incandescent and arc lamps, while examples of detectors are photodiodes and photomultiplier tubes. The central axes, marginal rays, and chief rays of the illuminator and receiver are also shown in Figure 1 as dashed, thin, and thick lines, respectively.

The illuminator and receiver are optical systems with aperture and field stops. These stops determine the illuminator and receiver beams, which are the collections of rays that can pass through the systems. The images of the aperture stops as viewed from the reference plane are the pupils. The illuminator axis is the central axis of the illuminator beam, and is usually the optical axis of the illuminator, although it could also be the centroid of the distribution of rays within the beam. The illuminator axis has an angle of illumination with respect to the normal of the reference plane. Likewise, the receiver axis is the central axis of the receiver beam and has an angle of observation (or viewing) with respect to the normal of the reference plane. The intersections of the illuminator and receiver beams with the reference plane are the illuminator and receiver regions, respectively.



Key

1 director

2 source

3 illuminator

4 receiver

5 detector

6 collector

7 reference plane

Figure 1 — A schematic representation of the three components of an instrument used for densitometry (illuminator, reference plane, and receiver) and their parts