INTERNATIONAL STANDARD

ISO 9236-1

Second edition
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Photography — Sensitometry of screen/film systems for medical radiography —

Part 1: Determination of sensitometric curve shape, speed and average gradient

Photographie — Sensitométrie des ensembles film/écran pour la radiographie médicale —

Partie 1: Détermination de la forme de la courbe sensitométrique, de la sensibilité et du contraste moyen

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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 9236-1 was prepared by Technical Committee ISO/TC 42, *Photography*.

This second edition cancels and replaces the first edition (ISO 9236-1:1996), which has been technically revised to incorporate the following technical and major editorial changes:

- a spherical ionization chamber, or an equivalent detector, is required for dosimetry;
- only high frequency or 12-pulse high-voltage generators are allowed, 6-pulse high-voltage generators are excluded;
- the allowed uncertainty for the density measurement has been increased in order to comply with the other parts of the ISO 9236 series;
- the exposure times for the determination of speed and sensitometric curve shape have been reduced to match the current state of the art;
- the phantom of Technique IV has been changed (leaving the beam quality unchanged) in order to reduce the air kerma rate;
- the distances between the focal spot of the x-ray tube and the screen-film combination when determining speed and average gradient may now be in the range from 1,5 m to 4,0 m;
- the use of a monitoring detector is no longer mandatory, because the precision of modern x-ray tubes and high-voltage generators is often superior to that of monitoring detectors;
- the total uncertainty which can be reached has been changed;
- an informative annex has been added in order to describe the background of speed and curve shape measurements, the choice of phantoms, and the energy dependence of speed values.

ISO 9236 consists of the following parts, under the general title Photography — Sensitometry of screen/film systems for medical radiography:

- *Part 1: Determination of sensitometric curve shape, speed and average gradient*
- *Part 3: Determination of sensitometric curve shape, speed and average gradient for mammography*

The following part is under preparation:

- *Part 2: Method for determining modulation transfer function (MTF)*

Introduction

This part of ISO 9236 provides methods for determining the sensitometric curve shape, the average gradient and the speed of radiographic screen/film/filmholder/processing systems used in medical radiography, except in mammography and dental radiography.

The sensitometric curve shape, which is also needed for the determination of other properties (as, for example, the modulation transfer function), is measured under low scatter conditions via intensity scale X-ray sensitometry, preferably using an inverse square sensitometer. For the determination of the sensitometric curve shape, as well as for a subsequent determination of the average gradient from the measured curve, but not for speed, the irradiation of the screen/film/filmholder combination need to be measured only in relative units.

Speed is measured in a separate way, under exposure conditions which simulate medical practice more closely, including realistic fractions of scattered radiation. Different types of medical exposures are simulated by using appropriate phantoms and X-ray tube voltages, and the screen/film/filmholder combination is exposed behind the respective phantom. The irradiation is measured in absolute units of air kerma (gray, Gy) in order to determine the speed.

Four different techniques are defined, differing in beam quality and fraction of scattered radiation, simulating the imaging of extremities, skull, lumbar spine and colon, and chest. Speed may be measured for each technique of interest. Owing to its dependence on X-ray energy and scatter, screen/film system speed varies widely in medical practice. The four measurement conditions described in this part of ISO 9236 provide values that are representative of those found under practical conditions.

Photography — Sensitometry of screen/film systems for medical radiography —

Part 1:
Determination of sensitometric curve shape, speed and average gradient

1 Scope

This part of ISO 9236 specifies methods for the determination of the sensitometric curve shape, average gradient and speed of a single sample of a screen/film/filmholder/processing system for medical radiography. It is not applicable to special radiographic applications such as mammography, dental radiography and direct-exposing medical radiographic systems (see for example ISO 5799 [3]).

The filmholder can be any means that ensures close screen/film contact and prevents the film from being exposed to ambient light. In particular, the filmholder can be a light-tight vacuum bag, as often used in the laboratory, or a radiographic cassette as used in medical radiography.

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 5-2:2001, *Photography — Density measurements — Part 2: Geometric conditions for transmission density*

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

ISO 554:1976, *Standard atmospheres for conditioning and/or testing — Specifications*

IEC 60522:1999, *Determination of the permanent filtration of X-ray tube assemblies*

3 Terms and definitions

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

3.1
screen/film system
radiographic imaging system consisting of screen(s), film, filmholder and film processing

NOTE Hereafter, screen/film/filmholder combinations will be referred to as “combinations” and will be referred to as “systems” when the processing is included.

3.2
air kerma
K
sum of the initial kinetic energies of all charged particles (e.g., electrons) liberated by uncharged particles (e.g., X-ray photons) from air molecules, divided by the mass of air in that volume where the charged particles are liberated

NOTE The unit is the gray (Gy).

3.3
sensitometric curve
plot of the density of a processed photographic film as a function of the logarithm to the base 10 of the exposure

3.4
speed
S
quantitative measure of the response of the screen/film system to radiant energy for the specified conditions of exposure, processing and density measurement

3.5
average gradient
$\overline{G}$
slope of the straight line joining two specified points on a sensitometric curve

3.6
net density
D
density of an exposed and processed film minus the density of an unexposed and processed sample of that film

3.7
coverage factor
k
numerical factor, used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

NOTE The coverage factor is explained in the *Guide to the expression of uncertainty in measurement* [8]. Its value is typically in the range of 2 to 3. The coverage factor is chosen based on the level of confidence desired. A coverage factor (*k*) of 2 generally will result in a level of confidence of approximately 95 %, and a coverage factor of 3 generally will result in a level of confidence of approximately 99 %. This association of confidence level and coverage factor is based on an assumption regarding the probability distribution of measurement results.

4 General requirements

4.1 Storage and handling conditions

The film and screens shall be stored according to the manufacturer's recommendations. Before and during exposures, the temperatures of the films and screens shall be maintained at 23 °C ± 2 °C (see ISO 554) and the moisture content of the film shall be such that it will be in equilibrium at a relative humidity of (50 ± 20) %.

4.2 Safelights

To eliminate the possibility of safelight illumination affecting the sensitometric results, all films shall be kept in total darkness during handling, exposure and processing.

4.3 X-ray equipment

For all tests described in this part of ISO 9236, high frequency (multipulse) high voltage generators or at least 12-pulse high voltage generators shall be used.

For all tests described in this part of ISO 9236, X-ray tubes equipped with fixed anodes or rotating anodes may be used. In either case, the target material shall be tungsten or a tungsten-based alloy.

NOTE 1 The target is that part of the anode onto which the electron beam is directed to produce X-radiation. For technological reasons it is common practice to use alloys of tungsten with up to 10 % rhenium for the target, while other parts of the anode can consist of other materials (e.g. molybdenum).

The permanent filtration of the X-ray tube and its housing, as defined in IEC 60522, shall be equivalent to 2,5 mm ± 0,2 mm of aluminium.

NOTE 2 The permanent filtration of the X-ray tube and its housing is effected by permanently fixed materials intercepting the X-ray beam, which are not intended to be removed for any application. As the permanent filtration is usually stated on the X-ray tube housing and in the accompanying documents, its measurement, as described in IEC 60522, is not necessary.

4.4 Air kerma meter

For the air kerma measurement, calibrated detectors shall be used. The uncertainty of air kerma measurement (level of confidence 95 %) shall be less than 3 % for collimated beams without scatter, and less than 5 % for radiation measurements behind the phantom when scattered radiation is included.

A spherical ionization chamber of 30 cm^3 to 100 cm^3 volume should be used for measurements where scattered radiation is involved. The chamber shall be calibrated for the beam qualities given in Table 2, including scattered radiation. The centre of the spherical chamber is to be considered the reference point; the stem of the spherical chamber should point in a direction opposite to the radiation source.

NOTE During calibration of the air kerma meter and during usage, scattered radiation originating not from the phantom but from, for example, the stem of the chamber, can be minimized in order to meet the specified uncertainty requirement.

4.5 Processing

Screen/film systems, including either manual or automatic processing, may be tested in accordance with this part of ISO 9236. Processing should be carried out in accordance with the film manufacturer's recommendations. Nothing shall be construed to require the disclosure of proprietary information.

No processing specifications are described in this part of ISO 9236 in recognition of the wide range of chemicals and equipment used. Speed and average gradient values provided by film manufacturers generally apply to the system when the film is processed in accordance with their recommendations so that the photographic characteristics specified for the process are produced. Processing information shall be provided by the film manufacturer or others who quote speed and average gradient values and shall specify the processing chemicals, times, temperatures, agitation, equipment and procedures used for each of the processing steps, and any additional information required to obtain the sensitometric results described. The values for speed and average gradient obtained using other processing procedures may differ significantly. The processing conditions selected by a person using this part of ISO 9236 are, in any case, part of the system being tested.

NOTE 1 Different speeds for a particular film can be achieved by varying the processes. However, these variations to the processes can cause other undesirable changes.

In order to minimize any effects due to latent-image instability or process variability, all film samples shall be processed together, neither less than 30 min nor more than 4 h after exposure. Between exposure and processing, the temperature of the film shall be maintained at 23 °C ± 2 °C and its moisture content shall be such that the film will be in equilibrium at a relative humidity of (50 ± 20) %.

Since films are generally processed in practice a few minutes after exposure, the speed observed in practice may differ from that determined by this part of ISO 9236 due to latent-image fading of some films. Therefore, the speed measured with a time delay of 30 min to 4 h between exposure and processing shall be corrected to the value one would obtain if the film were processed soon after exposure. For the purposes of this part of ISO 9236, a time delay of 5,0 min is used for computing speed.

NOTE 2 One means of obtaining the information about the necessary correction is by exposing film strips in a light sensitometer and varying the time between exposure and processing. In this case, both front and back emulsions are exposed equally by the sensitometer.

NOTE 3 Since the time required for the many individual exposures to obtain the sensitometric curve is comparatively long, a time delay of at least 30 min between exposure and processing is necessary. This time delay is considered to be sufficient to minimize any differences in latent-image fading for the individual exposures.

The following processing information and accuracies shall be specified:

a) trade designations of all chemicals, if proprietary; otherwise, the formulae;

b) temperature of the developer to within ± 0,3 °C;

c) temperature of other solutions to within ± 2 °C;

d) immersion times in the developer, fix and washing solutions to within the greater of 3 % or 1 s; these times shall be measured from the time the leading edge enters the solution until the leading edge exits the solution;

e) whether the developer is fresh or "seasoned" (if "seasoned", the type and amount of film used for seasoning), the density of the processed film and the replenishment procedure;

f) agitation specifications, in terms of volume of solution recirculated or rate at which a gas is used, if used at all;

g) drying temperature to within ± 5 °C and drying time within the greater of 3 % or 1 s; the drying time shall be measured from the time the leading edge enters this stage until the leading edge exits this stage;

h) trade designation of processing equipment.

NOTE 4 The term "seasoned developer" means that the developer is no longer unused or fresh, but is already used and in a "normal working condition".

4.6 Densitometry

ISO standard visual diffuse transmission density of the processed images shall be measured using a densitometer complying with the geometric conditions specified in ISO 5-2 and spectral conditions specified in ISO 5-3. Readings shall be made in a uniform area of the image. The optical density shall be measured such that the expanded uncertainty U (level of confidence 95 %) associated with the result of measurement D, is U = 0,02, or that the relative expanded uncertainty is U/D = 0,02, whichever is the greater.

5 Determination of sensitometric curve shape

5.1 General

In this part of ISO 9236, intensity scale sensitometry is used to determine curve shape. The intensity is modified according to the inverse-square law by a change of the distance between the radiation source and the combination. As a consequence of filters and other secondary radiation sources in the beam, the relationship between exposure and distance may not obey the inverse-square law. Therefore that relationship shall be calibrated.

5.2 Beam qualities

For the determination of the sensitometric curve shape, any of the four beam qualities specified in Table 1 may be used. The beam qualities can be achieved by an iterative procedure of half-value layer (HVL) measurements using the specified added filtration. The approximate X-ray tube voltages are recommended as starting values for this procedure (see 7.2.6).

Table 1 — Beam qualities for the determination of the sensitometric curve shape

Beam quality number	Approximate X-ray tube voltage	Half-value layer HVL[a]	Added filtration[b]	
	kV	mm Al	mm Al	mm Cu + mm Al
I	50	3,0	5,0	0,10 + 1,5
II	70	5,7	12,0	0,25 + 2,5
III	90	7,4	13,0	0,25 + 3,5
IV	120	8,5	10,0	0,20 + 2,5

[a] The tolerance for the HVL is ± 2 %.

[b] The added filter, consisting of copper plus aluminium, is an alternative to that filter, which consists of aluminium only. The aluminium used as filter material shall have a purity of at least 99,4 % and the copper a purity of at least 99,5 %. If a mixed filter is used, the last layer towards the detectors shall be aluminium. The inherent tube filtration is assumed to correspond to 2,5 mm of aluminium.

5.3 Geometry for curve shape determination

The measurement geometry shall comply with Figures 1 and 2. The diaphragm B1 and the added filter(s) shall be positioned near the radiation source. The diaphragms B1 and B2 and the added filter(s) shall be in a fixed relation to the radiation source. The diaphragm B3 and the screen/film/filmholder combination or the radiation detector R2 shall be in a fixed relation to each other at each distance from the radiation source. The incident face of diaphragm B3 shall be 100 mm in front of the plane of the radiographic film. If it has been confirmed that scattered radiation from walls, equipment, etc. does not influence the results, the diaphragm B3 may be omitted. To this end, the radiation aperture of diaphragm B2 may be made variable so that the beam remains tightly collimated as distance is changed.

A diaphragm B4, whose shortest dimension shall be at least 15 mm, may be positioned directly in front of the combination in order to limit the area of the exposure.

The attenuating properties of the diaphragms shall be such that their transmission into shielded areas does not contribute to the results of the measurements by more than 0,1 %. The radiation aperture of the diaphragm B1 shall be large enough so that the penumbra of the radiation beam will be outside the sensitive volume of the monitoring detector R1 and the radiation aperture of diaphragm B2.

The radiation aperture of diaphragm B2 shall be smaller than 100 mm; that of B3 shall have a diameter of 100 mm ± 10 mm.

A monitoring detector R1 may be inside the beam that exposes the combination if it is suitably transparent and free of structure, otherwise it shall be placed outside the beam. The precision of the monitoring detector shall be better than ± 2 %.

An attenuating protective barrier shall be at least 450 mm beyond the last area involved in the measurement. The space between the combination or the radiation detector R2 (see Figures 1 and 2) and the protective barrier shall contain nothing but air.