INTERNATIONAL STANDARD

ISO 5799

Second edition
1991-08-01

Photography — Direct-exposing medical and dental radiographic film/process systems — Determination of ISO speed and ISO average gradient

Photographie — Ensembles film/traitement destinés à la radiographie médicale sans écran et à la radiographie dentaire — Détermination de la sensibilité ISO et du contraste moyen ISO

Reference number
ISO 5799:1991(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 5799 was prepared by Technical Committee ISO/TC 42, *Photography*.

This second edition cancels and replaces the first edition (ISO 5799:1981), which has been technically revised.

Annexes A, B, C and D of this International Standard are for information only.

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Introduction

This revision of ISO 5799 has been primarily necessitated by the decision to adopt the recommendation of the International Commission of Radiation Units and Measurements to use the gray as a measure of X and γ radiation in place of coulombs per kilogram of air. This has required changing the speed constant. The International Standard now includes updated references, and speed and average gradient tables compatible with the format of other radiographic film standards.

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Photography — Direct-exposing medical and dental radiographic film/process systems — Determination of ISO speed and ISO average gradient

1 Scope

This International Standard specifies methods for determining the ISO speed and ISO average gradient of the film/process combinations used in medical and dental radiography other than mammography. Sensitometric procedures are described for films exposed directly to X-rays. The purpose of this International Standard is to provide a method for the measurement of ISO speed and ISO average gradient so that the characteristics of the film/process system can be obtained reproducibly and can also be compared with those of other systems.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard 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 5-2:1985, *Photography — Density measurements — Part 2: Geometric conditions for transmission density.*

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

ISO 4037:1979, *X and gamma reference radiations for calibrating dosemeters and dose ratemeters and for determining their response as a function of photon energy.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 air kerma, K: The energy, which is transferred by ionizing radiation (for instance X-rays) to air molecules, divided by the mass of air in that volume where the energy is released.

3.2 speed: A quantitative measure of the response of the photographic material to radiant energy for the specified conditions of exposure, processing, and image density measurement.

3.3 average gradient: The slope of the straight line joining two specified points on a sensitometric curve.

3.4 gray, Gy[1]: The absorbed dose of X and/or γ radiation in 1 kg of air which produces charged particles and imparts 1 J of initial kinetic energy to those charged particles.

4 Sampling and storage

In determining the ISO speed and ISO average gradient of a product, it is important that the samples evaluated yield the average results obtained by users. This will require evaluating several different batches periodically under conditions specified in this International Standard. Prior to evaluation, the samples shall be stored according to the manufacturers' recommendations for a length of time to simulate the average age at which the product is normally used. Several independent evaluations shall be made to ensure the proper calibration of

1) 1 Gy = 1 J/kg of air is equivalent to 114,5 R or is equivalent to 0,029 5 C/kg

equipment and processes. The basic objective in selecting and storing samples as described above is to ensure the film characteristics are representative of those obtained by a consumer at the time of use.

5 Method of test

5.1 Principle

Samples are exposed and processed as specified below. Measurements are obtained from the resultant images to produce a sensitometric curve from which values are taken and used to determine ISO speed and ISO average gradient.

5.2 Safelights

To eliminate the possibility of safelight illumination affecting the sensitometric results, all films shall be handled in complete darkness during exposing and processing.

5.3 Exposure

5.3.1 Film holders

Films shall be exposed in holders which provide less than 2 % absorption of the radiation specified (without lead screens).

Dental films shall be exposed in the original packet or a wrapping of equivalent absorption.

5.3.2 Sampling conditions

The sample shall be at a temperature of 23 °C ± 5 °C and be equilibrated with air at a relative humidity of (50 ± 20) % during exposure.

If the film packet contains two films, the film towards the side with the radiation source shall be used. If the packet contains lead backing, the backing shall be away from the radiation source.

5.3.3 Radiant energy quality

The tungsten target X-ray tube shall fulfil all reproduction conditions for radiation as specified in ISO 4037. Inherent filtration of the tube plus an additional aluminium[2] filter located as close to the target as possible shall provide a total filtration equivalent to 7,0 mm ± 0,5 mm of aluminium.

The kilovoltage[3] of the X-ray tube shall be adjusted until the half value in aluminium is 3,0 mm ± 0,2 mm, i.e. the exposure rate of the X-ray beam with a total filtration equivalent to 10,0 mm aluminium shall be one-half the value obtained with the total filtration equivalent to 7,0 mm of aluminium. The 3,0 mm aluminium half-value layer absorber shall be placed at a maximum from the target of one-half the distance between the X-ray target and the ion chamber.

5.3.4 Scattered radiation

To minimize scattered radiation when exposing test films, X-ray beams shall be collimated to as small a size as will permit a uniform exposure field for the films (and the measuring device, if included). The amount of scattered radiation reaching the film and measuring device shall be no greater than 5 % of the primary radiation. Constructing the supports for the film, filters, and ion chamber from low atomic number materials and making such structures as light in mass as possible will minimize scattered radiation (see annex C).

5.3.5 Modulation

The film shall be given a graduated series of exposures such as will result in a series of densities above base plus fog from 0,2 to 2,3. The exposure over the useful area of each exposure step shall be uniform to within 3 %. The $\log_{10}$ of the exposure increments shall not exceed 0,15. Each exposure shall be measured, in grays, by using an ionization chamber calibrated for the radiant energy quality and intensity used for exposing the film[4]. A separate sample of the film shall be left unexposed for measuring inherent base plus fog density.

5.4 Processing

5.4.1 Conditioning of samples

In the time interval between exposure and processing, the samples shall be kept at 23 °C ± 5 °C and be equilibrated with air at a relative humidity of (50 ± 20) %. The processing shall be started between 30 min and 8 h after exposure.

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2) Any grade in table 1 of ISO 209-1:1989, *Wrought aluminium and aluminium alloys — Chemical composition and forms of products — Part 1: Chemical composition*, may be used (the ISO symbols are Al 99,0 — Al 99,5 — Al 99,7 — Al 99,8).

3) In constant potential equipment, a value between 50 kV and 55 kV is required. In equipment without electrical smoothing, approximately 60 kV is satisfactory.

4) If the instrument can be calibrated only at certain half-value layers close to but not identical with those specified in 5.3.3, then interpolation at the specified half-value layer from a plot of the calibrations over a bracketing range of half-value layers is permissible. Annex A lists suitable radiant energy.

5.4.2 Processing specifications

No processing specifications are described in this International Standard in recognition of the wide range of chemicals and equipment used. ISO speed and ISO average gradient data provided by the film manufacturers generally apply to the film when it is processed in accordance with their recommendations to produce the photographic characteristics specified for the process. Process information shall be available from the film manufacturers or others who quote ISO speed and ISO average gradient. This shall specify the chemicals, times, temperatures, agitation, equipment, and procedure 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 various processing procedures may differ significantly. Although different speeds and average gradients for a particular film may be achieved by varying the process, the user should be aware that other sensitometric and physical changes may also accompany the speed and average gradient changes.

5.5 Densitometry

ISO standard visual diffuse transmission density of the processed images shall be measured using a densitometer complying with the geometric requirements specified in ISO 5-2 and spectral requirements specified in ISO 5-3. A minimum aperture of 7 mm^2 shall be used. Reading shall be at least 1 mm from the edge of the exposure.

5.6 Evaluation

5.6.1 Sensitometric curve

The ISO standard visual diffuse transmission density values shall be plotted against the logarithm to the base 10 of the corresponding air kerma, expressed in grays, to obtain a sensitometric curve similar to that shown in figure 1.

5.6.2 Base plus fog density

The combination of base plus fog density shall be determined from an unexposed sample of the same film processed simultaneously with the sample exposed for determining the sensitometric curve.

6 Product classification

6.1 ISO speed determination

The exposed and processed samples used for this determination shall be measured as described in 5.5. The densities shall be plotted against the logarithm to the base 10 of the measured air kerma, in grays[5], as in figure 1. From the speed point density, 1,0 above base plus fog density, the corresponding log kerma, $\log_{10} K_s$ shall be determined.

Raw speed values are derived from the formula

$$S = \frac{10^{-2}}{K_s}$$

ISO speed shall be obtained directly from $\log_{10} K_s$ by use of table 1 which shows the rounding to be used.

5) This use of SI units results in numerical values of speed which are not very different from current values. Current practice assigns an arbitrary speed of 100 to image recording systems which produce net densities of about 1,0 when exposed to 10 mR (milliroentgens). Since 10 mR = $8{,}732 \times 10^{-5}$ Gy (grays) the speed calculated for that exposure, using the formula proposed in this International Standard, yields a speed of 114,5.

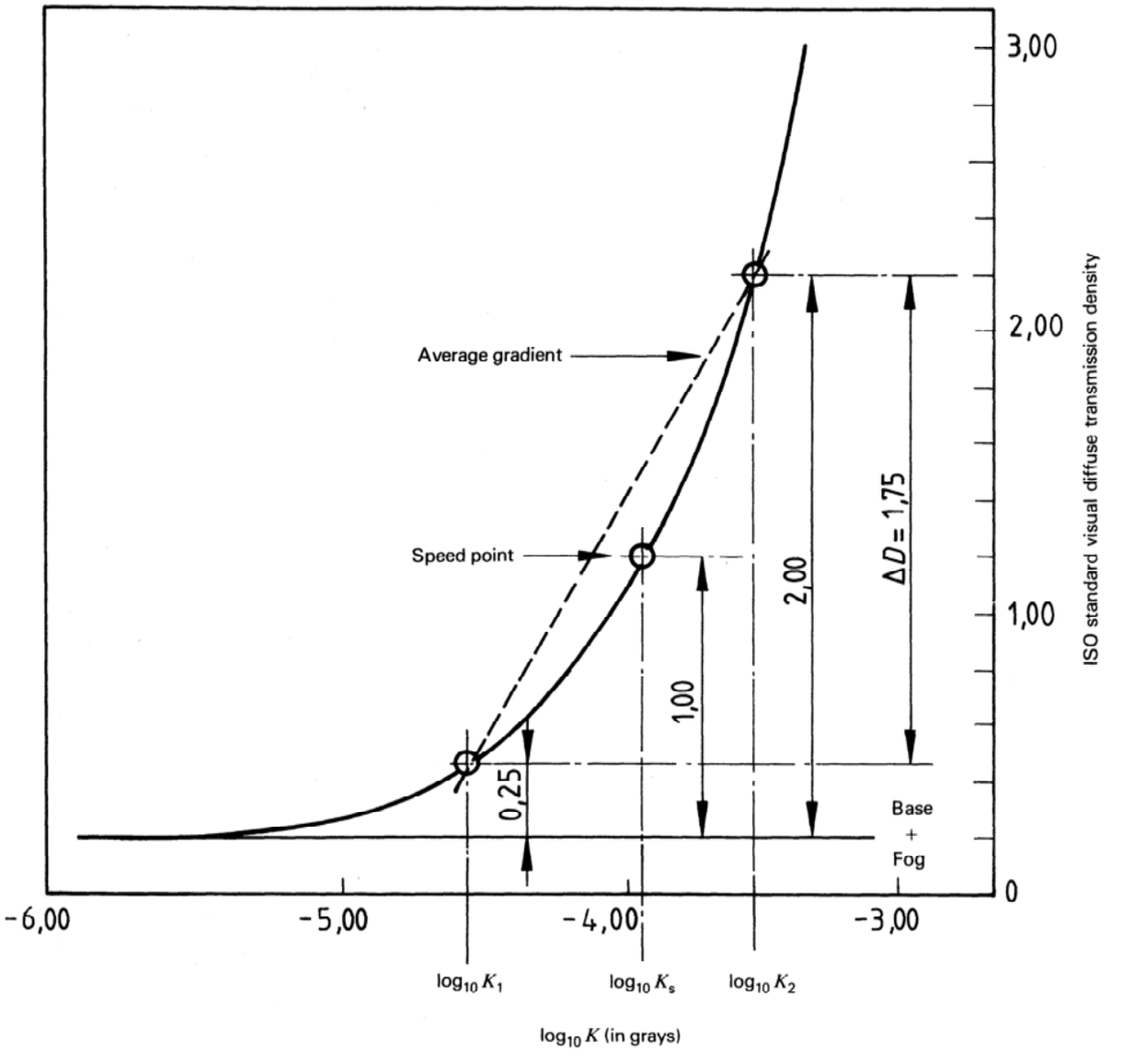

Figure 1 — Method for determining ISO speed and ISO average gradient

Table 1 — ISO speed scale

$\log_{10}K_s$		ISO speed (S)
From	To	
−5,05	−4,96	1 000
−4,95	−4,86	800
−4,85	−4,76	640
−4,75	−4,66	500
−4,65	−4,56	400
−4,55	−4,46	320
−4,45	−4,36	250
−4,35	−4,26	200
−4,25	−4,16	160
−4,15	−4,06	125
−4,05	−3,96	100
−3,95	−3,86	80
−3,85	−3,76	64
−3,75	−3,66	50
−3,65	−3,56	40
−3,55	−3,46	32
−3,45	−3,36	25
−3,35	−3,26	20
−3,25	−3,16	16
−3,15	−3,06	12
−3,05	−2,96	10
−2,95	−2,86	8
−2,85	−2,76	6
−2,75	−2,66	5
−2,65	−2,56	4

6.1.1 ISO speed of a product

The ISO speed of a product, as distinguished from that of a specific sample, shall be based on the arithmetic average of the logarithms, $\log_{10}K_s$, determined from various batches of the product when selected, stored, and tested as specified above. Since ISO speed is dependent on exposure and development conditions, these should be indicated when quoting ISO speed values.

6.1.2 Dental films

The speed of dental films is calculated using the formula given in 6.1 from the average value of K_s. The speed group letter is then obtained from the use of table 2.

Table 2 — ISO speed scale

ISO speed range[1)]	ISO speed group letter
7,0 to 14,0	C
14,0 to 28,0	D
28,0 to 56,0	E
56,0 to 112,0	F

1) The upper limit of each ISO speed range shall be excluded from that range.

6.2 ISO average gradient determination

6.2.1 ISO average gradient scale

The average gradients, $\overline{G}$, given in table 3 are derived from the equation

$$\overline{G} = \frac{D_2 - D_1}{\log_{10}K_2 - \log_{10}K_1} = \frac{1{,}75}{\log_{10}K_2 - \log_{10}K_1}$$

where

D_1 is the density of the point on the curve which is 0,25 above base plus fog density;

D_2 is the density of the point on the curve which is 2,00 above base plus fog density;

K_1 is the air kerma, in grays, associated with D_1;

K_2 is the air kerma, in grays, associated with D_2.

In some applications where the density range of radiographs is limited (as in the case of uniform specimens), an average gradient measurement close to the density level used may be more appropriate. For example, a $\overline{G}$ between 1,00 and 1,50 above base plus fog density may be advantageous in a situation where densities are close to 1,25 above base plus fog density. However, unless $\overline{G}$ is determined as specified in this International Standard, it cannot be referred to as an ISO average gradient. ISO average gradient shall be obtained directly from $\log_{10}K_2 - \log_{10}K_1$ by use of table 3 which shows the rounding method to be used.

6.2.2 ISO average gradient of a product

The ISO average gradient of a product, as distinguished from that of a specific example, shall be based on the arithmetic average of $\log_{10}K_2 - \log_{10}K_1$ for various batches of product when selected, stored, and tested as specified in this International Standard. The ISO average gradient of a product with proper rounding is then determined from the average value by use of table 3.

6.3 Accuracy

The calibration of the equipment and processes involved in determining film speed shall be adequate to ensure the error in $\log_{10}K_s$ is less than $\pm 0{,}05$ and for average gradient less than ± 5 %.

Table 3 — ISO average gradient scale

$\log_{10}K_2 - \log_{10}K_1$		ISO $\overline{G}$
From	To	
1,67	1,84	1,0
1,49	1,66	1,1
1,32	1,48	1,2
1,17	1,31	1,4
1,03	1,16	1,6
0,93	1,02	1,8
0,83	0,91	2,0
0,75	0,82	2,2
0,67	0,74	2,5
0,61	0,66	2,8
0,54	0,60	3,0
0,47	0,53	3,5
0,41	0,46	4,0
0,37	0,40	4,5

7 Product marking and labelling

7.1 ISO speed designation

The speed of a product determined by the method described in this International Standard should be designated ISO speed and denoted in the form ISO XD 100 for X-ray direct exposure techniques.

7.2 ISO average gradient designation

The average gradient of a product determined by the method specified in this International Standard, and expressed on the scale of table 3, should be designated ISO average gradient and denoted in the form ISO $\overline{G}$ 2,8.

7.3 General

Since ISO speed and ISO average gradient are not only dependent on the film but also on the process used to develop the image, the processing specification should be given when quoting values.

The values obtained from this International Standard are not comparable with those obtained by following the methods specified in other standards. For this reason it is suggested that the values used in the methods described in this International Standard be referred to as "Medical".

Annex A
(informative)

Calibration parameters

NBS technique	kV	Added filtration	HVL[1] (mm Al)
H 40 H 50 H 60	50 60 100	4,05 mm Al + 0,26 mm Cu 4,0 mm Al + 0,10 mm Pb 4,0 mm Al + 0,61 mm Cu	2,9 4,2 6,0
M 50 M 60 M 100	50 60 100	1,02 mm Al 1,51 mm Al 5,0 mm Al	1,02 1,68 5,0
S 60	60	4,0 mm Al	2,8
NOTE — Response at the desired characteristics (55 kV, 5,5 mm Al added filtration, 3,0 mm Al HVL) can be determined on a plot of half-value layer against chamber response only if interpolations are made using radiations from the **same** group (H or M).			
1) HVL: Half-value layer.			

Annex B
(informative)

Improvement of the reproducibility measurement of X-rays

To improve the reproducibility of measurement of X-radiation, the ionization chamber used shall fulfil the following requirements:

a) an ionization chamber shall be used when variation in response per unit exposure is small and known as a function of photon energy, over the energy range in question;

b) certain precautions shall be taken when measuring the ionization currents, in particular, it is essential that saturation conditions always apply and corrections be made for background radiation levels, electronic noise, or drift of measuring apparatus and for variations in atmospheric conditions;

c) a monitor chamber should be used in order to permit application of corrections for fluctuations in exposure rate.

Annex C
(informative)

Scattered radiation measurement

The method for determining the extent of scattered radiation contributing to the exposure may vary, depending on its origin. Where the diameter of the primary source is less than one-tenth its distance from the film, the use of the inverse square law may be employed to determine the contribution of scattered radiation to the exposure of a test as follows:

If d is the distance from the source, plot the (exposure rate $\times$ d^2) against d. Extrapolating the graph to zero distance yields the (exposure rate $\times$ d^2) value, P, resulting from the primary radiation only. In order to comply with this International Standard, the actual (exposure rate $\times$ d^2) value for the normal test distance shall not be more than 5 % greater than P.

Annex D
(informative)

Units of measurement

D.1 Radiation effect

The effect of X and γ radiation on matter can be expressed in terms of the number of charged particles produced by the release of electrons per unit mass. For example, 1 R will release $1{,}610 \times 10^{15}$ electrons per kilogram of air. This is equivalent to $2{,}58 \times 10^{-4}$ C/kg.

The same effect can also be measured in terms of the amount of initial kinetic energy released for all the charged particles created in a unit mass of air (kerma). To release $1{,}610 \times 10^{15}$ electrons in air requires $8{,}732 \times 10^{-3}$ J. The amount of energy in joules released per kilogram of air is designated in grays (1 J/kg = 1 Gy). Absorbed dose is also expressed in terms of grays.

In this International Standard, exposure, absorbed dose, or energy is expressed in grays. By use of the equations given below it can be shown that 1 Gy is equivalent to 114,5 R or 0,029 5 C/kg of air.

Likewise, 1 R is equivalent to $8{,}732 \times 10^{-3}$ Gy as seen in the following calculations:

$$1\ \mathrm{R} = \frac{1\ \mathrm{esu}}{0{,}001\ 293\ \mathrm{g\ air}}$$

$$= \left(\frac{1\ \mathrm{esu}}{0{,}001\ 293\ \mathrm{g}} \times 10^{-3}\ \frac{\mathrm{g}}{\mathrm{kg}} \right) \times$$

$$\times \left(\frac{2{,}082 \times 10^{9}\ \mathrm{electrons}}{1\ \mathrm{esu}} \right) \times \left(\frac{33{,}85\ \mathrm{eV}}{\mathrm{electron}} \right) \times$$

$$\times \left(\frac{1{,}602 \times 10^{-19}\ \mathrm{J}}{\mathrm{eV}} \right) = 8{,}732 \times 10^{-3}\ \mathrm{Gy}\ (\mathrm{J \cdot kg^{-1}})$$

1 C = $6{,}242 \times 10^{18}$ electrons

1 esu = $2{,}082 \times 10^{9}$ electrons

1 R produces 1 esu in 0,001 293 g of air (or $1{,}602 \times 10^{15}$ electrons per kilogram of air)

1 eV = $1{,}602 \times 10^{-12}$ ergs = $1{,}602 \times 10^{-19}$ J

33,85 eV $\pm$ 0,15 eV is the energy required for an electron to produce an ion pair in air [1].

D.2 Bibliography

[1] International Commission on Radiation Units Measurememt 1979 , *Report No. 31,* Average energy required to produce an ion pair.

[2] NCRP Report No. 82, SI Units in Radiation Protection and Measurements, *Recommendations of the National Council on Radiation Protection and Measurements,* issued 13 August 1985.

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