INTERNATIONAL STANDARD

ISO 7004

Second edition
2002-10-01

Photography — Industrial radiographic films — Determination of ISO speed, ISO average gradient and ISO gradients *G*2 and *G*4 when exposed to X- and gamma-radiation

Photographie — Films pour radiographie industrielle — Détermination de la sensibilité ISO, du contraste moyen ISO et des contrastes ISO G2 et G4 après exposition à des rayons X ou gamma

Reference number
ISO 7004:2002(E)

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Printed in Switzerland

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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 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 7004 was prepared by Technical Committee ISO/TC 42, *Photography*.

This second edition cancels and replaces the first edition (ISO 7004:1987), of which it constitutes a technical revision.

Annexes A to F of this International Standard are for information only.

Introduction

This International Standard specifies methods for measuring the ISO speed, ISO average gradient and ISO gradients *G*2 and *G*4 of industrial radiographic film systems when exposed directly to X- and γ-radiation. Many countries have had national standards relating to this subject for many years and may provide values which are different from those obtained by following the procedure specified in this International Standard. Because the photographic characteristics of a film system are dependent on the energy distribution in the wavelength spectrum, four representative sources are specified for determining sensitometric characteristics. To minimize the differences between national standards and this International Standard, the minimum requirements for X-ray tubes and X-ray generators have been considered mandatory and have been clearly specified in the subclause on radiation quality (5.3.3). This International Standard imposes limiting specifications on the thickness of the metallic screens often used in conjunction with the film as specified in the basic rules for good radiographic practice in ISO 5579.

Photographic results are also dependent on the chemical process used to develop the film. This International Standard does not attempt to specify the processing method; therefore, when ISO speed or ISO gradient values are given for a film system, it is necessary to specify not only the radiation quality used but also the process. This will permit the comparison of systems consisting of film and film processing.

Photography — Industrial radiographic films — Determination of ISO speed, ISO average gradient and ISO gradients *G*2 and *G*4 when exposed to X- and gamma-radiation

1 Scope

This International Standard specifies methods for determining sensitometric curve shape, ISO speed, ISO average gradient and ISO gradients *G*2 and *G*4 for industrial radiographic systems consisting of film and film processing when exposed directly to X-rays and γ-rays. The measurement of characteristics of film systems used in industrial radiography with fluorescent intensifying screens is not specified in this International Standard.

NOTE Units of measured energy are given for information in annex A.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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 4037-1:1996, *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 1: Radiation characteristics and production methods*

ISO 5579: 1998, *Non-destructive testing — Radiographic examination of metallic material by X- and gamma rays — Basic rules*

3 Terms and definitions

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

3.1
radiographic film
transparent plastic sheet coated on one or both sides with a photographically sensitive layer

3.2
film system
system consisting of a radiographic film, the film processing and, when in use, the lead foil(s) and film holder

3.3
system type
all film systems manufactured in the same way and of the same specification, but without consideration of the format

NOTE A particular system type is specified by the type of film, type of processing and, when in use, the type of lead foil(s) and film holder.

3.4
film/screen combination
radiographic film in direct contact with metallic screen(s) during exposure to X- or γ-radiation

NOTE Within the scope of this International Standard, the screens are lead foils.

3.5
radiation quality
characteristic of ionizing radiation, determined by its spectral distribution with respect to energy

3.6
exposure technique
radiation source and filtration of the radiation beam in order to obtain a specified radiation quality at the source side of the film or film/screen combination holder

3.7
minimum density
D_{min}
ISO standard visual diffuse transmission density, D_{T}, of an unexposed and processed sample of the film under test

3.8
net density
D_{N}
ISO standard visual diffuse transmission density, D_{T}, of an exposed and processed film minus the minimum density, D_{min}, of the film under test

3.9
speed
quantitative measure of the response of the photographic material to radiant energy for specified conditions of exposure, processing and image measurement

3.10
average gradient
$\bar{G}$
slope of the straight line joining two specified points on a sensitometric curve

3.11
gradient
Gx
slope $\mathrm{d}D/d \log K$ of the tangent to the sensitometric curve at a specified net density $D_{\mathrm{N}} = x$

NOTE It is a measure of the contrast obtainable with the film system.

3.12
gray
Gy
special name for the unit of air kerma and the unit of absorbed dose, which is joule per kilogram

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

4 Sampling and storage

In determining the sensitometric curve, ISO speed, ISO average gradient and ISO gradients *G*2 and *G*4 of a film system, 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 manufacturer's recommendations for a length of time that simulates the average age at which the product is normally used. Several independent evaluations shall be made to ensure the proper calibration of equipment and processes. The basic objective in selecting and storing samples as described above is to ensure that 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 in 5.3 and 5.4. Measurements are obtained from the resultant images to produce a sensitometric curve from which values are taken and used to determine ISO speed, ISO average gradient and ISO gradients *G*2 and *G*4.

5.2 Safelights

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

5.3 Exposure

5.3.1 Film holders

Film/screen combinations shall be exposed in holders which provide less than 2 % absorption of the radiation specified (without taking into account lead screens).

5.3.2 Sample condition

During exposure, the samples shall be at a temperature of 23 °C ± 5 °C and in equilibrium with air at a relative humidity of 50 % ± 20 %.

5.3.3 Radiation quality

5.3.3.1 General

Four specific exposing sources (two X-ray sources and two γ-ray sources) are recognized in this International Standard to cover the range of exposing conditions used in practice. The selection of which of the four sources is used to determine ISO speed, ISO average gradient and ISO gradients *G*2 and *G*4 depends on how the film system is used.

To improve the reproducibility of exposures when X-ray tubes are used, the X-ray generator shall fulfil the following requirements (based on ISO 4037-1):

a) X-radiations shall be produced by an X-ray unit of the constant-voltage type;

b) during an irradiation, the main value of the high voltage shall be stable within ± 1 %; it should be possible to display the mean value of the high voltage with a tolerance of ± 1 %;

c) the target of the X-ray tube shall be made of tungsten and shall be of the reflection type; the target angle should be about 22°.

5.3.3.2 X-rays from a low potential source

The film/screen combination under test shall be exposed to X-rays from tungsten target tubes. Inherent filtration of the tube, plus an additional copper filter located as close to the target as possible shall provide a filtration equivalent to 2,0 mm ± 0,1 mm of copper. All copper filters specified in this International Standard shall be made of 99,9 % pure copper.

The potential across the X-ray tube shall be adjusted until the half-value absorption is obtained with 1,0 mm ± 0,1 mm of copper (i.e. the intensity of the X-ray beam with a filtration equivalent to 3,0 mm shall be one-half the value obtained with the total filtration equivalent to 2,0 mm of copper).

A potential of approximately 120 kV generally meets this requirement. No lead screens shall be used.

This is designated source (1).

5.3.3.3 X-rays from a high potential source

The film/screen combination under test shall be exposed to X-rays from tungsten target tubes. Inherent filtration of the tube, plus an additional copper filter located as close to the target as possible shall provide a filtration equivalent to 8,00 mm ± 0,05 mm of copper. The potential across the X-ray tube shall be adjusted until the half-value absorption is obtained with 3,5 mm ± 0,2 mm of copper.

A potential of approximately 220 kV generally meets this requirement.

Film/screen combinations shall be exposed without interleaving paper and shall be between lead-foil screens. A trial exposure should be made to make sure that the lead-foil screens do not produce streaks or other obvious defects.

The front and back lead-foil screens shall be between 0,020 mm and 0,150 mm thick.

It should be noted that changes in screen thickness may result in changes in the sensitometric characteristics. Therefore, screen thickness shall be reported when quoting ISO speeds.

Single-coated films shall be exposed with the emulsion-coated surface facing the X-ray tube. To obtain sufficient contact, vacuum cassettes or pressure shall be used.

This is designated source (2).

5.3.3.4 Gamma rays from an iridium-192 (^{192}Ir) source

A filtration of 8,0 mm of copper near the source is required. Film thickness shall be between lead-foil screens with a thickness between 0,02 mm and 0,2 mm.

A trial exposure should be made to make sure that the lead-foil screens do not produce streaks or other obvious defects. It should be noted that changes in screen thickness may result in changes in the film speed. Therefore, screen thickness shall be reported when quoting ISO speeds.

This is designated source (3).

5.3.3.5 Gamma rays from a cobalt-60 (^{60}Co) source

Lead-foil screens shall be between 0,10 mm and 0,50 mm thick.

A trial exposure should be made to make sure that the lead-foil screens do not produce streaks or other obvious defects.

It should be noted that changes in screen thickness may result in changes in film speed. Therefore, screen thickness shall be reported when quoting ISO speeds.

This is designated source (4).

5.3.4 Scattered radiation

To minimize scattered radiation when exposing test film/screen combinations, X-ray and γ-ray beams shall be diaphragmed and 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 6 % of the primary radiation. Constructing the supports for the film system, filters and ion chamber from materials of low atomic number and making such structures as light in mass as possible will minimize scattered radiation (see informative annex B).

5.3.5 Modulation

To determine speed and gradient values, it is necessary to provide exposures that will result in a minimum of 12 data points distributed between the densities of 1,0 and 5,0 above minimum density. In practice, this is carried out by changing the exposure time, step by step, combined with a gradual change in radiation dose. The exposure over the useful area of each exposure step shall be uniform to within 3 %.

For each exposure, the air kerma, in grays, shall be measured by using an ionization chamber calibrated for the radiant energy quality and intensity used for exposing the film. (See annexes C and D for additional information.) A separate sample of the film shall be left unexposed for measuring inherent minimum 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 $\pm$ 5 °C and in equilibrium with air at a relative humidity of 50 % $\pm$ 20 %.

The processing shall be started between 30 min and 8 h after exposure.

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 gradient data provided by the film manufacturer generally apply to the film when it is processed in accordance with the manufacturer's recommendations to produce the photographic characteristics specified for the process.

Process information shall be available from the film manufacturer or others who quote ISO speed and ISO gradients. 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 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 the spectral requirements specified in ISO 5-3.

Readings shall be made in a uniform area of the image. Typically, this is at least 1 mm from the edge of the exposed area.

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 exposures, K, expressed in grays, to obtain a sensitometric curve similar to that illustrated in Figure 1.

5.6.2 Minimum density, D_{min}

The minimum 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

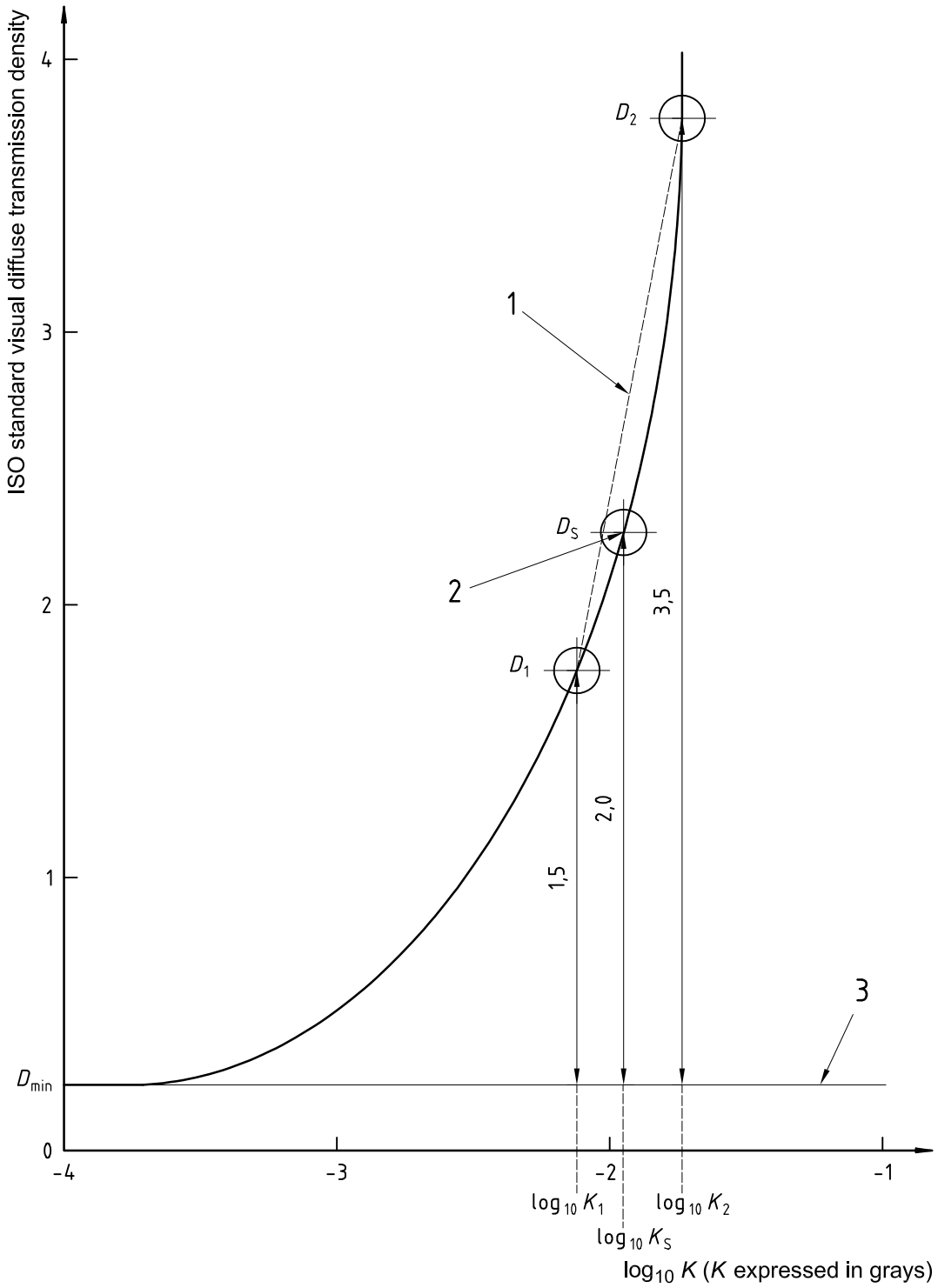
6.1 Speed calculation

6.1.1 General

Raw speed values are derived from the formula

$$S = \frac{1}{K_{\text{s}}}$$

where K_{s} is the air kerma, in grays, required to produce a net density of 2,00 (see Figure 1).



Key

1 Average gradient
2 Speed point
3 Minimum density

Figure 1 — Determination of speed and average gradient

6.1.2 ISO speed

The ISO speed shall be obtained directly from $\log_{10}K_S$ using Table 1, which effectively translates it to one of the designated ISO speeds in the ISO speed scale. The procedure is to first determine $\log_{10}K_S$ as in Figure 1. The appropriate $\log_{10}K_S$ range is then selected from the two columns on the left side of Table 1 and the corresponding ISO speed is found in the right-hand column of Table 1.

Table 1 — ISO speed scale

$\log_{10}K_S$		ISO speed
from	to	
– 3,05	– 2,96	1000
– 2,95	– 2,86	800
– 2,85	– 2,76	640
– 2,75	– 2,66	500
– 2,65	– 2,56	400
– 2,55	– 2,46	320
– 2,45	– 2,36	250
– 2,35	– 2,26	200
– 2,25	– 2,16	160
– 2,15	– 2,06	125
– 2,05	– 1,96	100
– 1,95	– 1,86	80
– 1,85	– 1,76	64
– 1,75	– 1,66	50
– 1,65	– 1,56	40
– 1,55	– 1,46	32
– 1,45	– 1,36	25
– 1,35	– 1,26	20
– 1,25	– 1,16	16
– 1,15	– 1,06	12
– 1,05	– 0,96	10
– 0,95	– 0,86	8
– 0,85	– 0,76	6
– 0,75	– 0,66	5
– 0,65	– 0,56	4

6.1.3 ISO speed of a system type

The ISO speed of a system type, as distinguished from that of a specific sample, shall be based on the arithmetic mean of the logarithms of exposures, $\log_{10}K_s$, determined from various batches of the system type when selected, stored and tested as specified above.

The ISO speed of a system type with proper rounding is then determined from the average value of $\log_{10}K_s$ using Table 1. Since ISO speed is dependent on exposure conditions, development conditions and lead-screen thicknesses, these shall be indicated when quoting ISO speed values.

6.2 Average gradient calculation

6.2.1 General

Raw average gradient values are derived from the equation

$$\bar{G} = \frac{D_2 - D_1}{\log_{10} K_2 - \log_{10} K_1} = \frac{2{,}00}{\log_{10} K_2 - \log_{10} K_1} \tag{1}$$

where

D_1 is the density of the point on the curve which is 1,50 above minimum density;

D_2 is the density of the point on the curve which is 3,50 above minimum density;

K_1 is the air kerma required to produce D_1;

K_2 is the air kerma required to produce D_2.

6.2.2 ISO average gradient

The ISO average gradient is rounded off to one digit after the comma, from the raw average gradient defined in 6.2.

In some applications where the density range of radiographs is very 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 $\bar{G}$ between 1,50 and 2,50 above minimum density may be advantageous in a situation where densities are close to 2,00 above minimum density. However, unless $\bar{G}$ is determined as specified in this International Standard, it cannot be referred to as an ISO average gradient.

6.2.3 ISO average gradient of a system type

The ISO average gradient of a system type, as distinguished from that of a specific sample, shall be based on the arithmetic mean of roundings off to one digit after the comma, from the raw average gradients defined in 6.2.

This will be done for various batches of the film/process combination when selected, stored and tested as specified in this International Standard.

6.3 Point gradient determination

6.3.1 Determination of gradients *G*2 and *G*4

Gradients *G*2 and *G*4 relate respectively to the gradients at net densities D_N = 2,00 and D_N = 4,00. They relate to a sensitometric curve, i.e. a diffuse transmission density versus $\log_{10} K_2$ plot. Within the scope of this International Standard, *G*2 and *G*4 however are calculated from the slope dK/dD of a K vs D curve at net densities of D_N = 2,00 and D_N = 4,00.

$$G = \frac{\mathrm{d}D}{\mathrm{d}\log_{10} K_x} = \frac{K_x}{\log_{10} \mathrm{e}} / \frac{\mathrm{d}K}{\mathrm{d}D} \tag{2}$$

where K_x represents the air kerma required to obtain the specified density x. (For the derivation of this relationship, see informative annex E.)

The K vs. D curve is approximated by a polynomial of the third order.

$$K = aD^3 + bD^2 + cD + d \tag{3}$$

$$\frac{\mathrm{d}K}{\mathrm{d}D} = 3aD^2 + 2bD + c \tag{4}$$

*G*2 and *G*4 are obtained by calculating dK/dD for net densities of 2,00 and 4,00 by means of equation (4) and then calculating *G*2 and *G*4 from equation (2) for the respective dK/dD values.

6.3.2 ISO gradients *G*2 and *G*4

ISO gradients *G*2 and *G*4 shall be obtained directly from the raw *G*2 and *G*4 values obtained using the above-mentioned equations and rounded off to one digit after the comma.

6.4 Uncertainty

The equipment involved in determining the speed, average gradient and gradients *G*2 and *G*4 shall be adequately calibrated to ensure that the expanded uncertainty (level of confidence of 95 %) for speed determination is less than 0,05 for $\log_{10} K_s$ and less than 5 % for gradients.

NOTE 1 This level of confidence will generally be achieved by use of a coverage factor k of approximately 2 (see reference [7] in the bibliography).

NOTE 2 This association of confidence level and coverage factor is based on assumptions regarding the probability distribution of measurement results. For a more thorough explanation, see reference [7] in the bibliography.

7 Marking and labelling

7.1 ISO speed

The ISO speed of a film system or a system type determined by the method described in this International Standard and expressed on the scale of Table 1 shall be designated ISO speed and denoted in the form

ISO (2) 100

The number in parentheses indicates the radiation used [i.e. (2) is for the source described in 5.3.3.3].

7.2 ISO average gradient

The average gradient of a film system or a system type determined by the method specified in this International Standard shall be designated the ISO average gradient and denoted in the form

ISO (2) $\bar{G}$ 4,3

7.3 ISO gradients *G*2 and *G*4

The point gradients *G*2 and *G*4 determined by the method specified in this International Standard shall be designated ISO gradients *G*2 and *G*4 and denoted in the form

ISO (2) *G*2 6,6

7.4 General

Since ISO speed, ISO average gradient and ISO gradients *G*2 and *G*4 are not only dependent on the film, but also on the process used to develop the image, on the source and on the screens employed, these shall be given when quoting the 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 determined using the methods described in this International Standard be referred to as “industrial”.

Annex A
(informative)

Units of measured energy

The quantity of X- and γ-radiation energy 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.

The amount of radiation energy 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 may be designated grays (1 J/kg = 1 Gy). Absorbed dose may also be expressed in terms of grays.

In this International Standard, absorbed dose, or energy deposited per unit mass is expressed in grays. Using 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 shown in the following calculations:

$$1\,\mathrm{R} = \frac{1\,\mathrm{esu}}{0{,}001\,293\ \mathrm{g\ air}} = \frac{1\,\mathrm{esu}}{0{,}001\,293\ \mathrm{g}} \times \frac{10^3\,g}{\mathrm{kg}} \times \frac{(2{,}082 \times 10^9\ \mathrm{electrons})}{(1\,\mathrm{esu})} \times \frac{(33{,}85\ \mathrm{eV})}{(\mathrm{electron})} \times$$

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

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

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

— 1 R produces $2{,}58 \times 10^{-4}$ C in 0,001 293 kg of air (or $1{,}610 \times 10^{15}$ electrons per kilogram of air)

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

— $33{,}85 \pm 0{,}15$ eV is the energy required for an electron to produce an ion pair in air (ICRU 31, see [3] in the bibliography).

Annex B
(informative)

Scattered radiation measurement

The method of 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 6 % greater than P.

Annex C
(informative)

Calibration of ionization chambers

It may not be possible to have ionization chambers calibrated with the radiation qualities mentioned in 5.3.3. In such a case, ionization chamber response at the required qualities may be determined by interpolation on a plot of calibrations over a bracketing range of half-value layers.

Ionization-chamber response for the half-value layers specified in 5.3.3.2 and 5.3.3.3 may be determined by interpolation on a plot of half-value layers against chamber response of the radiations[1)] given in informative annex F.

Instruments to be used with the γ-rays specified in 5.3.3.4 and 5.3.3.5 may be calibrated with the γ-rays from cobalt-60 or iridium-192.

In the determination of film speeds, it is permissible to calibrate the working instrument with which the film exposures are measured against an instrument calibrated by standards laboratories.

1) Test-fee schedule of NIST, appearing in Title 15 — Commerce and Foreign Trade, Chapter II — NIST (US Department of Commerce), Sub-chapter A, Test fee schedules, Part 204 — Radiation Physics, *Federal Register*, **25**(284) 1960-12-22: pp. 13215 - 13217; **26**(189) 1961-09-30: pp. 9224-9225.

Annex D
(informative)

Improvement of the reproducibility of measurement of X-radiation

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

a) An ionization chamber should be used when the 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 should 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 variations in atmospheric conditions.

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

Annex E
(informative)

Derivation of the relationship used in the determination of *G*2 and *G*4

The relationship shown in 6.3.1, $G = \frac{\mathrm{d}D}{\mathrm{d}\log_{10} K_x} = \frac{K_x}{\log_{10}\mathrm{e}} / \frac{\mathrm{d}K}{\mathrm{d}D}$, may be derived as follows:

$$\frac{\mathrm{d}D}{\mathrm{d}\log_{10} K_x} = \frac{\mathrm{d}D}{\log_{10}\mathrm{e} \cdot \mathrm{d}\log_{\mathrm{e}} K_x}$$

$$= \frac{\mathrm{d}D}{\log_{10}\mathrm{e} \cdot \dfrac{\mathrm{d}K}{K_x}}$$

$$= \frac{K_x}{\log_{10}\mathrm{e}} / \frac{\mathrm{d}K}{\mathrm{d}D}$$

Annex F
(informative)

Radiation quality code

NIST [a] designation	Constant potential	Approximate thickness of inherent filter	Thickness of added filter				Thickness of half-value layer
		Al	Pb	Sn	Cu	Al	Cu
	kV	mm	mm				mm
HFG	150	1,5	0	1,5	4,0	2,5	2,4
HF1	200	1,5	0,7	4,0	0,6	2,5	4,1

[a] National Institute of Standards & Technology (USA).

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