INTERNATIONAL STANDARD

ISO 9236-3

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

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

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

Partie 3: Détermination de la forme de la courbe sensitométrique, de la sensibilité et du contraste moyen pour la mammographie

Reference number
ISO 9236-3:1999(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 9236-3 was prepared by Technical Committee ISO/TC 42, *Photography*.

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 2: Determination of the modulation transfer function (MTF)*

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

Annexes A and B of this part of ISO 9236 are for information only.

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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 mammography.

The sensitometric curve, 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, using a sensitometer which is mainly based on the photometric inverse square law. For the determination of the sensitometric curve shape, the irradiation of the screen/film/filmholder combination need be measured only in relative units.

While the average gradient is determined from the sensitometric curve shape, speed has to be measured in a separate way, since the exposure conditions should simulate as closely as possible those which are used in practice. Therefore, scattered radiation is included, accompanied by a slight change of beam quality compared to the beam quality used for intensity scale sensitometry. The clinical exposure is simulated by using both an appropriate phantom and tube voltage. The screen/film/filmholder combination is exposed behind the phantom. The exposure shall be measured in absolute units (gray, Gy) in order to determine the speed.

Speed is generally dependent on X-ray energy, the amount of scattered radiation and the exposure time. Therefore, some variation in speed values may be expected under practical conditions. However, as the range of tube voltages applied in screen/film mammography is small, this part of ISO 9236 describes only one beam quality for speed measurement. The measurement conditions described in this part of ISO 9236 provide values for speed and average gradient which are representative of those found under practical conditions.

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

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

1 Scope

This part of ISO 9236 specifies methods for determination of the sensitometric curve shape, average gradient and speed of a single sample of a screen/film/filmholder/processing system in mammography.

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

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

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9236. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9236 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 5-2:1991, *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*.

3 Definitions

For the purposes of this part of ISO 9236, the following definitions apply.

3.1 **air kerma, K:** 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. The unit is the gray (Gy).

3.2 sensitometric curve: Plot of the density of a processed photographic film as a function of the logarithm of the exposure.

3.3 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.

3.4 average gradient, $\overline{G}$ **:** Slope of the straight line joining two specified points on a sensitometric curve.

3.5 net density D**:** Density of an exposed and processed film minus the density of an unexposed and processed sample of that film.

4 General requirements

4.1 Storage and handling conditions

The films and screens shall be stored according to the manufacturers' recommendations. Before and during exposures, the temperatures of the films and screens shall be maintained at (23 ± 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 a 6-pulse, 12-pulse, high frequency (multipulse), or constant-potential generator shall be used.

For dosimetry, a measuring detector shall be used that is calibrated to measure air kerma for the beam quality applied. The accuracy of readings shall be better than ± 5 % for collimated beams without scatter, and better than ± 7 % for radiation measurements behind the phantom when scattered radiation is included.

NOTE — A spherical ionization chamber is recommended for measurements where scattered radiation is involved. 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 focal spot direction.

4.4 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. Different speeds for a particular film may be achieved by varying the processes, but the user should be aware that other changes may accompany the speed 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 ± 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.

NOTES

1 The information about the necessary correction may easily be gained by exposing film strips in a light sensitometer and varying the time between exposure and processing. In the case of double-emulsion films, care should be taken that both front and back emulsions are exposed equally by the sensitometer.

2 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 prescribed. That 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 formula;

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 solution to within 3 %;

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;

g) drying temperature to within ± 5 °C;

h) trade designation of processing equipment.

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

4.5 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 densities, D, shall be measured with an accuracy of $\Delta D/D = \pm 0{,}02$ or $\Delta D = \pm 0{,}02$, whichever is the greater.

5 Determination of sensitometric curve shape

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

5.1 Beam qualities

For the determination of the sensitometric curve shape, either of the two 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 7.2.2 and figure 4).

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

Beam quality number	**Anode material**	**Approximate X-ray tube voltage** kV	**Inherent filtration** mm Mo	**Added filtration** mm Mo + mm Al	**Half value Layer** mm Al[1)]
I	Mo	28	0,03	0,00 2,1	0,63 ± 0,02
II	W	28	0,03	0,03 2,1	0,63 ± 0,02

1) The half-value layer is chosen to approximate the clinical exit beam from the breast. It shall be placed behind the added filtration.

Inherent and added filtration may differ from the numbers given in table 1, under the condition that the sum of the inherent filtration and the added filtration, known as total filtration, remains unchanged. For the total filtration, the tolerances are ± 0,005 mm for molybdenum filters and ± 0,1 mm for aluminium filters. The aluminium and molybdenum used as filter materials shall have a purity of at least 99,9 %.

5.2 Geometry for curve shape determination

The geometrical set-up of the measuring arrangement shall comply with figures 1 and 2. As a consequence of the influence of air on beam quality, the distance between the focal spot of the tube and the plane of the mammographic film shall not be greater than 3 m.

NOTE In practice, X-ray beams emerging from mammographic tubes are usually asymmetric insofar as they extend much more to the anode side than to the cathode side. In the laboratory, this beam asymmetry can often be reduced by changing diaphragming directly at the tube or by rotating the tube by several degrees. Symmetric X-ray beams, as shown in all the figures except figure 3, are not a precondition for applying the methods described in this part of ISO 9236.

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 measuring detector R2 shall be in a fixed relation at each distance from the radiation source. The incident face of the diaphragm B3 shall be (100 ± 5) mm in front of the plane of the mammographic 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 the diaphragm B2 may be made variable so that the beam remains tightly collimated as the distance is changed.

A diaphragm B4, whose shortest dimension shall be at least 5 mm, may be positioned directly in front of the combination in order to limit the area of the film exposed.

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 the diaphragm B2.

The radiation aperture of the diaphragm B2 shall be small enough that no part of the beam can pass outside the diaphragm plate of the diaphragm B3 or B4, respectively. Collimation performed by the radiation aperture of the diaphragm B3 shall be as narrow as possible but still permit the X-ray beam to cover the radiation aperture of the diaphragm B4 or the sensitive volume of the measuring detector R2, respectively.

A monitoring detector R1 may be placed inside the beam utilized to expose 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 R1 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 measuring detector R2 and the protective barrier shall contain nothing but air.

5.3 Exposure

Each exposure of the combination shall be achieved in one uninterrupted irradiation. The irradiation time shall be in the range of 0,5 s to 1,5 s and shall be kept constant for all exposures.

NOTE 1 With the use of intensifying screens, reciprocity law failure and the intermittency effect may occur. In order to avoid the influence of these effects, a single irradiation with a constant irradiation time in the specified range of irradiation times is required for each exposure.

The different values of air kerma shall be obtained preferably by varying the distance from the radiation source to the plane of the mammographic film. It shall be verified that the HVL, according to table 1, remains within the tolerance for all distances used. Additionally, the tube current may be varied. It shall be verified that the variation of tube current does not change the beam quality. The maximum increments of $\log_{10}$ exposure shall not be greater than 0,1.

Dimensions in metres

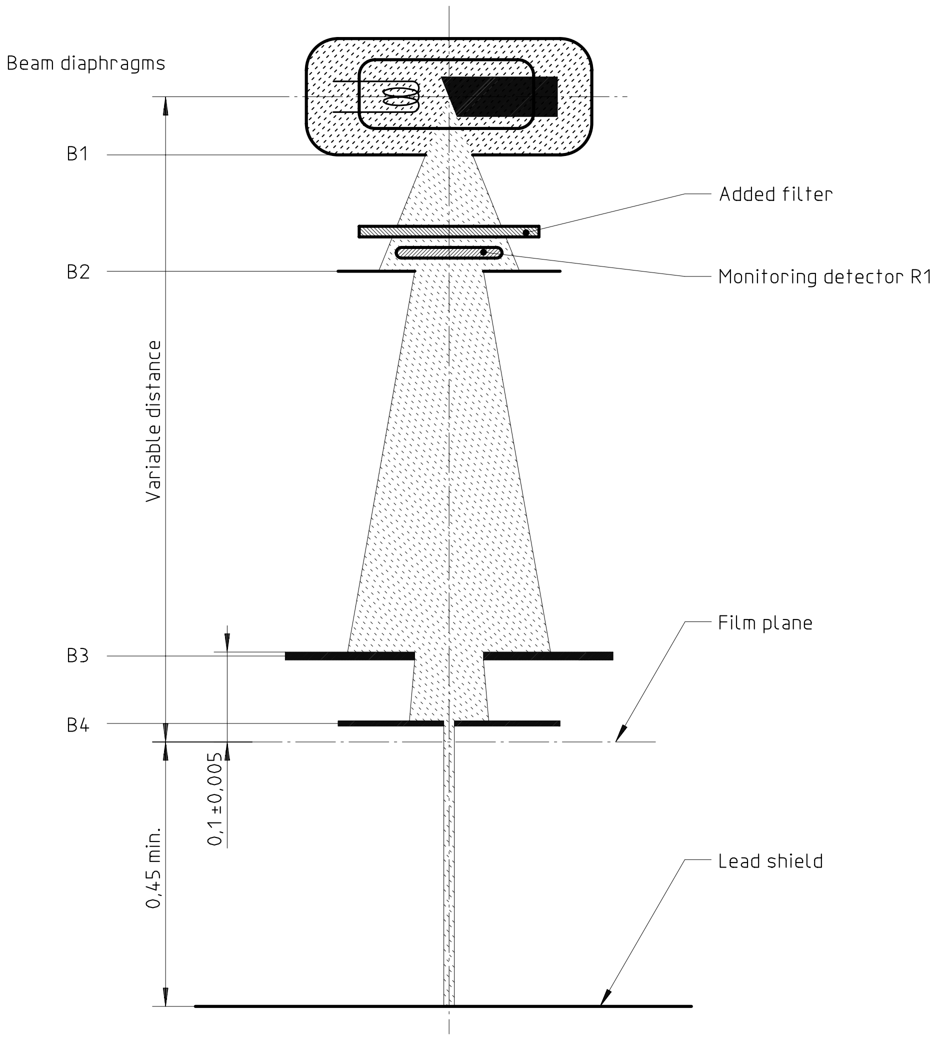


Figure 1 — Geometric set-up of the inverse-square-law sensitometer for irradiation of a screen/film/filmholder combination

Dimensions in metres

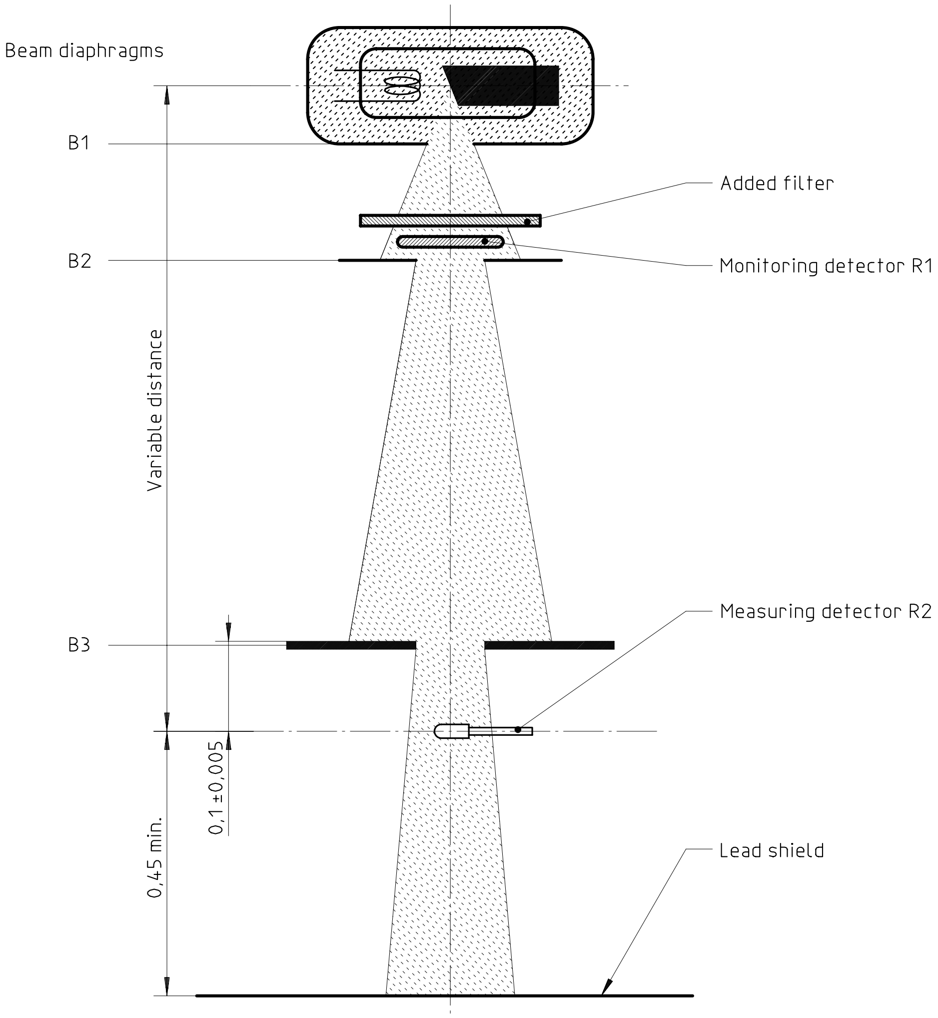


Figure 2 — Geometric set-up for calibration of the inverse-square-law sensitometer

For determination of the sensitometric curve, at least 20 different exposures are necessary, equally distributed on a logarithmic scale, that produce net densities from 0,1 to 2,1. To accurately define the curve at low densities, at least three exposures, producing net densities between 0,1 and 0,25, shall be made. The time interval between the different exposures should normally not exceed 30 s, but shall never exceed 2 min.

NOTES

2 An upper net density value of about 2,1 is just the minimum needed for determination of the average gradient $\overline{G}$ as described in clause 6. Especially in mammography, the sensitometric curve shape at much higher density values is also very important. In addition, if a mathematical algorithm is used to find a smooth curve describing the measured relation between $\log_{10}$ air kerma and density (see 5.4), then it may be necessary to produce net densities well above 2,1 to reduce a discontinuity error.

3 Since it is difficult to manage all necessary steps of moving the filmholder, changing the distance and verifying the monitor reading, an automated procedure is recommended (see annex A).

5.4 Evaluation

The density is plotted against the corresponding $\log_{10}$ air kerma values. Through the points, a smooth curve is drawn either by hand or by an appropriate algorithm. It should be possible to read densities and relative exposure values (log to the base 10 units) to the nearest 0,01 from the curve (figure 3).

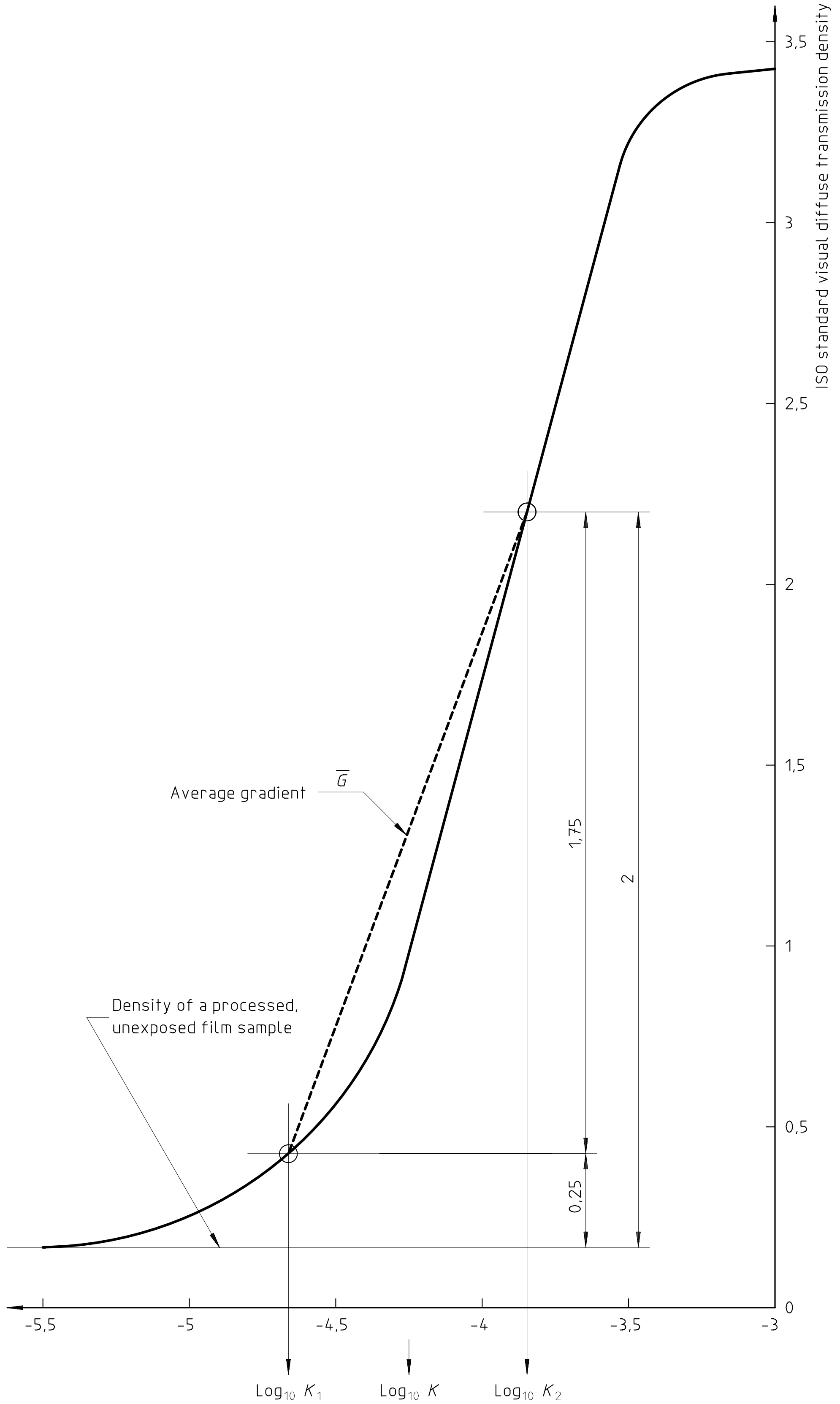


Figure 3 — Example of a sensitometric curve of a screen/film system for mammography

6 Determination of average gradient

The average gradient $\overline{G}$ is calculated from:

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

where

D_2 and D_1 are net densities having the values 2,00 and 0,25 respectively;

K_2 and K_1 are the corresponding relative values of air kerma extracted from the sensitometric curve.

For the determination of the average gradient, either of the two beam qualities specified in table 1 may be used.

NOTE — The average gradient as defined above is the most commonly used single sensitometric parameter used to predict the observed contrast of a developed radiographic image.

7 Determination of speed

7.1 Definition

The speed S is calculated from:

$$S = \frac{K_0}{K_s}$$

where

K_0 is 10^{-3} Gy;

K_s is the air kerma (in grays) incident on the combination behing a phantom to produce a net density of 1,0.

7.2 Exposure condition

To simulate the most common applications in screen/film mammography, with special emphasis on grid mammography, one exposure condition is defined and specified in table 2.

Table 2 — Exposure condition

Anode material	Approximate X-ray tube voltage 1) kV	Inherent filtration mm Mo	Half-value layer mm Al	Exposure time s	Distance between the back of phantom and the detector 2) mm
Mo	28	0,03 ± 0,005	0,63 ± 0,02	1,0 ± 0,1	100 ± 1

1) The geometry for establishing the tube voltage is described in 7.2.2. The beam quality I for determining the sensitometric curve shape (table 1) and the beam quality for determining the speed (this table) correspond to each other.

2) When the detector is the combination, the distance is measured to the film plane; otherwise it is measured to the reference point or plane of the measuring detector R2.

If it is impossible for technical reasons to use the exposure time given in table 2, then one exposure time in the range of 0,5 s to 2,0 s may be chosen, and the speed value belonging to an exposure time of 1,0 s may be determined by using the shape of the reciprocity-law-failure curve of the film, which will often be known from light sensitometry. If no reciprocity-law-failure curve of the film is used, then at least two other values of exposure time shall be chosen, and the speed value belonging to an exposure time of 1,0 s shall be determined by interpolation or extrapolation, respectively. If it is desired to investigate the dependance of speed on exposure time (reciprocity-law failure) in more detail, then additional values of exposure time may be chosen. All exposure-time values shall correspond to values used in clinical practice.

7.2.1 Phantom

For the determination of the speed, the combination shall be irradiated behind a phantom. This shall be a solid block of poly(methyl methacrylate) (PMMA) which has the shape of a cuboid. The outer dimensions of the phantom shall be:

length: 100 mm ± 1 mm; width: 100 mm ± 1 mm; height: 45 mm ± 0,5 mm.

7.2.2 Establishment of tube voltage

For all measurements of beam quality, the minimum distance between the focal spot and the measuring detector R2 shall be 1,0 m. Either the added filtration according to 5.1 or the phantom shall be placed between the tube and the second diaphragm (see figure 4). The distance between the second diaphragm and the measuring detector R2 shall be at least 0,8 m.

The tube voltage, given in tables 1 and 2, is recommended as a starting value. The tube voltage shall be adjusted until the measured half-value layer of aluminium is within ± 0,02 mm of the value given in tables 1 and 2. These adjustments shall be made at the tube currents used for the X-ray exposures which are described in 5.3 and 7.4.

Half-value-layer measurements shall be made with a detector whose spectral response is well known over the range of beam qualities used. Collimation at the tube, caused by the first diaphragm, shall be as narrow as possible but still permit the X-ray beam to cover the sensitive volume of the measuring detector R2. All subsequent screen/film exposures shall be made at the tube voltage and tube currents thus established.

7.3 Geometry

The geometry for the irradiation of the combination is shown in figure 5. The detector (either the combination or the measuring detector R2) is placed at a fixed distance, given in table 2, behind the back of the phantom. Collimation of the X-ray beam shall be as narrow as possible but still allow complete irradiation of the phantom's entrance area.

A monitoring-integrating detector R1 shall be mounted near the X-ray tube in such a way that it samples the intensity of the X-ray beam but does not, by its absorption, lead to a variation of radiant intensity over the radiation field defined by the collimating system. The monitoring detector R1 may be either outside or inside the beam used to irradiate the combination.

A measuring-integrating detector R2 replacing the combination shall be positioned as specified in figure 5 and subclause 4.3.

A lead shield shall be positioned at least 450 mm behind the combination or measuring detector R2.

7.4 Exposure

Subclause 7.1 states that speed is obtained from an air kerma K_S which results in a net density of 1,0. An approximate value for that air kerma may be estimated from the sensitometric curve, if density is not merely plotted as a function of relative exposure but as a function of air kerma. Otherwise, an approximate value for the air kerma shall be determined in preliminary measurements, using the phantom, and with the specified conditions of tube current and exposure time. Exposure time is either that given by the reading of the generator or by an external measuring device or shutter.

Measurements of air kerma and irradiations of the combination shall be done behind the phantom, with a focal spot-to-detector distance in the range of (1,0 ± 0,2) m.

Dimensions in metres

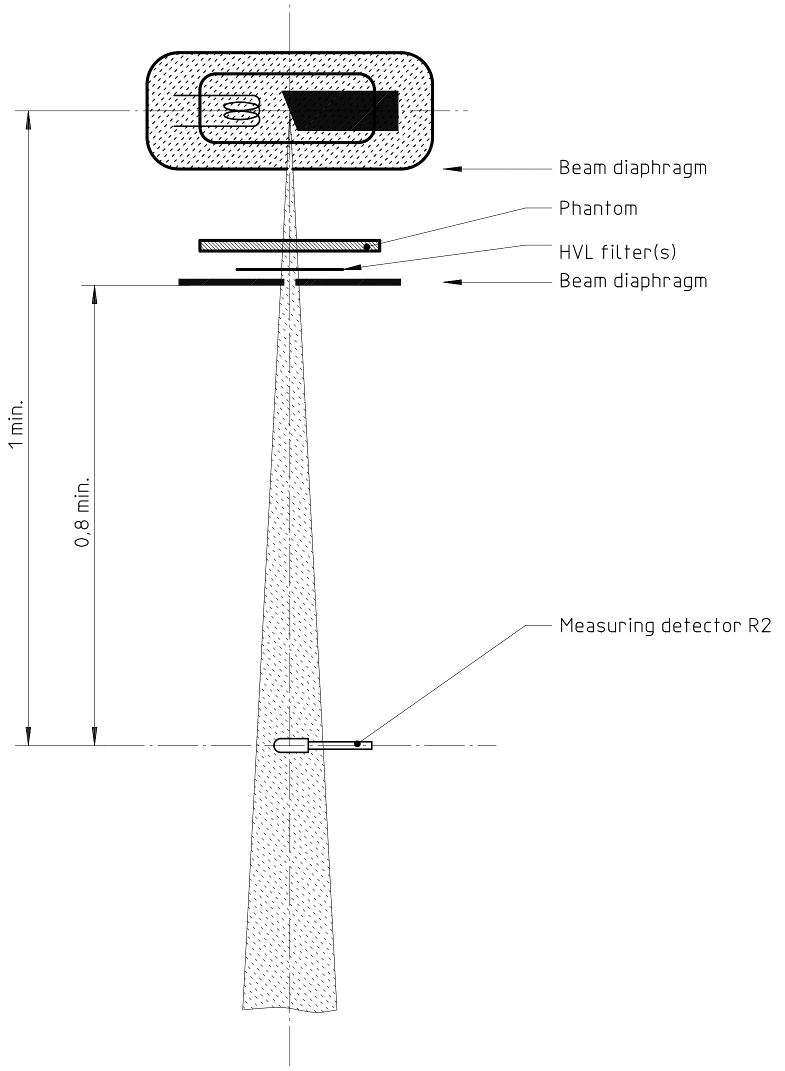


Figure 4 — Geometric set-up for measurement of half-value layer

Dimensions in metres

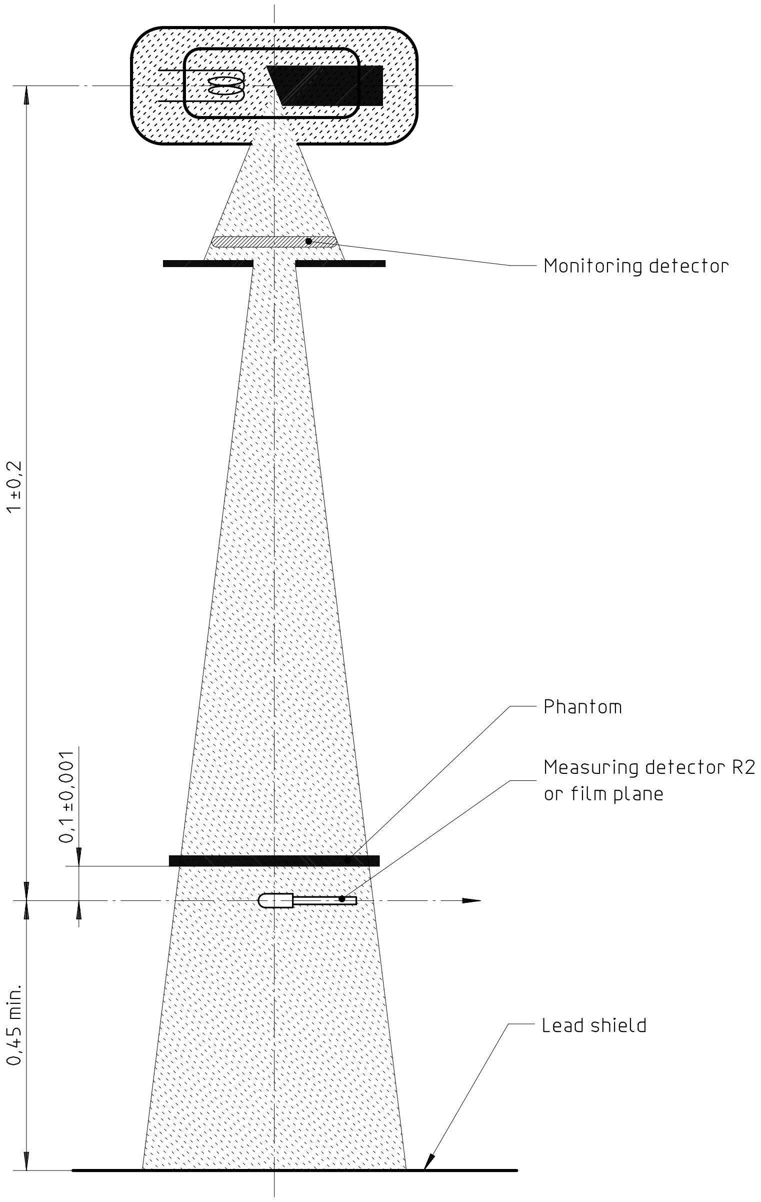


Figure 5 — Geometric set-up for determination of speed

A screen/film combination in the desired filmholder is then irradiated, and the film is processed. If the resulting net density is outside the range of 1,0 ± 0,3, the distance between focal spot and combination shall be corrected within the limits of 0,8 m to 1,2 m using the sensitometric curve as a guide. Three exposures are then made resulting in three images with net densities D_i = 1,0 ± 0,3. Air kerma values K_i corresponding to these three exposures are then calculated from the monitor readings M_i.

After the exposure of the combination, it is replaced by the measuring detector R2 and the exposure is repeated, holding the tube voltage, tube current, exposure time and distance to the tube unchanged. The reading X_{m} of the measuring detector R2 and the concurrent reading M_{m} of the monitoring detector R1 shall be recorded. If $\overline{X}_{\text{m}}$ and $\overline{M}_{\text{m}}$ are the means of three X-ray irradiations, the air kerma K_i of the combination may be calculated from the corresponding monitor reading M_i using the formula:

$$K_i = M_i(\overline{X}_{\text{m}} / \overline{M}_{\text{m}})$$

7.5 Evaluation

Using the sensitometric curve, the differences ΔD_i between net densities D_i and 1,0 are transformed into differences, $\Delta \log_{10} K_i$, which are used to correct the calculated K_i values to obtain K_i values for a net density of 1,0. The mean K_S of the three K_i values is used to calculate the speed *S* using the formula given in 7.1:

$$S = \frac{K_0}{K_S}$$

if K_S is given in grays and $K_0 = 10^{-3}$ Gy.

NOTE — Since, for the purpose of this part of ISO 9236, the shape of the sensitometric curve may be assumed to be the same for both beam qualities specified in table 1, the correction can be made with a curve produced by either of them.

8 Speed and average gradient determination without sensitometric curve

If there is interest only in speed and average gradient and not in the sensitometric curve shape, the following alternative procedure may be used.

The combination and the phantom shall be placed at positions which are in accordance with table 2 and figure 5. The tube current and, if necessary, the distance between the focal spot and the combination shall then be adjusted to produce a trial image whose processed net density is 1,0 ± 0,1, using an exposure time as specified in 7.2. The distance between focal spot and combination shall be (1,00 ± 0,15) m when the exposure for the trial image is made, and collimation of the X-ray beam shall be as narrow as possible but still allow irradiation of the phantom's entrance area completely. With the tube current used, the desired HVL, given in table 2, is adjusted according to 7.2.2. Then, three exposures of the combination shall be made at each of the distances 95 % and 105 % of the distance at which the trial image was produced, resulting in a total of six exposures. For each exposure, the reading M_i simultaneously produced by the monitoring detector R1 shall be recorded. The phantom-film distance shall be as specified in table 2 for all exposures.

Immediately following each set of three exposures, the filmholder containing the film and screen(s) shall be replaced by the measuring detector R2 and the previous exposure shall be repeated, holding the tube voltage, tube current, exposure time and phantom-detector distance unchanged. To provide a sufficient output reading from the measuring detector R2, the total air kerma may be increased by making multiple exposures. The air kerma K_i of the combination is calculated from M_i according to 7.4. For each of the six exposures producing net densities in the vicinity of 1,0, the densities shall be plotted against the measured air kerma. A best-fit straight line shall be drawn through the six points plotted and from this line the air kerma K_S to produce a net density of 1,0 shall be determined. The speed is calculated using the formula given in 7.5.

The average gradient shall be determined using the same mean distance as is used for the speed determination. Only the X-ray tube current shall be changed in order to adjust the exposure required to produce net densities of 0,25 ± 0,05 and 2,0 ± 0,1. After determining the tube currents required, the desired HVL, given in table 2, is adjusted according to 7.2.2 for each tube-current setting. Then, three exposures of the combination shall be made at each of the two different tube currents and at each of the distances 95 % and 105 % of the mean distance used for the speed determination, resulting in a total of 12 exposures. For each exposure, the reading M_i simultaneously produced by the monitoring detector R1 shall be recorded.

Immediately following each set of three exposures, the filmholder containing the film and screen(s) shall be replaced by the measuring detector R2 and the previous exposure shall be repeated, holding the tube voltage, tube current, exposure time and phantom-detector distance unchanged. The procedure, described above for speed determination, is repeated in order to determine the air kerma K_1 and K_2, to produce net densities of D_1 = 0,25 and D_2 = 2,0, respectively. The average gradient $\overline{G}$ is then calculated using the formula given in clause 6.

NOTE — Conventional mammographic X-ray generators usually operate at fixed tube currents for given values of tube voltage and focal spot size. With such equipment, determination of speed will still be possible, contrary to average gradient determination as described in this clause.

9 Accuracy

The specified accuracies for the detector, densitometer and beam quality calibration as well as the reproducibility of the monitor chamber, calibration error, beam inhomogeneity and uncontrolled scattering may cause the following uncertainties (σ-values):

$\Delta\overline{G} / \overline{G} = \pm$ 0,06 and

$\Delta S / S = \pm$ 0,10,

where the largest influence results from the detector calibration and beam quality measurement.

The influence of processing variability is not included.

With the above-mentioned accuracy of the method, the parameters of a specific single sample of a mammographic screen/film/filmholder/processing system may be measured.

10 Presentation

The sensitometric curve, speed and the average gradient shall be together with the following:

a) name of the test facility;

b) date of the measurement;

c) brand or trade name of the manufacturer or supplier, model or type reference, serial number or year of manufacture of the intensifying screen;

d) brand or trade name of the manufacturer or supplier, model or type reference, emulsion number or year of manufacture of the radiographic film;

e) type of filmholder:

   if a radiographic cassette is used as a filmholder, give the brand or trade name of the manufacturer or supplier, model or type reference, serial number or year of manufacture of the cassette;

f) exposure time;

g) processing conditions.

If the film is processed under conditions which differ from those recommended by the film manufacturer, then these conditions are to be reported in detail.

Annex A
(informative)

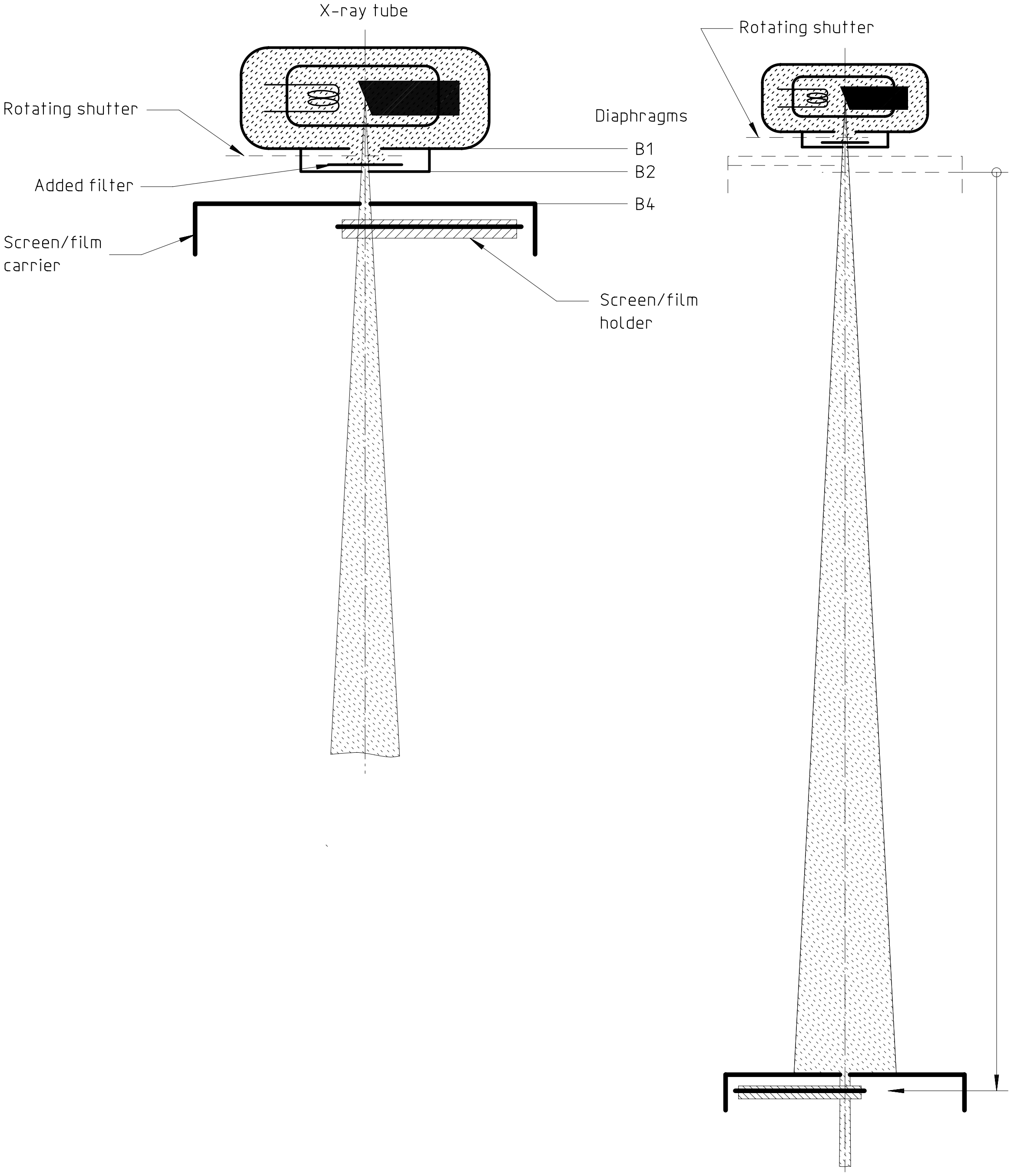
Example of an automated intensity-scale X-ray sensitometer

In this example of a sensitometer, a screen/film carrier is used for holding and moving the combination. Figure A.1 a) illustrates the position of the combination at its nearest position to the X-ray tube. Figure A.1 b) shows its position at one of the more remote distances.

The combination is moved incrementally within the carrier as the carrier moves in steps away from the X-ray tube. At each step, the carrier and the combination inside the carrier are automatically positioned and synchronized with the individual exposures. At each position, an unexposed area of the combination is presented for exposure.

In this example of a sensitometer, the high voltage of the generator is not switched off between the individual exposures. A rotating X-ray shutter wheel is used to select exposure time and to provide a constant exposure time for all positions of the carrier. These aims can also be reached by using an X-ray generator giving individual exposures of high reproducibility, but then a monitoring detector R1 should be used for verification.

The ratio of the focal-spot-to-film distance at the position nearest the X-ray tube to that at the most remote position determines the latitude of exposure available during a single run. The maximum distance used should be minimized to reduce air attenuation. Based on these considerations, diaphragm B3 is omitted in this example of a sensitometer to keep the nearest distance as small as possible. The size of B2 can be reduced as the carrier distance is increased to maintain tight diaphragming for additional scatter suppression.



a) Combination at its nearest position to the X-ray tube **b) Combination at one of the more remote distances**

Figure A.1 — Intensity-scale X-ray sensitometer

Annex B
(informative)

Bibliography

[1] ISO 5-1:1984, *Photography — Density measurements — Part 1: Terms, symbols and notations*.

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[3] ISO 5799:1991, *Photography — Direct-exposing medical and dental radiographic film/process systems — Determination of ISO speed and ISO average gradient.*

[4] ICRU Report 41 (1986), *Modulation Transfer Function of Screen-Film Systems.*[1)]

[5] ICRU Report 54 (1996), *Medical Imaging — The Assessment of Image Quality*.[1)]

1) These ICRU reports contain valuable information about X-ray imaging, X-ray sensitometry, bibliography and glossaries.

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Descriptors: photography, medical radiography, photographic film, radiographic film, tests, determination, sensitivity (photography).

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