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

Reference number
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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.

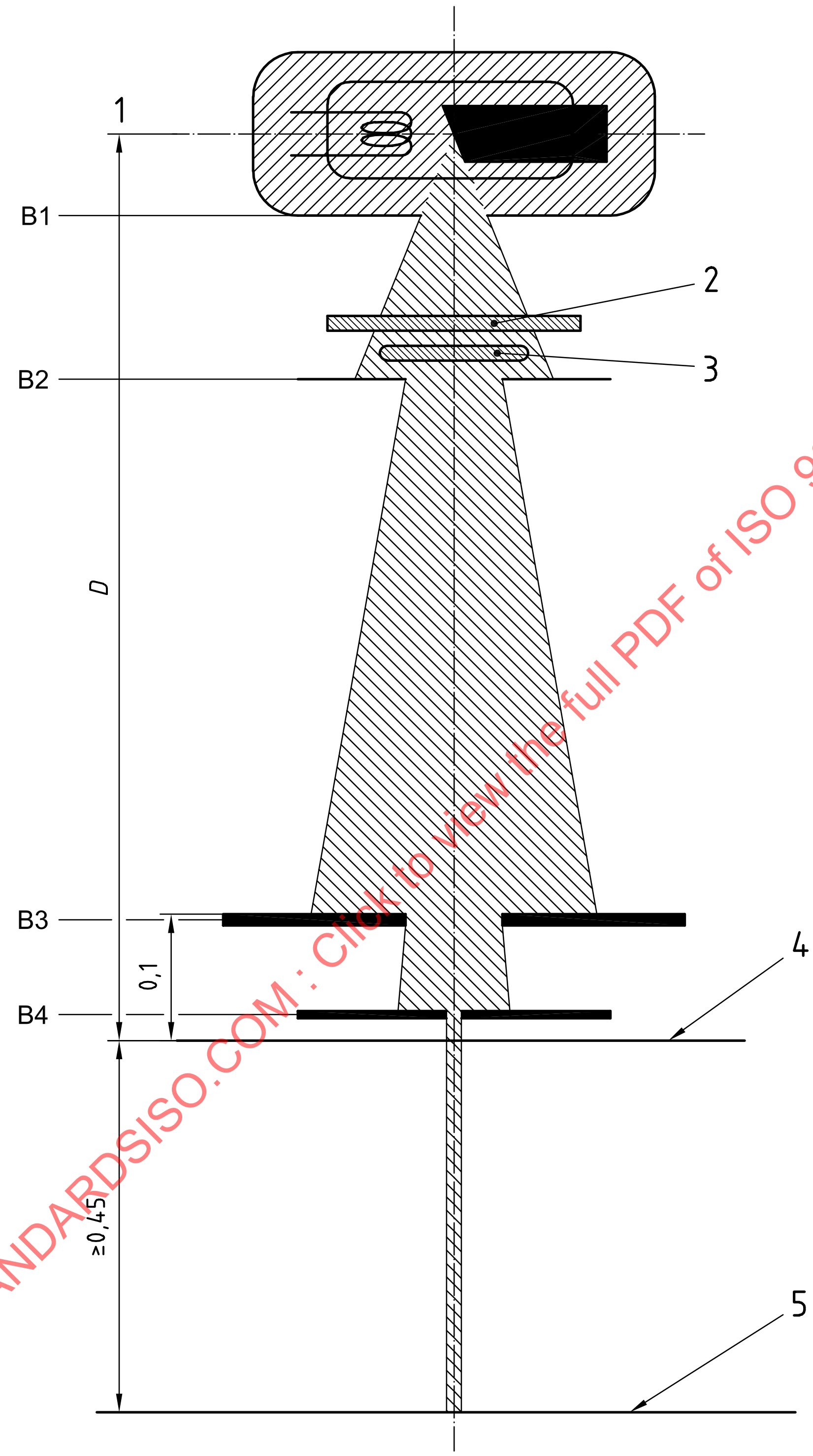
The attenuating properties of the diaphragms shall be such that their transmission into shielded areas does not contribute to the results of the measurements by more than 0,1 %. The radiation aperture of the diaphragm B1 shall be large enough so that the penumbra of the radiation beam will be outside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

Dimensions in metres

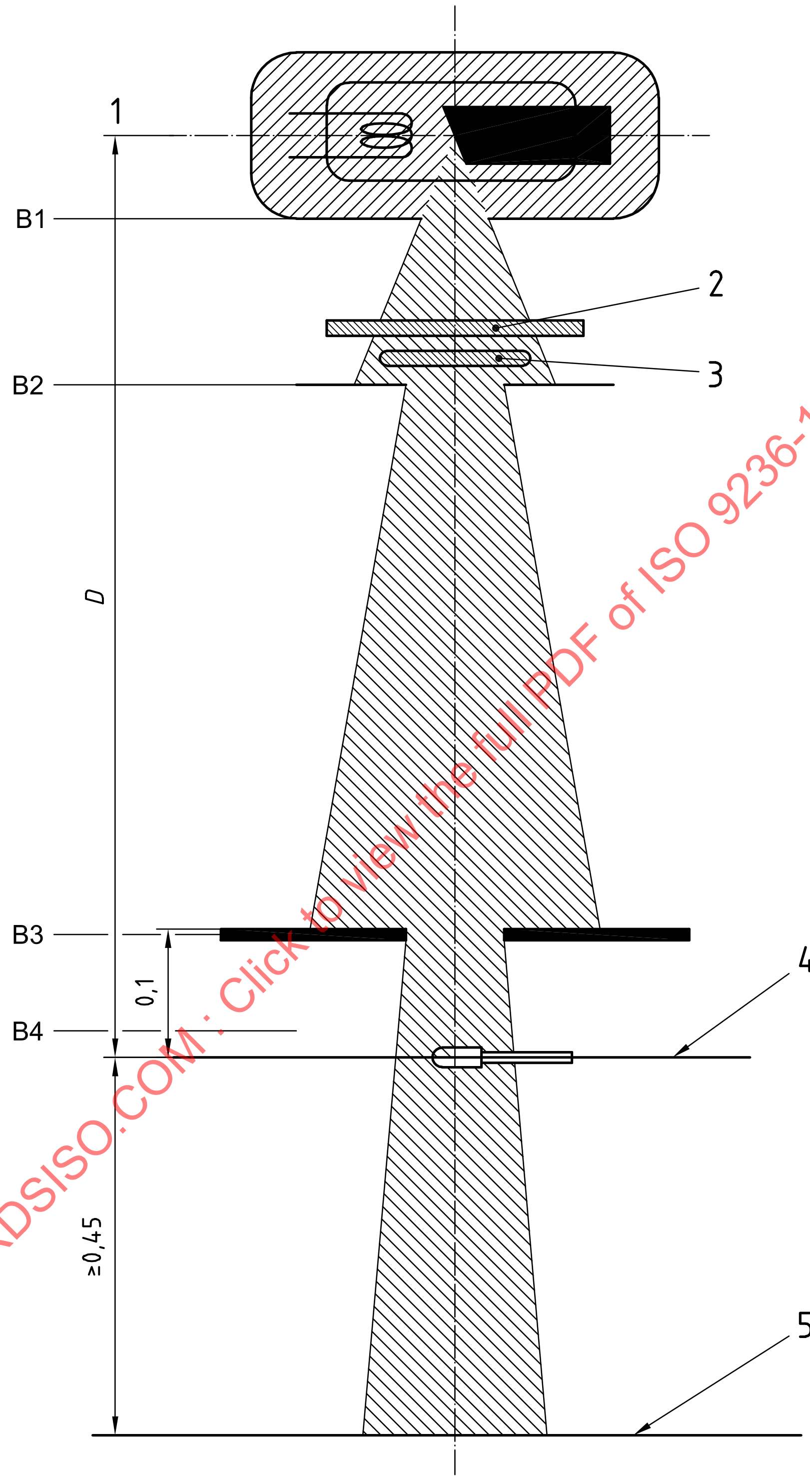


Key

1 beam diaphragms
2 added filter
3 monitoring detector (R1)
4 film plane
5 lead shield
D variable distance

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

Dimensions in metres



Key

1 beam diaphragms
2 added filter
3 monitoring detector (R1)
4 measuring detector (R2)
5 lead shield

D variable distance

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

5.4 Exposure

Each exposure of the combination shall be achieved in one uninterrupted irradiation. The exposure time shall be in the range (15 ± 5) ms to (60 ± 30) ms and shall be kept constant for all exposures.

NOTE 1 With the use of intensifying screens, reciprocity law failure and the intermittency effect can 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 necessary for each exposure.

The different values of air kerma shall be obtained exclusively by varying the distance from the radiation source to the plane of the radiographic film, with the exposure time and all other conditions of exposure constant. The increments of logarithmic (to the base 10) exposure shall not be greater than 0,1.

For determination of the sensitometric curve, 20 different exposures or more shall be made, equally distributed on a logarithmic scale, that produce net densities from 0,1 to at least 2,1. To define accurately 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 not exceed 30 s, but shall not exceed 2 min.

NOTE 2 An automated procedure such as that described in reference [4] in Bibliography can be used to manage the operation of moving the filmholder, changing the distance and verifying the monitor reading within the time period.

If one wishes to determine the shape of the sensitometric curve at much higher densities than 2,1 and the required intensity increase is not possible via decrease of distance, the exposure should be increased by an increase of the tube current, but it shall be verified that the higher tube current does not change the beam quality.

5.5 Evaluation

The density is plotted against the corresponding logarithmic (to the base 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 (logarithmic to the base 10 units) to the nearest 0,01 from the curve (see Figure 3).

6 Determination of average gradient

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

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

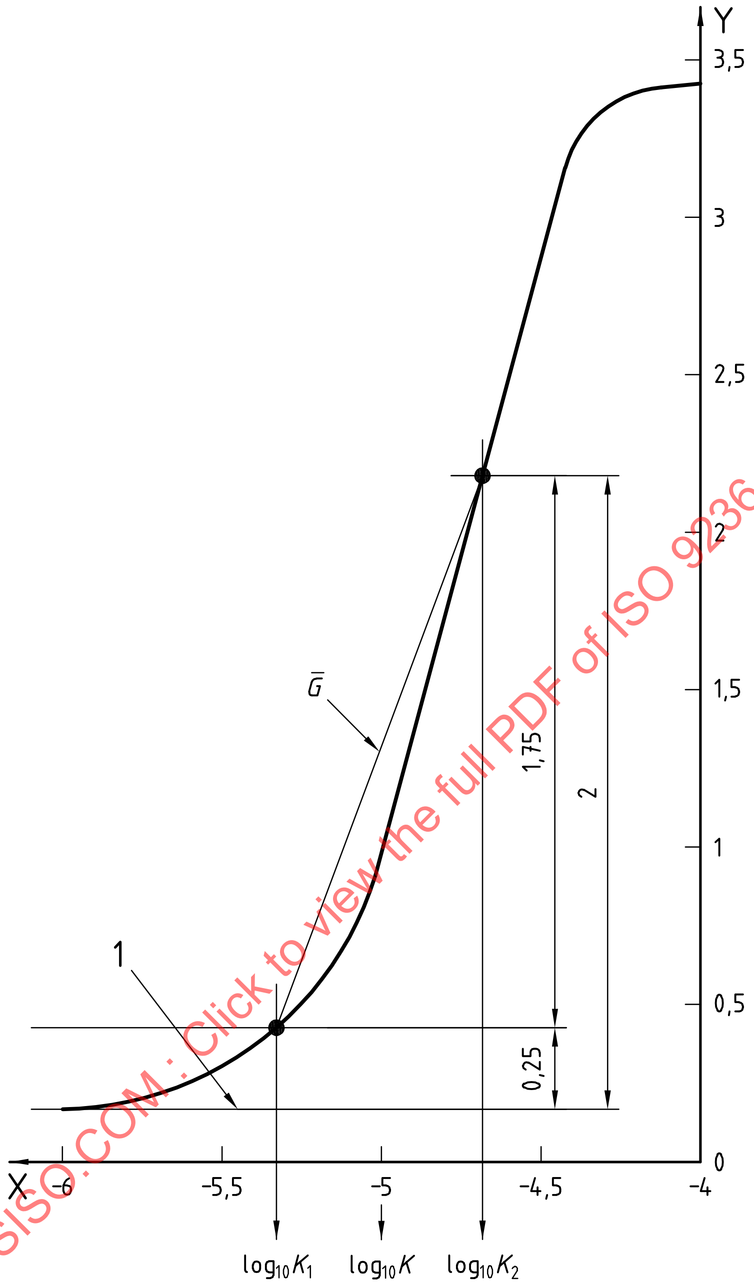
where

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

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

If a single beam quality is used to determine $\overline{G}$, the beam quality number II (see Table 1) should be selected.

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.



Key

X $\log_{10} K$

Y ISO standard visual diffuse transmission density

1 density of a processed, unexposed film sample

$\bar{G}$ average gradient

Figure 3 — Sensitometric curve

7 Determination of speed

7.1 Definition

The speed S is calculated from:

$$S = K_0/K_S$$

where

K_0 is equal to 10^{-3} Gy;

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

7.2 Beam qualities

7.2.1 General

For the determination of the speed, the combination shall be irradiated behind a phantom. To simulate the most common applications in general radiography, four exposure conditions are defined and specified in Table 2.

The phantoms are described in 7.2.2 to 7.2.5. The purity of the aluminium shall be at least 99,4 %.

Table 2 — Specification of techniques

Technique number		Approximate X-ray tube voltage[a] kV	Half-value layer mm Al	Exposure times ms	Distance between the back of the phantom and the detector[b] mm
I	Extremities	50	3,0	60 ± 30	60
II	Skull	70	5,7	60 ± 30	60
III	Lumbar spine and colon	90	7,4	60 ± 30	60
IV	Chest	120	8,5	15 ± 5	60

[a] The geometry for establishing the tube voltage is described in 7.2.6. The beam qualities for determination of the sensitometric curve shape (Table 1) and speed (Table 2) correspond to each other.

[b] 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.

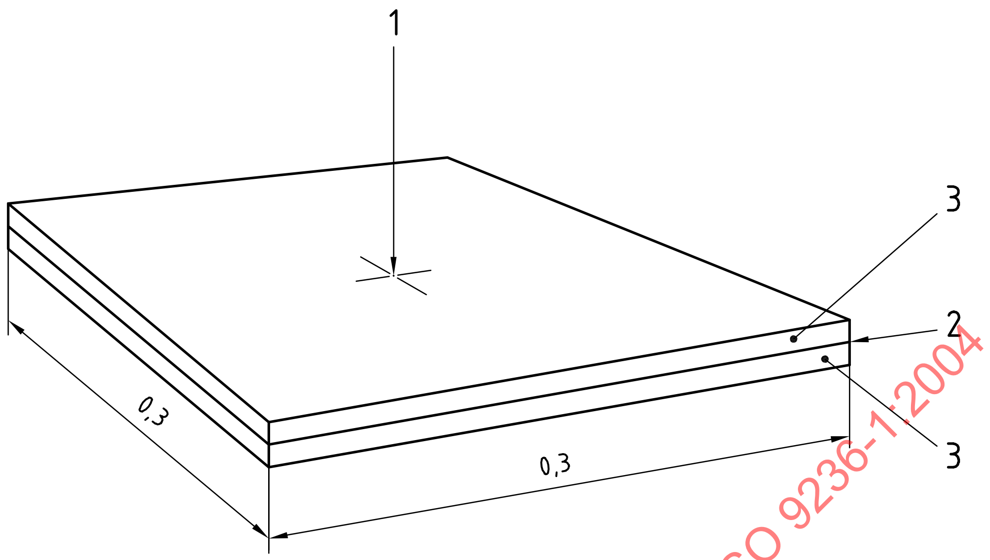
7.2.2 Phantom for Technique I

The phantom (see Figure 4) shall consist of two polymethyl methacrylate (PMMA) slabs, each (25 ± 1) mm thick by approximately 0,3 m square. Between the two slabs an aluminium sheet, (2,0 ± 0,1) mm thick and approximately 0,3 m square, shall be sandwiched.

7.2.3 Phantom for Technique II

The phantom shall consist of a slab of aluminium with a thickness of (12,0 ± 0,1) mm and approximately 0,3 m square.

Dimensions in metres



Key

1 X-ray beam (central beam)

2 aluminium (2 mm)

3 polymethyl methacrylate (25 mm)

Figure 4 — Phantom for Technique I

7.2.4 Phantom for Technique III

The phantom shall consist of the Technique II phantom augmented by a contiguous 1,0 mm thick sheet of aluminium for a total thickness of (13,0 ± 0,1) mm.

7.2.5 Phantom for Technique IV

The phantom shall consist of one slab of polymethyl methacrylate (PMMA), (70 ± 1) mm thick, and one slab of aluminium, (5,0 ± 0,1) mm thick, both of them approximately 0,3 m square. The PMMA slab is positioned near the focal spot of the X-ray tube (see Figure 7); the aluminium slab is positioned near the detector.

7.2.6 Establishment of X-ray tube voltage

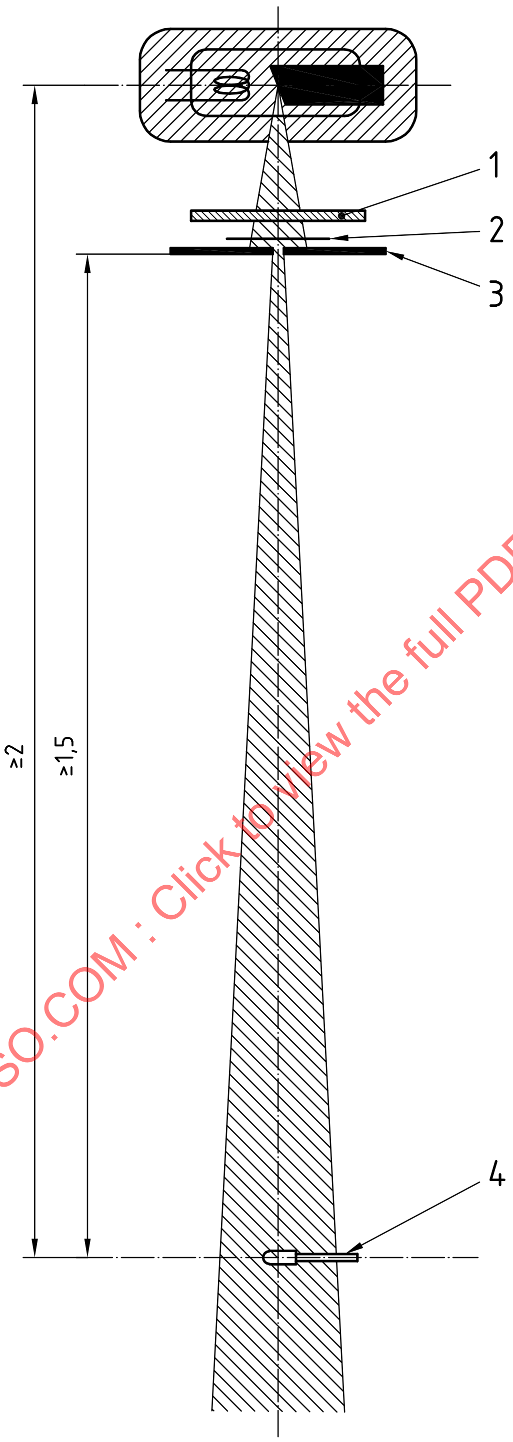
The minimum distance between the X-ray tube's focal spot and the detector shall be 2 m for all measurements of beam quality. Either the filtration listed in Table 1 or the corresponding phantoms shall be placed between the X-ray tube and the beam diaphragm. In case of Technique IV the two slabs (PMMA and aluminium) shall be in contact with each other, the PMMA facing the X-ray tube. The distance between the beam diaphragm and the detector shall be at least 1,5 m (see Figure 5).

The X-ray tube voltages given in Tables 1 and 2 should be used as starting values. For each of the techniques to be applied, the X-ray tube voltage shall be adjusted until the measured half-value layer of aluminium is within ± 2 % of the value given in Table 1 and Table 2. For Technique II, for example, the X-ray tube voltage shall be adjusted so that the air kerma rate measured with the skull phantom positioned at the X-ray tube will be halved when a slab of aluminium of 5,7 mm ± 0,1 mm thickness is introduced close to the phantom on the side away from the X-ray tube. These adjustments shall be made at the X-ray tube currents specified for X-ray exposures in 7.4.

Half-value-layer measurements shall be made with a detector whose spectral response is essentially uniform over the range of beam qualities tested and which is as far away as practicable from the X-ray tube. Collimation at the X-ray tube shall be as narrow as possible but still permit the X-ray beam to cover the sensitive volume of the measuring detector.

All subsequent screen/film exposures shall be made at the X-ray tube voltages and the X-ray tube currents thus established.

Dimensions in metres



Key

1 phantom

2 HVL filter(s)

3 beam diaphragm

4 measuring detector (R2)

Figure 5 — Geometric set-up for adjustment of beam qualities used for techniques I, II, III and IV

7.3 Geometry

The geometry for the irradiation of the combination is shown in Figures 6 and 7. The detector system (either the combination or the dosimeter) is placed at a fixed distance of 60 mm behind the back of the phantom.

Optionally, a monitoring-integrating detector may 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 may be either outside or inside the beam used to expose the combination. The diaphragm B2 shall be adjusted so that the phantom is always fully irradiated.

A measuring-integrating detector replacing the combination shall be positioned as specified in Figures 6 and 7 and subclause 4.3.

A lead shield shall be positioned at least 450 mm behind the last area involved in the measurement.

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 determined by measurement at the distance estimated to yield a net density 1,0 as interpolated from the sensitometric exposure series. This air kerma shall be reached using the appropriate phantom at a distance in the range of 1,5 m to 4,0 m between the focal spot and the combination, and with the appropriate conditions of tube voltage, tube current and exposure time. Exposure time is either that given by the reading of the generator or by an external shutter.

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 $1{,}0 \pm 0{,}3$, the distance between the focal spot and the phantom shall be adjusted within the limits of 1,5 m to 4,0 m using the sensitometric curve as a guide. Three exposures are then made resulting in three images with net densities $D_i = 1{,}0 \pm 0{,}3$. Air kerma values K_i corresponding to these three exposures are then determined either directly from the measuring detector readings or calculated from the monitor readings M_i.

After the exposure of the combination, it is replaced by the measuring detector and the exposure is repeated, holding the tube voltage, tube current, exposure time and distance to the tube unchanged. If a monitoring detector is used, the reading X_m of the measuring detector and the concurrent reading M_m of the monitoring detector shall be recorded. Letting $\overline{X}_m$ and $\overline{M}_m$ be 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:

$$K_i = M_i(\overline{X}_m / \overline{M}_m)$$

7.5 Evaluation

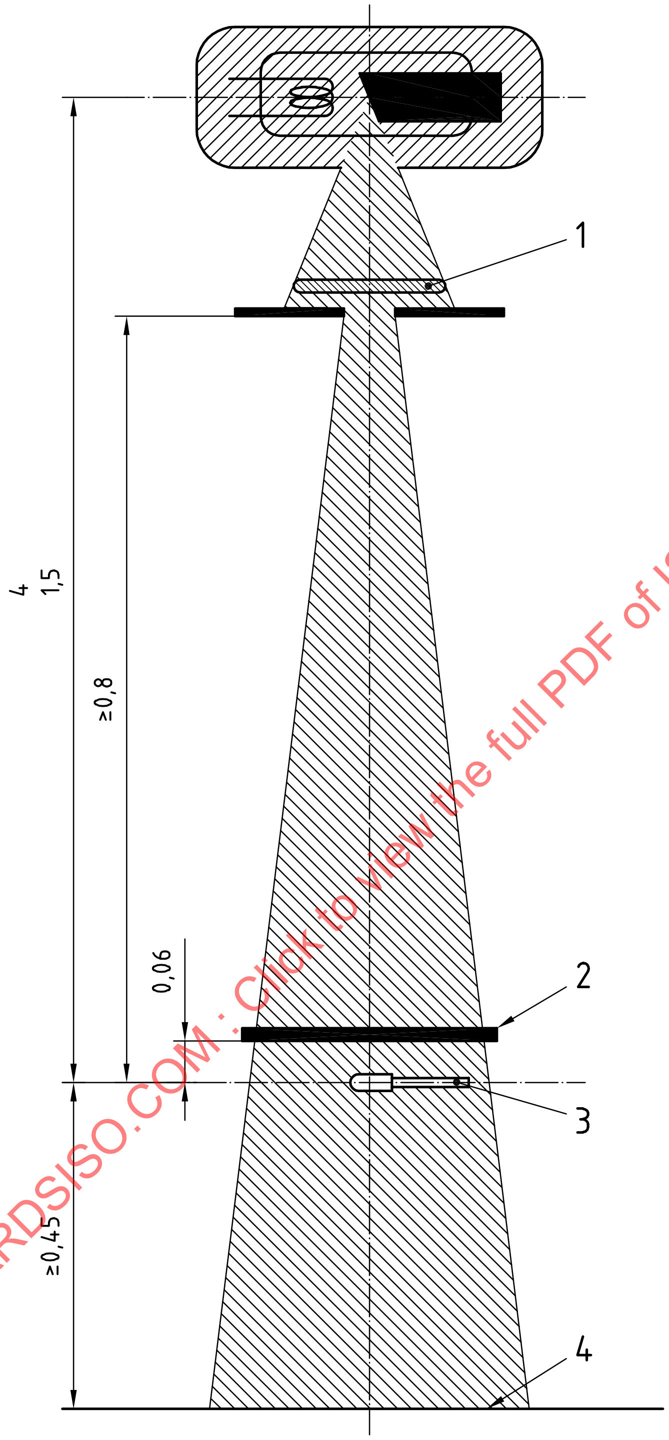
Using the sensitometric curve, the differences ΔD_i between D_i and 1,0 are transformed into differences, $\Delta \log_{10} K_i$, which are used to correct the calculated K_i values to obtain K_i values for a net density of 1,0. The mean K_S of the three K_i values is used to calculate the speed S using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

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

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

NOTE Since, for the purposes of this part of ISO 9236, the shape of the sensitometric curve may be assumed to be independent of beam quality, the correction can be made with a curve produced by any beam quality specified in Table 1.

Dimensions in metres



Key

1 monitoring detector

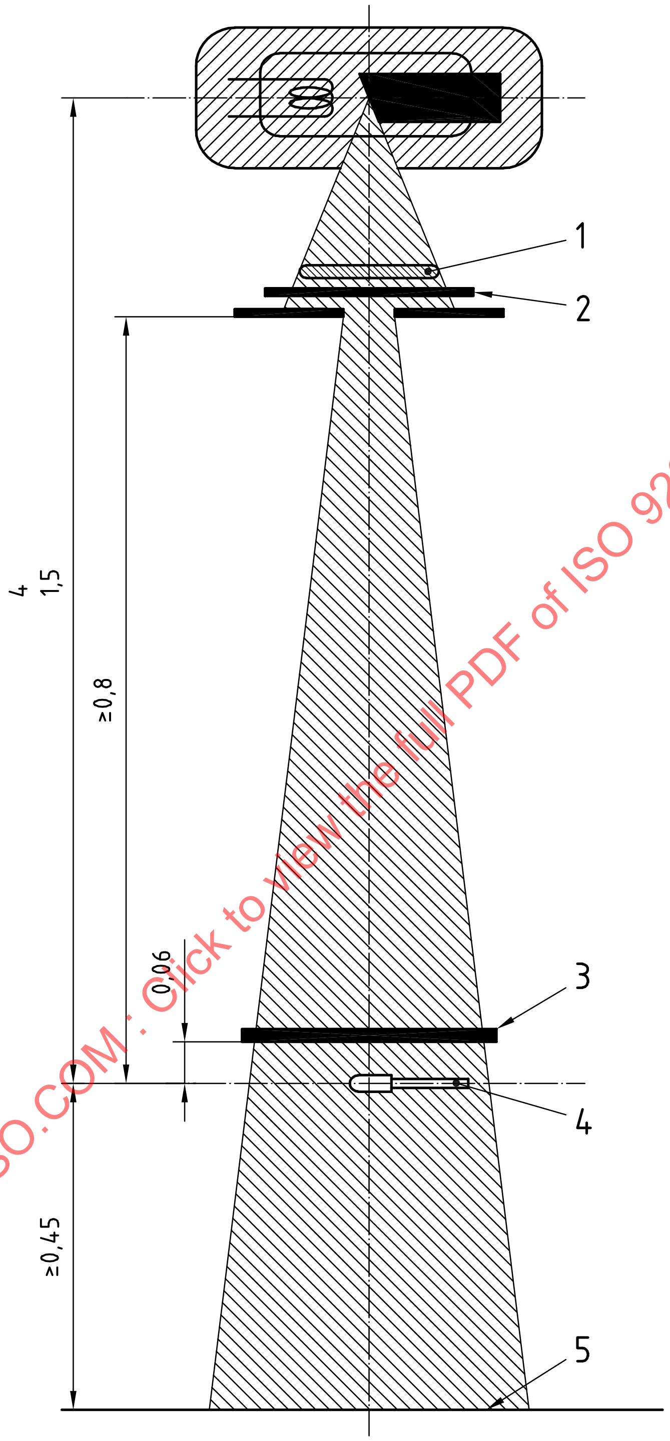
2 phantom

3 measuring detector or film plane

4 lead shield

Figure 6 — Geometric set-up for the measurement of speed (Techniques I, II and III)

Dimensions in metres



Key

1 monitoring detector
2 phantom
3 phantom
4 measuring detector or film plane
5 lead shield

Figure 7 — Geometric set-up for the measurement of speed (Technique IV)

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.

For every technique described in Table 2, the combination is placed at a distance in the range of 1,5 m to 4,0 m from the focal spot with the appropriate phantom in the beam (see Figures 6 and 7). The tube current shall be adjusted to produce a trial image whose processed net density is 1,0 ± 0,1. With this tube current, the desired HVL, given in Table 2, is adjusted according to 7.2.6. Then, three exposures of the combination shall be made at each of two distances 95 % and 105 % of the distance at which the tube current was set. The phantom-film distance shall remain constant at 60 mm during these adjustments.

If a monitoring detector is used, the reading M_i of the monitoring detector shall simultaneously be recorded.

Immediately following each set of the three exposures, the filmholder containing the film and screens shall be replaced by the measuring detector 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, the total air kerma may be increased by making multiple exposures. The air kerma K_i of the combination is calculated 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 densities plotted and from this line the air kerma K to produce a 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 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 7.2.6 for each tube current setting. Then, three exposures of the combination shall be made at each of the two different tube currents at each of two distances 95 % and 105 % of the distance at which the two tube currents were set, resulting in a total of twelve exposures. If a monitoring detector is used, for each exposure the reading M_i simultaneously produced by the monitoring detector shall be recorded.

Immediately following each set of the three exposures, the filmholder containing the film and screens shall be replaced by the measuring detector 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 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 is then calculated using the formula given in Clause 6.

9 Uncertainty

The uncertainty budget shall be calculated.

All parameters and quantities which may considerably influence the uncertainty budget shall be considered. Especially, the following factors influence the budget:

— the kerma meter,

— the densitometer,

— the repeatability and calibration factor of the monitor chamber,

— the calibration of beam quality,

— uncontrolled scattering,

— the processing variability.

