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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Photography — Industrial radiographic film — Determination of ISO speed and average gradient when exposed to X- and γ-radiation

Photographie — Film pour radiographie industrielle — Détermination de la sensibilité et du contraste moyen ISO après exposition à des rayons X ou γ

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Photography — Industrial radiographic film — Determination of ISO speed and average gradient when exposed to X- and γ-radiation

0 Introduction

This is the first International Standard to specify methods for measuring the ISO speed and ISO average gradient of industrial radiographic film 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. Since the photographic characteristics of a film are dependent on the energy distribution in the wavelength spectrum, four representative sources are specified for determining sensitometric characteristics.

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

1 Scope and field of application

This International Standard specifies methods for determining ISO speeds and ISO average gradients of industrial radiographic film/film process combinations when exposed directly to X- and γ-rays. The evaluation of films used in industrial radiography with fluorescent intensifying screens is not specified in this International Standard.

2 References

ISO 5, *Photography — Density measurements —*

Part 1: Terms, symbols and notations.

Part 2: Geometric conditions for transmission density.

Part 3: Spectral conditions.

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

3 Definitions

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

3.1 exposure (to X- or γ-rays), K: The time integral of the X- or γ-radiation incident on the film, expressed in terms of the kinetic energy of electrons released per kilogram of air measured in grays.

Exposure is often expressed in $\log_{10} K$ units.

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

3.3 average gradient, $\bar{G}$: The slope of the straight line joining two points on a sensitometric curve.

3.4 gray*: A measure of X and gamma radiation required to create 1 joule of initial kinetic energy of charged particles created by the radiation impinging on 1 kg of air.

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

4 Sampling and storage

In determining the ISO speed and ISO average gradient of a product, it is important that the samples evaluated yield the average results obtained by users. This will require evaluating several different batches periodically under conditions specified in this International Standard. Prior to evaluation, the samples shall be stored according to the manufacturers' recommendations for a length of time to simulate the average age at which the product is normally used. Several independent evaluations shall be made to ensure the proper calibration of equipment and processes. The basic objective in selecting and storing samples as described above is to ensure the film characteristics are representative of those obtained by a consumer at the time of use.

* See annex E.

5 Method of test

5.1 Principle

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

5.2 Safelights

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

5.3 Exposure [1)]

5.3.1 Film holders

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

5.3.2 Sample condition

During exposure, the samples shall be at a temperature of 23 ± 5 °C and a relative humidity of (50 ± 20) %.

5.3.3 Radiant energy quality [2)]

Four specific exposing sources are recognized in this International Standard for determining speed and average gradient to cover the range of exposing conditions used in practice. The selection of which of the four sources are used to determine ISO speed and ISO average gradient depends on how the film is used.

5.3.3.1 X-rays from a low potential source

Film under test shall be exposed to X-rays from tungsten target tubes. Inherent filtration of the tube, plus an additional copper filter [3)] located as close to the target as possible shall provide a filtration equivalent to 2,0 ± 0,1 mm of copper. The potential across the X-ray tube shall be adjusted until the half-value absorption is obtained with 1,0 ± 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 screen shall be used. [4)] This is designated source (1).

5.3.3.2 X-rays from a high potential source

Film 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 ± 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 ± 0,2 mm of copper. A potential of approximately 220 kV generally meets this requirement.

Films shall be exposed without interleaving paper and shall be between lead-foil screens. [2)] The front screen shall be 0,115 ± 0,020 mm thick. The total thickness of the back screen(s) shall be 0,20 ± 0,06 mm. Single-coated films shall be exposed with the emulsion-coated surface facing the X-ray tube. To obtain sufficient contact, vacuum cassettes shall be used. This is designated source (2).

5.3.3.3 γ-Rays from an iridium-192 (^{192}Ir) source

A filtration of 8,0 mm of copper near the source is required. Lead-foil screens shall be used as indicated in 5.3.3.2. This is designated source (3).

5.3.3.4 γ-Rays from a cobalt-60 (^{60}Co) source

Lead-foil screens shall be used as indicated in 5.3.3.2. This is designated source (4).

5.3.4 Scattered radiation

To minimize scattered radiation when exposing test films, X-ray and γ-ray beams shall be diaphragmed 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, filters, and ion chamber from low atomic number materials and making such structures as light in mass as possible will minimize scattered radiation (see annex D).

5.3.5 Modulation

The film shall be given a graduated series of exposures such as will result in a series of densities above base plus fog from 1,0 to 4,0. The exposure over the useful area of each exposure step shall be uniform to within 3 %. Exposure increments shall not exceed 0,15 $\log_{10} K$ units. Each exposure shall be measured in grays by using an ionization chamber calibrated for the radiant energy quality and intensity used for exposing the film. A separate sample of the film shall be left unexposed for measuring inherent base plus fog density.

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1) For convenience in this International Standard, exposure is expressed in terms of the air kerma (measured in grays) that would be produced in 1 kg of air. Kerma, specific energy and absorbed dose are all measurements of energy per unit mass imparted by ionizing radiation (see annex E).

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

3) All copper filters specified in this International Standard should be made of 99,9 % pure copper.

4) For films packaged by a manufacturer in light-tight exposures which contain intensifying screens, the film should be tested as packaged without the use of a film holder. The ISO speed or average gradient values for such films should include the trade designation of the product.

5.4 Processing

5.4.1 Conditioning of samples

In the time interval between exposure and processing, the samples shall be kept at 23 ± 5 °C and a relative humidity of (50 ± 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 average gradient data provided by the film manufacturer generally apply to the film when it is processed in accordance with his 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 average gradient. This shall specify the chemicals, times, temperatures, agitation, equipment, and procedure used for each of the processing steps, and any additional information required to obtain the sensitometric results described. The values for speed and average gradient obtained using various processing procedures may differ significantly. Although different speeds and average gradients for a particular film may be achieved by varying the process, the user should be aware that other sensitometric and physical changes may also accompany the speed and average gradient changes.

5.5 Densitometry

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

5.6 Evaluation

5.6.1 Sensitometric curve

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

5.6.2 Base plus fog density

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

6 Product classification

6.1 ISO speed

6.1.1 ISO speed scale

The speeds given in table 1 are derived from the formula

$$S = \frac{1}{K_s}$$

where K_s is the exposure, in grays, required to produce a density of 2,00 above base plus fog density.

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

6.1.2 ISO speed of a product

The ISO speed of a product, as distinguished from that of a specific sample, shall be based on the numerical average of the logarithms of exposures, $\log_{10} K_s$, determined from various batches of the product when selected, stored, and tested as specified above. The ISO speed of a product with proper rounding is then determined from the average value of $\log_{10} K_s$ by use of table 1. Since ISO speed is dependent on exposure and development conditions, these should be indicated when quoting ISO speed values.

Table 1 — ISO speed scale

$\log_{10} K_s$		ISO speed
From	To	
−3,05	−2,96	1 000
−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

6.2 ISO average gradient

6.2.1 ISO average gradient scale

The average gradients given in table 2 are derived from the equation

$$\bar{G} = \frac{D_2 - D_1}{\log_{10} K_2 - \log_{10} K_1} = \frac{2{,}0}{\log_{10} K_2 - \log_{10} K_1}$$

where

D_1 is the density of the point on the curve which is 1,50 above base plus fog density;

D_2 is the density of the point on the curve which is 3,50 above base plus fog density;

K_1 is the exposure required to produce D_1;

K_2 is the exposure required to produce D_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 base plus fog density may be advantageous in a situation where densities are close to 2,00 above base plus fog density. However, unless $\bar{G}$ is determined as specified in this International Standard, it cannot be referred to as an ISO average gradient.

ISO average gradient shall be obtained directly from $\log_{10} K_2 - \log_{10} K_1$ by use of table 2 which shows the rounding method to be used.

Table 2 — ISO average gradient scale

$\log_{10} K_2 - \log_{10} K_1$		ISO $\bar{G}$
From	To	
0,73	0,69	2,8
0,68	0,65	3,0
0,64	0,61	3,2
0,60	0,58	3,4
0,57	0,55	3,6
0,54	0,52	3,8
0,51	0,49	4,0
0,48	0,46	4,2
0,45	0,44	4,5
0,43	0,42	4,8
0,41	0,39	5,0
0,38	0,37	5,3
0,36	0,35	5,6
0,34	0,33	6,0
0,32	0,31	6,3

6.2.2 ISO average gradient of a product

The ISO average gradient of a product, as distinguished from that of a specific sample, shall be based on the numerical average of $\log_{10} K_2 - \log_{10} K_1$ for various batches of the product when selected, stored, and tested as specified in this International Standard. The ISO average gradient of a product with proper rounding is then determined from the average value by use of table 2.

6.3 Accuracy

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

7 Product marking and labelling

7.1 ISO speed

The speed of a product determined by the method described in this International Standard, and expressed on the scale of table 1, should be designated ISO speed and denoted in the form

ISO (1) 100

The number in parentheses indicates the radiation used [i.e. (1) is for the source described in 5.3.3.1].

7.2 ISO average gradient

The average gradient of a product determined by the method specified in this International Standard, and expressed on the scale of table 2, should be designated the ISO average gradient and denoted in the form

ISO (1) $\bar{G}$ 4,3

7.3 General

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

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

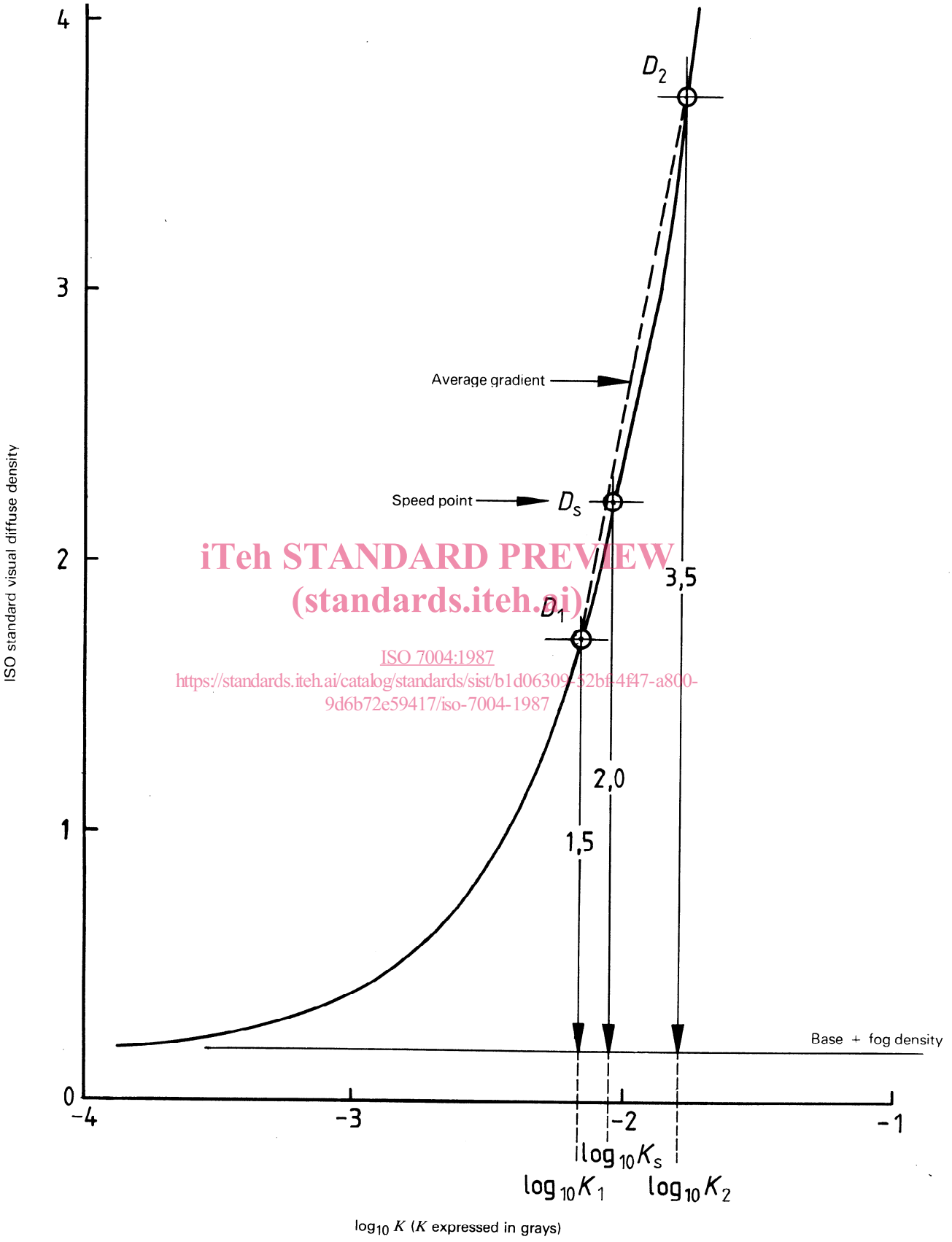

Figure — Determination of ISO speed and ISO average gradient

Annex A

Calibration of ionization chambers

(This annex does not form part of the standard.)

It may not be possible to have ionization chambers calibrated with the radiation qualities in 5.3.3. In such a case, ionization chamber response at the required radiation 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 5.3.3.1 and 5.3.3.2 may be determined by interpolation on a plot of half-value layers against chamber response of the radiations [1] given in annex B.

Instruments to be used with the γ-rays specified in 5.3.3.3 and 5.3.3.4 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 a standardizing organization.

Annex B

Beam quality code

(This annex does not form part of the standard.)

NBS* designation	Constant potential	Thickness of approximate 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
HFI	200	1,5	0,7	4,0	0,6	2,5	4,1

* National Bureau of Standards (USA).

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

Annex C

Improvement of the reproducibility of exposure to X-rays

(This annex does not form part of the standard.)

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);

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

b) during an irradiation, the mean 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.

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

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

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

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

Annex D

Scattered radiation measurement

(This annex does not form part of the standard.)

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

If d is the distance from the source, plot the (exposure rate $\times$ d^2) against d. Extrapolating the graph to zero distance yields the (exposure rate $\times$ d^2) value, P, resulting from the primary radiation only. In order to comply with this International Standard, the actual (exposure rate $\times$ d^2) value for the normal test distance shall not be more than 6 % greater than P.