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Non-destructive testing — Qualification of radiographic film digitisation systems —

Part 1: Definitions, quantitative measurements of image quality parameters, standard reference film and qualitative control

Essais non destructifs — Qualification des systèmes de numérisation des films radiographiques —

Partie 1: Définitions, mesures quantitatives des paramètres de qualité de l'image, film de référence normalisé et contrôle qualitatif

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Foreword

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This document was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 5, *Radiographic testing*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 138, *Non-destructive testing,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 14096-1:2005), which has been technically revised.

The main changes are as follows:

— definitions of terms 3.2, 3.6, 3.7, 3.13, 3.16 and 3.17 updated;

— Clause 4 symbols and abbreviations added;

— in 5.1.3, details added on digitisers capable to capture densities D > 4,5;

— in 5.1.5, details on the calculation of the standard deviation σ_D of the calibrated density $D(gl)$ and Note 2 added;

— determination of the basic spatial resolution of the digitiser (SR_b^D) added in the new subclause 5.2.5;

— clause 6 "Presentation of results" with a new Figure 2 added;

— Table 2 with quality numbers for representation of results in Figure 2 added;

— new Figure 1 presents examples of line pair test pattern for direct evaluation of SR_b^D;

— "MTF calculation" moved to Annex A and "standard reference film" description moved to Annex B;

— editorial revision.

A list of all parts in the ISO 14096 series can be found on the ISO website.

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Introduction

Radiographic film systems are used for industrial inspection by X- and gamma rays. For computer-supported analysis, transmission and storage, the information stored in the radiographic film is converted into digital data (digitisation). This document provides quantitative evaluation procedures which form the basis for minimum requirements specified in ISO 14096-2.

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Non-destructive testing — Qualification of radiographic film digitisation systems —

Part 1: Definitions, quantitative measurements of image quality parameters, standard reference film and qualitative control

1 Scope

This document specifies procedures for the evaluation of basic performance parameters of the radiographic film digitisation process, such as spatial resolution and spatial linearity, density range, density contrast sensitivity and characteristic transfer curve, which are applied in ISO 14096-2. These procedures can be integrated into the system software, and together with a standard reference film (see Annex B), used for quality control of the digitisation process. This reference film provides a series of test targets for performance evaluation. The test targets are suitable for evaluating a digitisation system with a basic spatial resolution down to 10 µm, a density contrast sensitivity down to 0,02 optical density, a density range of 0,5 to 4,5 and a film size capacity of (350 × 430) mm^2.

This document does not address signal processing and display of the digitised data.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 11699-1, *Non-destructive testing — Industrial radiographic film — Part 1: Classification of film systems for industrial radiography*

ISO 14096-2, *Non-destructive testing — Qualification of radiographic film digitisation systems — Part 2: Minimum requirements*

ISO 19232-5, *Non-destructive testing — Image quality of radiographs — Part 5: Determination of the image unsharpness and basic spatial resolution value using duplex wire-type image quality indicators*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
radiographic film digitisation system
digitiser
sequential application of the two functions below:

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a) detection of the diffuse transmittance of a small unit area of the film (pixel, picture element) by means of an optical detector, giving an electric output signal (geometrical digitisation);

b) conversion of the above electrical signal into a numerical value (densitometrical digitisation)

3.2
scanning aperture
S_A
spatial extension (area) on the radiographic film through which the digitiser performs the scanning of one pixel for geometrical digitisation

Note 1 to entry: The size of the scanning aperture corresponds:

a) in the case of rectangular aperture, to the longer side;

b) in the case of circular aperture, to the diameter.

Note 2 to entry: The scanning aperture limits the basic spatial resolution of the digitiser.

3.3
pixel size
P
geometrical centre-to-centre distance between adjacent pixels in a row (horizontal pitch P_h) or column (vertical pitch P_v) of the scanned image

Note 1 to entry: The pixel size is the limiting value of the basic spatial resolution SR_b^D of the digitization system.

3.4
optical density
D
logarithmic value to the base 10 of the diffuse light intensity ratio in front of (I_0) and behind (I_D) the radiographic film according to Formula (1):

$$D = \lg \frac{I_0}{I_D} \tag{1}$$

3.5
edge response function
ERF
resulting profile across a step function after digitisation into optical density values

3.6
digitiser unsharpness
U_D
blurring of sharp edges by the *scanning aperture* (3.2), scattered light, flare or electronic bandwidth

Note 1 to entry: The basic spatial resolution *SRbD* (3.13) of the digitiser in mm is the half of the value of U_D or the inverse of $2 \cdot f_{M,}$ approximately the spatial frequency value at 10 % MTF.

Note 2 to entry: Internal device algorithms for smoothing or interpolation influence U_D), thus the use of raw scan is often recommended.

3.7
spatial frequency
f
measure of how often sinusoidal components of the structure repeat per unit of distance

Note 1 to entry: The period of this function is measured in number of line pairs per millimetre (lp/mm).

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3.8
spatial frequency maximum value
f_c
value in number of line pairs per millimetre given by the Nyquist sampling theorem, see Formula (2):

$$f_c = 1/(2 \cdot P) \quad (2)$$

Note 1 to entry: In practice, the scanning aperture, the mechanics, and the electronics of the digitiser reduce this theoretical value.

3.9
modulation transfer function
MTF
normalised magnitude of the Fourier-transform (FT) of the differentiated spatial optical density *edge response function* (3.5) describing the unsharpness function of the digitiser (contrast transmission as a function of the object size)

Note 1 to entry: The principle of determining the MTF is visualised in Figure A.1.

Note 2 to entry: This MTF calculation is based on optical densities, which correspond to the X-ray dose.

3.10
density range
D_R
range of maximum and minimum optical densities measurable with the digitiser, where the digitiser guarantees a minimum *density contrast sensitivity* (3.14)

Note 1 to entry: Depending on the construction of the digitiser, this density range can be split into several *working ranges* (3.15), e.g., by a different illumination power and/or a different detector integration time.

3.11
characteristic transfer curve
CTC
relationship between the optical density of the film and the digitised data

3.12
digital resolution
number of bits provided by the analogue-to-digital converter of the digitiser used for densitometrical digitisation

Note 1 to entry: A digital resolution of N bits corresponds to 2^N digital values.

3.13
basic spatial resolution of the digitisation system
SR_b^D
half of the measured *digitiser unsharpness* (3.6)U_D measured in a row (horizontal) and in a column (vertical) of the scanned image, which corresponds to the effective pixel size and to the larger of both of the two measured values

Note 1 to entry: For the measurement of SR_b^D, a duplex wire IQI according to ISO 19232-5 is exposed directly on the film or a film print with sufficient resolution, can be used (see Figure 1 a and b for examples).

Note 2 to entry: The measurement of SR_b^D is described in ISO 19232-5:2018, as iSR_b^{image} measurement, illustrated in Figure B.1.

Note 3 to entry: See also 3.6, 5.2.4 and 5.2.5 for an alternative measurement using a sharp edge target and the 10 % value of the *Modulation Transfer Function* (3.9) of this edge target ($MTF_{10\,\%}$), see Annexes A and B.

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3.14
density contrast sensitivity
ΔD_{CS}
minimum density variation of the film, which is resolved by the digitiser

Note 1 to entry: ΔD_{CS} is mainly determined by the digitisation noise of the digitiser (noise of the light source and detector), if the film noise can be neglected.

3.15
working range
D_{WR}
range of optical densities, where the digitiser guarantees a minimum *density contrast sensitivity* (3.14) in one *single acquisition* (3.16)

Note 1 to entry: Only in this density range the digitised data can be used for evaluation. Depending on the digitiser construction there can be more than one working range, e.g. for brighter or darker films.

3.16
single acquisition
digitisation of one radiographic film performed in one single process

Note 1 to entry: The result of a single acquisition is a collection of data without any further processing. A specified and unique set of parameters of the digitisation system is used for this acquisition.

3.17
standard reference film
photographic image on an industrial radiographic film containing most of the reference targets described in this document

3.18
target
physical pattern on a radiograph that is used to evaluate the digitiser

4 Symbols and abbreviated terms

For the purposes of this document, the symbols and abbreviated terms given in Table 1 apply.

Table 1 — Symbols and abbreviated terms

Symbol or abbreviated term	Definition
CTC	characteristic transfer curve of the digitiser
D	optical density of film
D_A	constant optical density of an additional film
$D(gl)$	calibrated optical density according to the CTC at grey level gl
$D(gl_n)$	calibrated optical density according to the CTC at grey level gl_n
$D(gl_m)$	calibrated optical density according to the CTC at grey level gl_m
D_R	range of maximum and minimum optical densities, which can be measured by the digitiser with a guaranteed minimum density contrast sensitivity
ΔD_{CS}	density contrast sensitivity
D_{WR}	working range, optical density range in a single acquisition
ERF	edge response function
f	spatial frequency
f_c	spatial frequency maximum value
f_M	spatial frequency value at 10 % MTF
$gl_{j,i}$	digitised data values (grey levels) for an area of (15 × 15) pixels

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