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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

Essais non destructifs — Qualité d'image des radiogrammes —

Partie 5: Détermination de l'indice de flou de l'image et de la résolution spatiale de base à l'aide d'indicateurs de qualité d'image duplex à fils

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 5, *Radiation methods.*

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This third edition cancels and replaces the second edition (ISO 19232-5:2013), which has been technically revised. The main changes compared to the previous edition are as follows:

— new high definition duplex IQI;

— extended description of usage;

— extended table with basic spatial resolution and linepairs/mm;

— evaluation of duplex wire-type IQI by visual evaluation and evaluation with profile function in digital images.

A list of all parts in the ISO 19232 series can be found on the ISO website.

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

1 Scope

This document specifies a method of determining the total image unsharpness and basic spatial resolution of radiographs and radioscopic images. The IQI with up to 13 wire pairs can be used effectively with tube voltages up to 600 kV. The IQI with more than 13 wire pairs can be used effectively at tube voltages lower than 225 kV. When using source voltages in the megavolt range, it is possible that the results are not be completely satisfactory.

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 5576, *Non-destructive testing — Industrial X-ray and gamma-ray radiology — Vocabulary*

ISO/IEC 17050-1, *Conformity assessment — Supplier's declaration of conformity — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5576 and the following apply.

ISO and IEC maintain terminological 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
duplex wire-type image quality indicator
duplex wire-type IQI
image quality indicator specifically designed to assess the total image unsharpness and basic spatial image resolution of a radiograph or a digital image and composed of a series of pairs of wire elements made of high density metal

3.2
total image unsharpness value
U_T
smallest number of the duplex wire pair which is not sufficiently separable and corresponds to wire diameter plus wire spacing

Note 1 to entry: The corresponding unsharpness values are given in Table 1.

Note 2 to entry: U_T can be U_T^{visual}, $U_T^{20\%}$ or i$U_T^{20\%}$.

3.3
total image unsharpness value determined visually
U_T^{visual}
smallest number of the duplex wire pair, which is visually not separable in a film radiograph on a viewing station or on a monitor image

3.4
total image unsharpness value determined from a profile function in a digital image
$U_T^{20\%}$
smallest number of the duplex wire pair, which is not separable or separable by a profile function with less than 20 % modulation depth in a linearized profile

3.5
interpolated total image unsharpness value
$iU_T^{20\%}$
smallest number of the duplex wire pair which is separable, determined from a profile function in a digital image by interpolation from a linearized profile function and obtained by interpolation to 20 % modulation depth from neighbour element modulations

3.6
basic spatial resolution
SR_b
smallest geometrical detail which can be resolved and half of the measured unsharpness in a digital image or radiograph

Note 1 to entry: SR_b can be SR_b^{image} or $SR_b^{detector}$.

3.7
basic spatial detector resolution value
$SR_b^{detector}$
smallest geometrical detail, which can be resolved with a digital detector at magnification equal to one and corresponds to half of the measured detector unsharpness, U_T^{visual} or $U_T^{20\%}$, in a digital image and corresponds to the effective pixel size and is determined from the smallest number of the duplex wire pair, which is not separable by visual inspection or from the smallest number of the duplex wire pair with less than 20 % modulation depth in a linearized profile, measured with the IQI on the detector without object

Note 1 to entry: For this measurement, the duplex wire IQI is placed directly on the digital detector array or imaging plate.

3.8
basic spatial image resolution value
SR_b^{image}
smallest geometrical detail, which can be resolved in a digital image at magnification >1 and corresponds to half of the measured image unsharpness, U_T^{visual} or $U_T^{20\%}$, in a digital image and corresponds to the effective pixel size of the magnified image and is determined from the smallest number of the duplex wire pair, which is not separable by visual inspection or from the smallest number of the duplex wire pair with less than 20 % modulation depth in a linearized profile

3.9
interpolated basic spatial image resolution value
iSR_b^{image}
smallest geometrical detail, which can be resolved in a digital image at magnification >1 and corresponds to half of the measured image unsharpness, $iU_T^{20\%}$, in a digital image and corresponds to the interpolated effective pixel size of the magnified image and is determined from a profile function in a digital image by interpolation from a linearized profile function and obtained by interpolation to 20 % modulation depth from neighbour element modulations

Note 1 to entry: For measurement of $iSR_b^{detector}$, the duplex wire IQI is placed directly on the digital detector array or imaging plate and $iSR_b^{detector}$ is equal to iSR_b^{image}.

3.10
linepair per mm value
lp/mm
duplex wire pair values or interpolated values corresponding to $1/U_T$, where U_T can be U_T^{visual}, $U_T^{20\%}$ or $iU_T^{20\%}$

Note 1 to entry: The corresponding values are given in Table 1.

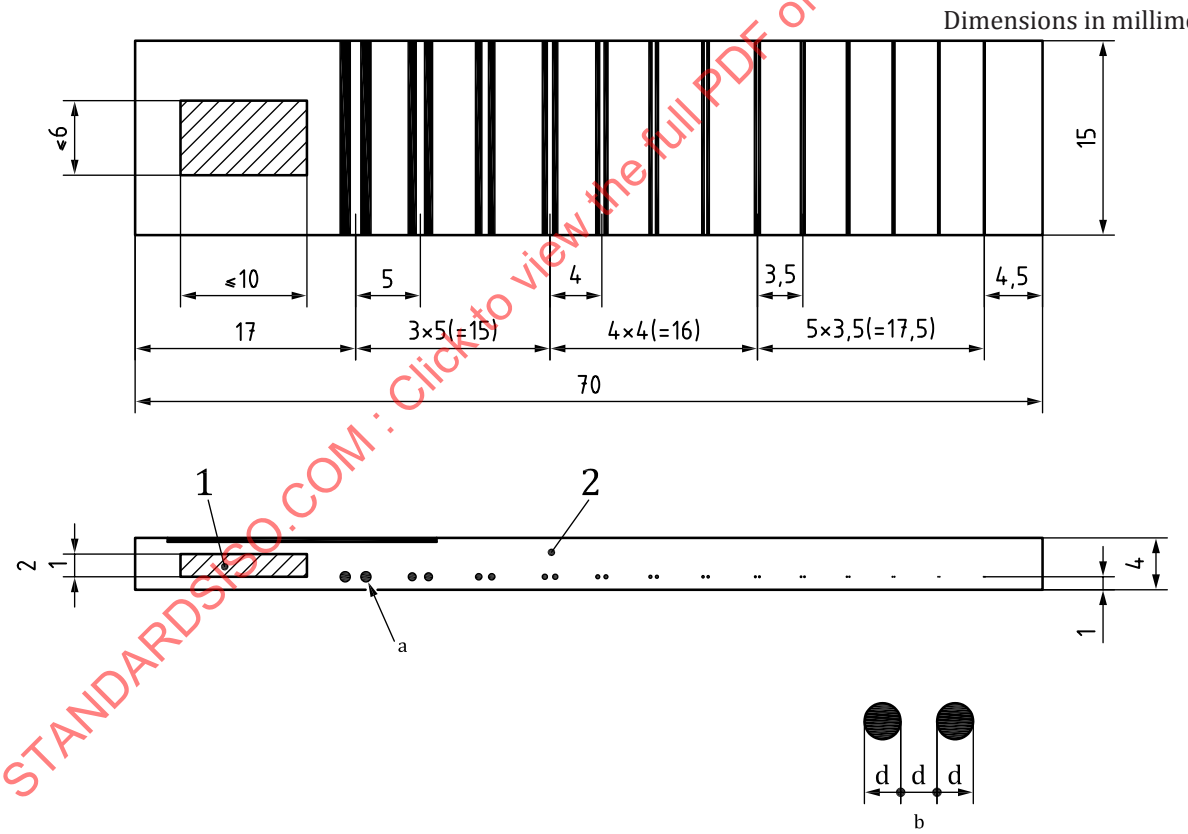
4 Specification of duplex wire-type IQI

4.1 Dimensions, manufacture, and marking

4.1.1 Dimensions and material

The standard duplex wire-type IQI shall consist of a series of 13 elements placed in a transparent rigid plastic holder. Each element shall consist of a pair of wires of circular section. The elements D1 to D3 are of tungsten, the others of platinum.

The dimensions shall be in accordance with Figure 1.



Key

1 space for identification marking
2 rigid plastic mounting
d wire diameter (equals spacing between the wires)
a Wire diameter, *d*, equals spacing between the wires.
b Enlarged view of each wire pair (element).

Figure 1 — Duplex wire-type IQI

4.1.2 Manufacture

The wire diameters and spacing of the wires are shown in Table 1.

4.1.3 Marking

The IQI shall be identified by marking "ISO D (or ISO 19232-5) and a serial number". Marking shall be performed by any suitable means. IQIs with the letters "EN D, or EN 462-5 or ASTM E 2002 or JIS Z 2307" are considered to be identical to IQIs with the letters ISO.

4.2 Declaration of conformity

Each IQI shall be delivered with a declaration of conformity according to ISO/IEC 17050-1, which confirms that the IQI complies with this document. For identification, the IQI shall be numbered and marked by the producer.

Table 1 — Duplex wire number, corresponding total unsharpness, basic spatial resolution, linepair readings and wire diameters and its tolerances[a]

Wire material	Duplex wire number	Corresponding unsharpness value U_T mm	Corresponding basic spatial resolution[b] SR_b value mm	Corresponding linepair value (lp/mm)	Wire diameter and spacing d (mm)	Tolerance of wire diameter and wire spacing (mm)
Pt[c]	D 13	0,10	0,050	10,0	0,050	
Pt	D 12	0,13	0,063	7,94	0,063	
Pt	D 11	0,16	0,080	6,25	0,080	±0,005
Pt	D 10	0,20	0,100	5,00	0,100	
Pt	D 9	0,26	0,130	3,85	0,130	
Pt	D 8	0,32	0,160	3,13	0,16	
Pt	D 7	0,40	0,200	2,50	0,20	
Pt	D 6	0,50	0,250	2,00	0,25	±0,01
Pt	D 5	0,64	0,320	1,56	0,32	
Pt	D 4	0,80	0,400	1,25	0,40	
W[d]	D 3	1,00	0,500	1,00	0,50	
W	D 2	1,26	0,630	0,79	0,63	±0,02
W	D 1	1,60	0,800	0,63	0,80	

[a] All unsharpness values are rounded to two digits after the comma.

[b] For conversion of the SR_b-values to µm, multiply values which are given in mm by 1 000.

[c] Pt = Platinum.

[d] W = Tungsten.

5 Use of duplex wire

5.1 General

A radiograph shall be made or an image displayed on a monitor with the duplex wire placed on the source side of the item being examined, or the IQI may be placed on a block representing the material

and total thickness of the item being examined. The duplex wire IQI should be aligned, as closely as possible, normal to the axis of the radiation beam.

NOTE If the IQI is placed directly on the detector, the inherent detector unsharpness and detector $SR_b^{detector}$ is measured.

The evaluation of the duplex wire pair images are based on a visual evaluation by an operator of films on a viewing station or images on a monitor or by measurement with a profile function if digital images are available. The total image unsharpness U_T is given by $2d$, where d is the corresponding diameter of the duplex wires and is also the wire spacing distance (see Figure 1). The value of d is considered as the basic spatial resolution of the image. The term $1 / (2d)$ is considered as linepair/mm value.

5.2 Visual evaluation

The image of the duplex wire IQI shall be examined using magnification up to 4 times on film or on a monitor. For evaluation of D12 and higher on films a magnification lens >2 times shall be used. The element with smallest wire number (that is pair of wires) of which the image has just merged into single form without an identifiable space between the images of the two wires, is taken as the limit of visual discernibility for radiography and radioscopy.

Visual determination of the first unresolved wire pair can depend on the contrast-to-noise ratio (CNR) and signal-to-noise ratio (SNR) for digital systems or radioscopic systems, or can depend on the film system class and tube kV. Therefore, the visual evaluation of reference images should be performed at CNR or SNR values (for digital systems) or using the film system class and kV values typically used for the production radiographs.

5.3 Evaluation of digital images with profile function

If digital images are evaluated with a profile function the element with smallest wire number, of the duplex wire pair, which is separable by a profile function with less than 20 % modulation depth, is taken as the limit of discernibility for digital radiography. See Figure 2. The profile function shall be evaluated from linearized pixel profiles.

The duplex wire IQI shall be positioned at an angle of approximately 2° to 5° towards the pixel line or column orientation as shown in Figure 2 a) in order to reduce aliasing effects in the digital images.

The total unsharpness or the basic spatial resolution of digital images is based on the determination of the first duplex wire pair (smallest number) with less than 20 % modulation depth (dip).

The measurement shall be done with a profile function of an image processing software across the middle area of the IQI image integrating along the wires of about 30 % to 60 % of the duplex wires length in order to obtain a robust repeatable value, but shall use a minimum of an 11 pixel width line profile to avoid variability along the length of the wires [Figure 2 b) and Figure 2 c)].

5.4 Evaluation of digital images with profile function by interpolation

For more accurate measurement of the total unsharpness, iU_T, or the basic spatial resolution of digital images (iSR_b) the measurement of the 20 % modulation depth should be performed by interpolation or approximation. This can be required for manufacturer qualification or if specified by contracting parties. See Figure 3. The profile function shall be evaluated from linearized pixel profiles.

The duplex wire IQI shall be positioned at an angle of approximately 2° to 5° towards the pixel line or column orientation as shown in Figure 2 a) in order to reduce aliasing effects in the digital images.

The measurement shall be done with a profile function of an image processing software across the middle area of the IQI image integrating along the wires of about 30 % to 60 % of the duplex wires length in order to obtain a robust repeatable value, but shall use a minimum of an 11 pixel width line profile to avoid variability along the length of the wires [Figures 2 a), 2 b) and 2 c)].

For improved accuracy in the measurement of the iU_T and the iSR_b value, the 20 % modulation depth (dip) value shall be approximated from the modulation depth (dip) values of the neighbour duplex wire modulations. Figure 3 visualizes the corresponding procedure.

The iSR_b is calculated as the polynomial approximation of the modulation depth (dip) vs. the wire pair spacing of neighboured wire pairs with at least two wire pairs with more than 20 % dip between the wires in the profile and at least two wire pairs with less than 20 % dip between the wires in the linearized profile (see Figure 3), if their values are larger than zero. If no values are available with dip <20 %, the next wire pair value with the dip of zero shall be used. If the measured iSR_b is smaller than the pixel size, e.g. due to aliasing effects. iSR_b shall be qualified as iSR_b = pixel size.

The interpolated total unsharpness, iU_T, is calculated from iSR_b by Formula (1):

$$iU_T = 2 \cdot iSR_b \quad (1)$$

The resulting approximated or interpolated basic spatial resolution value [see Figure 3 b)] shall be documented as "interpolated SR_b-value" or iSR_b. The resulting approximated or interpolated total unsharpness value shall be documented as "interpolated U_T-value" or iU_T.

The dependence of modulation depth (dip) from wire pair spacing should be fitted with a polynomial function of second order for calculation of the intersection with the 20 % line as indicated in Figure 3 b).

5.5 Image quality classes

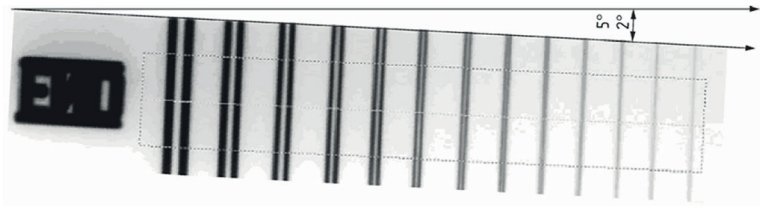
Image quality classes or levels of unsharpness of images or detectors are relative to the user's applications and shall be specified in the purchaser/supplier agreement or in reference to standard practices, as ISO 17636-2 for example.

5.6 Application of duplex wire IQI

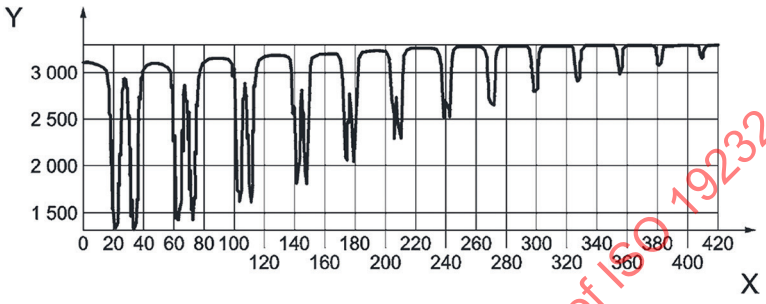
The duplex wire IQI may be applied to monitor the geometric unsharpness, U_g, the total unsharpness, U_T, the image unsharpness, U_{im}, and basic spatial resolution, SR_b^{image}, in radiographic images. It may be used for reference exposures to determine the inherent unsharpness, U_i, of film screen systems or radioscopic systems, or the basic spatial resolution, $SR_b^{detector}$, of digital detectors.

NOTE The duplex wire IQI relates only to unsharpness and is not an alternative for the wire, plate/hole or step/hole type IQIs.

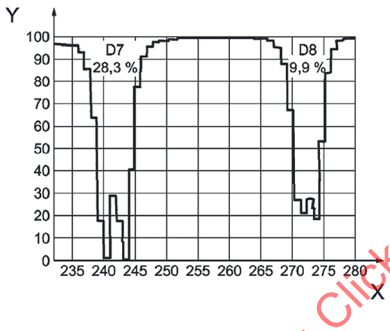
An example of the wire-pair image analysis for calculation of basic spatial resolution, SR_b, and total unsharpness, U_T, of digital images is shown in Figure 2. The lowest wire pair value shall be determined which has a modulation depth (dip) <20 %. The modulation depth is determined in the profile function as shown in Figures 2 c) and 2 d). The first "unsharp" wire pair in Figure 2 c) is D8. The resulting values correspond to Table 1: SR_b = 0,16 mm and U_T = 0,32 mm.



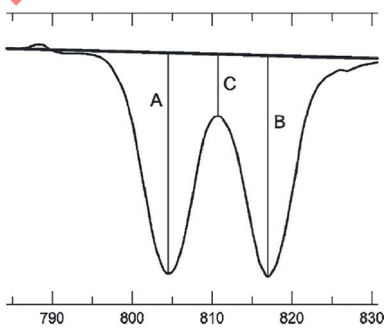
a) Image of duplex wire IQI as shown in a digital radiograph with indicated profile line and its integration window



b) Zoomed profile of a duplex wire IQI, averaged from profile lines, covering 30 % to 60 % of the wire length



c) Zoomed profile of wire pair D7 and D8



d) Scheme of the calculation of the dip value in % with Dip = 100 × (*A* + *B* − 2*C*) / (*A* + *B*)

Key

A intensity value of the first minimum in reference to the base line

B intensity value of second minimum in reference to the base line

C smallest intensity value between the minima A and B in reference to the base line

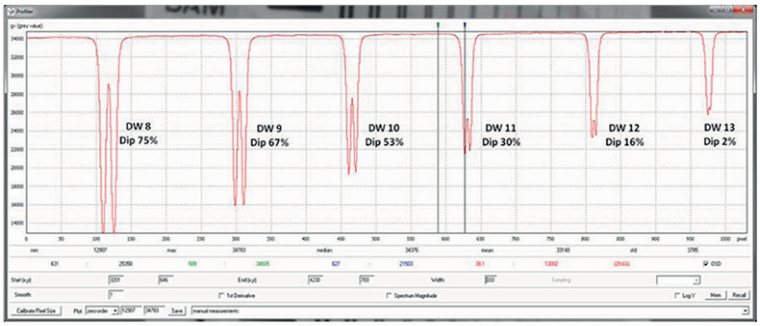
X distance

Y amplitude

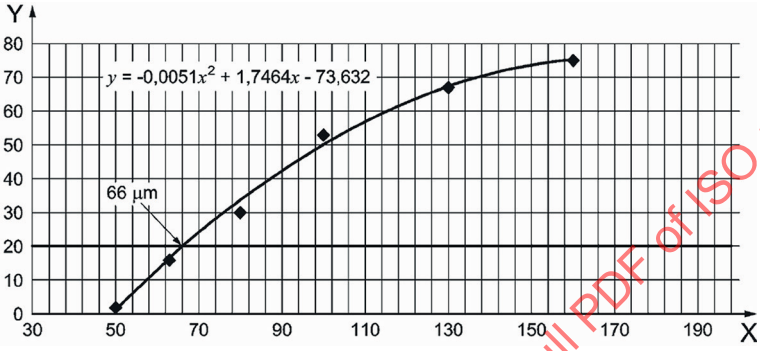
Figure 2 — Wire-pair image analysis for calculation of basic spatial resolution, SR_b, and total unsharpness, U_T, of digital images

NOTE Digitized films and CR images are typically presented and acquired in negative presentation. These images and their line profile plots will be inverted compared to the examples shown (i.e. white = more dense material).

An example of the wire-pair image analysis for calculation of interpolated basic spatial resolution, iSR_b^{image}, and interpolated total unsharpness, U_T, of digital images with $iU_T = 2 \cdot iSR_b^{image}$ is shown in Figure 3.



a) Profile plot of a measured profile of a high resolution system with determined modulation depth (dip)



b) Approximation of modulation depth vs. duplex wire pair spacing[a]

Key

X wire pair spacing in µm

Y modulation depth (dip) in %

a The 20 % value is determined from the intersection with the 20 % line resulting in iSR_b = 0,066 mm and iU_T = 0,132 mm.

Figure 3 — Wire-pair image analysis for calculation of interpolated basic spatial resolution, iSR_b^{image}, and interpolated total unsharpness, U_T, of digital images with $iU_T = 2 \cdot iSR_b^{image}$

6 High resolution IQI with increased measurement range

For special applications, it can be required to measure lower unsharpness values than given in Figure 1 and Table 1. Therefore, alternative high resolution duplex wire IQIs (HR Duplex Wire IQIs) may be used with higher numbers of wire pairs than 13.

These IQIs shall be constructed as described in the example scheme of Figure 4, which describes a HR-IQI with 15 wire pairs. A larger gap of 5 mm is required between the 13th and 14th wire pair to enable the operator a reliable recognition of the higher wire pair values (see Figure 4). HR IQIs can have more than the 15 wire pairs as shown in Figure 4.

Table 2 provides information about the corresponding HR IQI construction requirements of the wire pairs and the corresponding readings of U_T, SR_b and lp/mm for the HR IQI wire pairs with up to 18 wire pairs.

HR duplex wire IQIs may have a reduced number of low-resolution wire pairs for practical reasons. The IQI wire pairs can start with D 4, if more than 15 duplex pairs are available. This needs to be indicated on the IQI with "HR4".

NOTE Duplex wire IQIs with more than 13 wire pairs for readings of higher than D13 can be applicable at lower X-ray tube voltages than 225 kV only. This depends on the properties of the test objects. Users can take test exposures to verify the suitable application and kV range.