INTERNATIONAL STANDARD

ISO 8600-5

Second edition
2020-10

Optics and photonics — Medical endoscopes and endotherapy devices —

Part 5: Determination of optical resolution of rigid endoscopes with optics

Optique et photonique — Endoscopes médicaux et dispositifs d'endothérapie —

Partie 5: Détermination de la résolution optique des endoscopes optiques rigides

Reference number
ISO 8600-5:2020(E)

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Foreword

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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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 172 *Optics and photonics*, Subcommittee SC 5, *Microscopes and endoscopes*.

This second edition cancels and replaces the first edition (ISO 8600-5:2005), which has been technically revised.

The main changes compared to the previous edition are as follows:

— document has been restructured;

— Clause 2 added;

— Clause 3 revised and updated;

— quality characteristics “Contrast Transfer Function” and “Modulation Transfer Function” as measurement methods are introduced;

— Measurement with limiting resolution moved to informative Annex A;

— informative Annex B added;

— informative Annex C added;

— normative Annex D added;

— informative Annex E added;

— informative Annex F added;

— informative Annex G added.

A list of all parts in the ISO 8600 series can be found on the ISO website.

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.

Optics and photonics — Medical endoscopes and endotherapy devices —

Part 5: Determination of optical resolution of rigid endoscopes with optics

1 Scope

This document applies to rigid endoscopes designed for use in the practice of medicine. Endoscopes having a fibre-optic or opto-electronic imaging system are excluded. It specifies a test method for determining the optical resolution of endoscopes.

This document provides a measurement method for characterizing three aspects of the optical resolution of a rigid endoscope. Characteristic A is used to provide a simple measurement of the limiting resolution of the endoscope image. Characteristic B provides a measurement of low spatial frequency resolution and characterizes the sharpness, or contrast, of the endoscope image. Characteristic C provides a measurement of the spatial frequency response of the endoscope image.

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 9334, *Optics and photonics — Optical transfer function — Definitions and mathematical relationships*

ISO 12233:2017, *Photography — Electronic still picture imaging — Resolution and spatial frequency responses*

ISO 15529:2010, *Optics and photonics — Optical transfer function — Principles of measurement of modulation transfer function (MTF) of sampled imaging systems*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 http://www.electropedia.org/

3.1
angular limiting resolution
smallest angle whose vertex is at the entrance pupil (can be approximated by the distal window surface if the target distance from the distal window is significantly larger than the distance between the distal window surface and the entrance pupil) of the endoscope at which a line pair (lp) at a given working distance d can just be resolved with normal visual acuity, with the unit of degrees/lp

Note 1 to entry: Angular limiting resolution is calculated using the formula

$$\alpha = \arctan \frac{1}{d \cdot r(d)}$$

where $r(d)$ is the limiting resolution.

3.2
camera
image detector used in the measurement, which is connected to the endoscope under test via coupling optics

Note 1 to entry: As used in this standard, the camera includes an image detector (typically CCD or CMOS image sensor), supporting electronics, and firmware/software used to obtain a digital sampling of the image formed by the coupling optics.

3.3
contrast
ratio of the difference between the intensities of the brightest and the darkest regions of a bar test target with square-wave modulation or its image divided by the sum of the intensities of the brightest and the darkest regions of the target or its image, and subsequently multiplied by 100 to measure as a percentage

Note 1 to entry: Contrast is given by

$$C(\%) = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} \times 100$$

where I_{max} and I_{min} are the intensities of the brightest and darkest regions of the target or its image, respectively.

3.4
contrast transfer function
CTF

plot of *contrast* (3.3) transfer factor, C_{TF}, as a function of *spatial frequency* (3.13), u

Note 1 to entry: Contrast transfer factor is given by

$$C_{TF}(u) = \frac{C(u)_{out}}{C(u)_{in}}$$

where $C(u)_{out}$ is the output contrast (i.e. the image contrast) and $C(u)_{in}$ is the input contrast (i.e. the target contrast).

Note 2 to entry: If the target has high contrast so that $C(u)_{in}$ is close to one, $C_{TF}(u)$ can be approximated by $C(u)_{out}$. If C_{TF} is normalized to 1 at zero frequency, constant $C(u)_{in}$ will get factored out in the normalization. The CTF of an endoscope can be obtained by measuring a series of square-wave bar targets with different *spatial frequencies*. The low-frequency contrast of the target as imaged through the endoscope may be measured with target patches of light and dark large enough that the intensity profile through the patch clearly reaches a steady value.

Note 3 to entry: For the purposes of the test specified in Characteristic B of this document, the "targets" will be the bar test targets specified in 4.2.5.2 and the measured results will be the CTF.

3.5
limiting resolution
r(*d*)
maximum number of line pairs per mm (lp/mm) which can be resolved at a given working distance *d* of the endoscope

Note 1 to entry: The limiting resolution is only applicable to Characteristic A.

3.6
maximum image height
radius of a circle which circumscribes the image

Note 1 to entry: If the image is rectangular, the maximum image height is half of the diagonal.

Note 2 to entry: If the image is circular, the maximum image height is the radius of the image circle.

3.7
maximum object height
radius of a circle which circumscribes the portion of the object which can be imaged by the endoscope

Note 1 to entry: If the image is rectangular, the maximum object height is half of the distance between the object points which map to the corners of the image rectangle.

Note 2 to entry: If the image is circular, the maximum object height is the radius of the object space circle which maps to the image circle.

3.8
modulation
M
ratio of the difference between the intensities of the brightest and the darkest regions of a sinusoidal test target or its image divided by the sum of the intensities of the brightest and the darkest regions of the target or its image, and subsequently multiplied by 100 to measure as a percentage

Note 1 to entry: Modulation is given by

$$M(\%)=\frac{I_{max}-I_{min}}{I_{max}+I_{min}}\times 100$$

where I_{max} and I_{min} are the intensities of the brightest and darkest regions of the image, respectively.

3.9
modulation transfer function
MTF
plot of the *modulation* (3.8) transfer factor, M_{TF}, as a function of *spatial frequency* (3.13) *u*, for a sine-wave target

Note 1 to entry: M_{TF} is a measure of the transfer of modulation from the object to the image.

Note 2 to entry: Modulation transfer factor is given by

$$M_{TF}(u)=\frac{M(u)_{out}}{M(u)_{in}}$$

where $M(u)_{out}$ is the output modulation (i.e. the image modulation) and $M(u)_{in}$ is the input modulation (i.e. the target modulation).

Note 3 to entry: If the target has high contrast so that $M(u)_{in}$ is close to one, $M_{TF}(u)$ can be approximated by $M(u)_{out}$. On the other hand, M_{TF} curves are always normalized to 1 at zero frequency, which make a constant $M(u)_{in}$ negligible. The MTF of an endoscope can be obtained by measuring a series of sinusoidal targets with different spatial frequencies, or by other methods such as a slanted-edge target as discussed in 4.2.5.3.

3.10
off-axis limiting resolution
limiting resolution (3.5) at an image point at 70 % of the *maximum image height* (3.6)

Note 1 to entry: See Figure A.1.

3.11
on-axis limiting resolution
limiting resolution (3.5) at the image centre

Note 1 to entry: See Figure A.1.

3.12
optical resolution
numerical measure of the image quality of an optical system

3.13
spatial frequency
u
measure of how often a structure (e.g., sine-wave or square-wave bars) on the target or image repeats per unit distance or angle

Note 1 to entry: Spatial frequency has different units (e.g. lp/mm, lp/degree, lp/pixel), depending on whether the *target period* is measured in distance or angle units.

Note 2 to entry: The narrower definition of spatial frequency only refers to the sinusoidal components of the structure.

Note 3 to entry: The units of lp and cycles are often used interchangeably; in this standard, the unit of lp is used when referring to a square-wave or bar target (limiting resolution and CTF measurement), and cycles are used when referring to sine wave components (MTF) and to spatial frequencies in general.

3.14
working distance
d
design distance defined by the manufacturer between the object and distal end of the endoscope

Note 1 to entry: For the purposes of the test specified in this document the "object" will be the resolution target specified in 4.2.5.

4 Test method

4.1 General

Three characteristics of endoscope resolution are given in the method below. At least one characteristic should be measured. Table 1 may be used as a guide to determine the appropriate characteristic. See Annex A, B and C for acceptable test methods. Other methods of measuring the characteristics are allowed; if an alternative method is used, it shall be described in the test report.

Table 1 — Characteristics and measuring

Characteristic	Where Appropriate
A – Limiting resolution	A single-valued subjective metric for rapid manufacturing testing, quality assurance (e.g. in end of line endoscope assembly testing), or for providing a simple metric that can be easily understood by end users. See Annex A for information on the measurement procedure.
B – Contrast transfer function (CTF)	A multi-valued objective metric for device validation and verification. It is less scientifically sophisticated than MTF, but it is mathematically simple, can be easily understood by end users, and can be measured with a square-wave target that can be easily produced. Multiple target images are needed to obtain CTF measurements at different spatial frequencies. See Annex B for information on the measurement procedure.

Table 1 *(continued)*

Characteristic	Where Appropriate
C – Modulation transfer function (MTF)	A multi-valued objective metric where all values can be obtained from a single target; most used in engineering (e.g. design verification), diagnostic, and image evaluation purposes and serves as an umbrella function to derive other metrics (e.g. sharpness, acutance). It is widely used in scientific fields. See Annex C for information on the measurement procedure.

NOTE Annex E gives advice on the conversion of spatial frequencies. Annex G shows examples for relay optics.

4.2 Apparatus

4.2.1 Optical bench/optical rail, with mounting apparatus for endoscope and resolution target.

4.2.2 Coupling optics, to magnify a portion of the endoscope's field of view and image it onto the camera. Examples of coupling optics designed to meet the requirements of endoscope resolution measurement are discussed in Annex F. The coupling optics shall not change the measured limiting resolution significantly (Characteristic A only). The entrance pupil diameter of the coupling optics shall be larger than the exit pupil of the endoscope; the coupling optics shall not cut off rays of the endoscope. On-axis and off-axis measurement shall be made at the same focus.

NOTE The coupling optics still can have a significant influence on the result, because of coherent coupling between the coupling optics and the endoscope.

4.2.3 Camera, with monitor and means of digitally recording the relative intensity of each pixel. As described in D.4, the response of the system shall be maintained within the linear operating range of the camera (e.g. any sharpening or image enhancement is turned off, and gamma is set to 1,0).

NOTE If the camera cannot be set within the linear operating range, the intensity of a target image can be converted to linear intensity based on the opto-electric conversion function (OECF) of the camera. The camera OECF can be measured based on the ISO 14524.

4.2.4 Light source, white light, unless the endoscope is specifically designed for a specific wavelength, in which case this specific wavelength should be used.

NOTE It is acceptable to use a magnified image of a part of the endoscope's field of view containing the target, projected onto the test camera, to reduce the resolution requirements of the camera. Examples of coupling optics designed to meet the requirements of endoscope resolution measurement are discussed in Annex F.

4.2.5 Resolution target

4.2.5.1 Characteristic A: Resolution target, having adequately graduated black and white test patterns arranged at least in two directions, tangential and sagittal. Note that, for inclined direction of view endoscopes (endoscopes having a non-zero direction of view), tangential and sagittal are defined with respect to the direction of view. A resolution target consists exclusively of on-axis and off-axis test patterns arranged as in Figure A.1. Resolution test patterns consist of two transmittance or reflective values (Figure A.2). Alternatively, a single test pattern may be used if it is moved perpendicular to the optical axis to obtain off-axis measurements. It shall be ensured that the endoscope's resolution is determined and not the resolution of the target (see D.5).

4.2.5.2 Characteristic B: CTF target, having a black and white pattern that consists exclusively of two transmittance or reflectance values (Figure A.2). The surface of a reflectance target should be a Lambertian surface. The resolution target should contain on-axis and off-axis test patterns arranged as in Figure A.1. Alternatively, a single test pattern may be used if it is moved perpendicular to the optical axis to obtain off-axis measurements. It shall be ensured that the endoscope's resolution is determined and not the resolution of the target (see D.5).

