



BSI Standards Publication

Guidelines for in-service inspections for primary coolant circuit components of light water reactors

Part 4: Visual testing

National foreword

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Guidelines for in-service inspections
for primary coolant circuit
components of light water reactors —
Part 4:
Visual testing

*Lignes directrices pour les contrôles périodiques des composants du
circuit primaire des réacteurs à eau légère —
Partie 4: Examen visuel*



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CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
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Foreword

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This document was prepared by ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 6, *Reactor technology*.

A list of all parts in the ISO 20890 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.

Guidelines for in-service inspections for primary coolant circuit components of light water reactors —

Part 4: Visual testing

1 Scope

This document gives guidelines for pre-service inspection (PSI) and in-service inspections (ISI) for reactor coolant circuit components of light water reactors and their installations as direct or remote visual testing in the form of a

- general visual testing (overview), or
- selective visual testing (specific properties).

This document is also applicable to other components of nuclear installations. The requirements in this document focuses on remote (mechanized) visual testing, but also specifies global requirements for direct visual testing. For specific requirements for direct visual testing of welds see [ISO 17637](#).

This document is not applicable to tests in respect to the general state that are carried out in conjunction with pressure and leak tests and regular plant inspections.

This document specifies test methods that allow deviations from the expected state to be recognised, requirements for the equipment technology and test personnel, the preparation and performance of the testing as well as the recording.

NOTE Data concerning the test section, test extent, inspection period, inspection interval and evaluation of indications is defined in the applicable national nuclear safety standards.

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 8596](#), *Ophthalmic optics — Visual acuity testing — Standard and clinical optotypes and their presentation*

[ISO 9712:2012](#), *Non-destructive testing — Qualification and certification of NDT personnel*

[ISO 18490](#), *Non-destructive testing — Evaluation of vision acuity of NDT personnel*

[EN 1330-10](#), *Non-destructive testing — Terminology — Part 10: Terms used in visual testing*

[EN 13018](#), *Non-destructive testing — Visual testing — General principles*

[EN 13927](#), *Non-destructive testing — Visual testing — Equipment*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in [EN 1330-10](#) and the following apply.

3.9**selective visual testing**

local visual testing for unique recognition of specified properties

Note 1 to entry: The selective visual testing is used in order to record the state of parts, *components* (3.10) or surfaces to be examined in respect to cracks, wear, corrosion, erosion or mechanical damage on the surface of the parts or *components* (3.10).

3.10**component**

part of a system delimited according to structural or functional aspects, which can still implement independent sub-functions

3.11**reference standard**

<visual testing> specimen for inspecting the settings of the test system and its function during the testing

Note 1 to entry: Test images (e.g. colour boards according to [Annex A](#) or similar test images) are used as reference standards during the visual testing. Depending on the test assignment and device system, a scalability of test images can be necessary.

3.12**mechanized visual testing**

remote visual testing (3.8) with mechanized guidance of camera or video-endoscope

3.13**test section**

part of the *test area* (3.15)

3.14**test supervisor**

responsible for application of the test method and for the individual details of the test performance including monitoring of the activities for preparation and performance of the test as well as analysis of the test results

3.15**test area**

defined area on the *test object* (3.17) over which the tests are to be conducted

[SOURCE: ISO 5577:2017, 6.2.2]

3.16**test surface**

surface of the *test object* (3.17) to be tested

3.17**test object**

part of a *component* (3.10) to be tested

3.18**visual testing**

method of non-destructive testing using electromagnetic radiation in the optical range

[SOURCE: EN 1330-10:2003, 2.53]

Note 1 to entry: The visual testing serves to acquire the actual state of a test object with the human eye for comparison with the expected target state.

3.19

reference block

piece of material, with specified metallurgical, geometrical and dimensional characteristics, used for calibration and assessment of equipment for visual testing

Note 1 to entry: Specified metallurgical, geometrical and dimensional characteristics means for example material, weld seam implementation, form, wall thickness, any cladding present) with reference characteristics (e.g. grooves, bores) that are adapted to the test assignment.

Note 2 to entry: Depending on the test assignment, the properties relevant to the inspection technique can be determined by *hue* (3.4), *colour intensity* (3.3), reflectivity or texture of the surface.

4 Inspection technique

Visual testing is used to recognise deviations from the expected state. This state is specified in the test procedures. Depending on the test assignment, the visual testing is conducted either as a general visual testing or a selective visual testing. Depending on the accessibility and required detail recognition, direct or remote visual testing is used, whereby the latter can be carried out as a mechanized visual testing. The local radiation dose rate shall be considered when selecting the inspection techniques and auxiliaries.

The suitability of the inspection technique and the combined device system shall be validated according to the requirements of the applicable nuclear safety standards.

NOTE 1 The procedure for the qualification of the inspection techniques or the combined device system is described in ENIQ report nr. 31[3].

NOTE 2 The visual testing test method discussed in this document involves a standardized test method whose application is realised based on standard test procedures relating to nuclear power plants. A qualification as above can be necessary in individual cases if there are significant deviations from the specifications from the test procedures.

A general test procedure shall be prepared. [Annex B](#) contains the items of the general test procedure.

5 Requirements

5.1 Test personnel

5.1.1 Task of NDT personnel

NDT personnel[4] have a great responsibility, not only with respect to their employers or contractors but also under the rules of good workmanship. The NDT personnel shall be independent and free from economic influences with regard to his test results, otherwise the results may be compromised. The NDT personnel shall be aware of the importance of his signature and the consequences of incorrect test results for safety, health and environment. Under legal aspects, the falsification of certificates is an offence and judged according to the national legal regulations. A tester may find himself in a conflicting situation about his findings with his employer, the responsible authorities or legal requirements.

Finally, the NDT personnel is responsible for all interpretations of test results carrying his signature. NDT personnel should never sign test reports beyond their certification (see [Table 1](#)).

NOTE For reasons of readability, the male form is used with personal names, however the female form is also always intended.

5.1.2 Personnel requirements

The test personnel comprise the test inspector, the test supervisor and possibly the operating personnel for the test robot.

Those personnel, using qualified non-destructive testing (NDT) procedures and equipment, should be qualified through one or any combination of the following:

- certification through a national NDT personnel certification scheme;
- theoretical and/or open trials;
- blind trials.

Any personnel certification requirements invoking relevant national NDT personnel certification schemes (e.g. [ISO 9712](#)) should be validated according to [Table 1](#). Any additional personnel training requirements should also be specified in the qualification dossier.

If no relevant scheme exists or if extra personnel qualification is needed, the qualification body should determine the additional practical and theoretical examinations needed beyond those in the national certification scheme, include these in the qualification procedure and ensure that the NDT procedure also includes the necessary requirements. The qualification procedure should describe the proposed system.

The test supervisor is responsible for the application of the NDT qualified system and shall have the knowledge required for his tasks as well as sufficient knowledge of the application options and limitations of the test methods and have knowledge about the characteristic appearances of operationally induced faults. Conspicuous indications requiring more extensive measures shall be evaluated by the test supervisor, who has the requisite experience in respect to the test object, test assignment, test method and combined device system.

The test inspectors shall have the skills to perform the work they are to carry out. In particular, they shall have sufficient experience in conducting visual testing and knowledge in respect to this concerning the test object and appearance of conspicuous indications that can result during operation.

The operating personnel for test robots and the test inspectors during mechanized testing shall be trained for the requirements of the work to be carried out.

Test personnel performing NDT and the evaluation of the results shall be qualified in accordance with [ISO 9712](#) or equivalent at an appropriate level in the relevant industrial sector.

Table 1 — Minimum requirements for the test personnel

Test personnel	Qualification
Operating personnel for test robots	Validation by training
Test inspector	Certified with at least level 2 according to ISO 9712 or comparable qualification
Test supervisor	Certified with at least level 2, in case of mechanized tests certified with level 3, according to ISO 9712 respectively

The test personnel shall fulfil the vision requirements of [ISO 9712:2012](#), 7.4.

The test personnel shall provide annual validation of their visual ability, which has been determined by an ophthalmologist, optician or other medically recognised person. The vision requirements of [ISO 9712](#) shall be fulfilled. The following modifications can be used as a substitute to [ISO 9712](#).

- The visual acuity testing shall be conducted using standard symbols in accordance with [ISO 8596](#) (Landolt rings) or [ISO 18490](#) (E shaped character). Here a near vision acuity of 1,0 at a test distance of 0,33 m and a with at least one eye, with or without optical aid shall be validated.
- The ability to distinguish between colours and between grey shadowing shall be validated with colour sense test boards. The validation can typically be conducted with the help of Ishihara colour boards as well as the "shades of grey test". In case of anomalies, the employer shall decide whether the ability to see colours is sufficient for the test assignment.

If disorders in the adaptability are determined, these shall be considered.

5.2 Test area

The test area shall be accessible directly or remotely with optical auxiliaries. The viewing section shall be illuminated sufficiently. Interfering reflections shall be avoided, insofar as possible. Interfering deposits shall be removed, insofar as possible, unless they represent an indication of a relevant change.

During testing under water, it shall be ensured that vision is not inadmissibly impaired by suspended matter and streak formation.

5.3 Optical auxiliaries and combined device system

5.3.1 General

The use of optical auxiliaries and combined device systems during visual testing is necessary if

- concealed test objects or test objects inaccessible due to ionising radiation have to be made accessible to observation,
- the detail resolution is inadequate,
- image documentation is required.

Optical auxiliaries and combined device systems used shall fulfil the requirements of [EN 13927](#) as well as the requirements according to [5.3.2](#) to [5.3.6](#).

5.3.2 Image quality and resolution

The examination equipment shall fulfil the following requirements:

- The image quality of the examination equipment shall be validated at a reference standard (e.g. test image according to [Annex A](#) or a similar test image). The calibration of the device system shall be documented;
- The reference standard shall be reproduced to fill the format on the screen without any zoom in direct view. The minimum distance between the screen and observer is minimum 30 cm when checking the image quality. The resolution of the camera should be at least 400 lines or 600 kpixels (depending on the referenced test chart).

If a resolution of 400 lines cannot be attained, the attained resolution shall be documented in the technical justification. The working distance between the camera and reference standard or the zoom level of the camera shall be selected so that the required resolution of 400 lines is attained in the mapped partial section of the reference standard. This distance or this zoom level shall be documented and considered during the testing.

- The individual stages of the colour circle and colour bars shall be distinguishable both for the colour reproduction and for the black-white reproduction (see [Annex A](#) test image) and shall reproduce the corresponding hue (chromatic and achromatic colour) and colour intensity. The grey tones shall be resolved. The geometry distortions may not impair the visual testing;
- The validation of the image quality shall be provided and documented. The validation shall be performed at the screen used for analysis and evaluation of the visual testing. All essential parameters for validation have to be described in a Technical Justification (e.g. zoom level, working distance, incidence angle, etc.)

The image quality and resolution depend on the system used in the case of remote VT systems (e.g. video endoscopes). The requirements in place for conducting the test are specified in the test procedures.

The performance of the examination equipment shall be validated at a reference block adapted to the test assignment. The detail resolution shall be determined and documented. The working distance and zoom level shall be documented and considered in the test.

The recorders and playback devices shall meet the requirements of this subclause in respect to the image quality of the optical auxiliaries. The playback device shall have frame-to-frame playback.

In case of underwater tests, an inspection of the function, image quality and capability of the immersed equipment is necessary. The inspection shall be documented.

5.3.3 Construction

5.3.3.1 General

The optical auxiliaries and combined device systems shall be selected with consideration of the application conditions in such way that

- they can be handled in a time-saving manner in respect to the radiation exposure of the test personnel,
- they are easy to decontaminate,
- the materials used, in particular glass as well as electrical and electronic components are resistant to ionising radiation and do not release or exhibit any impermissible impurities,
- the effect of ionising radiation on the image quality is kept as low as possible by corresponding measures (e.g. shielding),
- they can be used in a temperature range required for the application,
- adjustable lighting equipment is available, which is protected against bursting and mechanical damage,
- connection options for recorders are available in examination equipment (for remote VT),
- visualisation of the following data is possible in combined device systems:
 - place, date, time;
 - component, test item, comments.

5.3.3.2 Endoscopes and video-endoscopes

Endoscopes and video-endoscopes shall be selected in relation to the test assignment in such way that

- focussing, if necessary,
- if there is a light cable, then the shaft needs to be rotatable,
- the probes are corrosion resistant and, insofar as required, watertight in design,
- if necessary, a scale or scaling function is available for measure the dimension of indications.

5.3.3.3 Cameras

Cameras shall be selected with consideration of the terms of reference and the application conditions.

EXAMPLE

Camera can be equipped with

- autofocus,
- automatic aperture control,

- automatic brightness control,
- zoom and macro function, and
- pan-tilt function.

It shall be possible to switch on/off the automatic functions.

5.3.4 Lighting equipment for the remote visual testing

The luminous flux of the lighting equipment shall be selected in such way that a sufficient illuminance is attained on the test surface. The illuminance and the light type shall be examined at the reference block or at known structures of the component and monitored during the test. Comparable conditions shall be present on the test surface. The light distribution on the test surface should be as uniform as possible. According to [ISO 17637](#) for direct VT illuminance on the area to be inspected should be at least 350 lx, but 500 lx are recommended. For remote (mechanized) VT the illuminance depends on the environmental conditions so that an illuminance lower than 350 lx can be practical.

The lighting equipment should be able to be positionable and adjustable.

Valid calibration certificates shall be provided for measuring instruments of the illuminance. These shall not be older than 12 months.

5.3.5 Data storage medium

The data storage medium shall be designed in such way that

- they enable a labelling for identification,
- an unintentional overwrite is prevented,
- the suitability for storage is ensured.

It shall be ensured that measuring data can be read and processed by the next in-service inspection.

NOTE The operating system or hardware modifications could render it necessary to transfer original data to other data storage medium types.

5.3.6 Test robots

Test robots (also called remote handling manipulator) shall be designed so that they can be

- used at the test section of the relevant test object,
- controlled and aligned remotely, and
- positioned corresponding to the test assignment.

6 Testing

6.1 Preparation

6.1.1 General

The test personnel shall be timely instructed prior to the inspection concerning the performance, scope and target objectives of the testing. All requisite documents, such as test procedures, drawings or piping isometries necessary for conducting the testing shall be provided.

Before using mechanized combined device systems in areas exposed to radiation, training measures for rapid assembly and disassembly shall be realised for reducing the time personnel remain in such areas. The training measures shall be documented and, if necessary, validated by the test service provider.

6.1.2 Test location

The control devices, recorders and playback devices shall be set up in such way that

- heat accumulation is avoided,
- the operation is not prevented,
- interfering reflections are avoided,
- the test can be conducted without impediment.

6.2 Performance

6.2.1 General

According to the defects that could appear in service the test surface shall be inspected before a cleaning or processing, as deposits and corrosion are signs of changes. Insofar as necessary, the test surfaces shall be cleaned. When doing so, it shall be ensured that the surface structure is not changed.

The test surface shall be sufficiently illuminated. This shall be evaluated based on the detail recognition of known surface structures in the surroundings of the test section.

The illumination direction to the test object and to the optical axis shall be selected in such way that an optimal image contrast results. Interfering reflections and shadows shall be avoided, insofar as possible. The view of the test surface shall be optimised in case of conspicuous indications from various directions of view with variation of the illumination. If the hue is a test property, a suitable spectrum of the light source shall be ensured.

The function, image quality and capability of the combined device system shall be checked before the test, after longer interruptions, after replacing components or a conversion of the system and after testing. The result of these checks shall be documented. The measures in case of deviations shall be defined in the test procedures.

The actual state of the test area shall be recorded in comparison to the expected target state. Deviations from the target state shall be documented as conspicuous indications. Deviations from the expected state can be e.g.

- surface changes;
- material separations;
- mechanical damage;
- corrosion, erosion, wear;
- conspicuous indications at screw connections;
- conspicuous indications at connections of measuring points and lines;
- indications of leaks;
- displacement of components;
- loose and lost parts;
- deposits or foreign bodies.

Conspicuous indications that have been detected when conducting a general visual testing shall be examined and evaluated via a selective visual testing. The result shall be documented.

If conspicuous indications are detected, their location, appearance and, if possible, their size shall be determined and documented in the test record.

6.2.2 Direct visual testing

The requirements of [6.2.1](#) shall be met. General visual testing shall be conducted in accordance with [EN 13018](#). Selective visual testing shall be conducted as local visual testing in accordance with [EN 13018](#). If access to the test area is not possible, mirrors or endoscopes may be used.

6.2.3 Remote visual testing

The requirements of [6.2.1](#) shall be met. The following requirements also apply.

- a) Combined device systems corresponding to the selection criteria according to [5.3.3](#) to [5.3.6](#) shall be used for the remote visual testing.
- b) In case of high radiation black and white cameras shall be used due to a better resistance against radiation. For very high radiation black and white tube cameras have a better sensitivity and life expectancy than CCD or CMOS cameras.
- c) During the test, the operating conditions shall remain within the limits that guarantee the inspection sensitivity; these limits are defined during the inspection performance evaluation (see [5.3.2](#)).
- d) The following measures are possible in order to improve the detail recognition in case of conspicuous indications, if required:
 - Magnification of the conspicuous indications with simultaneous use of a reference scale,
 - Recording from another direction of view,
 - Change in the illumination,
 - Use of a camera with higher resolution.

6.2.4 Mechanized visual testing

The requirements of [6.2.1](#) and [6.2.3](#) shall be met. The following requirements also apply.

- a) A test robot according to [5.3.6](#) shall be used. Before testing, a functional check of the test robot including monitoring of the movement directions shall be conducted. In case of underwater tests, it is also necessary to monitor the function of the immersed equipment. In general, this is realised with the overall test of the combined devices systems.
- b) The image information with the associated locational coordinates shall be recorded.
- c) To be able to ensure the reproducibility of the test, the test position and memory location on the data storage medium shall be uniquely assigned to one another in the drive program. Conspicuous indications at the test object shall be documented.
- d) Setpoint values such as test speed, travel paths, maximum distance between camera and test surface (working distance) or the visualisation scale shall be specified and the actual values entered in the drive program, if necessary.
- e) The test speed (acquisition speed) shall be selected so that the defects looked for are detectable at inspection speed. In special cases the analysis speed has to be lower than the acquisition speed.

6.3 Evaluation

The evaluation of deviations shall be conducted corresponding to the specifications of the applicable national nuclear safety standards.

6.4 Final measures

The records on data storage medium shall be checked randomly in respect to their image quality.

7 Recording

A test record or test report shall be compiled concerning the testing. The test documentation of the mechanical testing should also be backed up in digital form in addition to paper form.

The following data shall be included:

- date of the testing;
- name of the power plant;
- test procedures;
- test object, test scope and test section:
 - location of the test section;
 - reference point;
 - coordinates;
 - surface condition (e.g., cleaned, not cleaned);
- inspection technique:
 - test technique used (general or selective);
 - inspection technique used (direct or remote);
 - examination equipment and device system (e.g., mirror, magnifying glass, endoscope, video endoscope, camera, test robot, lighting) with data on the following:
 - test parameters;
 - in the case of remote testing, reference standards and reference blocks used;
 - in the case of mechanized testing, actual values (i.e. drive programme);
 - in the case of mechanized testing, test robot settings;
 - optical auxiliaries (e.g. luxmeter);
- result of the test and, if necessary, results comparison with the previous in-service testing:
 - attained image quality and performance,
 - conspicuous indications (e.g., type, location, appearance, possible size),
 - relevant indications,
- image documentation of findings and possibly conspicuous indications;
- deviations from the specifications of the test procedures;

- name of the test organisation;
- place, date, name, signature, certificate number of the test inspectors and test supervisors of the operator or the test company commissioned by him and the third party.

Annex A
(informative)

Examples of a test image

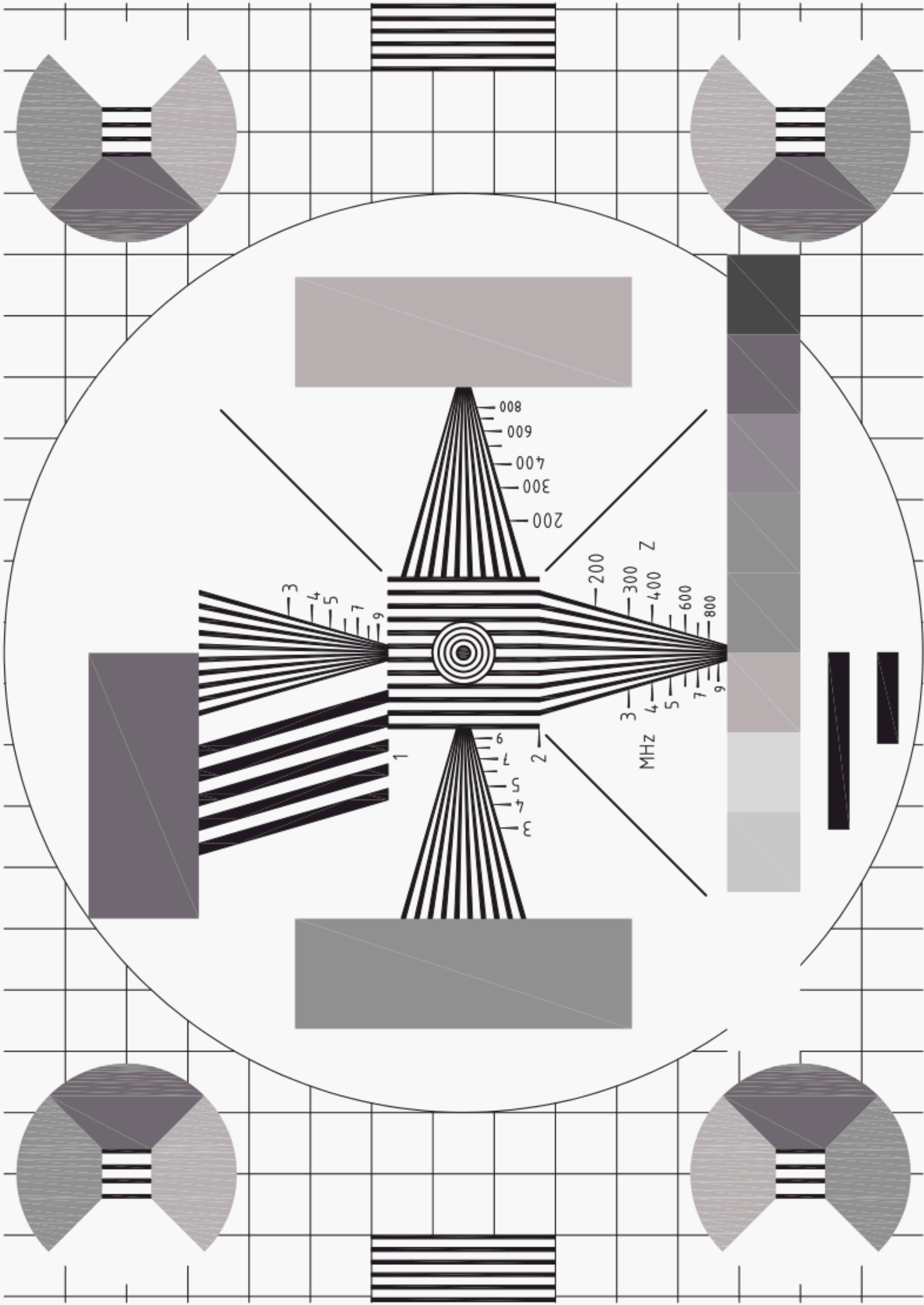


Figure A.1 — Black and white test image

Annex B **(informative)**

Test procedures

The test procedure contains at least the following data:

- scope of validity;
- jointly applicable regulations, standards and instructions;
- test objective and properties to be validated (e.g. surface changes, mechanical damage, leaks);
- personnel qualifications;
- data on the test object and possibly data on the test scope and date of test;
- data on test preconditions;
- test method (general or selective);
- inspection technique (direct or remote);
- combined device system (examination equipment e.g., endoscope, camera, test robot, illumination; auxiliaries, e.g., luxmeter);
- data on the inspection of the combined device system;
- data on the test performance and analysis as well as evaluation of conspicuous indications;
- data concerning applicable documents, in which the descriptions of the combined device system are provided (e.g. data on test robots, optical auxiliaries, recorders and playback devices), the test performance including drive program for the test robots, data on the reference points at the test object and information concerning the evaluation, type and scope of the documentation as well as information on particular characteristics;
- type and scope of the recording.

Bibliography

- [1] [ISO 5577:2017](#), *Non-destructive testing — Ultrasonic testing — Vocabulary*
- [2] ISO/TS 18173:2005, *Non-destructive testing — General terms and definitions*
- [3] ENIQ report n° 31, European Methodology For Qualification Of Non- Destructive Testing
- [4] [ISO/TS 25107:2019](#), *Non-destructive testing — NDT training syllabuses*

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BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

