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## **In-service inspections for primary coolant circuit components of light water reactors — Part 4: Visual testing**

*Contrôles périodiques des composants du circuit primaire des réacteurs à eau légère — Examen visual*

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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](http://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](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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](http://www.iso.org/iso/foreword.html).

The committee responsible for this document is ISO/85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 6, *Reactor technology*.

ISO 20890 consists of the following parts.

- *Part 1: Mechanized ultrasonic testing*
- *Part 2: Magnetic particle testing and penetrant testing*
- *Part 3: Hydrostatic testing*
- *Part 4: Visual testing*
- *Part 5: Eddy current testing of steam generator heating tubes*
- *Part 6: Radiographic testing*

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

## 1 Scope

This standard is applicable to in-service inspections for reactor coolant circuit components of light water reactors and their installations as direct or remote visual testing in the form of a

- a) general visual testing;
- b) selective visual testing.

This standard is also applicable to other components of nuclear installations.

This standard 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 standard 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 scope, date of testing, test 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 optotype and its presentation*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

EN 13018, *Non-destructive testing — Visual testing — General principles*

EN 1330-10:2003, *Non-destructive testing — Terminology — Part 10: Terms used in visual testing;*

EN 13927, *Non-destructive testing — Visual testing — Equipment*

ENIQ report nr. 31, *European Methodology For Qualification Of Non- Destructive Testing )*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1330-10 and the following apply.

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

### 3.1

#### **Conspicuous indications**

deviations in the actual state recorded during the visual testing from the expected target state

### 3.2

#### **Relevant indication**

<Visual testing> NDT indication (conspicuous indication) that is caused by a condition or type of discontinuity that requires evaluation

[SOURCE: ISO/TS 18173:2005-01, 2.24]

### 3.3

#### **Colour intensity**

difference in a colour from the equally bright achromatic colour

Note 1 to entry: Colours with equally bright achromatic colour create the same grey tone in the black-white appearance.

### 3.4

#### **Hue**

chromatic type of a colour

Note 1 to entry: Words like red, yellow, green etc. are used to refer to this in daily life.

### 3.5

#### **Data storage medium**

<Visual testing> storage medium for the storage of image information

### 3.6

#### **Direct visual testing**

visual testing where there is an uninterrupted optical path from the observer's eye to the test area

[SOURCE: EN 1330-10:2003-05, 2.12]

Note 1 to entry: This test can be carried out with or without auxiliaries, e.g. magnifying glass, mirror, binoculars, endoscope or fibre-optic device.

### 3.7

#### **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 or surfaces to be examined in respect to cracks, wear, corrosion, erosion or mechanical damage on the surface of the parts or components.

### 3.8

#### **Remote visual testing**

visual testing where there is an interrupted optical path from the observer's eye to the test area

[SOURCE: EN 1330-10:2003-05, 2.37]

Note 1 to entry: Remote visual testing includes a device system that records, communicates, visualises and, if necessary, stores image information.

**3.9****General visual testing**

visual testing over areas of the component to observe overall condition, integrity and state of degradation

[SOURCE: EN 1330-10, 2.18]

**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****Mechanised visual testing**

remote visual testing with mechanised guidance of camera or video-endoscope

**3.13****Test section**

Part of the test area

**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**

area of the test object to be tested

**3.16****Test surface**

surface of the test object to be tested

**3.17****Test object**

part of a component to be tested

**3.18****Visual testing**

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

[SOURCE: EN 1330-10:2003-05, 2.53]

Note 1 to entry: The visual testing serves for recording 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 the calibration and assessment of equipment

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, colour intensity, 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 mechanised visual testing.

The suitability of the inspection technique and the combined device system shall be validated according to the requirements of the applicable nuclear safety standards. The procedure for the qualification of the inspection techniques or the combined device system is described in ENIQ report nr. 31.

NOTE The visual testing test method discussed in this part of the standard series involves a standardised 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.

## 5 Requirements

### 5.1 Test personnel

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

The test supervisor shall have the knowledge required for his tasks as well as know the application options and limits 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 testings 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 mechanised 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. The qualifications of the test personnel shall be validated according to Table 1.



**Table 1 — 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
Test supervisor	Certified with at least level 2, in case of mechanised tests certified with level 3, according to ISO 9712 respectively

The test personnel shall fulfil the vision requirements of ISO 9712, section 7.2

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 modification can be used as a substitute to ISO 9712:

- a) The visual acuity testing shall be conducted using standard symbols according to ISO 8596 (Landolt rings) or equivalent. Here a near vision value of 1.0 at 0.33 m test distance and additional a far vision value of 0.8 with at least one eye, with or without vision aid shall be validated;
- b) 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 indirectly 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:

- a) concealed test objects or test objects inaccessible due to ionising radiation have to be made accessible to observation;
- b) the detail detection is inadequate;
- c) 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 5.3.7.

### 5.3.2 Image quality and resolution

The examination equipment shall fulfil the following requirements:

- a) 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;
- b) The reference standard shall be reproduced to fill the format on the screen. The minimum distance between the screen and observer is minimum 30 cm when checking the image quality. The resolution should be at least 400 lines;

If a resolution of 400 lines cannot be attained in individual cases, the attained resolution shall be documented. The distance between the camera and reference standard or the zoom range 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 range shall be documented and considered during the testing.

- c) The individual stages of the colour circle and colour bars shall be distinguishable both for the colour reproduction and for the black-white reproduction and shall reproduce the corresponding hue. The grey tones shall be resolved. The geometry distortions may not impair the visual testing;
- d) 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.

The image quality and resolution depend on the system used in the case of 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 recognition shall be determined and documented. The distance used and zoom range shall be documented and considered in the test.

### 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

- a) they can be handled in a time-saving manner in respect to the radiation exposure of the test personnel;
- b) they are easy to decontaminate;
- c) 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 ;
- d) the effect of ionising radiation on the image quality is kept as low as possible by corresponding measures (e.g. shielding);
- e) they can be used in a temperature range required for the application;
- f) adjustable lighting equipment is available, which is protected against bursting and mechanical damage;
- g) connection options for recorders are available in examination equipment;
- h) visualisation of the following data is possible in combined device systems:

- i) place, date, time;
- j) 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

- a) focussing is possible;
- b) the shaft is rotatable so that there is no need to turn the light cable as well;
- c) the probes are corrosion resistant and, insofar as required, watertight in design.
- d) if necessary, a scale or scaling function is available.

### 5.3.3.3 Cameras

Cameras shall be selected with consideration of the terms of reference and the application conditions in such way that they are equipped with

- a) autofocus;
- b) automatic aperture control;
- c) automatic brightness control;
- d) zoom and macro function;
- e) pan-tilt function.

It shall be possible to switch 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 during this. The light distribution on the test surface should be as uniform as possible.

The lighting equipment should be able to be positioned and regulated.

### 5.3.5 Recorder and play back device

The recorders and playback devices shall meet the requirements specified in 5.3.2 in respect to the image quality of the optical auxiliaries.

The Playback device shall have frame-to-frame playback.

### 5.3.6 Data storage medium

The data storage medium shall be designed in such way that

- a) they enable a labelling for identification;
- b) an unintentional overwrite is prevented;

- c) 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 might render it necessary to transfer original data to other data storage medium types.

### 5.3.7 Test robots

Test robots shall be designed so that they can be

- a) used at the test section of the relevant test object;
- b) controlled and aligned remotely;
- c) positioned corresponding to the test assignment.

## 6 Test procedures

The test procedures shall contain the following data:

- a) Scope of validity;
- b) Jointly applicable regulations, standards and instructions;
- c) Test objective and properties to be validated (e.g. surface changes, mechanical damage, leaks);
- d) Personnel qualifications;
- e) Data on the test object and possibly data on the test scope and date of test;
- f) Data on test preconditions;
- g) Test method (general or selective);
- h) Inspection technique (direct or remote);
- i) Combined device system (examination equipment e.g.: endoscope, camera, test robot, illumination; auxiliaries, e.g.: lux meter);
- j) Data on the inspection of the combined device system;
- k) Data on the test performance and analysis as well as evaluation of conspicuous indications;
- l) 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;
- m) Type and scope of the recording.

## 7 Testing

### 7.1 Preparation

#### 7.1.1 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 mechanised 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.

#### 7.1.2 Selection of the inspection technique

The local dose rate shall be considered when selecting the inspection techniques and auxiliaries.

#### 7.1.3 Test location

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

- a) heat accumulation is avoided;
- b) the operation is not prevented;
- c) interfering reflections are avoided;
- d) the test can be conducted without impediment.

### 7.2 Performance

#### 7.2.1 General

Generally 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:

- a) surface changes;

- b) material separations;
- c) mechanical damage;
- d) corrosion, erosion, wear;
- e) conspicuous indications at screw connections;
- f) conspicuous indications at connections of measuring points and lines;
- g) indications of leaks;
- h) displacement of components;
- i) loose and lost parts;
- j) deposits, 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.

### 7.2.2 Direct visual testing

The requirements of 7.2.1 shall be met. General visual testings shall be conducted according to EN 13018. Selective visual testings shall be conducted as local visual testings according to EN 13018 . If access to the test area is not possible, mirrors or endoscopes may be used.

### 7.2.3 Remote visual testing

The requirements of 7.2.1 shall be met. The following also applies:

- a) in case of tests under water, an inspection of the function, image quality and capability of the immersed equipment is necessary. The inspection shall be documented;
- b) Combined device systems corresponding to the selection criteria according to 5.3.3 to 5.3.7 shall be used for the remote visual testing. As a rule, the use of colour-reproducing device systems is preferable, as these have the greatest possible information content;
- c) Black-white tube cameras may be used if:
  - 1) ionising radiation prevents the use of CCD colour cameras,
  - 2) the properties specified in the standard instructions or test specifications permit the use.
- d) as constant an image quality and capability as possible shall be complied with during the test;
- e) The following measures are possible in order to improve the detail recognition in case of conspicuous indications, if required:
  - 1) Magnification of the conspicuous indications with simultaneous use of a reference scale,
  - 2) Recording from another direction of view,

- 3) Change in the illumination,
- 4) Use of a camera with higher resolution.

#### 7.2.4 Mechanised visual testing

The requirements of 7.2.1 and 7.2.3 shall be met. The following also applies:

- a) A test robot according to 5.3.7 shall be used. Before testing, a functional check of the test robot including monitoring of the movement directions shall be conducted. In case of tests under water, 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 or the visualisation scale shall be specified and the actual values entered in the drive program, if necessary;
- e) The test speed shall be selected so that a unique evaluation of the surface to be tested is ensured.

### 7.3 Evaluation

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

### 7.4 Final measures

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

## 8 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:

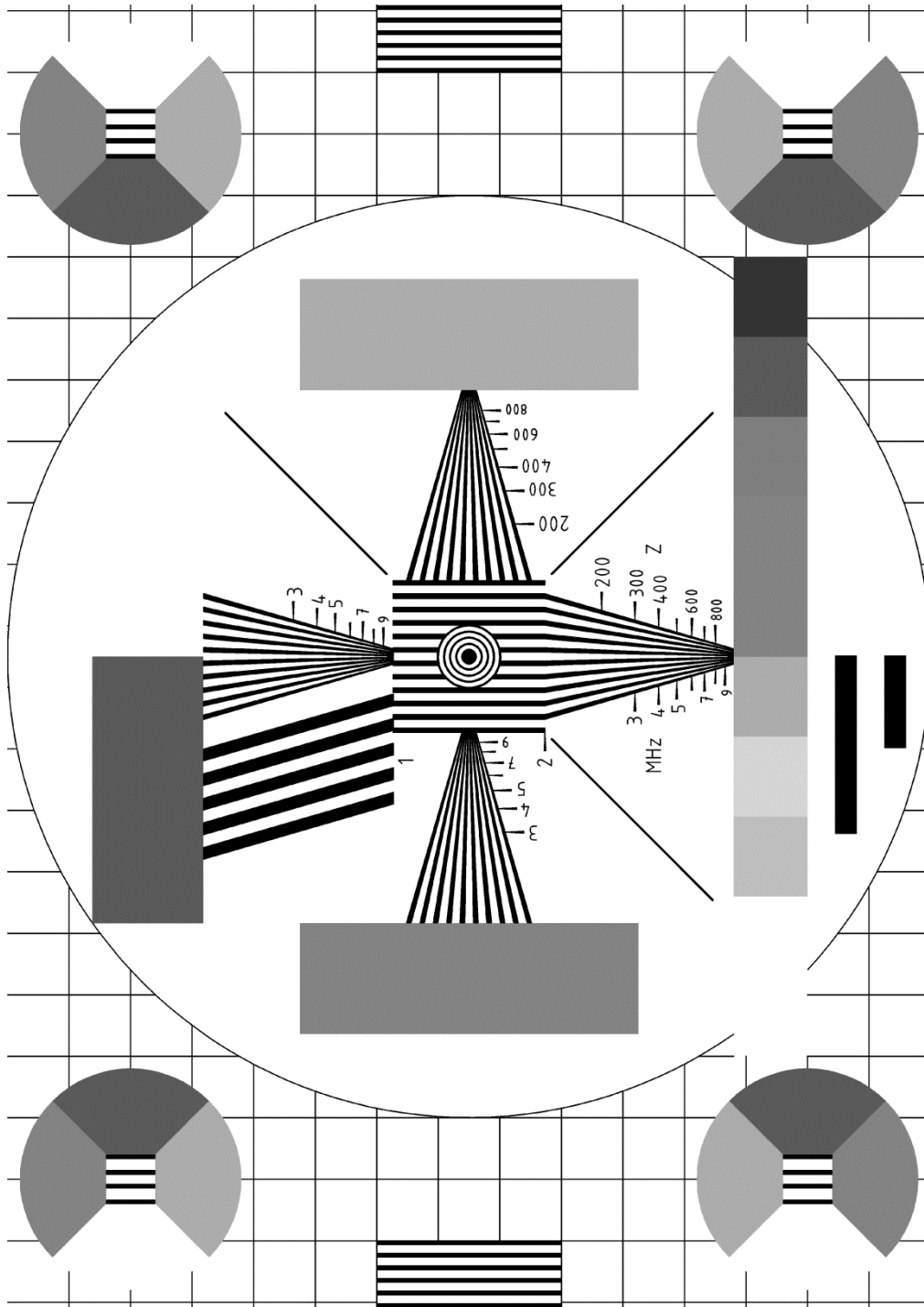
- a) date of the testing;
- b) name of the power plant;
- c) test procedures;
- d) test object, test scope and test section:
  - 1) location of the test section,
  - 2) reference point,
  - 3) coordinates,
  - 4) surface state (e.g.: cleaned, not cleaned);

- e) inspection technique:
  - 1) test method used (general or selective),
  - 2) inspection technique used (direct or remote),
  - 3) examination equipment and device system (e.g.: Mirror, magnifying glass, endoscope, video endoscope, camera, test robot, lighting) with data on:
    - i) test parameters,
    - ii) reference standards and reference blocks used (in case of remote testing),
    - iii) actual values (drive programme) (in case of mechanised testing),
    - iv) test robot settings (in case of mechanised testing),
  - 4) optical auxiliaries (e.g.: lux meter);
- f) result of the test and, if necessary, results comparison with the previous in-service testing:
  - 1) attained image quality and performance,
  - 2) conspicuous indications (e.g.: type, location, appearance, possible size),
  - 3) , relevant indications
  - 4) image documentation of relevant indications and possibly conspicuous indications;
- g) deviations from the specifications of the test procedures;
- h) name of the test organisation;
- i) 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)

**Example of a test image**



**Figure 1 — Test image**

## Bibliography

- [1] ISO 20890-1:2016, *In-service inspections for primary coolant circuit components of light water reactors — Part 1: Automated ultrasonic testing*
- [2] ISO 20890-2:2016, *In-service inspections for primary coolant circuit components of light water reactors — Part 2: Magnetic particle and penetrant testing*