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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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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.

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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.

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
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 condition or type of discontinuity that requires evaluation

[SOURCE: ISO/TS 18173:2005, 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 and achromatic type of a colour

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

Note 2 to entry: In this document achromatic colours means black and white and any type of grey.

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

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

[SOURCE: EN 1330-10:2003, 2.12, modified — The examples given in the Note are different.]

3.7
remote visual testing
visual testing where there is an interrupted optical path from the observer's eye to the test area

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

[SOURCE: EN 1330-10:2003, 2.37, modified — Different systems are named in the Note.]

3.8
general visual testing
visual testing over areas of the *component* (3.10) to observe overall condition, integrity and state of degradation

[SOURCE: EN 1330-10: 2003, 2.18]

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.

a) 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.

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 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 described in a Technical Justification (e.g. zoom level, working distance, incidence angel, 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,