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

Part 2: Magnetic particle and penetrant testing

Lignes directrices pour les contrôles périodiques des composants du circuit primaire des réacteurs à eau légère —

Partie 2: Contrôle par poudre magnétique et ressuage

Reference number
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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).

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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 2: Magnetic particle and penetrant testing

1 Scope

This document gives guidelines for pre-service inspections (PSI) and in-service inspections (ISI) of the surfaces using the magnetic particle testing and penetrant testing on components of the reactor coolant circuit of light water reactors. This document is also applicable to other components of nuclear installations.

Test systems for the localisation of surface inhomogeneities and requirements for test personnel, test devices, test media, accessories as well as optical auxiliaries, the preparation and implementation of the test as well as the recording are defined.

NOTE 1 Data concerning the test section, test extent, inspection period, inspection interval and evaluation of indications are defined in the applicable national nuclear safety standards.

NOTE 2 In general, this document is in accordance with ISO 3452 and ISO 9934 series. This document provides details to be considered in the standard test procedure (see Annex A).

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 3059, *Non-destructive testing — Penetrant testing and magnetic particle testing — Viewing conditions*

ISO 3452-1, *Non-destructive testing — Penetrant testing — Part 1: General principles*

ISO 3452-2, *Non-destructive testing — Penetrant testing — Part 2: Testing of penetrant materials*

ISO 3452-3, *Non-destructive testing — Penetrant testing — Part 3: Reference test blocks*

ISO 3452-4, *Non-destructive testing — Penetrant testing — Part 4: Equipment*

ISO 3452-5, *Non-destructive testing — Penetrant testing — Part 5: Penetrant testing at temperatures higher than 50 °C*

ISO 3452-6, *Non-destructive testing — Penetrant testing — Part 6: Penetrant testing at temperatures lower than 10 °C*

ISO 8596, *Ophthalmic optics — Visual acuity testing — Standard and clinical optotypes and their presentation*

ISO 9934-1, *Non-destructive testing — Magnetic particle testing — Part 1: General principles*

ISO 9934-2:2015, *Non-destructive testing — Magnetic particle testing — Part 2: Detection media*

ISO 9934-3, *Non-destructive testing — Magnetic particle testing — Part 3: Equipment*

ISO 9712:2012, *Non-destructive testing — Qualification and certification of NDT personnel*

ISO 12706, *Non-destructive testing — Penetrant testing — Vocabulary*

ISO 12707, *Non-destructive testing — Magnetic particle testing — Vocabulary*

ISO 18490, *Non-destructive testing — Evaluation of vision acuity of NDT personnel*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12706, ISO 12707 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
component
part of a system delimited according to structural or functional aspects, which can still implement independent sub-functions

3.2
test section
part of the *test area* (3.4)

3.3
test supervisor
responsible for application of the test method and for the individual details of the test implementation including monitoring of the activities for preparation and implementation of the test as well as analysis of the test results

3.4
test area
defined area on the *test object* (3.6) over which the tests are to be conducted

[SOURCE: ISO 5577:2017, 6.2.2]

3.5
test surface
surface of the *test object* (3.6) to be tested

3.6
test object
part of a *component* (3.1) to be tested

3.7
test medium
<magnetic particle testing> magnetic particles suspended in liquid or in dry powder form, ready for use

[SOURCE: ISO 12707:2016, 2.17]

3.8
test medium
<penetrant testing> products consisting of cleaner, penetrants, removers and developers

[SOURCE: ISO 12706:2009, 2.19]

4 Requirements

4.1 Test personnel

4.1.1 Task of NDT personnel

NDT personnel[3] 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 should 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.

4.1.2 Personnel requirements

The test personnel comprise test inspectors and the test supervisor.

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

— certification through a national NDT personnel certification scheme;

— theoretical and/or open trials.

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

If no relevant scheme exists or if extra personnel qualification is needed, the qualification body shall 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 shall 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. Indications beyond the evaluation limit shall be evaluated by the test supervisor, who has the requisite experience in respect to the test object, test assignment, test method and device system.

The test inspectors shall have the skills to perform the work they are to carry out. In particular, they shall have adequate experience in the implementation of magnetic particle testing, penetrant testing and knowledge about the test object in respect to this.

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
Test inspector	Certified with at least level 2 according to ISO 9712
Test supervisor	Certified with at least level 2 according to ISO 9712

The test personnel shall fulfil the vision requirements of ISO 9712:2012, 7.4 or comparable.

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 substitutes to ISO 9712.

a) The visual acuity testing shall be conducted in accordance using standard symbols according to 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 with at least one eye, with or without optical aid shall be validated; or

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.

4.2 Data storage medium

Data storage medium shall be designed in such way that

— they enable a labelling for identification,

— an unintentional overwrite is prevented, and

— the suitability of storage is ensured.

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

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

5 Testing

5.1 Preliminary remark

Most of the technical requirements of this document are referencing to other ISO standards and are accepted in applicable national nuclear safety standards. Whilst all mandatory parameter for PSI/ISI specified in a general test procedure following to this document no system qualification has to be performed. Otherwise application of the selected parameter shall be validated by special qualification.

NOTE The procedure for the qualification is described in ENIQ report no. 31[6].

A general test procedure shall be prepared. Annex A contains the items of the standard test procedure.

The test media to be used shall be certified by supplier and monitored and released by the licensee/operator.

5.2 Magnetic particle testing

5.2.1 Preparation

5.2.1.1 General

The specifications in accordance with ISO 9934-1, ISO 9934-2 and ISO 9934-3 shall apply in respect to the general preparation for the magnetic particle testing.

5.2.1.2 Requirements for surfaces

The test surfaces shall be accessible, cleaned and free of interfering impurities (e.g. loose colour residues, rust, dirt, grease, oil) and ground to be notch-free grinded where surface irregularities could mask indications due to discontinuities or weld root leads to pseudo exposure.

NOTE Surfaces with a thin non-magnetic colour layer, e.g. paint, can also be tested, on condition that the colour layer is firmly adhesive, not interrupted and the thickness of the layer does not exceed 50 µm.

The temperature of the test surface should be between 10 °C and 50 °C. The precise range of the surface temperature in the test area is specified by the test medium to be used. The ambient temperature in the immediate working range should not be greater than 40 °C with consideration of the test personnel (to ensure their safety and health). Special arrangements shall be agreed for higher temperatures.

5.2.1.3 Equipment

Measuring instruments are used for determination of the

— illuminance,

— irradiance for the UV range, and

— tangential field strength.

The following test devices are used:

a) test device for magnetisation (mobile: yoke, coil, cable; stationary: test bench);

b) UV-A sources;

c) Artificial light source when using non-fluorescent test media and in the absence of daylight (monochromatic sources such as sodium vapour lamps may not be used).

The technical data of the measuring and test devices used shall be provided. The corresponding occupational health and safety regulations shall be complied with (e.g. protective low voltage, protective partition, protective insulation, UV-A radiation).

It shall be possible to use the measuring and test devices in the prevailing temperature range. In the case of hand electromagnets or portable electromagnets, the relative duty cycle shall be minimum 20 % and the duty time shall be minimum 5 s. In case of transportable current generators, the relative duty cycle shall be minimum 10 % and the duty time shall be minimum 5 s.

Valid calibration certificates shall be provided for the measuring devices to be used. Certificates from the test media monitoring shall be provided for test devices. These shall not be older than 12 months.

5.2.1.4 Test media

Wet test media shall basically be used because of the smaller magnetic particles to locate smaller discontinuities than dry test media. Suspensions comprising carrier liquid (light petroleum distillate or water with conditioning agents) and magnetic particles serve as test media here and use in spray cans (ready-to-use) or open containers as mixed suspensions. Depending on the wet method applied, coloured or fluorescent magnetic powder is used. If the external conditions allow, the method with fluorescent magnetic medium shall be used. In cases where nonfluorescent magnetic medium is used, contrast-improving substrate colours (e.g. white background) may be applied.

The particle size distribution is described by the particle diameter (lower, medium, upper). The particle size distribution, magnetic particle content and content of corrosive elements in the test medium as well as the applied measuring method shall be indicated by the manufacturer in writing. The following nominal particle diameters shall be applicable.

Table 2 — Particle size of magnetic particles for magnetic test medium

Test Medium	Fluorescent	Nonfluorescent
lower particle diameter d_l	≥1,5 µm	≥0,5 µm
average particle diameter d_a	≤8 µm	≤8 µm
upper particle diameter d_u	≤30 µm	≤30 µm

In case of mixed test medium suspensions, the magnetic particle content can be determined by ascertaining the sedimentation volume in a centrifuge tube; see ASTM D4007[4]. Here the sedimentation volume for fluorescent test medium shall be from 0,1 ml/100 ml to 0,4 ml/100 ml and for nonfluorescent test medium from 1,2 ml/100 ml to 2,4 ml/100 ml.

The limit values for corrosive elements (sulphur and halogens) shall be complied with ISO 9934-2:2015, 7.15. The corrosive property of the test medium shall be determined in accordance with ISO 9934-2:2015, Annex C. Therefore Stage 0 specified in Table C.1 regarding of this annex shall be observed.

If oil is used as a carrier medium, this shall be easy to remove and may not leave disturbing residues behind.

In justified cases (e.g. at high temperatures ≥100 °C), dry test medium can be used for the test. Here it shall be noted that the lower particle diameter is generally ≥40 µm. The validation sensitivity is reduced in this way. Only metallic dry powder is permissible as a test medium.

5.2.1.5 Magnetisation and field strength

The magnetisation methods indicated below shall be applied (these illustrated as examples in Figures 1, 2 and 3):

— Yoke magnetisation using hand electromagnets (AC) or portable electromagnets (AC);

— Magnetisation with current-carrying conductor (AC); and

— Axial current flow.

The magnetisation method shall be selected in relation to the form and geometry of the test object as well as the expected defect position. Alternating current magnetisation shall be applied. The application of direct current magnetisation or rectified current shall be agreed in individual cases. Magnetisation with electrodes is not allowed due to the risks of cracks.

The tangential field strength on the surface shall be minimum 2×10^3 A/m and may not exceed 6×10^3 A/m (rms-value) in the case of alternating current magnetisation.

NOTE The required flux density in the surface of the test object of minimum 1 T is attained with a tangential field strength of 2 kA/m in low-alloy or low-carbon unalloyed steels with high relative permeability. Higher field strength can be necessary for other steels with low permeability. If the magnetisation is too high, relevant indications can be covered by structurally induced indications (apparent indications).

The validation of sufficient magnetisation shall be provided with a suitable medium, e.g. tangential field strength measuring device.