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

Part 1: Mechanized ultrasonic testing

Lignes directrices pour les contrôles périodiques des composants du circuit primaire des réacteurs à eau légère —
Partie 1: Contrôle mécanique par ultrasons

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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).

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This document was prepared by Technical Committee 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 1: Mechanized ultrasonic testing

1 Scope

This document gives guidelines for pre-service-inspections (PSI) and in-service inspections (ISI) with mechanized ultrasonic test (UT) devices on components of the reactor coolant circuit of light water reactors. This document is also applicable on other components of nuclear installations.

Mechanized ultrasonic inspections are carried out in order to enable an evaluation in case of

— fault indications (e.g. on austenitic weld seams or complex geometry),

— indications due to geometry (e.g. in case of root concavity),

— complex geometries (e.g. fitting weld seams), or

— if a reduction in the radiation exposure of the test personnel can be attained in this way.

Ultrasonic test methods are defined for the validation of discontinuities (volume or surface open), requirements for the ultrasonic test equipment, for the preparation of test and device systems, for the implementation of the test and for the recording.

This document is applicable for the detection of indications by UT using normal-beam probes and angle-beam probes both in contact technique. It is to be used for UT examination on ferritic and austenitic welds and base material as search techniques and for comparison with acceptance criteria by the national referencing nuclear safety standards. Immersion technique and techniques for sizing are not in the scope of this document and are independent qualified.

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.

Unless otherwise specified in national nuclear safety standards the minimum requirements of this document are applicable. This document does not define:

— extent of examination and scanning plans;

— acceptance criteria;

— UT techniques for dissimilar metal welds and for sizing (have to be qualified separately);

— immersion techniques;

— time-of-flight diffraction technique (TOFD).

It is recommended that UT examinations are nearly related to the component, the type and size of defects to be considered and are reviewed in specific national inspection qualifications.

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 5577, *Non-destructive testing — Ultrasonic testing — Vocabulary*

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

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

ISO 16811, *Non-destructive testing — Ultrasonic testing — Sensitivity and range setting*

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

EN 12668-1, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 1: Instruments*

EN 12668-2, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 2: Probes*

ISO 18563-1, *Non-destructive testing — Characterization and verification of ultrasonic phased array equipment — Part 1: Instruments*

ISO 18563-2, *Non-destructive testing — Characterization and verification of ultrasonic phased array equipment — Part 2: Probes*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577 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
analysis scan
test scan with adopted parameters that is required for more precise characterisation of an *indication* (3.3)

3.2
analysis technique
test technique that is applied for more precise characterisation of *indications* (3.3) subject to analysis

3.3
indication
representation or signal from a discontinuity in the format allowed by the NDT method used

[SOURCE: ISO/TS 18173:2005, 2.14]

Note 1 to entry: Signal that is initiated by operationally induced damage mechanisms, geometrical as well as, material or design induced influences

3.4
evaluation
assessment (3.5) of *indications* (3.3) revealed by NDT against a predefined level

Note 1 to entry: Inspection of the recorded measured data in respect to completeness and analysis capacity, localisation and registration of indications according to defined criteria, representation of the test results

[SOURCE: EN 1330-2:1998, 2.10]

3.5
assessment
comparison of the analysed measuring results with specified criteria

3.6
data storage medium
storage medium for storing digital media

3.7
focal length
focal distance
distance from the probe to the focal point

[SOURCE: ISO 5577:2017, 4.2.13]

3.8
focus range
focal zone
zone in sound beam of a probe in which the sound pressure remains above a defined level related to its maximum

[SOURCE: ISO 5577:2017, 4.2.14]

Note 1 to entry: During measurement with the electrodynamic probe in sound transmission, this value corresponds to a decrease in the signal level by 3 dB in comparison to the maximum value.

Note 2 to entry: In general limitation by the decline in the signal level by 6 dB.

3.9
focus depth
focal point
point where the sound pressure on the beam axis is at its maximum

[SOURCE: ISO 5577:2017, 4.2.12]

3.10
adjustment
setting the ultrasonic test device based on specified parameters

3.11
calibration
<ultrasonic testing> determination of the measuring value range of an ultrasonic test device in relation to a calibrated test standard

3.12
calibration block
<ultrasonic testing> piece of material of specified composition, surface finish, heat treatment and geometric form, by means of which *ultrasonic test equipment* (3.43) can be assessed and calibrated

[SOURCE: ISO 5577:2017, 5.4.1]

Note 1 to entry: The calibration blocks according to ISO 2400 and ISO 7963 can be used as calibration blocks according to this document.

3.13
calibration reflector
reflector of a known geometry and size in or on the *calibration block* (3.12), test *reference block* (3.15) on the test *calibration block*, for distance or sensitivity adjustment of the *ultrasonic test instrument* (3.44)

3.14
component
part of a system delimited according to structural or functional aspects, which can still implement independent sub-functions

3.15
reference block
block of material representative of the material to be tested with similar acoustic properties containing well-defined reflectors, used to adjust the sensitivity and/or time base of the *ultrasonic instrument* (3.44) in order to compare detected discontinuity *indications* (3.3) with those arising from the known reflectors

[SOURCE: ISO 5577:2017, 5.4.2]

3.16
time of flight
time it takes an ultrasonic pulse to travel from the transmitter probe through the *test object* (3.27) to the receiver probe

[SOURCE: ISO 5577:2017, 3.2.6]

Note 1 to entry: This comprises the lead time in the UT probe and the time of flight in the component; it is the time that an ultrasonic pulse requires from the oscillator to a reflector and back to the oscillator.

3.17
LLL technique
test technique based on the reflection of the sound package at the back wall and at a planar reflector in the inspection volume using /utilizing longitudinal waves

Note 1 to entry: See Annex A, no. 7.

3.18
LLT technique
test technique based on reflection of the sound bundle at the back wall and at a planar reflector in the inspection volume using/utilizing the mode conversion of longitudinal waves and transversal waves

Note 1 to entry: See Annex A, no. 7.

3.19
measurement scan
movement of the UT probes with simultaneous recording of measured data

3.20
raw data
all measured data and setting parameters saved by the ultrasonic test equipment during the measurement run (recorded and saved data)

Note 1 to entry: Examples of raw data include amplitude, time of flight, and coordinates.

3.21
test section
part of the *test area* (3.23)

3.22
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* (3.24)

3.23
test area
defined area on the *test object* (3.27) over which the tests are to be conducted

[SOURCE: ISO 5577:2017, 6.2.2]

3.24
test result
summarising evaluation of all measured data and comparison with the previous test

3.25
test scan
measuring run with the characteristics specified in the test specifications

3.26
test function
test task assigned to a UT probe or UT probe combination, e.g. coupling check

3.27
test object
object to be tested; object under test or examination; part of a component to be tested

3.28
test robots
scanner
mechanical device with control for guiding the UT probes

3.29
noise level
amplitudes of background noise in an ultrasonic system

Note 1 to entry: 95 % value of the sum frequency of the amplitudes, measured during the reference run or test run in an indication-free range

[SOURCE: ISO 5577:2017, 6.5.16]

3.30
signal to noise ratio

ratio of the amplitude of a signal arising from a discontinuity in a material to the amplitude of the average background *noise level* (3.29)

[SOURCE: EN 1330-2:1998, 2.16]

3.31
reference scan
measuring run for the functional control and functional adaptation of the ultrasonic test equipment

3.32
hysteresis correction
correction to the decrease in the calibration level resulting during the tandem test or during the test with a comparable test system, if the planar reflectors are not oriented vertically to the surface or vertically to the sound incidence level

3.33
transmitter-receiver technique (TR-technique)
pitch and catch technique
double probe technique
ultrasonic testing technique involving the use of two probes both of which can be used as transmitter and receiver

3.34
track offset correction
correction to the decrease in the calibration level of planar reflectors in the middle between two tracks

3.35
tandem zone correction
correction to the decrease in the calibration level of the calibration reflector to the tandem zone edges

3.36
test block
defined piece of material which allows tests for the accuracy and/or performance of an *ultrasonic test system* (3.43)

[SOURCE: ISO 5577:2017, 5.4.3]

Note 1 to entry: Specimen for examining properties of a test method, an ultrasonic test instrument or a test system.

3.37
depth zone
sub-range of the wall thicknesses to be tested

3.38
transfer correction
correction of the gain setting of the *ultrasonic test instrument* (3.44) when transferring the probe from a *calibration* (3.12) or *reference block* (3.15) to the test object

[SOURCE: ISO 5577:2017, 5.4.5]

3.39
trigger distance
path that the UT probes travels between two test cycles of the same test function following in succession

3.40
scan without couplant
measurement scan (3.19) without coupling between the UT probe and *test object* (3.27)

3.41
TTT technique
test technique based on reflection of the sound bundle at the back wall and at a planar reflector in the test volume using / utilizing shear waves

Note 1 to entry: See Annex A, no. 7.

3.42
ultrasonic test equipment
equipment consisting of an *ultrasonic instrument* (3.44), probes, cables and all devices connected to the instrument during testing

[SOURCE: ISO 5577:2017, 5.3.1]

Note 1 to entry: Connected devices consist also test robot and analysis unit including software, digitalisation unit and, if necessary, operating PC including software.

3.43
ultrasonic test instrument
instrument used together with the probe or probes, which transmits, receives, processes and displays ultrasonic signals for NDT purposes

[SOURCE: ISO 5577:2017, 5.1.1]

3.44
ultrasonic test technique
application-relevant technique for the localisation of discontinuities (internal or surface open)

Note 1 to entry: In relation to the application, requirements result for these ultrasonic test techniques in respect to the test parameters such as oscillation variable, beam angle, wave type and frequency.

Note 2 to entry: Test techniques are e.g. pulse-echo system (PE), transmitter-receiver system (TR), tandem system, phased-array system (PA).

3.45
reference reflector
reflector (natural or artificial) with known form, size and distance from the test surface in the *calibration block* (3.12) or *reference block* (3.15), which is used for calibration or assessment of detection sensitivity

Note 1 to entry: A reference reflector can also be used as a calibration reflector.

3.46
angle-dependent amplification compensation
correction to the echo level for compensation of the sound pressure change in relation to the beam angle at phased-array probes

Note 1 to entry: See Figures D.2 and D.3.

[SOURCE: ISO 5577:2017, 6.4.2]

4 Test systems

4.1 Preliminary remark

The suitability of the test technique and the test device system shall be validated corresponding to the requirements of the applicable national nuclear safety standards.

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

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

4.2 General

The test techniques described below are used to locate discontinuities (search techniques). Test techniques for the analysis of indications can be found in 6.4.

The relevant test sections shall be checked so that the required registration thresholds are complied with in even the least favourable case. This results in requirements e.g. for the track offset correction, the transfer correction, the trigger distance and the travel speed, that depend on the relevant selection of probes (e.g. oscillation variable, test frequency, beam angle) and the depth range to be tested.

Depending on the test assignment, the following probes shall be used in contact technique:

— Single transducer probes;

— TR-probes;

— Phased-array probes;

— Electromagnetic acoustic transducer (EMAT).

NOTE The specific requirements for the use of EMAT probes are not discussed in this document.

In the case of tests on austenitic components and dissimilar metal welds, the test capacity can be impaired by the weld metal structure (e.g. inherent coarse-grained and/or a directionally-oriented structure). This can cause variations in attenuation, reflection, refraction at grain boundaries and velocity changes within the grains. It usually is necessary to modify and/or supplement the general settings of this standard when examining such welds or base materials. Additional items could be weld mock-ups with reference reflectors in the weld deposit and weld area and single or dual longitudinal angle beam probes.