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In-service inspections for primary coolant circuit components of light water reactors — Part 5: Eddy current testing of steam generator heating tubes

Contrôles periodiques des composants du circuit primaire des réacteurs à eau légère — Essai de tuyaux de chauffage pour générateurs de vapeur par courant de Foucault

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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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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.

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: Automated ultrasonic testing*

— *Part 2: Magnetic particle 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 5: Eddy current testing of steam generator heating tubes

1 Scope

This standard is applicable for in-service eddy current tests on non-ferromagnetic steam generator heating tubes of light water reactors, whereby the test is carried out using mechanised test equipment outwards from the tube inner side.

An in-service eddy current test of steam generator heating tube plugs as a component of the primary circuit is not an object of this standard. Owing to the different embodiments of steam generator heating tube plugs, the use of specially adapted test systems to be qualified is necessary.

Test systems for the localisation of inhomogeneities (surface) and requirements for test personnel, test devices, the preparation of test and device systems, the implementation of the testing as well as the recording are defined.

NOTE Data concerning the test section, test scope, test time, test interval and evaluation of indications is defined in the 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*

ISO 12718:2009-, *Non-destructive testing — Eddy current testing — Vocabulary*

ISO 15548-1, *Non-destructive testing — Equipment for eddy current examination — Part 1: Instrument characteristics and verification*

ENIQ report nr. 31, *European Methodology For Qualification Of Non- Destructive Testing*[1]

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12718 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/

1) Luxemburg, Office for Official Publications of the European Communities, 2007. ISSN 1018-5593

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
Analysis system
<Eddy current testing> test system that is used with scanning sensors or segment sensors at steam generator heating tubes for more precise characterisation of indications

3.2
Indication
Representation or signal from a discontinuity in the format allowed by the NDT method used

[SOURCE: ISO/TS 18173:2005-01, 2.14]

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

3.3
Evaluation
Assessment of indications revealed by NDT against a predefined level

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

[SOURCE: EN 1330-2:1998-12, 2.10]

3.4
Basic frequency
Test frequency that is used primarily for the localisation and analysis of indications in the standard technique

3.5
Assessment
Comparison of the analysed measuring data with specified criteria

3.6
Form indication
Signal that is caused by geometrically induced influences

3.7
Probe fill factor
<Internal bobbin probe> Ratio of the external cross-sectional area of the product to be tested to the internal cross-sectional area of the probe (sensor)

[SOURCE: ISO 12718:2009, 4.43.1]

3.8
Calibration
<Eddy current testing> Determination of the interrelation between the output measured data of the eddy current test device and the associated indications, resulting from definite reference defects at reference specimens

3.9
Calibration block
<Eddy current testing> piece of material of specified composition, surface finish, heat treatment and geometric form, by means of which eddy current test equipment can be assessed and calibrated

[SOURCE: in conformity with ISO 5577:2000-05, 601]

3.10
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

3.11
Test sensitivity
change to the initial variable of the eddy current test system (amplitude/phase), in relation to the change in the underlying input variable (e.g. wall thickness attenuation)

3.12
Probe
body containing exciter elements (e.g. coils) and measuring elements

3.13
Standard technique
<Eddy current testing> test system that is carried out with internal bobbin probes with coaxial coils at steam generator heating tubes

3.14
Interference signals
Signals that impede the detection and analysis of indications

3.15
reference block
<Eddy current testing> Block of similar composition to component/material under test containing well-defined reflectors, used to adjust the amplitude and/or phase of the eddy current test equipment in order to compare detected discontinuity indications with those arising from the known reflectors

[SOURCE: ISO 5577:2000-05, 603]

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

[SOURCE: ISO/TS 18173:2005-01, 2.22]

3.16
Eddy current instrument
part of an eddy current testing system used to perform a measurement

Note 1 to entry: Generally it consists of a generator, an amplifier, a demodulator, and an indication unit.

[SOURCE: ISO 12718:2009, 5.12]

3.17
Eddy current test equipment
Eddy current test system, test robot and its measured data logging as well as the analysis unit including software

3.18
Eddy current testing system
system for test or measurement using eddy currents, consisting at least of an eddy current instrument, a probe and appropriate connecting cables

[SOURCE: ISO 12718:2009, 5.13]

4 Inspection technique

4.1 Preliminary remark

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

4.2 General

During the eddy current testing of steam generator heating tubes, it is the task of the evaluation to differentiate the recorded signals according to:

a) operational indications (location, expansion and possibly their type, e.g. cracks, abrasions, dents);

b) geometric indications (e.g. of structural parts such as spacers, tube bottom, rolled-in slugs);

c) Other indications (e.g. of local fluctuations in the electrical conductivity and permeability, electrical interference, wobble effect of the probes, impurities on the inside or outside of the tube, production indications as well as any external parts present).

To attain a sufficiently accurate reproduction of the signal sequence, a spatial resolution of minimum two measured data per millimetre is necessary.

The following inspection technique can be used for the eddy current testing of steam generator heating tubes as part of the standard technique.

1) Multiple frequency technique with internal bobbin probe (differential arrangement, see 4.3.1; absolute arrangement, see 4.3.3);

2) Linking of the signals of multiple frequencies with internal bobbin probe in differential arrangement (see 4.3.2).

If the standard technique is inadequate for evaluation of the eddy current signals, eddy current techniques for more extensive evaluation (e.g. with rotating scanning probes, matrix probes with T/R technique) or other non-destructive testing methods (e.g. ultrasonic testing, visual inspection) shall be applied.

Supplementary to the standard technique, eddy current techniques for more extensive analyses can also be used as localisation systems in case of specific requirements (e.g. testing in the area of tube bottom/roll-in slugs).

4.3 Standard technique

4.3.1 Multiple frequency technique with internal bobbin probe in differential arrangement

4.3.1.1 Basic frequency

The total tube circumference is recorded integrally when testing with an internal bobbin probe. The extension of indication can therefore only be determined in the axial direction. In the undisturbed area, evaluation of the signals of a frequency for determining location, depth and axial extension of an operational change is sufficient.

If indications overlap (e.g. operational indications and form indications), a statement is generally only possible with restrictions. The multifrequency technique shall then be used in the mix (linking of multiple frequencies) (see 4.3.2).

When testing operationally indications, the test frequencies used are generally in the range from 10 kHz to 1 MHz. The basic frequency shall be selected so that the phase offset angle between a wall thickness weakening of 20 % applied on the outside of a reference specimen and a wall penetrating reference fault is in the range from 90° to 120°.

4.3.1.2 Comparison between the signals of several individual frequencies with internal bobbin probe

If indications occur, further frequencies can be used for the differentiation of interference signals and operationally indications in addition to the basic frequency. The individual frequencies shall be selected so that a significant phase offset angle is reached between indications and interference signals.

4.3.2 Linking the signals of multiple frequencies with internal bobbin probe in differential arrangement (mixed technique)

4.3.2.1 General

Two to four frequencies are used for this inspection technique.

Linking the signals of multiple frequencies allows a quantitative analysis of operationally indications even when indications with interference signals overlap. However, the test sensitivity (fault detectability) generally declines for areas in which the evaluation is conducted in the mix.

The following links shall be used as a minimum:

a) 2-frequency mix for the area of the spacers and the area of the tube bottom;

b) 3-frequency mix for the area of tube bottom with roll-in slugs.

4.3.2.2 2-frequency mix

The frequencies shall be selected so that the interference signals of all structural parts (e.g. spacers, corrugated iron, oscillation limiters) are suppressed. The mix phase offset angle between a wall thickness weakening of 20 % applied on the outside of a reference specimen and a wall penetrating reference fault shall be in the range from 80° to 100°.

4.3.2.3 3-frequency mix

The frequencies shall be selected so that the interference signals of rolling and tube bend upper edges or support plates and “pilger effects” are suppressed simultaneously. In addition, the mix phase offset angle for

wall thickness weakening applied to the outside of a reference specimen of 60 % and 20 % shall exhibit a difference of minimum 40°.

4.3.3 Multifrequency system with internal bobbin probe in absolute arrangement

In contrast to the multiple frequency technique in differential arrangement, the absolute arrangement serves for localising and evaluating flat incident indications with large extension in the axial direction (e.g. large area abrasion in the area of tube bends) or for determining the sedimentation level in the area above the tube bottom.

4.4 Inspection techniques for more extensive analyses

To supplement the standard inspection technique, probes are specifically used for the analysis of already localised operational indications. These probes serve for characterisation of the indications in respect to

a) circumferential expansion;

b) longitudinal expansion;

c) for determining the number of indications both in the longitudinal and circumferential direction;

d) Indication orientation;

e) Indication type.

Here a detailed determination of the indication position in relation to structural parts can be made. Owing to the smaller coil length of coverage, the smaller zone of interaction or the width of coverage, the test sensitivity is increased in the longitudinal direction and in the circumferential direction (i.e. in the entire range of the tube circumference). The multiple frequency technique is usually used here in the same way as the standard inspection technique. The following are typically used as analysis probes:

1) Rotating scanning probes;

2) Segment probes;

3) Matrix probes (array probes).

The following sections in this standard define the requirements for the standard inspection techniques and shall be applied correspondingly to the analysis techniques used. Special requirements for the analysis techniques require separate definition.

5 Requirements

5.1 Test personnel

The test personnel comprises operating personnel for test robots, operating personnel for eddy current test devices, analysts and evaluators as well as the test supervisor.

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 defects. 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 operating personnel for test robots and eddy current test devices shall be trained for the special requirements of the work to be performed. In particular, they shall have adequate experience in the implementation of eddy current tests and knowledge about the test object in respect to this.

The analysts and evaluators shall be trained for the special requirements of the work to be performed and have experience in the analysis and evaluation of indications as well as knowledge of the test object and the characteristic appearance of indications.

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
Operating personnel for eddy current test devices	Certified with at least level 2 according to ISO 9712 or comparable qualification
Analysts and evaluators	Certified with at least level 2 according to ISO 9712 or comparable qualification
Test supervisor	Certified with level 3 according to ISO 9712

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, ophthalmic 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:

f) 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 with at least one eye, with or without vision aid shall be validated;

g) 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.

5.2 Steam generator heating tubes

The internal surfaces of the steam generator heating tubes shall be in a state that allows testing. The internal surfaces should be smooth and free of substances that could be affected adversely by performing the test and the quality of the test results.

5.3 Eddy current test equipment

5.3.1 General

The eddy current test equipment comprises

a) Test robot;

b) Eddy current test system for measured data logging;

c) Analysis unit including software.

All components of the eddy current test equipment that are installed in the steam generator (e.g. sliding hose of the test sensor, sensor bodies, test robot) shall be made from halogen-free material.

5.3.2 Test robot

The test robot consists of

— Probe positioning unit;

— Probe feeding unit.

The test robot shall be designed so that

a) it can be controlled remotely;

b) all tubes can be moved to in a definite manner and the required test length is recorded;

c) the movement of the probe into the tube to be tested can be monitored with a video camera;

d) a positioning accuracy of the probe feeding unit ≤ 10 mm between two form indications due to the structure is complied with in the drawing direction;

e) the position change of the probe in the tube longitudinal direction is displayed in 1-mm steps;

f) the position data of the probe positioning unit

   1) are available

   2) are indicated in object-relevant coordinates so that executed test robot movements are comprehensible;

g) the test speed (probe drawing speed) can be monitored in an axial direction;

h) a reference specimen can be guided as well;

i) the interference level arising from the probe positioning and probe sliding units does not affect the test adversely;

j) the radiation exposure of the personnel when installing and removing the test robot and also during the test is as low as possible;

k) it can be extensively decontaminated.

5.3.3 Eddy current test system

5.3.3.1 General

The eddy current test system consists of the following parts:

a) remote-controlled eddy current test device with digital output;

b) equipment for operating the eddy current test device and the measured data logging;

c) Probes;

d) Connecting cable;

e) Reference specimen.

5.3.3.2 Requirements for the eddy current test device

The device shall be able to support the test systems described at 4.3 and 4.4. The following technical requirements apply in individual detail:

a) adjustable test frequencies;

b) at least four test frequencies;

c) Frequency range; 10 kHz to 1 MHz;

d) absolute and differential arrangement in parallel available for all frequencies.

Only devices are approved for test application, which have undergone at least one detailed functional test and calibration (verification level 2 according to ISO 15548-1) not older than twelve month. This shall be documented and validated.

5.3.3.3 Requirements for the probes

The probes shall fulfil the following requirements:

a) Probe fill factor basically ≥ 0,8

   If probes with minus allowance (probe fill factor < 0.8) are used for the test in the area of dents and close tube bends or on tubes with small radius, the suitability of the probe shall be validated as part of the qualification of the eddy current test system;

b) Self-centring guide in the steam generator heating tubes;

c) Differential arrangement with the option of being able to operate it in absolute arrangement. Type relevant data sheets shall be provided for the probes to be used.

5.3.3.4 Requirements for the connecting cables

The connecting cables may not exhibit any damage that impairs their mechanical or electrical properties.

5.3.3.5 Requirements for reference specimens and calibration block

5.3.3.5.1 General

Reference specimens contain definite reference defects (e.g. through bore hole, flat bottom hole, notches) and simulated structural parts. These reference specimens assists for qualification of the eddy current test system as well as for calibration of the eddy current test system including compilation of the evaluation characteristic curve.

The reference specimens shall

a) correspond to the test object in the test system relevant properties (material, geometry – in particular diameter and wall thickness – as well as manufacture) with reference faults that are adapted to the test assignment;

b) be free of non-defined irregularities that affect the signals of the defined reference defects and the simulated structural parts.

The definite reference defects shall

c) exhibit distances to one another and from the tube ends that are large enough so that their signals do not mutually influence each other;

d) be installed so that the electrical and magnetic properties of the material are not changed and no local deformations result;

e) are measured and recorded (actual dimensions). The actual dimensions shall be used for calibration of the eddy current test system.

If operational defects, structural parts, geometry changes and deposits in the reference specimen are simulated, it shall be ensured that they are representative. In addition, the structural parts present in the steam generator can be used for the calibration, in particular for the mixed system (see 4.3.2).

5.3.3.5.2 Reference specimen for determining the analysis characteristic curves during calibration of the standard test systems

When determining the analysis characteristic curves (see 7.2.3.2) of the individual frequencies and their links, reference specimens shall be used, which contain comparison defects in the form of drilled holes or flat bottom holes or notches. The diameter of through bore holes should be 1.3 mm in case of four drilled holes distributed evenly over the circumference and 1.7 mm in case of only one drilled hole. The variables of the further reference defects (flat bottom holes, notches) shall be selected so that their signal amplitudes are in the same order of magnitude as the through bore holes for the basic frequency. Reference defects with at least the following wall thickness reduction shall be included:

a) 100 %;

b) 40 % to 60 % (outer);

c) 20 % to 30 % (outer).

5.3.3.5.3 Calibration block for checking the eddy current test system

The calibration block serves for inspecting the settings of the eddy current test system and its function during the testing. Therefore it may deviate from the test object in the test system relevant properties (material, geometry, manufacture).

The calibration block exhibits definite reference defects. Based on reference measurements between the calibration block and reference specimen used for the calibration, the transferability of the performed settings and the correct function of the test system is ensured.

A reference specimen may also be used as a calibration block.

5.3.4 Analysis system

The analysis system shall enable an automated and manual evaluation as well as monitoring for completeness of the test.

The evaluation characteristic curves are compiled for the calibration using the evaluation system. Phase angle and amplitude are calibrated. The percentage wall thickness reduction is determined using the

evaluation characteristic curves. The axial assignment of indications is automated, in relation to the position of known structural parts.

5.4 Data storage medium

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

6 Test specifications

The test specifications shall contain the following data:

a) Scope of validity;

b) Jointly applicable rules, standards and work instructions;

c) Test objective;

d) Personnel qualifications;

e) Data on the test object (steam generator heating tubes)

   1) Material,

   2) Dimensions,

   3) Data on the test scope or corresponding references to additional documents.

f) Data on test preconditions;

g) Device descriptions or corresponding references to additional documents;

h) Data on the test system

   1) Type of probes and their arrangement,

   2) Test frequencies and their linkage,

   3) Test sensitivity,

   4) Qualification validations for the inspection technique,

   5) Data on the eddy current test equipment;

i) Characteristic data for the test robot

1) Sensor drawing speed,

2) Monitoring of the positioning;

j) Eddy current test system

1) Device type,

2) Probe type and probe dimensions,

3) Connecting cable type and length,

4) Sampling rate;

k) Data on the calibration

1) Description of the calibration,

2) Determination of the evaluation characteristic curves,

3) Representation of the evaluation characteristic curves,

4) Time points and inspection of the calibration with indication of the approved deviations,

5) Reference specimens used for calibration and their documentation;

l) Data on the test implementation;

m) Data on the evaluation and assessment of indications

1) Criteria for the indication evaluation and assessment

2) Decision plan for evaluation and assessment of the results,

3) Typical examples of indications;

n) Type and scope of the recording and documentation.

7 Testing

7.1 Preparations

The test personnel shall be timely instructed prior to the testing concerning the implementation, scope and target objectives of the testing. All requisite documents, such as test procedures, drawings or tube sheet necessary for conducting the testing shall be made provided.

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

7.2 Implementation

7.2.1 General

The basic adjustment of the test system shall be set before conducting the test. This includes:

a) test frequencies;

b) scanning rate;

c) channel assignment (absolute measurement/difference measurement);

d) basic gain (eddy current test device);

e) coil assignment.

The actual testing is divided into data acquisition (with storage on a data storage medium) and data evaluation (based on the acquired data).

7.2.2 Data acquisition

At the start of the test, the defined reference defects of the reference specimen are recorded with the basic assignment. The measuring data at the reference specimen shall be collected with the same speed as during the measuring data collection of the heating tubes to be tested. The probe pulling speed shall be set so that the required spatial resolution according to 4.2 is ensured at the selected sampling rate.

The phase angle of the signal slope of the through bore hole (wall thickness reduction of 100 %) shall be set to 40° for the basic setting of the measuring data logging. The run direction of the indication begins when pulling the probe with a downwards movement in the lower right quadrant of the image (see Figure 1, curve section 1).

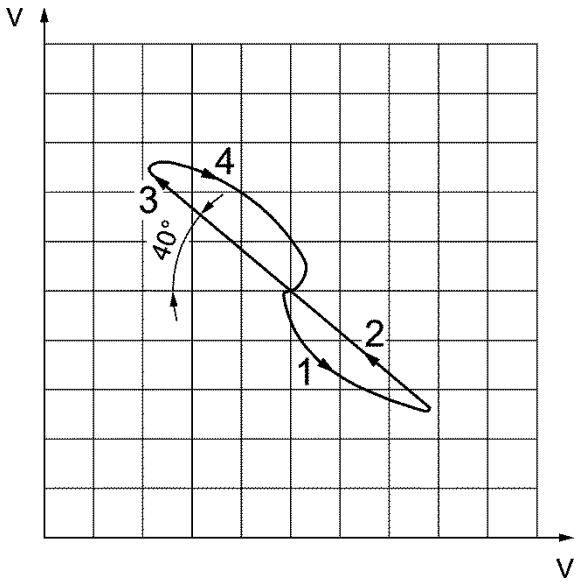

Figure 1 — Indication of a wall penetrating reference defect (through bore holes) when pulling the probe

The indication of the wall penetrating reference defect shall be set to about 80 % FSH.

The test system relevant parameters (e.g. test frequencies, sampling rate, and basic amplification) are automatically saved with the raw data. The following shall also be documented:

a) identification number of the calibration block;

b) eddy current test device and identification number;

c) sensor type and identification number;

d) date and time.

The data acquisition at the heating tubes is performed with the basic adjustment (see 7.2.1) and the basic settings corresponding to a test plan in which the test scope (number and position of the heating tubes to be tested, test lengths, sensor type) is specified.

The following shall be monitored continuously during the measuring data acquisition:

1) Functionality of the test system by visual monitoring of the eddy current data;

2) External disturbances by visual monitoring of the interference level;

3) Recording of the measuring data;

4) The accordance of actual and target coordinates of the relevant test positions.

A data acquisition shall be performed on the reference specimen every 4 hours to monitor the test system. A calibration block according to 5.3.3.5.3 can also be used for this.

A data acquisition on the reference specimen shall also be conducted upon:

— beginning and end of the data acquisition;

— interruption of the data acquisition > 4 h;

— every sensor change;

— changes in the analogous part of the equipment;

— other disturbances.

If disturbances occur, the causes shall be identified and eliminated. After elimination of the disturbances, the data acquisition of inadequately tested areas shall be repeated.

7.2.3 Data analysis

7.2.3.1 General

The aim of the evaluation is to analyse indications with respect to their type, location and extension as well as, if applicable, a quantification of wall thickness reduction. The evaluation is conducted based on the digitally recorded measured data.

7.2.3.2 Calibration

At the beginning of the data evaluation, a calibration (initial calibration) shall be performed based on the eddy current data recorded according to 7.2.2 for defined reference defects of the reference specimen. This calibration ensures that the test sensitivity during the evaluation is on the same level as set in the qualification. The calibration includes:

a) the required multifrequency combinations;

b) the settings of the phase angles and the amplitudes for all test frequencies and multifrequency combinations;

c) the generation of evaluation curves for selected frequencies and multifrequency combinations. An example of an evaluation curve (phase curve) is shown in Figure 2.

Key

X Wall thickness reduction

Y Phase angle

1 Internal defect

2 External defect

Figure 2 — Example of an evaluation curve: Wall thickness reduction in % of the wall thickness as a function of the phase angle of the indication at a test frequency

Based on the acquired data at the reference specimen, the calibration shall be checked cyclically. When checking the calibration, the value may deviate from the determined values of the initial calibration by max. ± 3° or ± 20 % in respect to the phase and signal amplitude of the basic frequency.

If these values are exceeded, a new initial calibration shall be performed and the data acquisition shall be repeated for the relevant tube positions.

7.2.3.3 Data Evaluation

The data evaluation may be conducted manually as well as automatically or as a combination of both. The first checks are in respect to completeness (e.g. position and test length) and sufficient data quality (e.g. signal/noise ratio).

The search for indications according to 4.2 is performed by evaluating the signals of the basic frequency or a multiple frequency link qualified for this. In general, an indication is described by evaluation of the basic frequency (determination of the wall thickness reduction, type, axial location and length of an indication). If the evaluation of the basic frequency does not supply clear information (e.g. in the area of structural parts), the signals of other frequencies and links of frequencies are also evaluated.

If the standard system is inadequate to describe the test results, test systems for more extensive evaluations according to 4.4 should be applied.

7.2.3.4 Assessment of measuring data

The assessment of indications shall be conducted corresponding to the national safety standards.

7.3 Final measures

Before completing the testing (i.e. disassembly of the test equipment), the following measures shall be performed:

a) checking the test scope by target-actual comparison of the test plan in respect to completeness;

b) checking the test results and their documentation in respect to completeness.

Once the checks are passed, the release may be issued to remove or disassemble the test equipment.

8 Recording

8.1 Test record and test report

A test record or test report shall be compiled concerning the testing. The test documentation 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 principle (test procedure, test specifications);

d) test object, test range and test section (tube positions and tube sections);

e) test equipment used (test device, test robot);

f) calibrations of the eddy current test system;

g) result of the test (indication list and possibly findings record) and as well as results comparison with the previous in-service testing;

h) deviations from the specifications of the test specifications;

i) name of the test organisation;

j) 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.

8.2 Indication list

Indications according to 7.2.3.3 and evaluated as not form indications or defect indications are recorded in the indication list. The indication list shall include:

a) coordinates of the indications (series, column, height coordinates), in relation to the component;

b) test system with which the indication was validated (sensor type, test frequency);

c) wall thickness reduction, if this can be determined;

d) amplitude and signal phase;

e) indication type.

8.3 Findings record

The findings record is used to log those indications from the indication list which reach or exceed the assessment limit according to national nuclear safety standards and which are not assessed as geometric indications or interference indications. In addition to the data in the indication list, the following is required for the findings record:

a) performed analysis for first findings or change of the indication;

b) indication extension (if possible in axial direction and in circumferential direction).

Bibliography

ISO xx-1:2014-01, *In-service inspections for primary coolant circuit components of light water reactors — Part 1: Automated ultrasonic testing*

EN 1330-1:1998-12, *Non-destructive testing — Terminology — Part 1: List of general terms*