Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 3201.4 (2016-11)

Components of the Reactor Coolant Pressure Boundary of Light Water Reactors
Part 4: In-service Inspections and Operational Monitoring

(Komponenten des Primärkreises von Leichtwasserreaktoren;
Teil 4: Wiederkehrende Prüfungen und Betriebsüberwachung)

Previous versions of this Safety Standard were issued 1982-06, 1990-06, 1999-06 and 2010-11

Editor:

KTA-Geschaeftsstelle c/o Bundesamt fuer kerntechnische Entsorgungs-sicherheit (BfE) • Willy-Brandt-Strasse 5 • 38226 Salzgitter • Germany
Telephone +49-30-18-333-1621 • Telefax +49-30-18-333-1625

KTA SAFETY STANDARD

2016-11	Components of the Reactor Coolant Pressure Boundary of Light Water Reactors; Part 4: In-service Inspections and Operational Monitoring	KTA 3201.4

CONTENTS

Comments by the editor:

Taking into account the meaning and usage of auxiliary verbs in the German language, in this translation the following agreements are effective:

shall	indicates a mandatory requirement,
shall basically	is used in the case of mandatory requirements to which specific exceptions (and only those!) are permitted. It is a requirement of the KTA that these exceptions - other than those in the case of **shall normally** - are specified in the text of the safety standard,
shall normally	indicates a requirement to which exceptions are allowed. However, the exceptions used, shall be substantiated during the licensing procedure,
should	indicates a recommendation or an example of good practice,
may	indicates an acceptable or permissible method within the scope of this safety standard.

Fundamentals

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the objective to specify safety-related requirements, compliance of which provides the necessary precautions in accordance with the state of the art in science and technology against damage arising from the construction and operation of the facility (Sec. 7 para. 2 subpara. 3 Atomic Energy Act - AtG) in order to achieve the fundamental safety functions specified in the Atomic Energy Act and the Radiological Protection Ordinance (StrlSchV) and further detailed in the Safety Requirements for Nuclear Power Plants as well as in the Interpretations on the Safety Requirements for Nuclear Power Plants.

(2) No. 3.1 of the Safety Requirements for Nuclear Power Plants, among other things, sets high requirements for the quality assurance and reliability of fabrication, the use of qualified materials, the safeguarding and maintenance of quality features during fabrication as well as the performance of in-service inspections to the extent of safety required. Requirement no. 3.4 requires, among other things, that the reactor coolant pressure boundary shall be constructed, arranged and operated such that the occurrence of rapidly extending cracks and brittle fractures need not be assumed. Furthermore, requirement no. 3.4 requires that for the purpose of safeguarding and evaluating the required quality of reactor coolant pressure boundary components a concept for maintaining integrity during operation shall be established. Safety standard KTA 3201.4 "In-Service Inspections and Operational Monitoring" is intended to specify detailed measures which shall be taken to meet these requirements within the scope of its application. For this purpose, a large number of standards from conventional engineering, in particular DIN standards, are also referenced; these are specified in each particular case. For the components of the reactor coolant pressure boundary the requirements of the aforementioned safety criteria are further concretised with the following safety standards

KTA 3201.1 Materials and Product Forms,

KTA 3201.2 Design and Analysis,

KTA 3201.3 Manufacture

as well as with

KTA 3203 Surveillance of the Irradiation Behaviour of Reactor Pressure Vessel Materials of LWR Facilities.

(3) The requirements specified under KTA 3201.4 address, in particular, the

a) reliable monitoring of operating conditions,

b) adequate extent of non-destructive examinations and,

c) documentation, evaluation, safety-oriented application and up-dating of operating experience,

d) foresighted identifiability of changes of the as-fabricated condition of the reactor coolant pressure boundary by means of in-service inspections and operational monitoring,

e) evaluation of the results of inservice expections and operational monitoring

(4) The pressure boundary of the primary circuit has the task of safely retaining the reactor coolant. To ensure that this task is fulfilled during the service life of the reactor, the quality of the pressure boundary is monitored (operational monitoring), evaluated and in-service inspections are performed at specified time intervals to demonstrate the integrity of the pressure boundary. The functional capability of the safeguards against excessive pressure is subject to functional testing at regular intervals.

(5) The task of this safety standard with respect to operational monitoring is to determine measures regarding the monitoring of causes and consequences as well as the foresighted evaluation of damage mechanisms.

a) Monitoring of causes:

   aa) monitoring of the parameters and data relevant to primary circuit integrity by standard instrumentation,

   ab) monitoring of the quality of water chemistry in the primary and secondary circuit.

b) Monitoring of consequences by:

   ba) in-service inspections,

   bb) leakage monitoring of the primary circuit for the detection of leakage to the outside as well as from the primary to the secondary circuit,

   bc) loose parts monitoring,

   bd) monitoring of the vibration behaviour of the primary circuit components for the early detection of changes.

c) Documentation and continuous recording of the monitoring results along with a foresighted evaluation in order to limit operational damage mechanisms.

(6) The task of this safety standard with respect to in-service inspections is to determine the relevant measures as listed in a) to d) hereinafter in order to ascertain and evaluate the actual component condition at the date of testing by:

a) non-destructive examinations of the external and internal surfaces and, as far as required by this safety standard, of the volume of the pressure retaining wall,

b) evaluation of the general condition during regular plant inspection,

c) pressure tests as integral loading test,

d) functional tests addressing the safeguards against excessive pressure.

All above tests and examinations shall be documented in a so-called "test and inspection schedule" which takes into consideration the requirements for the individual component of the primary circuit and contains the entire extent of in-service inspections.

(7) During in-service inspections, test and examination procedures are used to detect defects in the reactor coolant pressure boundary in due time prior to reaching the acceptance level. When determining the extent of tests and examinations as well as the items to be examined, the design, material properties, fabrication processes and loading of the respective component as well as experience gained with already performed inspections shall be taken into consideration.

(8) The quality of the component with regard to materials, design and manufacture shall be documented and be evaluated in a foresighted manner by continuously recording the accumulated operational loadings including commissioning, and the results of the in-service inspections.

1 Scope

(1) This safety standard shall apply after first criticality to the in-service inspections and operational monitoring of pressure retaining components of the primary circuit of light-water reactors.

(2) In the case of pressurised water reactors, the reactor coolant pressure boundary comprises the following components without internals:

a) the reactor pressure vessel,

b) the primary side of the steam generators, the secondary shell of the steam generators including the feedwater inlet and main steam exit nozzles up to the pipe connecting welds, but not the minor nozzles and nipples, shall also be treated in accordance with this safety standard,

c) the pressurizer,
d) the reactor cooling pump casing,
e) the connecting pipes between the above components and the valve casings of any type contained in the piping system,
f) the pipes branching off from the above components and their connecting pipes including the valve bodies installed in the piping system up to and including the first shut-off valve,
g) the pressure retaining walls of the control rod drives and the in-core instrumentation,
h) the integral parts of the component support structures in accordance with Fig. 8.5-1 of KTA 3201.2 and the welded attachments.

(3) In the case of boiling water reactors, the reactor coolant pressure boundary comprises the following components without internals:

a) the reactor pressure vessel,
b) the pipework belonging to the same pressure space as the reactor pressure vessel including the installed valve bodies up to and including the first shut-off valve; pipework penetrating the containment shell and belonging to the same pressure space as the reactor pressure vessel up to and including the last shut-off valve located outside the containment shell,
c) the pressure retaining walls of the control rod drive and in-core instrumentation,
d) the integral parts of the component support structures in accordance with Fig. 8.5-1 of KTA 3201.2 and the welded attachments.

(4) This safety standard shall apply to components where the design and manufacture have been based on the safety standards KTA 3201.1, KTA 3201.2 and KTA 3201.3.

(5) This safety standard may also apply to components of the primary circuit of light water reactors or to regions of these components where a re-evaluation in accordance with Section 3 para. 5 shows that deviations from requirements in KTA 3201.1, KTA 3201.2 or KTA 3201.3 do not require additional measures regarding in-service inspections and operational monitoring.

(6) In the case of components that do not meet the prerequisites under subpara. (4) or (5), additional requirements regarding in-service inspections and operational monitoring shall be specified, if necessary, on the basis of the specific situation.

Where the design essentially deviates from the safety standards KTA 3201.1, KTA 3201.2 or KTA 3201.3, the significant zones (e.g. longitudinal welds) shall be considered to be representative within the extent of tests and inspections.

(7) Internals of shut-off valves required to isolate the pressure space shall be considered part of the pressure boundary. Requirements for the in-service inspections and operational monitoring of such parts shall be laid down in each individual case in due consideration of their functions.

(8) This safety standard also lays down the requirements for in-service inspections of piping ≤ DN 50.

2 Definitions

(1) Pipe attachment weld

The pipe attachment weld is a weld seam that connects the nozzle with the corresponding pipe section.

(2) Indications and types of flaws

The correlation between indications and flaws are shown in **Figure 2-1**.

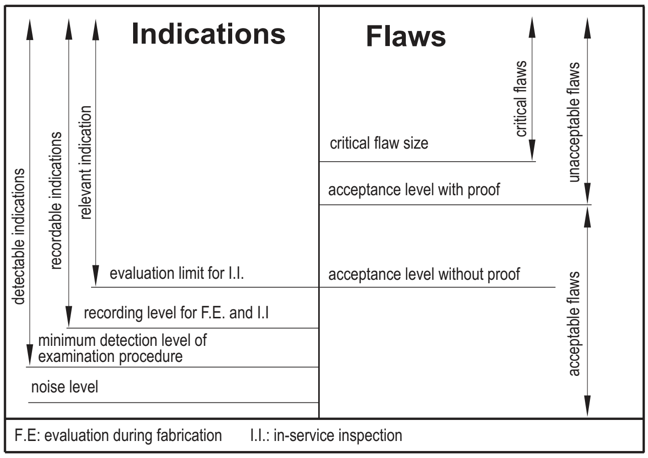


Figure 2-1: Indications and types of flaws

(3) Relevant indication

Relevant indication is an indication reaching or exeeding the evaluation limit.

(4) Echo height evaluation

Echo height evaluation means the evaluation of indications by comparing the echo amplitude (signal amplitude of the ultrasonic signal generated at the reflector) with the recording level and the evaluation limit as shown in **Fig. 2-1**. Echo height evaluation does not include the sizing of reflectors.

(5) Operational flaws

Operational flaws are flaws due to operational damage mechanisms.

(6) Higher stress locations

Higher stress locations are such locations of a component or component part that

a) compared to the general level of stress intensity are more highly stressed taking the frequency additionally into account

or

b) are more susceptible to corrosive action.

(7) Integrity

Integrity is the condition of a component or barrier, at which the required safety criteria with regard to strength, resistance to fracture and leak tightness are met.

(8) Reference standard

Reference standards to adjust and examine the test system or to examine the detection medium are

a) in the case of ultrasonic testing: unclad test blocks of a known material, with predetermined surface quality and geometry, e.g. calibration block no. 1 to DIN EN ISO 2400 or calibration block no. 2 to DIN EN ISO 7963,
b) in the case of penetrant testing: reference block 2 to DIN EN ISO 3452-3,
c) in the case of magnetic particle testing: flux indicator for controlling the detection medium (reference block 1 to DIN EN ISO 9934-2 Annex B),
d) in the case of visual testing: test pattern to DIN 25435-4,
e) in the case of radiographic testing: image quality indicator to DIN EN ISO 19232-1,
f) in the case of eddy current testing: reference block adapted to the task, made of a known material and with a specific surface quality and geometry.

(9) Measured values

Measured values are documented and stored values (e.g. pressure, temperature, amplitude, time of flight, position).

(10) Detection threshold

Detection threshold is the lowest limit of detection of indications.

(11) Types of tests, test procedures and techniques

The terms, their acronyms and correlation of the types of tests, test procedures and techniques are shown in **Table 2-1**.

(12) Surface inspection

Surface inspection is the non-destructive testing of surfaces using techniques which allow detecting indications on the surface and near-surface regions in which case the depth examined depends on the method used.

(13) Volumetric examination

A volumetric examination is a non-destructive examination using techniques, which allow detecting indications inside the body of the wall over its entire cross section.

(14) Quality

Quality means the condition of a part, component or system with respect to their capability of meeting the specified requirements.

Serial Number	Type of Test	Test Procedure	Test Technique
1	Surface inspection	Magnetic particle testing (MT)	e.g. field magnetization by magnetomotive force
		Penetrant testing (PT)	e.g. colour contrast penetrant testing
		Ultrasonic testing (UT)	e.g. surface waves, wave conversion, dual element probe technique, phased-array technique
		Eddy-current testing (ET)	Single frequency, multiple frequency
		Radiographic testing (RT)	X-ray, Radioisotope
		Visual testing (VT)	Selective or integral visual testing with or without optical means
2	Volumetric examination	Ultrasonic testing (UT)	e.g. single transducer probe technique with straight or angle beam scanning, phased-array technique, tandem (pitch-catch) technique, wave conversion
		Radiographic testing (RT)	X-ray, radioisotope
		Eddy-current testing for thin walls (ET)	Single frequency, multiple frequency
3	Evaluation of the general condition	Regular plant inspection	
4	Pressure test	Hydrostatic test	
5	Functional test		

Table 2-1: Type of tests, test procedures and techniques

(15) Noise

Depending on the test conditions, randomly distributed additional signals in the screen image due to reflections from the structure of the material, its surface condition or the electronics.

(16) Noise level

Noise level means the 95 % value of the cumulative frequency of the echo heights of the noise in the examined volume free from defects.

(17) Recording level

Recording level means the specified threshold at which, when being reached or exceeded, indications from the test object are recorded and entered in a list of indications.

(18) Representative locations, components or component parts

Such locations, components or component parts are considered to be representative where the in-service inspection will lead to sufficiently comparable safety related results for other locations, components or component parts, taking into consideration the material composition, design and manufacturing quality as well as the stress type, level and frequency.

(19) Authorized inspector

The authorized inspector for the tests and inspections to be conducted in accordance with this safety standard is the authorized inspector called in by the licensing or supervisory authority in accordance with Section 20 of the Atomic Energy Act.

(20) Damage mechanisms

Damage mechanisms are all physical, chemical and biological processes which may impair the integrity or function of a component.

(21) Standard instrumentation

The standard instrumentation serves to monitor the parameters and data relevant to the integrity of components within the scope of this safety standard and comprises measuring equipment to monitor global loadings and - if required - measuring equipment to monitor local loadings.

(22) Nozzle attachment and insertion weld

A nozzle attachment and insertion weld is a weld seam that connects the nozzle with the vessel wall or the pipe wall.

(23) Welded joint

A welded joint is a weld seam that joins component parts the cross-sections of which have been adapted in the connecting area.

(24) Reference block

A reference block is a block corresponding to the test object with respect to test-relevant characteristics (e.g. material, weld design, shape, wall thickness, weld claddings if any) and that contains reference flaws (e.g. notches, bores) adapted to the individual testing task.

(25) Acceptance level with proof

The acceptance level with proof relates to a defect size that can be accepted when being proved (e.g. by fracture mechanics verification) to be less than rejectable.

(26) Acceptance level without proof

The acceptance level without proof relates to a defect condition that is left unchanged and can be accepted without further proof.

3 Safeguarding of component integrity during operation

(1) To ensure component integrity during operation the principles outlined hereinafter shall be met so as to ascertain and evaluate the actual component quality, the required operational monitoring and in-service inspections (see also **Fig. 3-1**).

(2) Where components deviate from the requirements of the safety standards KTA 3201.1, KTA 3201.2 and KTA 3201.3 such deviations shall be documented and evaluated as to what extent increased requirements for in-service inspections and operational monitoring have to be laid down.

(3) The causes of operational damage mechanisms shall be monitored in accordance with Section 9 (e.g. monitoring of loadings, monitoring of the quality of water chemistry) and be evaluated in a foresighted manner to ensure the required component quality. It shall be ensured that the selection of measuring locations, parameters, extent of measurement and measuring equipment takes into account the operational parameters and the mode of operation as well as the function of individual structural components (e.g. supports, valves) and possible switching operations.

(4) To monitor the presumed consequences of operational damage mechanisms

a) in-service inspections in representative areas, and

b) operational monitoring measures

shall be performed.

Note:

Additional measures to enlarge the knowledge on prevailing operational damage mechanisms may be supplementary examinations, e.g. extended non-destructive examinations, destructive examinations on representative locations of parts exchanged for the purpose of replacement measures.

(5) Changes in the state of knowledge, e.g. due to new requirements for incident control, due to damage occurred, in the case of assessment of ageing phenomenons or in the case of other safety analyses, shall be considered within the re-evaluation of component integrity safeguarding during further operation (see also **Figure 3-1**).

(6) A foresighted evalutaion shall be as follows:

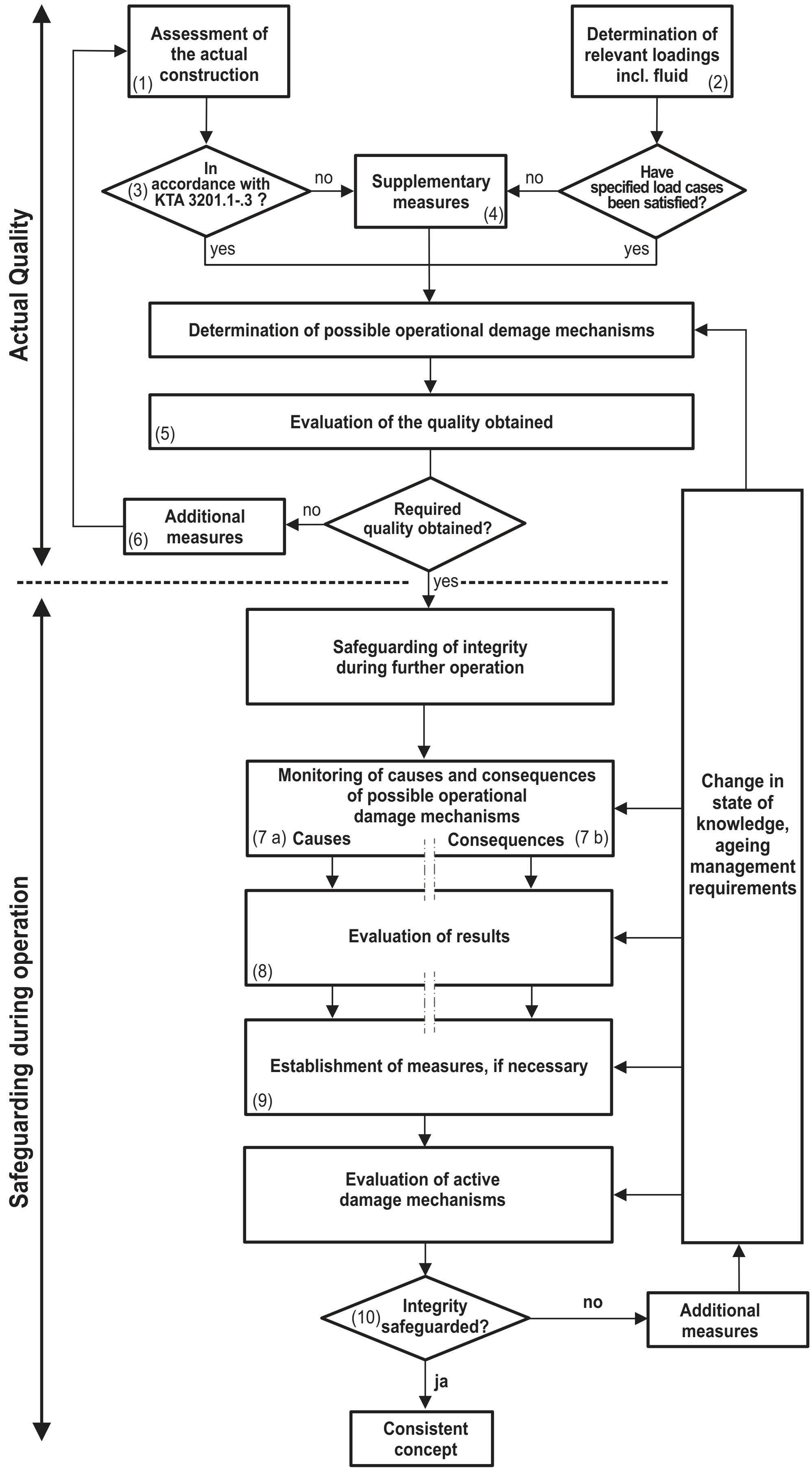
a) At first an evalution of the component quality resulting from the design, construction and manufacture shall be made in due consideration of the operating experience made up to that point in time and the results of in-service inspections Where the required component quality has not been obtained, measures for safeguarding the component integrity shall be taken.

b) The stipulations in the test and inspection handbook shall be checked whether, in consideration of the actual state of knowledge, they are suitable and sufficient to confirm the assumptions on the current component quality. Where this is not the case or only to a limited extent, non-destructive tests as special examinations (only once) or as in-service inspections shall be laid down. Where required, the test methods, recording levels, evaluation limits, extent of testing, test intervals shall be adapted accordingly for in-service inspections.

c) Where defects due to operation are detected, the damage shall be investigated to determine the damage mechanism and defect cause (influence by medium, loadings). The transferability of the damage mechanism to other similar components shall be assessed.

d) Where the assessment by comparison of the actual operational loadings leads to new findings with respect to the specified loadings, it shall be checked whether supplementary measures are to be specified for plant operation, operational monitoring (monitoring of causes of operational damage mechanisms) or for in-servie inspections.

e) The in-service inspections to be performed in representative areas, which shall be fixed to monitor the consequences of operational damage mechanisms result from the abovementioned integrity assessment of the operational loadings occurred. The selection of test procedures as well as the checking of the required inspection intervals shall be related to the component in dependence of the actual component quality with respect to the operational damage mechanisms expected, in which case the fracture-mechanic assessment of critical crack sizes and assumed crack growth values shall be taken into account.



(1) Criteria
- material
- welding
- design
  - shape
  - weld seam
  - dimensions
- existing relevant indications

(2) Data
- operation
  - monitoring
  - state of knowledge
- Incidents
  - state of knowledge
- regarding
  - stress analysis
  - fatigue analysis
  - fracture-mechanic assessment

(3) This check is only possible for components > DN 50.
This test criterion is deemed to have been met if the deviations from the safety standards KTA 3201.1, KTA 3201.2 or KTA 3201.3 do not require additional stipulations for in-service inspections or operational monitoring.
For components ≤ DN 50 the same applies accordingly in which case concrete requirements for the actual construction shall be individually laid down for each plant.

(4) Additional measures
- more detailed analysis
- materials testing
- special tests and examinations
- monitoring
  - loads
  - chemical water quality
- adaptation of the in-service inspection concept

(5) Evaluation criteria
- stresses
- fatigue analysis usage factor
- safety margin to failure
- crack growth values
- corrosion

(6) Measures
- modification of
  - process technology
  - hardware

(7 a) Causes
- mechanical and thermal loadings
- water chemistry

Measures regarding monitoring of causes (examples)
- measuring sensor
- measuring point (local, global loads)
- recording (monitoring of data)

(7 b) Consequences
- cracking
- reduction of wall thickness

Measures regarding monitoring of consequences (examples)
- non-destructive examination
- monitoring for loose parts
- leakage monitoring
- destructive tests

(8) Evaluation criteria
- stresses
- fatigue analysis usage factor
- safety margin to failure
- crack growth values
- corrosion

(9) Measures
- modification of
  - process technology
  - hardware
- operational monitoring
- special tests and examinations
- adaptation of the in-service inspection concept

(10) Criteria
- possible operational damage mechanisms safeguarded
- new active damage mechanisms

Figure 3-1: Safeguarding of component integrity during operation

4 Test procedures and techniques

4.1 General requirements

4.1.1 Selection of test procedures and techniques

(1) The test procedures and techniques shall be chosen such that service-induced flaws with their possible orientations will be detected. Such orientations are:

a) planes perpendicular to the directions of principal stress,

b) planes parallel to the fusion faces of weld seams (longitudinal flaws),

c) planes perpendicular to the direction of welding progress (transverse flaws).

(2) The test procedures as per **Table 2-1** as well as per Sections 4.2 and 4.3 shall basically be applied. Other test procedures are permitted provided their suitability for achieving the test objective has been demonstrated.

(3) The surfaces of components made of ferritic materials shall preferably be examined by magnetic particle testing. In the case of components made of austenitic materials the surfaces shall preferably be examined by penetrant or eddy-current testing.

(4) The test procedures and techniques for testing steam generator tubes shall be chosen such that

a) flaws on the inside and outside surfaces,

b) any local wall thinning

will be detected.

(5) The test procedures and techniques for testing areas of of austenitc steel base metals for stress corrosion cracking shall be selected such that defects oriented in both axial and circumferential direction can be detected.

(6) In the case of ultrasonic testing, several techniques may be applied, where required, to fulfil the testing task.

Note:
See DIN 25435-1 Annex A for test techniques.

(7) During ultrasonic testing scanning from both sides is basically required. Where, for design reasons, scanning from both sides is not possible, it shall be verified within the suitability check to para. 4.1.2 that the findings obtained during scanning of the entire examination area from one direction only are not impaired by flaws due to external contour or spurious echoes, and a sufficient testing level is obtained.

(8) Mechanised examinations are required if in the case of

a) spurious echoes (e.g. on austenitic welds),

b) flaws due to external contour (e.g. in the case of root notches),

c) complex geometries (e.g. nozzle welds),

an evaluation is not possible without extensive recordings and representation of measured data to DIN 25435-1 is not possible, or

d) by this means a reduction of radiation exposure of NDT personnel can be achieved.

(9) The criteria as per (8) apply accordingly for other test procedures.

(10) If the test results from one procedure alone deliver insufficient information, then an additional procedure shall be applied that is based on a physical interaction different from the first. Where the results obtained from the additional test procedure are not sufficient, further steps shall be laid down by agreement with the authorized inspector.

(11) The test procedures and techniques to be applied as well as the verification of the defect orientation are indicated in **Tables 5-1** to **5-9** for each component as regards the respective items to be examined. Here, eddy-current testing may be perfomed alternatively or additionally for surface examination.

4.1.2 Suitability of test procedures

(1) The suitability of test procedures and techniques the application of which for the respective testing task is not sufficiently described in standards, shall basically be verified to the methodology of VGB Guideline R 516 (VGB-ENIQ-Guideline). Where test procedures or techniques are to be applied for which a qualified test technique is available and the applicability of which has been ascertained by the authroized inspector, no further proof of suitability is required.

(2) The test procedures and techniques are suited if their capability of detecting defects as required by Sections 4.2 and 4.3 in consideration of the type and location of the defects is satisfied.

(3) In the case of materials or complex geometries that are difficult to examine, the suitability of the test procedures shall be demonstrated on reference blocks.

(4) Where the required detection capability is not achieved in limited areas by the test procedures selected, special proofs shall be furnished regarding the effectiveness of the test or an analytical proof (e.g. fracture mechanic analysis) shall be performed. Where required, the inspection intervals e.g. shall be reduced.

4.1.3 Comparability of the results of consecutive tests

(1) The results of consecutive tests must be comparable to each other. If the test procedure or technique is changed, a proof of the comparability of results shall be furnished. This may e.g. made by evaluating possible deviations or supplementary use of the preceding test procedures or techniques.

(2) If in-service inspections are to be performed in a mechanized way, a reference test is initially required using the same testing equipment as will later be used for the in-service inspections provided that the results of the mechanized tests are not comparable to the tests performed during fabrication.

(3) If in-service inspections are performed manually, the results of the first in-service inspection shall be compared with that production test which qualifies the final fabrication condition of the component.

4.1.4 Recording of test results

(1) In the case of mechanically performed tests, all measured values and the corresponding coordinates shall be documented by automatic recording equipment.

(2) In the case of manually performed tests all indications reaching or exceeding the recording level and the corresponding coordinates shall be recorded.

(3) The radiographs shall show the coordinates (e,g, item to be examined, zero point, direction of counting).

4.2 Surface inspection

4.2.1 Magnetic particle testing

When performing magnetic particle testing, the requirements of DIN 25435-2 shall be met.

4.2.2 Penetrant testing

When performing penetrant testing, the requirements of DIN 25435-2 shall be met.

4.2.3 Ultrasonic testing procedures

4.2.3.1 Surfaces and their near-surface regions close to the probe

(1) When testing surfaces and their near-surface regions close to the probe, a testing technique or several testing techniques with which the testing level to para. 4.2.3.3.4 can be obtained shall be employed to detect planar discontinuities.

(2) Ultrasonic testing techniques considered to be suitable are, e.g., techniques employing surface waves and creeping waves, the dual element probe with longitudinal waves, or techniques exploiting the corner effect after reflection of the sound beam. The testing for flaws in the transition region between cladding and base metal shall be performed with testing techniques especially designed for this depth.

4.2.3.2 Surfaces and their near-surface regions away from the probe

(1) When testing the surface away from the probe with its near-surface regions for planar discontinuities, a testing technique or several testing techniques with which the testing level to para. 4.2.3.3.4 can be obtained shall be employed. When selecting the testing technique, the acoustical properties (absorption, scattering, refraction, defraction) shall be considered. Where permitted by the geometry and acoustical properties, such testing techniques shall be preferred as to permit the echo height evaluation to subpara. 4.2.3.3.3 (3).

(2) Depending on examination task and test object the following testing techniques may e.g. be applied:

a) vertically polarized transverse waves with the incident angle of the sound beam in the range between 35 and 55 degrees (technique utilizing the corner effect),

b) vertically polarized transverse waves with the incident angle of the sound beam in the range between 60 and 70 degrees,

c) longitudinal waves,

d) wave conversion techniques to KTA 3201.3, Annex C, Section C 7 and C 8,

e) the angled pitch-catch technique to KTA 3201.3, Annex D.

Note:

The testing techniques under a) and b) in general permit an echo height evaluation on homogenous materials.

(3) If, for reasons of test object geometry or of microstructure (e.g. in the case of clad surfaces, austenitic weld seams and dissimilar material weld seams), the required demonstration of suitability of the above mentioned techniques cannot be achieved, an optimized testing technique or a combination of techniques shall be used, provided a prior verification of suitability was performed. Optimized testing techniques are, e.g.

a) testing frequencies ≤ 2 MHz,

b) probes with highly attenuated transducers,

c) dual-element probe techniques with signal overlapping in the half skip area,

d) horizontally polarized transverse waves.

4.2.3.3 Procedural requirements

4.2.3.3.1 General requirements

(1) The testing level setting shall be performed on reference blocks with notches where the reflecting surface is oriented perpendicular to the surface.

(2) Fluctuations of the ultrasonic signals due to coupling, absorption and scattering shall be considered in the testing level adjustment and in the evaluation.

(3) In the case of mechanized testing with liquid column coupling an adjustment of the probe is required where the radius of curvature of the part surface would lead to a gap ≥ 0.5 mm under the probe. In the case of manual scanning of curved surface parts the probes shall be adjusted to meet the requirements of KTA 3201.3 Annex C.

4.2.3.3.2 Reference blocks

(1) The reflectors provided in the reference blocks shall be rectangular notches and be sufficient as regards their number and variation of dimensions and location so as to make possible statements on the test technique's detection capability.

(2) The notches shall not be wider than 1.5 mm. Their acoustically effective length shall normally be 20 mm.

(3) Where the opposing surface influences the test method applied, then the wall thickness should deviate less than 10 % from that of the component to be tested.

(4) When using contoured probes or if the curvature of the opposite surface impairs the reflection behaviour (ratio of wall thickness s to outer diameter d_a of the test objet to exceed 0.2), the deviation of the test object diameter shall not exceed 10 % of the diameter of the component to be examined.

Deviating here from plane reference blocks may be used in case of pulse-echo probes if the following requirements are satisfied:

a) The test object diameter does not require the use of contoured probes.

b) The reflection behaviour is not impaired by the curvature of the opposite surface (ratio of wall thickness s to outer diameter d_a of the test objet less than or equal to 0.2).

c) No wave conversion technique is used.

(5) If a weld does not cause geometric or material-related disturbances on the test object, an unwelded reference block may be used.

(6) Where reference blocks are provided with welds, the acoustic properties of the reference block shall be examined across the weld length, e.g. by means of V-transmission, and be considered accordingly when arranging the reflectors to be used.

4.2.3.3.3 Demonstration of suitability of the test technique

(1) When performing the transverse wave probe technique exploiting the corner effect to examine

a) welded joints between ferritic steels and

b) base metal zones

in items to be examined showing simple geometric contours, this test technique is suited if the echo height of the notch to be selected as per **Table 4-2** exceeds the noise level by 12 dB or more and the echo from the edge simulating a through-wall crack exceeds the echo height of the notch to be selected as per **Table 4-2** by at least 6 dB (see **Table 4-1**, case 1).

(2) In the case of materials difficult to examine and geometrically complex contours, the suitability of the test technique shall be demonstrated for each angle of incidence and each testing area to be covered on a reference block having notches with varying depths. The notches shall be provided as shown in **Figures 4-1** to **4-4**.

At least three rectangular notches with varying depths as well as the edge of the reference block shall be scanned and the echo heights be entered in a diagram as a function of the notch depths. For testing in accordance with subparas (6) and (7), one notch shall have a greater depth and one notch have a lower depth than the notch as per **Table 4-2** required to adjust the testing level.

For the testing of clad surfaces as per subpara. (8) the echo heights of the edge simulating a through-wall crack and of notches no. 1, no. 2 and no. 3 as per **Figure 4-4** shall be entered in a diagram in dependence of the notch depths. Where in the brittle fracture analysis an integrity proof of the cladding is required, notch no. 4 shall be included.

Instead of the edge simulating a through-wall crack an additional, sufficiently deep notch may be used.

The test technique is considerd to be suited if the criteria of subparas. (3) to (8) are satisfied.

(3) When testing butt welds and unclad base metal zones the test technique will be suited if (see **Table 4-1,** case 1)

a) the echo heights increase with an increase in notch depth when scanning across the base metal of the reference block,

b) the echo heights increase with an increase in notch depth when scanning across the weld metal or the buttering of the reference block,

c) the echo height of the notch to be selected (reference notch) as per **Table 4-2** exceeds the noise level by 12 dB or more in the case of angles of incidence as shown in **Figures 4-1** to **4-3**,

d) the edge echo or the echo height of the additional sufficently deep notch exceeds the echo height of the reference notch by at least 6 dB in the case of angles of incidence as shown in **Figures 4-1** to **4-3**.

(4) When testing clad surfaces the test technique will be suited if

a) the echo heights increase with an increase in notch depth,

b) notch no. 2 as per **Figure 4-4** exceeds the noise level by at least 12 dB and notch no. 3 is verifiable, where no integrity proof of the cladding is required in the brittle fracture analysis,

c) notch no. 3 as per **Figure 4-4** exceeds the noise level by at least 12 dB and notch no. 4 is verifiable, where an integrity proof of the cladding is required in the brittle fracture analysis,

d) the edge echo or the echo height of notch no. 1 exceeds the echo height of the reference reflector selected as per subpara. 4.2.3.3.4 (6) by at least 6 dB.

	Case 1	Case 2
Evaluation method	Echo height evaluation to subpara. 4.2.3.3.3 (1) or 4.2.3.3.3 (3)	Pattern recognition to subpara. 4.2.3.3.3 (5)
Reference notch	Notch to be selected to Table 4-2	Notch to be selected to Table 4-2 or deeper notch [1)]
Difference in echo heights between reference notch and noise level	≥ 12 dB	≥ 6 dB [1)]
Difference in echo heights between edge simulating a through-wall crack and reference notch	≥ 6 dB	≥ 0 dB
Recording level	Reference notch plus a sensitivity allowance of 6 dB	Noise level
Recording	Any indication the echo height of which reaches or exceeds the recording level	Any pattern recognition equal to or exceeding the noise level
Evaluation	As per 8.2.2.2.2 (2)	As per 8.2.2.2.2 (3)

1) Where the difference in echo height is less than the required value, a notch with greater depth is to be selected as reference notch which meets the requirement. In such case, a safety evaluation is required.

Table 4-1: Criteria to be followed during the demonstration of suitability of examination techniques for ultrasonic testing of butt welds and unclad base metal zones

(5) Where the criteria of (3) and (4) in parts of the testing area (e.g. in the case of dissimilar welds with buttering where the test is made for longitudinal defects at the buttering to weld metal transition, or for transverse defects) cannot be satisfied, the following procedure applies (see **Table 4-1** case 2):

On the basis of the results obtained from reference block measurements the reference notch for testing level adjustment shall be a notch with an echo height of at least 6 dB in excess of the noise level by including a transfer correction, if any. Where the capability of detecting defects cannot be proved with the available notches, further notches with graded depths or realistic reference defects (cracks) shall be provided in the reference block. All notches having a greater depth than the reference notch shall show an echo height of at least 6 dB in excess of the noise level by including a transfer correction, if any.

A differentiation shall be given between the reference notch pattern and the noise signals as well as a clear distinction between the reference notch pattern and the edge pattern simulating a through-wall crack. The evaluation criteria for comparing the patterns shall be fixed in the test instructions on the basis of reference block measurements (e.g. pattern dynamics, correlation of indication patterns in the case of different angles of incidence and wave modes, crack-tip signal detection).

Where the reference notch shows a greater depth than the notch to be selected as per **Table 4-2**, a safety evaluation shall be made regarding the conclusiveness of the test in which case the re-calculations shall be based on a conservative defect with respect to its longitudinal and depth extension (reference value: double the depth of the reference notch with a length corresponding to the entire area for which the reference notch with a greater depth than that of the notch to be selected as per **Table 4-2** is used).

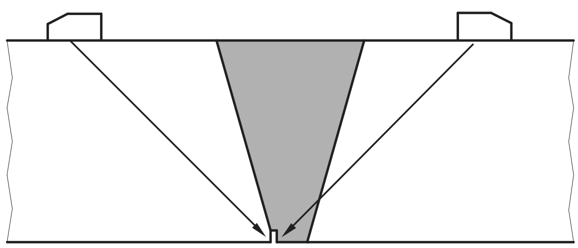


Figure 4-1: Location of notches and beam angles for the test of welded joints between ferritic steels and between austenitic steels

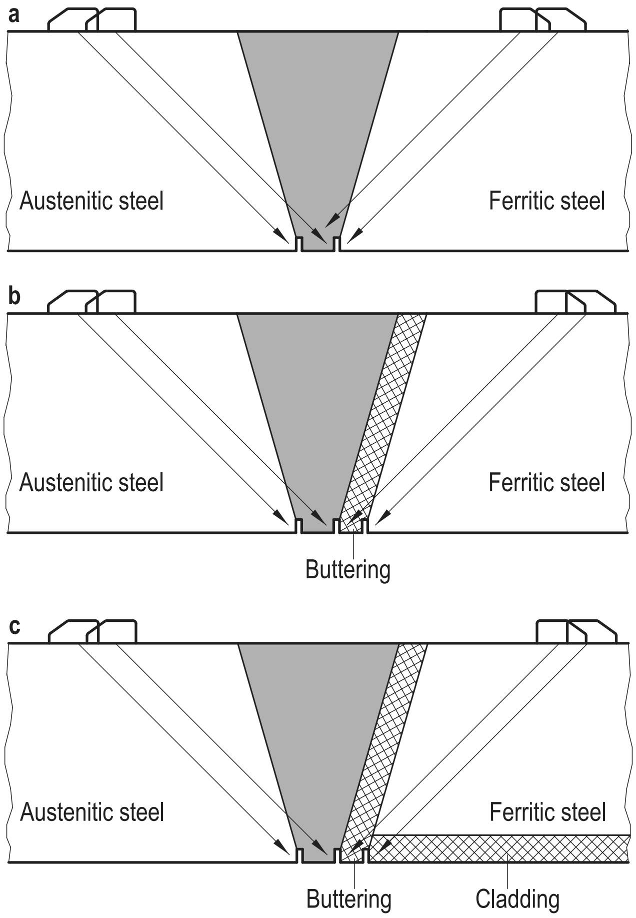


Figure 4-2: Location of notches and beam angles for the test for longitudinal defects of welded joints between ferritic and austenitic steels

(6) The following applies to the location of notches and their related angles of incidence for the test of butt welds and unclad base metal zones for longitudinal defects:

a) Testing of the inner surface of welds between ferritic steels

Notches shall be provided in the base metal of the reference block and be scanned from both sides. Where geometrical or material-related discontinuities are found (e.g. excess penetration, coarse grain structure), the notches shall be provided in the base metal adjacent to the base metal/weld metal transition as shown in **Figure 4-1** and be scanned from both sides of the weld.

b) Testing of the inner surface of welds between austenitic steels

Notches shall be provided at the austenitic base metal/weld metal transition as shown in **Figure 4-1** and be scanned from both sides of the weld.

c) Testing of the inner surface of welded joints without buttering between ferritic and austenitic steels with austenitic or nickel-alloyed weld metal.

Notches shall be provided at the transitions between austenitic base metal and weld metal as well as between ferritic base metal and weld metal as shown in **Figure 4-2 a** and be scanned from both sides of the weld.

d) Testing of the inner surface of welded joints with buttering between ferritic and austenitic steels with austenitic or nickel-alloyed weld metal.

Notches shall be provided at the transitions between austenitic base metal and weld metal, between weld metal and buttering as well as between buttering anf ferritic base metal or between buttering and cladding as shown in **Figure 4-2 b** or **Figure 4-2 c**. The notches at the austenitic base metal/weld metal transition shall be scanned from the austenitic side; the notches at the transition between buttering/ferritic base metal or between buttering/cladding shall be scanned from the ferritic side and the notches at the weld metal/buttering transition shall be scanned from both sides of the weld.

(7) The following applies to to the location of notches and their related angles of incidence for the test of butt welds and unclad base metal zones for transverse defects:

a) Testing of the inner surface of welds between ferritic steels

Notches shall be provided in the reference block and be scanned from two sides in positions 1 and 2 as shown in **Figure 4-3 a**. Where geometrical or material-related discontinuities are found (e.g. excess penetration, coarse grain structure), the notches shall be provided in the weld metal transverse to the direction of welding progress. Where the width of the weld metal is less than 20 mm, the notch may also enter the base metal area.

b) Testing of the inner surface of welded joints between ferritic and austenitic steels with nickel-alloyed weld metal

Notches transverse to the direction of welding progress shall be provided in the reference block as shown in **Figures 4-3 a** and **4-3 b**. The notches shall be positioned in the weld metal and the buttering. Where the width of the weld metal (inclding the buttering) is less than 20 mm, the notch length shall be limited to the width of the weld metal (including the buttering) on the inner surface. The notches shall be scanned from both sides with either test technique a or test technique b as shown in **Figure 4-3 a**.

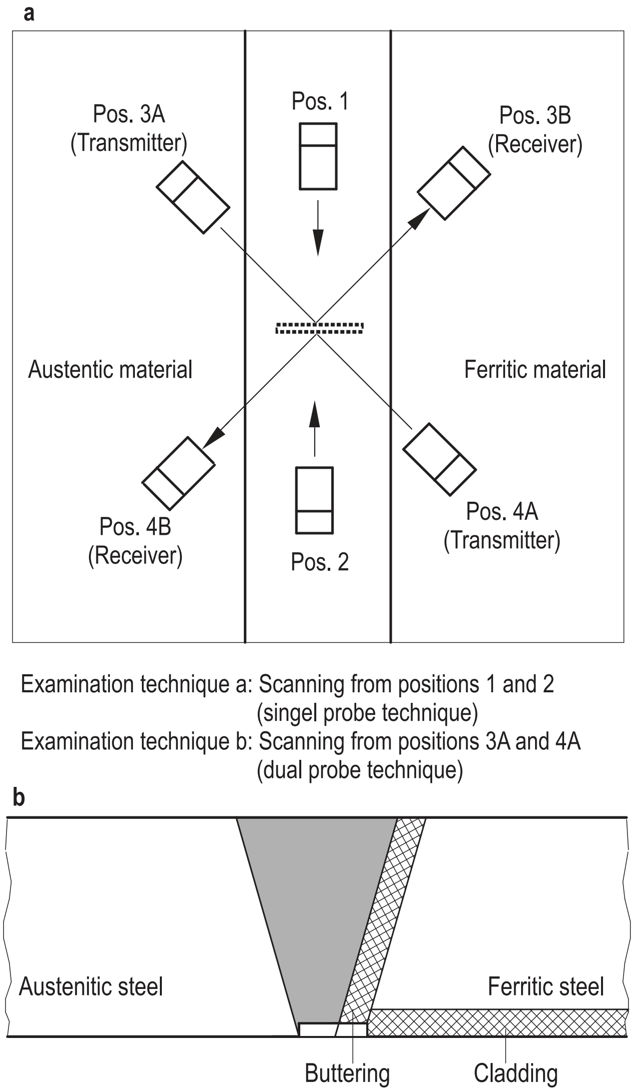


Figure 4-3: Location of notches and beam angles for the examination for transverse defects of welded joints

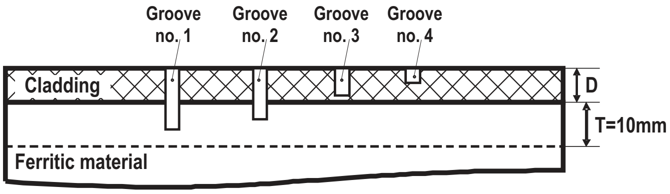
(8) When examining clad surfaces of ferritic components (base metal zone or welded joint areas), the notches shall be provided as shown in **Figure 4-4**. Notch no. 4 is only required to demonstrate the suitability of the test techniques that are intended to be employed for the examination of clad surfaces on reactor pressure vessels for which an integrity proof of the cladding is required within the verification of brittle fracture resistance. The notches' depth shall be selected as follows:

a) Notch no. 1: Cladding thickness plus two-times the depth of the notch to be selected as per **Table 4-2**,

b) Notch no.2: Cladding thickness plus the depth of the notch to be selected as per **Table 4-2**,

c) Notch no. 3: one millimeter less than the cladding thickness, or lesser value,

d) Notch no. 4: half of the cladding thickness.



D + T: Area to be examined

Figure 4-4: Location of notches for the examination of clad surfaces

4.2.3.3.4 Testing level adjustment

(1) General requirements

a) **Table 4-2** shows the depth of the notches as a function of the wall thickness.

When examining clad surfaces, the procedure of subpara. (6) shall be followed.

When examining base metal areas of austenitic steels for damage due to transgranular stress corrosion cracking, the testing level shall be adjusted on a 1 mm deep notch.

Wall thickness s, mm	8 < s ≤ 20	20 < s ≤ 40	s > 40
Notch depth, mm	1.5	2	3

Table 4-2: Notch depth for adjusting the testing level on unclad test objects

b) The testing level for contoured probes shall be adjusted on a curved reference block the radius of curvature of which shall not deviate from that of the component by more than 10%.

c) Differences between the reference block and the test object shall be considered by transfer measurements (V transmission) in the base metal (weld-adjacent zone). In the case of circumferential welds, these measurements shall be made on representative measuring points distributed over the circumference, unless no documented measured values are available.

d) If, during testing, it is found out that the V transmission echo deviates by 6 dB or more from the reference block echo, sufficient testing level shall be ensured by suitable measures (e.g. through-transmission on the reference block and on the test object with an additional angle of incidence, by use of probes with other nominal frequencies, dual-element probe technique with longitudinal waves or wave conversion technique). Where the required testing level cannot be obtained even in the case of adapted testing techniques, the further procedure shall be fixed in consideration of subparas. 4.1.1 (10) and 4.1.2 (4).

(2) Testing on ferritic materials

For the purpose of setting the testing level, the reference reflector as per **Table 4-2** shall be subject to direct scanning over the entire testing area.

(3) Testing of the inner surface of austenitic welds and of welded joints without buttering between ferritic and austenitic steels with austenitic or nickel-alloyed weld metal for longituduinal defects

For the purpose of setting the testing level, the reference reflector as per **Table 4-2** and **Figure 4-1** or **Figure 4-2a** shall be subject to direct scanning over the testing area "weld- adjacent zone". For the testing area "weld root" the reference reflector shall be scanned through the weld metal. The acoustic differences on the reference block when scanning from both sides of the weld shall be taken into account.

(4) Testing of the inner surface of welded joints with buttering between ferritic and austenitic steels with austenitic or nickel-alloyed weld metal for longitudinal defects.

For the purpose of setting the testing level, the reference reflector as per **Table 4-2** and **Figure 4-2b** or **Figure 4-2c** shall be subject to direct scanning over the testing area "weld-adjacent zone". For the testing area "weld root including buttering" the reference reflector in the weld/buttering transition zone shall be scanned from both the ferritic and austenitic base metal side.

(5) Testing of the inner surface of welded joints between ferritic and austenitic steels with nickel-alloyed weld metal for transverse defects.

For the purpose of setting the testing level, the reference reflector as per **Table 4-2** and **Figure 4-3** shall be subject to direct scanning.

(6) Testing of clad surfaces

a) For the purpose of setting the testing level, notch no. 2 as per 4.2.3.3.3 (8) taken as reference reflector shall be subject to direct scanning.

b) Where

ba) for the brittle fracture analysis the cladding integrity is to be confirmed, or

bb) the cladding as per KTA 3201.2 subpara. 7.1.3 (2) is to be considered during the analysis of its mechanical behaviour,

notch no. 3 as per 4.2.3.3.3 (8) taken as reference reflector shall be subject to direct scanning for the purpose of setting the testing level in the clad area.

Note:

The setting of testing level for the clad weld-adjacent area of welded joints with buttering between ferritic and austenitic steels is laid down in (4) and (5).

(7) Where the test techniques to subpara. 4.2.3.3.3 (5) are used, the procedural requirements laid down in these subparas regarding testing level setting shall be followed. In this case, the differences in sound attenuation between component and reference block shall be determined by comparison of the noise levels in the testing area (e.g. comparison of C-scan images, statistical evaluation of noise level).

4.2.4 Eddy-current testing

4.2.4.1 Test techniques

(1) When performing eddy-current testing for the surface inspection it is required that probes and test frequencies adapted to the individual testing task are used.

(2) Depending on the testing task, eddy-current techniques shall be used which make possible the determination of

a) shape and orientation of flaws or

b) flaw depth by evaluating the phase and amplitude of eddy-current signals.

(3) Suitable test techniques are e.g.

a) Direct-field technique

Note:

Direct-field techniques may be used as single- or multiple-frequency technique in differential or absolute arrangement. To suppress noise caused by test object geometry or structure multiple-frequency techniques with superposition of the eddy-current signals from single-frequencies (mixture of frequencies) can be used.

aa) using internal co-axial probe coils for the examination of tubes,

ab) using surface probe coils with coiling perpendicular to the test object surface for the detection of flaws oriented parallel to the coil axis,

ac) using flat coils (so-called rotating pancake probes) oriented in parallel to the surface for the detection of flaws in any direction

ad) using surface probes with two coils arranged mutually perpendicular to and above each other (so-called plus-point probes) for the detection of flaws oriented longitudinally and transverse to the direction of probe travel,

ae) using array probes containing a great number of individual coils arranged in a specific matrix in which case any adjacent two coils are switched in the transmit-receive mode to detect flaws oriented longitudinally and transverse to the direction of array probe travel,

b) far-field technique with separate exciter and measuring probe for examining surfaces far from the probe.

4.2.4.2 Procedural requirements

4.2.4.2.1 General

(1) The testing level shall be set on reference reflectors in which case notches are to be used for the detection of crack-like defects and boreholes be used for the detection of wall-thickness reductions.

(2) It shall normally be ensured by the selection of suitable test parameters and application of signal processing algorithms that noise signals (e.g. caused by lift-off, local variations of electromagnetic material parameters) will not impair the test results. Where this is impossible, the effects on the useful signal shall be considered when setting the testing level.

4.2.4.2.2 Reference block

(1) The notches provided as reference objects in reference blocks shall be electro-eroded rectangular slots. Boreholes used as reference objects shall be bored such that they do not cause local deformations of the reference block.

(2) The notches shall not be wider than 0.3 mm. The notch length shall be greater than the effective probe width. The diameter of through-bores shall be 1.3 mm. In the case of flat-bottem holes their diameters shall be selected such that the bore volume equals the through-bore volume.

(3) The reference objects shall be provided in the reference block as follows:

a) for the testing of steam generator tubes where the influence of discontinuities (tubesheet and spacers) is to be simulated appropriately:

aa) notches longitudinally and transverse to the tube axis at locations remote from discontinuities, in the tube expanded portion subject to deformation and in the transitional area to the tube remote from discontinuities,

ab) boreholes in the tube area remote from discontinuities,

b) for the testing of threaded areas: notches at thread root areas,

c) for the testing of welded joints, claddings and other base material areas: notches oriented in and transverse to the direction of probe travel,

d) for the testing of pipes (base material): notches longitudinal and transverse to the tube axis.

The notch number and dimensional variation as well as position shall suffice to make statements possible on the verification capability of the testing technique.

4.2.4.2.3 Suitability of test procedures

(1) The suitability of the test technique shall be proved on the basis of reference block measurements by means of a characteristic curve. To this end, eddy-current signals of reference objects of varying depths and with the required orientations shall be used.

(2) The number and depths of the reference objects shall be determined such that the depth region required by the testing task is completely covered and the accuracy of defect-size determination (wall thickness reduction, length) can be determined.

(3) The measured characteristic parameters (phase and amplitude) shall be entered in a diagram as a function of the depth of the reference objects. The evaluation area shall be determined in dependence of the characterisitc parameters. The detection threshold and the accuracy of defect-size determination shall be read from the diagram and be documented.

(4) The test technique is suited if

a) during the examination of threaded areas, welds, claddings as well as base material zones the recording levels required as per subpara. 4.2.7 (5) b) exceed the noise level by 6 dB or more,

b) the characteristic curves clearly increase or decrease with the depth of the reference objects (depending on the test technique),

c) a clear phase separation of defect and noise signals is ensured.

d) the accuracy of

da) the wall thickness reduction during the testing of the steam generator tubes is better than 10% of the wall thickness,

db) the depth determination during the testing of other test objects is better than 50% of the depth of the reference objects assigned to the recording level.

(5) Where individual criteria of (4) cannot be satisfied, the thus caused restrictions of the test statement shall be evaluated and additional test techniques be used, where required.

4.2.4.3 Testing level adjustment

(1) The testing of steam generator tubes shall be performed to DIN 25435-6.

(2) During the testing of threaded areas, welds, claddings as well as base metal zones, in dependence of the dimensions the notches as per **Table 4-2** shall be used as reference objects in case of a wall thickness of 8 mm and above, and in case of a wall thickness less than 8 mm a notch with a depth of 20% of the wall thickness, but not deeper than 1.5 mm.

(3) During the testing of base metal zones of austenitic steels for damage due to stress corrosion cracking the testing level shall be adjusted on a notch with a depth of 1 mm.

(4) Changes of the eddy-current signals caused by geometry influences and variations of material properties shall be considered when adjusting the testing level.

4.2.5 Radiographic testing

(1) When performing radiographic tests, the requirements of DIN 25435-7 shall be met.

(2) The application of radiographic testing shall normally be limited to a wall thickness s of less than or equal to 20 mm (in the case of double-wall radiography, the thickness of the radiographed wall w ≤ 40 mm).

4.2.6 Visual testing

(1) When performing visual testing the requirements of DIN 25435-4 shall be met.

(2) Depending on the task, visual testing shall be either made as integral visual testing or as selective testing, in which case

a) integral visual testing is performed to evaluate the general condition of components

b) selective visual testing is performed as local visual examination for the unambiguous detection of specific characteristics

of the examined region.

(3) Visual testing shall be performed as a direct visual testing by the human eye and, if necessary, with the help of optical instruments (e.g. magnifying glasses, mirror, endoscope) or as an indirect visual testing by the human eye and with the help of a system of equipment receiving, transferring and displaying or recording the image.

(4) During visual testing the following shall especially be taken into consideration:

a) mechanical damage (points of friction, bends and tears),

b) material separations,

c) corrosion, erosion, wear,

d) indications of leakage,

e) defects on

ea) bolt connections (loosening, condition of the bolt locking devices),

eb) connections of measuring points and instrument lines,

ec) insulation,

f) displacement of components (free end displacement of pipes, damage to foundations and anchor points),

g) deposits, foreign matter.

(5) The object distance during direct visual testing and the recognizability of details during indirect visual testing shall be determined in dependence of the testing task.

4.2.7 Recording levels

(1) All indications reaching or exceeding the recording level shall be recorded.

(2) Magnetic particle and penetrant testing

The recording level corresponds to an indication with an extension of 3 mm. Where more than two indications are detected on an area of 1000 mm^2 they shall be considered an accumulation of indications and shall also be recorded even if the extension of the individual indication is less than 3 mm. Indications suggesting planar flaws shall be redorded independently of their extension.

(3) Ultrasonic testing

a) Examination of unclad surfaces

In the case of ultrasonic testing both in close vicinity of the probe down to a depth of less than or equal 10 mm and of the corresponding opposing surface, the recording level corresponds to the echo height of the reference reflector to para 4.2.3.3.4, plus a sensitivity allowance of 6 dB.

b) Examination of clad surfaces

ba) The recording level in the depth region equal to or less than 10 mm plus the cladding thickness corresponds to the echo height of the reference reflector notch no. 2 as per subpara. 4.2.3.3.3 (8) plus a sensitivity allowance of 6 dB.

bb) Where in the brittle fracture analysis an integrity proof of the cladding is required or the cladding as per KTA 3201.2 subpara. 7.1.3 (2) has to be considered in the analysis of the mechanical behaviour, the recording level corresponds to the echo height of the reference reflector notch no. 3 as per subpara. 4.2.3.3.3 (8) plus a sensitivity allowance of 6 dB.

c) Use of test techniques as per subpara. 4.2.3.3.3 (5)

All indications shall be recorded and be evaluated which show characteristic features of the indicated patterns determined on the reference reflectors in which case all indications above the noise level shall be evaluated.

The influence of the microstructure or of the shape of the weld seam on the ultrasonic signals shall be monitored on the test object itself or on the reference block and shall be taken into consideration when specifying the recording level.

(4) Radiographic testing

Indications visible on the radiographs shall be recorded and be classified to DIN EN ISO 6520-1.

(5) Eddy-current testing

a) Testing of steam generator tubes

Any indications suggesting planar flaws or a reduction in wall thickness exceeding 20 % as well as indications of tube denting the amplitude value of which exceeds twice the amplitude of a wall thickness reduction of 20% shall be recorded.

b) Testing of threaded areas, welds, claddings and base material zones

The recording level shall correspond to

ba) the signal height of the reference objects as per 4.2.4.3 (2) plus a sensitivity allowance of 6 dB in the case of ferritic steels,

bb) the signal height of the reference objects as per 4.2.4.3 (2) and (3) in the case of austenitic steels.

(6) Visual testing

Deviations of the covered actual condition from the expected required condition shall be recorded as conspicuous indications.

4.3 Volumetric examination

4.3.1 Ultrasonic testing

(1) The volume of the wall in a depth region further down than 10 mm (plus the thickness of cladding in the case of clad components) shall be examined with the single probe technique and, in the case of a nominal wall thickness equal to or exceeding 100 mm, additionally with techniques for detecting planar flaws perpendicular to the surface. To this end,

a) the tandem technique – preferably with transverse waves – or

b) wave conversion techniques on the basis of longitudinal wave dual-element probes, LLT search units or phased-array search units

may be used for plane-parallel and concentric surfaces.

When determining the nominal wall thickness, the thickness of the cladding shall not be taken into account. In well-founded individual cases and depending on the results of previous in-service inspections and on the actual loadings, deviations from the specified nominal wall thickness are permitted.

(2) If, in special cases with a nominal wall thickness exceeding 100 mm, ultrasonic testing using tandem or wave conversion techniques for flaws oriented perpendicular to the surface is impossible or not meaningful on account of the geometry, then an incident angle shall be chosen where the angular deviation between the sound beam axis and the surface normal to the flaw does not exceed 20°.

4.3.2 Radiographic testing

(1) When performing radiographic tests, the examination procedures to DIN 25435-7 shall be applied.

(2) The application of radiographic testing shall normally be limited to a wall thickness s of less than or equal to 20 mm (in the case of double-wall radiography, the thickness of the radiographed wall w shall be less than or equal to 40 mm).

4.3.3 Recording levels

(1) In the case of ultrasonic testing, the following shall apply:

a) Where a test technique is applied basing on the fact that the angle of incidence of the sound beam is 90° to the crack surface of the expected flaw orientation, or where the tandem or wave conversion technique is applied, all echo signals shall be recorded where the amplitude is equal to or exceeds the echo amplitude of a disc shaped reflector with a diameter of 10 mm. The dependence of the planar angle of the reflector may be generally considered by lowering the recording level by 6 dB.

b) If, in the case of a single probe technique, only the diffusely scattered radiation is used for the indication of flaw surfaces, then those echo amplitudes shall be recorded that correspond to perpendicularly encountered disc shaped reflectors as specified in **Table 4-2**.

Wall thickness s, mm	$8 \leq s \leq 20$	$20 < s \leq 40$	$s > 40$
Disc shaped reflector, mm	1.5	2	3

Table 4-3: Diameter of disc shaped reflectors for sensitivity adjustment

These recording levels shall be observed over the entire test region. Where the testing level to be adjusted cannot be observed due to signals obtained from the cladding, the further procedure shall be agreed with the authorised inspector.

c) The testing level adjustment may be performed on reference blocks with transverse bore holes. The resulting testing level shall be corrected such that it corresponds to the recording level specified in subpara. b).

(2) During radiographic testing all indications recognizable on the radiographs shall be recorded and be classified to DIN EN ISO 6520-1.

4.4 Inspection of the general condition

(1) After shutdown and prior to restart of the unit, an inspection serving to assess the general condition of systems and components shall be performed. These inspections are usually performed within plant inspection without removing any insulation material.

(2) During the inspection of the general condition the following shall especially be taken into consideration:

a) mechanical damage (points of friction, bends and tears),

b) indications of leakage, especially in system parts containing flange connections,

c) defects on
   ca) bolt connections (loosening, condition of the bolt locking devices),
   cb) connections of measuring points and instrument lines,
   cc) insulation,

d) displacement of components (free end displacement of pipes, damage to foundations and anchor points).

(3) In the case of piping with ≤ DN 100 the laying of the pipes including support functions shall be inspected during plant shutdown. The requirements, extent, performance and documentation of these inspections shall be laid down in the test instruction for each individual plant.

4.5 Pressure test

4.5.1 Test conditions

(1) Pressure tests shall basically be performed at 1.3 times the design pressure. If, in periodic pressure tests, a deviation from from this value is made, care shall be taken that safety-relevant information is obtained that is comparable to the initial pressure test.

(2) To ensure resistance to brittle failure at level P (periodic pressure tests) suitable pressure test conditions shall be established.

To this end, the test temperature shall be based on the Pellini concept to exceed the governing reference temperature by at least 33 K (maximum from RT_{NDT} + 33 K and RT_{NDTj} + 33 K). The test temperature shall not exceed the governing reference temperature by more than 55 K.

Note:

The determination of RT_{NDT} is laid down in KTA 3201.1. For the determination of RT_{NDTj} see KTA 3203.

In individual cases, lower test temperatures are permitted if the resistance to brittle fracture has been proven by fracture mechanic testing.

(3) To obtain relevant results from the pressure test the following conditions shall be met:

a) The rate of change of pressure and temperature shall be selected in accordance with the start-up and shutdown diagram specified in the operating manual until the respective test temperature of the components is reached.

b) After reaching the respective test temperature, the change rate of the test pressure shall not exceed 10 bar per minute up to the allowable working gauge pressure, and then, not more than 1 to 2 bar per minute up to the test pressure.

c) The holding time at test pressure shall be at least 30 minutes.

(4) Before starting the leakage check in accordance with para. 7.2 (8) the pressure shall be reduced to the operating pressure.

4.5.2 Non-destructive tests and examinations following the pressure test

(1) Subsequent to the periodic pressure tests non-destructive tests and examinations shall basically be performed on components of the pressure boundary in areas more highly stessed by pressure testing

(2) On the prerequisite that

a) the condition remains unchanged upon proof by the last periodic inspection performed to (1) and

b) it is proved that no change is to be expected upon periodic pressure testing,

the non-destructive tests and examinations to be performed to (1) may also be performed prior to the periodic pressure test.

4.6 Functional tests on safeguards against excessive pressure

All safeguards against excessive pressure shall be subjected to functional testing at regular intervals. In these tests the following shall be checked:

a) the response pressure,

b) the opening and closing behaviour.

Parameters relevant to function (e.g. dead times, actuating force reserves) shall be evaluated with respect to the specific plant and design.

5 Extent of testing and test intervals

5.1 General requirements

(1) In-service tests and inspections shall basically be performed to the extent as specified in Section 5.2.

(2) Where new findings are made from the monitoring of consequences and causes of operational damage mechanisms as well as from the observation of the state of knowledge of the plant condition as per **Figure 3-1**, the stipulations of Sections 5.2 and 5.3 shall be re-evaluated with respect to the specific plant. To this end, the testing procedures, areas and intervals for the component groups mentioned in Section 1 under (4), (5) and (6) shall be adapted accordingly.

(3) If the design, construction, fabrication or other aspects significantly limit the extent of testing, additional measures shall be taken (e.g. fracture mechanic analyses) that lead to the required information on safety. Any limitations with regard to the specifications of this safety standard shall be noted in the test instructions.

(4) If operational loading is one of the criteria in Section 5.2 for selecting the component areas to be tested, then representative higher stress locations shall be included within the intended extent of testing. Besides the usage factor operational experience shall also be taken into account.

(5) The distribution of extent of testing within the test intervals for components installed in multiple number as specified in the Tables of Section 5 is based on the 4-loop or 4-circuit power plant concept. In the case of two or three primary coolant loops or circuits, the distribution shall be specified by agreement with the authorized inspector.

(6) In relation to each specific plant, tests and examinations for damage by stress corrosion on austenitic pipes and components including instrumentation and control lines shall be laid down. The areas to be examined shall be laid down according to the following criteria:

a) stagnant fluid during operation, dead pockets,

b) partly filled horizontal pipe sections,

c) valves, flanged joints where ingress of foreign matter is possible.

5.2 Extent of testing

5.2.1 Non-destructive tests and examinations

5.2.1.1 General

(1) When testing weld seams, the examination shall include the weld metal (including buttering in the case of weld connections between ferritic and austenitic steels) and the base metal zone on both sides of the weld seam.

The base metal zone to be included shall normally have a width of not less than 10 mm for a wall thickness ≤ 30 mm and a width of at least 20 mm on both sides for a wall thickness exceeding 30 mm.

When testing insertion and attachment weld seams of nozzles, the width of the adjacent base metal to be included in the examination is defined by the wall thickness of the connecting nozzle or attachment wall thickness respectively.

(2) When testing surface and sub-surface areas by means of ultrasonic testing, an area with a depth of at least 10 mm (for clad structural steels at least 10 mm below the cladding) shall be covered. The imaging of the results obtained in mechanised ultrasonic testing shall ensure that the echo dynamics of recordable indications are fully reflected.

(3) Where a percentage share of welded joints is examined, some of the welds to be examined shall vary from test cycle to test cycle by agreement with the authorized inspector.

(4) Locations of former auxiliary welds shall be included in the extent of test and inspection if it cannot be ensured that the strain-hardened area of the heat affected zone has been completely removed by dressing.

(5) Component areas where the insulation has to be disassembled for the purpose of non-destructive tests and examinations, shall be subjected to an integral visual testing.

5.2.1.2 Reactor pressure vessel

(1) The extent of testing to be performed on the reactor pressure vessel is specified in **Table 5-1**. All ligaments (shortest distance between two openings) in nozzle fields of the reactor pressure vessel cover or head shall be subjected to ultrasonic testing where the test technique shall primarily be used for the detection of cracks extending to the centre of the ligaments and being located in the near-surface region. The volume areas covered by the test as well as the areas between the ligaments shall be included in the evaluation of the test results. In the case of inaccessible ligaments, para. 5.1 (3) shall apply.

(2) If a reference test in accordance with Section 4.1.3 is required for the reactor pressure vessel, the reference test shall be performed on all items to be examined in accordance with **Table 5-1** prior to commissioning the plant but after the pressure test. However, it shall be ensured that all the base metal zones are accessible for testing.

5.2.1.3 Pressure thickness of control rod drives

The extent of testing to be performed on the pressure retaining wall of control rod drives is specified in **Table 5-2**.

5.2.1.4 Steam generator

The extent of testing to be performed on the steam generator is specified in **Tables 5-3** and **5-4**. The external and internal surfaces with their near-surface regions shall be examined.

5.2.1.5 Pressurizer

(1) The extent of testing to be performed on the pressurizer is specified in **Table 5-5**. The external and internal surfaces with their near-surface regions shall be examined.

(2) Special measures shall be taken for the ligaments in the nozzle field of the pressurizer head (e.g. fracture mechanic analysis, leakage detection).

5.2.1.6 Pipework

(1) The extent of testing to be performed on the pipework is specified in Tables **5-6**, **5-7** and **5-9**. In addition, examinations for the detection of stress-corrosion cracking shall be laid down to clause 5.1 (6).

(2) For piping with nominal sizes ≤ DN 50 the following applies:

a) Those pipes shall be determined the failure of which will directly or consequently lead to the response of safety devices. The periodic non-destructive tests and examinations to be performed on internal and external surfaces of these pipes (methods, extent and intervals of examinations) shall be laid down with respect to plant-specific requirements.

b) On pipes the failure of which will not lead to the response of safety devices, non-destructive tests and examinations shall be performed to a representative extent; the methods, extent and intervals of tests and examinations shall be laid down with respect to plant-specific requirements.

c) During each refueling, component connections with nickel-alloyed weld metal shall be subjected to an integral visual testing of the external surfaces as per clause 4.2.6 for traces of leakage; the extent of testing shall be laid down with respect to plant-specific requirements.

5.2.1.7 Main coolant pump casing

At least once within 10 years (8 years) a selective visual testing of the internal surfaces of the main coolant pump casing shall be performed. The extent of testing shall be fixed with respect to the specific plant and to the design.

Note:

See subpara 5.3 (7) as to the applicable testing interval.

5.2.1.8 Valves

On valves with a nominal diameter equal to or greater than DN 50, a selective visual testing of the valve body shall be performed in conjunction with an inspection (opening of the valve body). Where possible, the test shall cover the areas including the pipe connection along with the pipe weld. Valve internal components (trim) required to seal the pressure space shall be subjected to a selective visual testing.

In addition, penetrant testing shall be performed on austenitic steel valves where the risk of damage due to stress corrosion cracking exists (e.g. in no-flow zones where the risk of corrosive fluid concentration exists).

5.2.1.9 Bolted joints

(1) The extent of testing to be performed on bolted joints on pressure-retaining walls of reactor pressure vessels, steam generators, pressurisers, main coolant pump casings as well as on bolted joints of valve bodies and control rod drives is specified in **Tables 5-1** and **5-8**.

(2) Upon disassembly of the bolted joints the adjacent flange areas shall be subjected to a selective visual testing for damage and traces of leakage (e.g. for deposition of boric acid).

5.2.1.10 Welded joints between ferritic and austenitic steels

The extent of testing to be performed is specified in **Tables 5-1**, **5-2**, **5-5** and **5-9**.

5.2.2 Inspection of the general condition

The extent of inspection of the general condition shall depend on the inspection objectives stated in Section 4.4 and shall be specified for each individual plant.

5.2.3 Pressure tests

All components within the scope of this safety standard shall be subjected to periodic pressure tests.

5.2.4 Functional testing of safeguards against excessive pressure

All safeguards against excessive pressure shall be subjected to functional tests. If the safety device consists of a pilot and a main valve, the test shall be performed such that in addition to the function of the pilot and main valve the functional capability of the control lines can also be assessed. The performance of the test shall be specified with respect to the specific plant design and construction.

5.3 Test intervals

(1) All test intervals start at the time of first criticality of the reactor. The time intervals within which the specified tests have to be performed are specified in Section 5.2. The in-service inspections in accordance with Section 5.2 shall be performed during plant shutdown (e.g. during refueling).

(2) The non-destructive tests and examinations in accordance with 5.2.1 shall be performed in test intervals of 5 years (4 years), unless specified otherwise in clause 5.2.1. In justified cases the non-destructive tests and examinations specified for the test interval may be performed, by agreement with the authorized inspector, during the next plant shutdown intended for refueling and following the test interval. If similar components are installed in multiple number and if the operating conditions are the same, then the extent of testing may be distributed over 2 succeeding test intervals where the extent of testing shall be combined such that at each test interval an entire loop or circuit is tested.

Note:

See subpara (7) as regards the applicable test interval.

(3) An inspection of the general condition in accordance with 5.2.2 shall be performed after plant shutdown for refueling and in the course of plant restart.

(4) The pressure test in accordance with 5.2.3 shall be performed every 10 years (8 years). In justified cases deviations herefrom may be agreed with the authorized inspector.

Note:

See subpara (7) as regards the applicable test interval.

(5) Functional tests of the safeguards against excessive pressure in accordance with 5.2.4 shall be performed during regular plant shutdowns for refueling.

(6) Since the time interval between two refuelings can be up to 18 months, the individual tests shall be performed during that refueling that is closest to the due date of the tests. If this leads to longer time intervals than specified in this Section, the due dates for the next in-service inspections shall be advanced accordingly such that in the long run the time intervals remain as specified. In the case of plant shutdowns of more than 6 months, special arrangements may be agreed.

(7) The test intervals specified in (2) and (4) as well as in 5.2.1.7 shall apply to components satisfying the conditions of para. 1 (4) or 1 (5). Otherwise, the bracketed intervals apply, and the tests shall be performed as follows:

a) tests to subcl. (2) at an interval of 4 years if clause 5.2.1 prescribes 5 years, and at an interval of 8 years if clause 5.2.1 prescribes 10 years,

b) tests to subpara. (4) at an interval of 8 years,

c) tests as per cl. 5.2.1.7 at an interval of 8 years,

or it shall specifically be verified that the measures taken to monitor the causes or consequences of operational damage mechanisms justify an interval of 5 years.

Item to be inspected	Test procedure / Test technique	Flaw orientation	Extent of testing	Test interval [1]
Longitudinal and circumferential welds	UT [2]	l and t	all weld seams, entire length, entire volume as well as the surface areas with their near-surface regions	5 years (4 years)
Nozzle attachment and set-in welds of the following systems: PWR: reactor coolant line BWR: live steam line, feedwater pipe, deluge system, head spray cooling system, reactor water clean-up system, axial pumps	UT	l and t [8]		
Nozzle-to-fitting welds (dissimilar welds) in BWR plants	UT [3]	l and t [4]	surface areas with their near-surface regions	
Connecting areas of thermal sleeves in BWR plants	UT or selective VT [12]	l in the case of UT any in the case of VT	due to different designs the test extent shall be specified for each individual plant	
Nozzle inside edge ≥ DN 250 [5]	UT [2]	r	surface areas with their near-surface regions of the entire inside edges of all nozzles	
		l and t	adjacent area in nozzle pipe in the case of BWR plants	
	selective VT	any	surfaces of inside edges of representative nozzles	
Ligaments in nozzle fields	UT [7]	r	all ligaments with respect to surface areas with their near-surface regions as well as the centres of ligaments	
	selective VT	any	outside surface	
Inner surface	integral and selective VT [12]	any	representative locations, in particular of the - RPV cover - belt-line area of the RPV cylinder - nozzles - RPV bottom end the test extent shall be specified for each individual plant	
Screw bolts	UT or MT or ET	transverse to the bolt axis	surface areas with their near-surface regions of all bolts, entire tensioned length including the threaded regions [9]	Within 5 years (4 years) [6] at least 25 % of the bolts with the corresponding threaded blind holes, nuts and washers, however, at three successive test intervals of 5 years (4 years) 100 % shall be tested. Alternatively, the test may be performed at intervals of 10 years (8 years) [6] where 100 % each shall be tested.
	selective VT	any		
Threaded blind holes	UT or ET	transverse to the thread axis	surface areas with their near-surface regions of all blind holes, entire thread length	
	selective VT [10]	any		
Nuts	selective VT or ET or UT	- VT: any - ET and UT: transverse to the thread axis	threaded region and loaded end face (contact surface) of all nuts	
Washers	selective VT	any	both contact surfaces as well as the surface of the washer hole	

Table 5-1: Non-destructive in-service tests and inspections on the reactor pressure vessel (continued on next page)

Item to be inspected	Test procedure / Test technique	Flaw orientation	Extent of testing	Test interval [1)]
Attachment welds	Agreements shall be made because of the differing design details. The type and extent of the tests shall be incorporated in the test instructions.			
Auxiliary welds	MT or UT	The requirements shall be specified in accordance with 5.2.1.1 (4).		
Outside surface	integral and selective VT [12)]	any	representative locations, the test extent shall be specified for each individual plant [13)]	5 years (4 years) [11)]

Abbreviations for the test procedures and techniques are explained in **Table 2-1**.
l : longitudinal flaw t : transverse flaw r : radial flaw (e.g. for nozzle inside edges or ligaments in nozzle fields)

1) See clause 5.3 (7) as regards the applicable inspection interval.
2) Where a confirmation of the cladding integrity is required in the brittle fracture analysis, the testing level for examining the cladding shall be adjusted to 4.2.3.3.3 (9).
3) Head spray nozzle: selective VT on fluid-wetted surface instead of UT.
4) In the case of welded joints provided with Ni-alloy weld metal on the fluid-wetted surface, an examination for transverse defects shall be performed from both sides additionally to the examination for longitudinal defects. This examination is also required if between the Ni-alloy weld metal and the fluid-wetted surface an austenitic root ≤ 3 mm is provided.
5) In the case of nominal diameters of the connecting pipe less than DN 250, the requirement for in-service inspections shall be reviewed from case to case.
6) VT of stud bolts (where accessible), nuts and washers after each unbolting of bolted joints.
7) The test requirements shall be laid down for PWR and BWR plants in dependence of the test objective.
8) On axial pumps only examination for longitudinal defects.
9) Selective VT only where accssible, if stud bolts are not disassembled.
10) For BWR plants: if stud bolts are disassembled for operational reasons.
11) PWR cover: integral VT for traces of leakage during each overhaul.
12) The test procedures / test techniques to be used shall be specified for each individual plant.
13) For pipe connections with nickel alloyed weld metal see cl. 5.2.1.6 (2) c).

Table 5-1: Non-destructive in-service tests and inspections on the reactor pressure vessel (continued)

Item to be inspected	Test procedure / Test technique	Flaw orientation	Extent of testing	Test interval [1)]
Circumferential welds PWR [2)]				
Dissimilar weld on cover nozzle	ET	l and t	Inner surface of representative welds on 10 % of pipes in due consideration of accessibility	5 years (4 years)
Circumferential welds on pressure pipes				
CW no. 1 [3) 4)]	UT or RT or PT or ET	l and t	Inner surface	
CW no. 2 [3)], CW no. 3, CW no. 4	ET	l and t	Inner surface of representative welds on 10 % of pipes in due consideration of accessibility	
Circumferential welds BWR				
Connecting weld on control rod nozzle	UT	l	Connecting welds of 4 pipes of control rod drive housing [5) 6)]	10 years (8 years) [6)]
Circumferential welds of control rod drive housing	UT	l	Outside surface of the connecting welds of 4 control rod drive housings [5) 6)]	
	ET	l and t	Inner surface of the connecting welds of 4 control rod drive housings [5) 6)]	
	selective VT	any	Inner surface of the connecting welds of 4 control rod drive housings [5) 6)]	

Abbreviations for the test procedures and techniques are explained in **Table 2-1**. l : longitudinal flaw t : transverse flaw

1) See cl. 5.3 (7) as regards the applicable inspection interval.
2) These cover the welds with nickel-alloyed weld metal of the core instrumentation and control rod nozzles as well as of the venting nozzle.
3) dissimilar metal weld
4) Inspection only if pressure pipe is dismounted and latch units are pulled out.
5) Where more than 4 control rod drives are disassembled for operational reasons, the extent of testing on the welds of these control rod housings shall be laid down for each individual plant.
6) The extent of testing shall be laid down such that two welds each are examined at inspection intervals of 5 years (4 years).

Table 5-2: Non-destructive in-service tests and inspections on pressure-retaining walls of control rod drives

<table>
<tr><th>Item to be inspected</th><th>Test procedure / Test technique</th><th>Flaw orientation</th><th>Extent of testing</th><th>Test interval 1)</th></tr>
<tr><td>Base metal zones</td><td>UT</td><td>circumferential direction</td><td>entire extent of the fillets in the transition between tubesheet and crown, the inside surface with its near-surface regions</td><td rowspan="5">Every 5 years (4 years) one half of the steam generators; however, at 2 successive test intervals of 5 years (4 years) each, all steam generators shall be covered</td></tr>
<tr><td>Circumferential welds</td><td>UT or MT</td><td rowspan="2">l and t</td><td>connecting seam between tube-sheet and crown, the outside and inside surfaces with their near-surface regions over the entire seam length</td></tr>
<tr><td>Nozzle-to-shell welds ≥ DN 250</td><td>UT or MT</td><td>one reactor coolant nozzle, preferably the inlet nozzle, the inside and outside surfaces with their near-surface regions over the entire seam length</td></tr>
<tr><td>Nozzle inside edges ≥ DN 250</td><td>UT</td><td>r</td><td>one reactor coolant nozzle, preferably the inlet nozzle, the inside and outside surfaces with their near-surface regions over the entire inside edge</td></tr>
<tr><td>Primary side inner surface 2)</td><td>integral and selective VT</td><td>any</td><td>cladding, partition wall, SG tube set-in weld, nozzle</td></tr>
<tr><td>Steam generator tubes</td><td>ET</td><td>flaws on the outside and inside surface, wall thickness</td><td>in each steam generator 20 % of all tubes 3) over the entire length down the lowest rolled-in joint</td><td>Every 5 years (4 years); however, within 3 years (2 years) one half of the steam generators shall be covered</td></tr>
<tr><td>Support bracket attachment welds</td><td>MT or PT</td><td>any</td><td>all tension loaded regions of outside surfaces</td><td>Every 5 years (4 years) one steam generator; however, at 4 successive test intervals of 5 years (4 years) each, all steam generators shall be covered</td></tr>
<tr><td>Other attachment welds</td><td colspan="4">Special agreements shall be made because of the differing design details.
The type and extent of the tests shall be incorporated in the test instruction.</td></tr>
<tr><td>Auxiliary welds</td><td>MT or UT</td><td colspan="3">The requirements shall be specified in accordance with 5.2.1.1 (4).</td></tr>
<tr><td colspan="5">Abbreviations for the test procedures and test techniques are explained in Table 2-1.
l : longitudinal flaw   t : transverse flaw   r : radial flaw (e.g. for nozzle inside edges)</td></tr>
<tr><td colspan="5">1) See cl. 5.3 (7) as regards the applicable inspection interval
2) The test techniques to be used and the extent of testing shall be specified for each individual plant.
3) During each in-service inspection those tube locations shall be taken into consideration, when specifying the extent of testing, which are known from design and operational experience to be more susceptible to damage.
See cl. 5.2.1.6 (2) c) as regards the examination of pipe connections with nickel-alloyed weld metal.</td></tr>
</table>

Table 5-3: Non-destructive in-service tests and inspections on the steam generators, primary side

Item to be inspected	Test procedure / Test technique	Flaw orientation	Extent of testing	Test interval 1)
Regions of base metal	UT	circumferential direction	- fillets in the transition tubesheet / secondary shroud, inside surface with its near-surface region over the entire circumference, - knuckle of the dished head, inside surface with its near-surface region over the entire circumference	Every 5 years (4 years) one half of the steam generators; however, at 2 successive test intervals of 5 years (4 years) each, all steam generators shall be covered
Circumferential and longitudinal weld seams	UT or MT	l and t	- connecting seam of the tubesheet, - one further representative circumferential seam, - 25 % of the number of all longitudinal seams, the inside and outside surfaces with their near-surface regions over the entire seam length	
Pipe connecting nozzles		depending on the examination task	- entire circumference of one feedwater nozzle in highly stressed zones of the thermal sleeve - complete nozzle inside edge circumference of one further representative nozzle $\geq$ DN 250 in each case the surface with its near-surface region	
Steam generator tube supports in the bent tube region	VT integral	any	supports, where insight view is not obstructed	Every 5 years (4 years) one steam generator; however, at 4 successive test intervals of 5 years (4 years) each, all steam generators shall be covered
Inner surface	integral and selective VT 2)	any	nozzles, internals pressure-retaining wall, where view is not obstructed	
Attachment welds	Special agreements shall be made because of the differing design details. The type and extent of the tests shall be incorporated in the test instruction.			
Auxiliary welds	MT or UT	The requirements shall be specified in accordance with cl. 5.2.1.1 (4).		

Abbreviations for the test procedures and test techniques are explained in **Table 2-1**.

l : longitudinal flaw t : transverse flaw

1) See cl. 5.3 (7) as regards the applicable inspection interval

2) The test techniques to be used shall be specified for each individual plant.

Table 5-4: Non-destructive in-service tests and inspections on the steam generators, secondary side

Item to be inspected	Test procedure / Test technique	Flaw orientation	Extent of testing	Test interval 1)
Circumferential and longitudinal weld seams	UT or MT	l and t	- entire circumference of one crown connection seam, outside and inside surface with their near-surface regions - entire seam length of 25 % of all longitudinal welds, in each case the outside and inside surface with their near-surface regions	5 years (4 years)
Dissimilar welds of nozzle				
Surge line nozzle	UT or PT	l and t 2)	inside and outside surfaces with their near-surface regions	
Pressurizer relief nozzle 3)	UT or RT or PT	l and t 2)	inside and outside surfaces with their near-surface regions of one weld seam	
Spray nozzle 3)	UT or RT or PT	l and t 2)	inside and outside surfaces with their near-surface regions of two weld seams	
Nozzles	UT	depending on the examination task	- set-in weld of the surge line nozzle - highly stressed zone of the thermal sleeve to the surge line - base material highly stressed zone of the thermal sleeve of one representative spray nozzle in each case the surface with its near-surface region	
Inner surface 4)	integral and selective VT	any	cladding, nozzles, thermal sleeves, heating rods, set-in welds with nickel alloyed weld metal and internals	
Attachment welds	Special agreements shall be made because of the differing design details. The type and extent of the tests shall be incorporated in the test instruction.			
Auxiliary welds	MT or UT	The requirements shall be specified in accordance with 5.2.1.1 (4).		

Abbreviations for the test procedures and test techniques are explained in **Table 2-1**.

l : longitudinal flaw t : transverse flaw

1) See cl. 5.3 (7) as regards the applicable inspection interval

2) In the case of welded joints provided with Ni-alloy weld metal on the fluid-wetted surface, an examination for transverse defects shall be performed from both sides additionally to the examination for longitudinal defects. This examination is also required if between the Ni-alloy weld metal and the fluid-wetted surface an austenitic root ≤ 3 mm is provided.

3) Dissimilar welds shall be examined to the representative extent in which case the following criteria apply to the selection of the welds to be examined:

a) welds with repaired areas shall preferably be examined,

b) the other welds to be examined shall vary from one inspection interval to the next.

4) The test techniques to be used and the extent of testing shall be specified for each individual plant.

See cl. 5.2.1.6 (2) c) as regards the examination of pipe connections with nickel alloyed weld metal.

Table 5-5: Non-destructive in-service tests and inspections on the pressurizer

Item to be inspected	Test procedure/ Test technique	Flaw orien-tation	Extent of testing PWR	Extent of testing BWR	Test interval [1]
Weld seams on straight tubes and elbows DN ≥ 250 [2]	MT or UT	l and t	- all connection welds to the reactor pressure vessel [3] - connection welds and (if any) longitudinal welds of the highest loaded elbow in each loop - one further seam in each loop, changing seams from one test interval to the next In each case the outside and inside surface with their near-surface regions of the entire seam length shall be examined.	30 % of all pipe weld seams consisting of the following partial entities: a) all connections to the RPV [4] b) further attachment and connection welds to be selected in accordance with the following criteria: - attachment welds on vessels, valves, pumps, - connection welds of T-joints and elbows, - operational loading also taking corrosion into account, - composite materials (only ferrites), - fabrication quality with regard to seam surface. c) 4 % of all other attachment and connection welds even of pipes with stagnating steam; these shall vary from test interval to test interval. In each case the outside and inside surface with their near-surface regions of the entire seam length shall be examined.	Within 5 years (4 years) one half of the number of loops (PWR) or circuits (BWR), however, the entire number of loops or circuits shall be covered at two successive test intervals.
Weld cladded elbows ≥ DN 250	MT or UT	l and t (relative to the axis)	highest loaded base metal region of one representative elbow in each loop, outside and inside surface with their near-surface regions	—	
Nozzles for connecting pipes ≥ DN 250	MT or UT	l	connection weld of one nozzle [5] in each loop. In each case the outside and inside surface with the near-surface region of the entire weld length shall be examined.	connection weld of one nozzle [5] in each circuit. In each case the outside and inside surface with their near-surface regions of the entire weld length shall be examined.	
Inner surface of the reactor coolant line	integral and selective VT [6]	any	representative locations, in particular cladding, instrument nozzles, inner nozzle edges, thermal sleeves. The extent of testing shall be specified for each individual plant.	—	
Bends and elbows ≥ DN 250 not weld cladded	MT or UT	l and t	—	highest loaded base metal region of one representative elbow, outside and inside surface with their near-surface regions	5 years (4 years)
Bends and elbows DN ≥ 250 not weld -clad with steam flow-through [7]	UT (wall thickness)	p	—	one elbow with a bend angle ≥ 90°, wall thickness determination in a point grid	
Small lines (≤ DN 50)	See para 5.2.1.6 (2)				
Attachment welds	Special agreements shall be made because of the differing design details. The type and extent of the tests shall be incorporated in the test instruction.				
Auxiliary welds	MT or UT	The requirements shall be specified in accordance with 5.2.1.1 (4).			

Abbreviations for the test procedures and test techniques are explained in **Table 2-1**.
l : longitudinal flaw t : transverse flaw p : flaw parallel to the surface

1) See cl. 5.3 (7) as regards the applicable inspection interval.
2) As regards the in-service inspections to be performed on piping with 50 < DN < 250 in BWR plants, the requirements shall be laid down for each individual plant.
3) All connection welds within 5 years (4 years).
4) Connection welds of the feedwater line: all connection welds within 5 years (4 years).
5) The selection of nozzles shall be based on the following criteria:
- the loading is restricted to normal operation or to incidents, loading collective
- fabrication quality.
6) The test techniques to be used shall be specified for each individual plant.
7) Bends and elbows through which steam flows continuously during normal operation.

Table 5-6: Non-destructive in-service tests and inspections on ferritic pipes

Item to be inspected		Test procedure/ Test technique	Flaw orientation	Extent of testing PWR	Extent of testing BWR	Test interval [1]
Surge line		PT or UT or RT or ET	l	one connection weld and the highest loaded bend or elbow, in each case the outside and inside surface with their near-surface regions	—	5 years (4 years)
Weld seams on straight pipes, on bends and elbows or higher stress locations	≥ DN 150			20 % of all connection or attachment welds; selection in accordance with loading criteria In each case the outside and inside surface with their near-surface regions of the entire seam length shall be examined. By agreement with the authorized inspector the pipes subjected to testing shall normally vary from test cycle to test cycle.		The extent of testing may be distributed over two successive test intervals of 5 years (4 years) each (cf. para. 5.3 (2))
	< DN 150 > DN 50			10 % of all connection or attachment welds; selection in accordance with loading criteria In each case the outside and inside surface with their near-surface regions of the entire seam length shall be examined. By agreement with the authorized inspector the pipes subjected to testing shall normally vary from test cycle to test cycle.		
Attachment welds		Special agreements shall be made because of the differing design details. The type and extent of the tests shall be incorporated in the test instruction.				
Small lines (≤ DN 50)		See para 5.2.1.6 (2)				
Abbreviations for the test procedures and test techniques are explained in **Table 2-1**. l : longitudinal flaw						

[1] See cl. 5.3 (7) as regards the applicable inspection interval.

Table 5-7: Non-destructive in-service tests and inspections on austenitic pipes

Item to be inspected	Test procedure/ Test technique	Extent of testing	Test interval
Threaded bolts	Selective VT	Surface of the visible region of all threaded bolts	Upon each unbolting of the bolted joint
Nuts		Region of threads and the loaded end face (contact surface)	
Washers		Entire surface	
Adjacent flange regions		Contact surfaces	
Abbreviations for the test procedures and test techniques are explained in **Table 2-1**.			

Table 5-8: In-service tests and inspections of bolted joints in the pressure retaining wall of steam generators, pressurizers, primary coolant pump casings as well as valve bodies, control rod drives, and pipes

Item to be inspected	Test procedure/ Test technique	Test procedure/ Test technique	Extent of testing	Test interval [1]
Dissimilar metal welds on nozzles of PWR reactor coolant line				
surge line	UT or PT	l and t [2]	The outside and inside surface with their near-surface regions of the entire seam length including the connection areas of thermal sleeves (radiuses) shall be examined.	
emergency core cooling and residual heat removal lines	UT or PT	l and t [2]	Two [3] weld seams [4]; the outside and inside surface with their near-surface regions of the entire seam length including the connection areas of thermal sleeves (radiuses) shall be examined.	5 years (4 years)
spray lines	UT or RT or PT	l and t [2]	One weld seam [4]; the outside and inside surface with their near-surface regions of the entire seam length shall be examined.	
volume control system	UT or RT or PT	l and t [2]	One weld seam [3] [4], the outside and inside surface with their near-surface regions of the entire seam length including the connection areas of thermal sleeves (radiuses) shall be examined.	
Small lines (≤ DN 50)	See para 5.2.1.6 (2)			
Dissimilar metal welds on BWR valves	UT or RT or PT	l and t [2]	25 % [3] of all weld seams [4]; the outside and inside surface with their near-surface regions of the entire seam length shall be tested.	5 years (4 years)

Abbreviations for the test procedures and test techniques are explained in **Table 2-1**.
l : longitudinal flaw t : transverse flaw

1) See cl. 5.3 (7) as regards the applicable inspection interval.

2) In the case of welded joints provided with Ni-alloy weld metal on the fluid-wetted surface, an examination for transverse defects shall be performed from both sides additionally to the examination for longitudinal defects. This examination is also required if between the Ni-alloy weld metal and the fluid-wetted surface an austenitic root ≤ 3 mm is provided.

3) In the case of Ni-alloy weld metal or an austenitic root ≤ 3 mm on the fluid-wetted surface, the extent of testing shall be doubled.

4) Dissimilar welds shall be tested to the representative extent indicated in which case the following criteria apply to the selection of welds to be examined:

a) welds subject to operating temperatures > 300 °C and weld repairs shall be tested in any case,

b) welds subject to operating temperatures > 300 °C (without weld repairs) as well as welds with repair weldings and subject to operating temperatures ≤ 300 °C shall preferably be tested,

c) the other welds to be examined shall vary from one inspection interval to the next.

Table 5-9: Non-destructive in-service tests and inspections of welded joints between ferritic and austenitic steels on pipes and valves

6 Test and inspection schedule

6.1 Preparation

The test and inspection schedule shall be prepared in accordance with Section 5.1 and shall be available and agreed upon by the authorized inspector at the latest at the time of first criticality (see also KTA 1202).

6.2 Review and updating

Prior to each, even partial, in-service inspection the type, extent and date of testing shall be reviewed for each individual component and shall be updated, if necessary. Here, the following shall be taken into consideration:

a) Previous in-service inspections

The results of previous in-service inspections shall be taken into account. This may lead to an updating of the type, extent and date of testing for the previously specified in-service inspections as well as to a change in the specified test location within the range of items to be tested.

b) Repair or replacement

After performance of repair or replacement it shall be decided upon whether or not in-service inspections should be introduced at these locations or whether or not the type, extent and date of already specified in-service inspections should be changed. This also applies to the sealing of steam generator tubes by means of plugging.

c) Irradiation influences

The evaluation of tests on accelerated irradiation specimens shall be considered when performing periodic pressure tests and non-destructive in-service inspections.

d) Operational monitoring

The results of operational monitoring in accordance with Section 9 shall be considered in the reviewing and updating procedure.

e) Operational experience

The operational experience from the own plant as well as from other plants shall be considered in the reviewing and updating procedure.

7 Preparation and performance of tests

7.1 General

The working conditions during the preparation, performance and evaluation of the tests (e.h. pressure of time, ambient temperature, noise, radiation) shall be such that negative influences on the quality of the test are avoided. For nuclear power plant overhauls, the time schedule and sequence of tests and inspections on pressure boundary components shall be planned accordingly.

7.2 Preparation

(1) The tests shall be adequately prepared with respect to general organization and required equipment. The preparation shall especially include the planning of the employment of test personnel taking the general organization of work, the Radiological Protection Ordinance and Guideline “Radiological Protection“ into consideration.

(2) The areas of the components that will be subjected to testing shall be put in a condition suitable to testing. Cleaning and further measures, if any, for preparing the non-destructive in-service testing areas shall be effected upon visual testing.

(3) Details of the tests shall be specified in test instructions (cf. KTA 1202). These include specifications of the locations to be tested, the test procedures to be applied and references to the corresponding standard test instructions or test specifications.

(4) The NDT personnel shall be instructed to become familiar with the specific testing task, the apperance of operational defects and the pertinent test boundary conditions (e.g. component geometry, impeded accessibility, work to be done under respiratory equipment, and exposure to dose rate).

7.3 Performance

(1) The test system adjustment and the checking of the adjustment as well as the checking of the test media to be used both in magnetic particle and penetrant testing shall be performed on reference standards.

(2) Penetrant tests shall be performed in accordance with DIN 25435-2.

(3) Magnetic particle testing shall be performed in accordance with DIN 25435-2 in conjunction with DIN EN ISO 9934-1.

(4) Eddy-current testing of steam generator tubes shall be performed in accordance with DIN 25435-6. The performance of eddy current testing on other components shall be specified in the test instructions.

(5) Radiographic testing shall be performed in accordance with DIN 25435-7.

(6) Automated ultrasonic testing shall be performed in accordance with DIN 25435-1.

(7) Manual ultrasonic testing shall be performed in accordance with Annex C of KTA 3201.3.

(8) Visual testing shall be performed in accordance with DIN 25435-4.

(9) Pressure tests shall be performed in accordance with DIN 25435-3

(10) Functional testing of the safeguards against excessive pressure shall be performed in accordance with the test and inspection manual.

7.4 Requirements regarding test personnel

(1) The test personnel shall have been qualified and certified to satisfy the requirements of DIN 25435-1 to DIN 25435-4, DIN 25435-6 and DIN 25435-7 for the test methods to be used.

(2) The test personnel for manual ultrasonic testing shall fulfil all requirements of DIN 25435-1 Table 2.

(3) The test personnel for eddy-current testing not performed on steam generator tubes shall satisfy the conditions of DIN 25435-6 Table 1.

(4) The test personnel for inspection of the general condition shall have the knowledge required to perform their tasks and shall have demonstrated sufficient visual capacity.

(5) The test personnel for functional tests shall have the knowledge required to perform their tasks.

8 Evaluation of test results

8.1 General

(1) Conspicuous findings and pecularities influencing the test result shall be recorded and evaluated.

(2) The test supervisory personnel of the testing agency, the plant owner and the authorized inspector shall convince themselves and confirm within the recording activities that the tests have been performed completely to the requirements and have been evaluated correctly to ensure reconstruction.

8.2 Volumetric examinations as well as inspection of surfaces and near-surface regions

Note:

*The steps specified in 8.2.1 and 8.2.2 refer to **Figure 8-1**.*

8.2.1 Decision-making process

(1) At the end of an operational period (Step 1), the n-th in-service inspection II_n (Step 2) is performed.

(2) If indications are found, the further procedure shall follow the decision-making procedure (**Figure 8-1**) structured as flow chart.

(3) When evaluating the results (Step 3) it shall be decided whether or not the indications have exceeded the acceptance level. If this is not the case, the component may be operated further (Step 12).

(4) If indications reach or exceed the acceptance level, they shall be termed relevant indications. At first, a comparison with the results of the previous in-service inspection II_{n-1} shall be performed (Step 4). If findings have changed, the results of in-service inspections lying further back shall also be taken into account to possibly detect the time history of the change. On the basis of the comparison of the measured values it shall be decided whether it is a first occurrence of the indication or whether an existing indication has grown larger (Step 5). If this is not the case, the component may be operated further (Step 12).

(5) In the case of ultrasonic testing techniques, evaluation methods may be used that are based on an image presentation of the test results. The procedure shall be specified in the test instruction.

(6) In the case of first occurrence of an indication or growth of an existing indication, an analysis to Section 8.2.3 is required that leads to information on its type, location and size. Where required, further tests employing more refined testing techniques (Step 6) shall be performed.

(7) If it is found out that it is a first occurrence of an indication or an existing indication has grown (Step 7), then the cause shall be determined and subsequently a safety analysis shall be performed (Step 8). This shall be based, among other things, on the operational records.

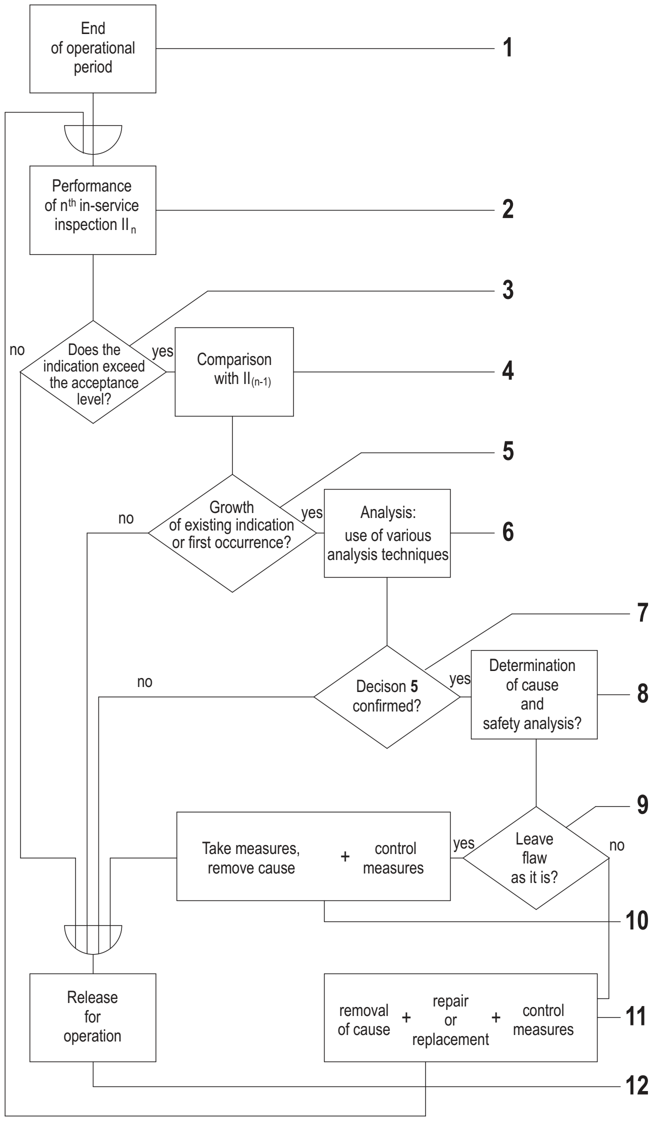


Figure 8-1: Schematic decision-making plan to evaluate the results of non-destructive tests and examinations

(8) The safety analysis may, for instance, comprise:

- a stress analysis, verifications of strength,
- fracture mechanic evaluations,
- laboratory experiments,
- checks on similar components in the case of indication of systematic defects,
- an evaluation of experience gained with other plants.

(9) The results of the cause determination and the safety analysis are decisive regarding the specification of the acceptance level, i.e., the decision whether or not a flaw may be left as it is (Step 9). If it follows that the flaw may be left in the component as it is, then the causes, where possible, shall be removed e.g. by the following measures:

a) change of the operational mode of the plant,

b) installation of additional structures (e.g. pipe support structures).

(10) The success of the measures taken shall be checked, e.g. by:

a) instrumentation for a continuous monitoring of the flaw location,

b) inclusion of the area with findings as location to be tested into the test and inspection manual and determination of shorter intervals of in-service inspections.

(11) Taking the measures specified above into account, the component may be operated further (Step 12).

(12) If it is established that the flaw as it is cannot be left in the component, the causes shall, as far as possible, be removed and a repair or replacement of the component initiated (Step 11). The success of the measures shall be checked, e.g., by

a) instrumentation,

b) shorter intervals of in-service inspections.

Prior to the release for operation, a production test or, if required in accordance with Section 4.1.3, a reference test shall be performed on the repaired component.

8.2.2 Acceptance levels

8.2.2.1 General

(1) To avoid that measured values which are scattered due to the test technique used are to be evaluated as relevant indications, the following acceptance levels are specified for in-service inspections.

(2) All indications reaching or exceeding the recording level shall be documented in a test record and those above the acceptance level (Step 3) shall be treated as relevant indications. The individual acceptance levels are defined by the values specified in Sections 8.2.2.2 and 8.2.2.3.

(3) Indications caused by the geometric shape of the test object or are clearly proved not to be caused by defects (e.g. wavy-type spalling in the cladding), shall be evaluated to be indications of shape, be identified as such and be entered in a list. In the case of periodically occurring indications of shape exemplary recording will suffice.

8.2.2.2 Surface inspection

8.2.2.2.1 Magnetic particle and penetrant testing

(1) The acceptance level shall be considered to be exceeded if indications

a) are deemed to be attributable to planar flaws,

b) show a linear dimension of more than 10 mm or

c) in the case of components made of austenitic steels, show linear dimensions exceeding 3 mm and are deemed to be attributable to corrosion.

(2) The acceptance level shall be considered to be exceeded if the size of areas containing accumulated indications with linear dimensions smaller than 3 mm is larger than 1000 mm^2.

8.2.2.2.2 Ultrasonic testing

(1) Indications not yet documented which have to be recorded in accordance with 4.2.7 (3) and cannot be explained by tolerances due to the test technique employed or when fixing anew the recording limit if an equivalent test method is applied, shall be liable to recording.

(2) When employing the test techniques with echo height evaluation to subparas. 4.2.3.3.3 (1), (3) or (4) the acceptance level is considered to have been exceeded if

a) the echo amplitudes of the indications exceed the recording level in accordance with Section 4.2.7 (3) by 6 dB or more or

b) the echo amplitudes of the indications reach or exceed the recording level and show a linear dimension exceeding
   - ba) 10 mm in the case of wall thicknesses less than 20 mm
   - bb) half the nominal wall thickness in the case of wall thicknesses ≥ 20 mm and less than 100 mm
   - bc) 50 mm in the case of wall thicknesses ≥ 100 mm

   in which case the linear dimension shall be determined by means of the half-amplitude technique.

(3) When employing the test techniques to cl. 4.2.3.3.3 (5), the acceptance level is considered to have been exceeded if indications show characteristic features of the indication patterns obtained on the reference reflectors.

8.2.2.2.3 Radiographic testing

In radiographic testing, indications which suggest the presence of crack-like defects or incomplete fusions as well as wall thinning due to corrosion shall be treated as relevant indications.

8.2.2.2.4 Eddy-current testing

(1) When examining threaded areas, welded joints, claddings, and base material zones, the acceptance level is deemd to be exceeded if

a) the amplitudes of the eddy-current signals exceed the recording level as per subpara. 4.2.7 (5) by 6 dB or more and their phase is located in the phase analysis range,

b) the amplitudes of the eddy-current signals reach or exceed the recording level as per subpara. 4.2.7 (5), their phase is located in the analysis range and the patterns suggest a planar flaw, or if their length is 10 mm or more in which case the linear dimension is to be determined to the half-amplitude technique.

(2) When subjecting steam generator tubes to eddy current testing, the acceptance level is deemed to be exceeded if the indication suggests the presence of planar flaws or a wall thickness reduction of 30 % or more. Where indications of denting reach or exceed the recording level as per 4.2.7 (5), the impairment of the eddy-current test caused by such denting shall be assessed.

8.2.2.2.5 Visual testing

Conspicuous indications as per subpara. 4.2.7 (6) found by visual testing shall be treated as relevant indications which require

a) measures for restoring the proper condition (e.g. leakage, cracks) or

b) measures for a more detailed assessment as regards acceptability.

8.2.2.3 Volumetric examinations

(1) In ultrasonic examinations the acceptance level is deeemed to be exceeded

a) if their echo amplitudes exceed the recording limit in accordance with Section 4.3.3 by 6 dB or

b) if their echo amplitudes reach or exceed the recording level in accordance with Section 4.3.3 and show a linear dimension exceeding half the nominal wall thickness or 50 mm in which case the linear dimension is to be determined to the half-amplitude technique.

(2) In radiographic testing indications which suggest the presence of crack-like defects or incomplete fusions shall be treated as relevant indications.

8.2.3 Analyses if relveant indications occur for the first time or are enlarged

(1) The following steps shall be taken in the analyses required by 8.2.1 (6):

a) Examination of the area of relevant indications with diverse testing methods or techniques, e.g. radiographic test, ultrasonic test with improved defect detection capability at the reflector location, visual testing, eddy-current test.

b) Where the examination of the area of relevant indication as per a) above does not provide further findings as to the type, size and location of the relevant indication, analyses shall be made to characterize the relevant indication regarding the following features:
   - ba) planar flaw or volumetric defect,
   - bb) in the case of planar flaws: whether they are open to the surface or not,
   - bc) in the case of planar flaws on clad components: location of flaw within the cladding or extending through the cladding into the ferritic material.

   Where the analysis does not clearly clarify the features to bb) and bc), a planar flaw open to the surface shall be assumed.

(2) Where there is indication of a planar flaw or the presence of such flaw is assumed, analyses techniques shall be applied which, for the purpose of safety-relevant evaluation, deliver sufficiently exact information on the size and location of the defect (extension over depth and length).

Note:
The following analyses techniques may e.g. be applied:
a) Synthetic aperture focussing technique (SAFT),
b) Time-of-flight diffraction technique (TOFD),
c) Crack-tip signal detection technique,
d) Echo tomography,
e) Mechanised radiography.

(3) The suitability of the analysis techniques to be applied shall be proved by means of reference block measurements, in which case the methodology of VGB Guideline R516 (VGB-ENIQ-Guideline) shall be applied.

8.3 Inspection of the general condition

If anything unusual is noticed in the course of inspection of the general condition, then it shall be decided in each individual case whether or not further tests and, if so, what kind of tests and examinations are required.

8.4 Pressure test

The pressure test is deemed to have been passed successfully if the components have withstood the required pressure level over the entire holding period (cf. Section 4.5).

8.5 Functional tests of safeguards against excessive pressure

The functional tests shall be considered to have been passed successfully if the values specified in the test instructions have been achieved.

9 Operational monitoring

9.1 General requirements

(1) Operational data that are important regarding the integrity of the components of the reactor coolant pressure boundary shall be monitored.

(2) Only measuring equipment suitable for the respective defined task (e.g. with respect to sensitivity, resolution of measured values for data recording and representation, set point of alarms) shall be used.

(3) If operating conditions occur that are not covered by the specified load regime, their causes shall be determined and these operating conditions shall be evaluated with special regard to their safety-relevant effects.

(4) Where changes of boundary conditions with expected safety-relevant influence on the integrity of the reactor coolant pressure boundary are made, the unchanged validity of the proofs of integrity performed within the design calculations to KTA 3102.2 shall be confirmed, e.g. as follows:

a) if load cases not substantiated by way of calculation occur, their influence on the brittle fracture resistance of the reactor pressure vessel shall be evaluated,

b) each load cycle cause by incidences of design loading level C shall be evaluated as to its contribution to component fatigue loading.

9.2 Monitoring of loadings

9.2.1 Monitoring of quasi-static mechanical and thermal loadings

(1) It shall be ensured that temporal and local temperature changes relevant to fatigue are monitored by a sufficiently dense net of measuring points of the standard instrumentation. When selecting the measuring points the effects of the mode of operation (little mass flows, indifferent pressure conditions, switching operations, temperature differentials) and the design (pipeline installation, isolating function of valves) shall be taken into account

(2) Where thermal stratification is expected to occur, the temperature measuring points shall be located such that all relevant loading variables across the pipe cross-section and axially to the pipe run can be measured.

(3) Pipelines shall be monitored directly (e.g. by evidence of pipe displacement) or indirectly (e.g. by proof of proper functioning of supports and penetrations) to ensure that unrestrained displacement of the pipeline (e.g. due to thermal expansion) is possible.

Note:

The checking of the proper functioning of supports and small pipes shall be made within the evaluation of the general condition see clause 4.4 (3).

(4) The results shall be evaluated in due time to find out whether relevant changes regarding the previous results of operational monitoring have occurred and are to be evaluated.

(5) The results of measurement shall be assigned to the relvevant operating conditions and be evaluated with respect to their effects on the components. The degree of cumulative damage (usage factor) shall be determined locally for the loadings occurred so that relevant statements on the component quality can be made.

(6) Where the operating conditions as per para. 9.1 (3) affect component fatigue, it is necessary to recalculate the predicted cumulative usage factor determined in accordance with the design as per equation (7.8-1) of KTA 3201.2.

When the levels of attention as shown hereafter are reached

a) D = 0.9

if influence of the fluid on component fatigue can be excluded,

b) D = 0.4

if influence of the fluid on component fatigue is to be expected and in accordance with KTA 3201.2, clause 7.8.3 (2) the exclusive measure to consider the fluid influence was the incorporation of the relevant component areas in a monitoring programme to KTA 3201.4,

it shall be ensured that the progress of fatigue is kept within safe permissible limits by appropriate measures taken with respect to operation, operational monitoring or in-service inspections, or by a combination of these measures.

To this end, proof shall be rendered that no crack formation has been detected by non-destructive testing and fracture mechanic analyses of postulated incipient cracks in due consideration of the fluid influence prove that there will only be a limited crack propagation in the time period until the next, maybe premature, in-service inspection.

Note:

Where the required measures are determined by fatigue evaluations made on the basis of the fatigue curve in Figure 7.8-2 of the KTA safety standard 3201.2 (1996-06) a value of D = 0.2 instead of D = 0.4 is considered to be adequate in the case of austenitic steels.

(7) If the results of operational monitoring or new knowledge gained lead to new requirements regarding operational monitoring, the measuring system shall be modified accordingly.

(8) The measuring results shall generally be evaluated once per refuelling cycle and be documented in a report. The type of recording of measured values shall be taken into account in the evaluation.

(9) As regards the determination of thermal loadings the requirements of DIN 25475-3 apply.

9.2.2 Vibration monitoring

(1) The vibration behaviour of the components of the primary coolant system shall be measured during the first commissioning of the plant. This shall also take representative small lines into consideration. The results shall be evaluated with regard to the analysis of cyclic strength and shall be used as comparative basis for operational vibration monitoring. In the case of a follow-up plant, a smaller measurement program is allowed than for a first plant of this type (see also Sec. 9.4.2 of KTA 3204).

(2) The instrumentation for measuring the vibrations during commissioning should be chosen such that these measurements can also be performed during operation of the nuclear power plant.

(3) The decision whether or not vibration monitoring is required during plant operation shall be made, taking into consideration the results of the vibration measurements during commissioning in conjunction with a substantiation by way of calculation as well as operational experience gained with comparable plants.

(4) If vibration monitoring is performed during operation, then the following boundary conditions shall be observed:

a) The monitoring shall aim at the detection of changes in the vibration behaviour at representative locations of the primary coolant system.

b) Vibration monitoring shall be possible at any time. It may be performed discontinuously.

c) At least two measurements shall be performed for each refuelling cycle. One of these measurements is required directly after refuelling and one before the next refuelling, with the plant being in steady-state operation.

d) If vibration monitoring fails due to partial or complete failure of the measuring equipment, the latter`s returning to service may be postponed at the latest to the next regularly scheduled plant shutdown.

(5) In the case of PWR plants the requirements of DIN 25475-2 shall apply to the system, the extent of monitoring of the reactor plant and the in-service inspections of the system.

9.2.3 Monitoring for effects due to sudden impact loadings

(1) It shall be ensured that sudden impact loadings (e.g. condensation shocks, water hammer, hydrogen explosion) are detected by suitable measures.

(2) Suitable measures are:

a) Monitoring and foresighted evaluation of the influence of dynamic loadings during putting into operation on the as-fabricated condition of the reactor coolant pressure boundary with documentation of the results obtained (on steady-state vibrations, switching operations, closing and opening of valves),

b) Reports of shift personnel (e.g. on hammers, pipe movements, deformed insulation of supports),

c) Visual testing during overhauls (e.g. ascertainment of deformed insulation of support as well as of indication of abrasion).

9.3 Monitoring of water chemistry

(1) The quality of the water in the primary and secondary circuit shall be monitored and be documented.

(2) The chemical and physical limit values to be obeserved when monitoring the water quality of the primary and secondary circuits as well as the frequency of measurements shall be specified by the plant manufacturer; these values shall be documented in the operating manual.

(3) Deviations from the chemical and physical values shall be evaluated in accordance with Section 3 (see **Figure 3-1** (7)).

9.4 Monitoring of accumulation of radiolysis gas

(1) Preventive measures shall be taken against the accumulation of radiolysis gas. To this end

a) the system areas where accumulation of radiolysis gas is possible shall be identified,

b) for each area the maximum effects of a radiolysis gas reaction shall be determined

c) in dependence of the maximum effects of a radiolysis gas reaction, active or passive preventive measures shall be taken for the areas identified

Note:

(1) Passive measures are e.g. the provision of flushing bores on valves, by-pass lines and discharge of radiolysis gas through non-isolatable vents.

(2) Active measures are e.g. the recombination of radiolysis gas by means of catalysts, discharge of radiolysis gas at top locations through isolatable vents, intermittent flushing of pipes.

The preventive measures shall be listed in a document which shall be adapted if the design or mode of operation is changed.

(2) The effectiveness of the preventive measures shall be monitored. To maintain the effectiveness of the preventive measures, specifically

a) for valves, the open position of which is important for the acumulation of radiolysis gas, the control of the open position and the safeguarding of the valve shall be regulated in test instructions,

b) in-service inspections of the vent bores and by-pass lines shall be performed,

c) the function and effectiveness of thermostatic steam traps and of catalysts within maintenance prescriptions shall be checked.

(3) Where temperature measurements are required to monitor accumulations of radiolysis gas, they shall meet the following requirements:

a) The measuring system shall be suited to safely detect inadmissible accumulations of radiolysis gas.

b) The temperature measurements shall be made by means of devices installed at fixed locations and automatic limit-value signalling.

c) Failure of temperature measurements shall be recognizable. Where temperature measurements are not available, suitable substitute measures for the discharge of radiolysis gas shall be fixed, e.g. preventive regular flushing.

d) A limit value for the maximum temperature decrease below a base value (final value) shall be laid down at which the automatic limit-value signalling responds.

Note:

As a rule, this limit value refers to a siutation where no explosive mixture exist.

e) Within in-service inspections it shall be proved that the proper functioning of the measuring system is ensured.

(4) Continuous variations of temperature not caused by intermittent flushing measures, shall be treated like radiolysis gas reactions; the components subject to such variations shall be checked and preventive measures be taken to avoid repetition.

(5) The extent and type of in-service inspections shall be laid down in the inspection manual. The inspection instructions shall be extended on the basis of operational experience.

9.5 Monitoring of changes of metal properties

(1) The irradiation behaviour of the belt-line materials of the pressure-retaining wall of the reactor pressure vessel shall be monitored in accordance with KTA 3203.

(2) From components repaced for retrofitting purposes, representative samples shall be taken which shall be examined for possible changes of material properties and damage due to operational influences. To this end, non-destructive and destructive examinations (determination of mechanical properties and examination of metallographic structure) shall be performed. The examination programm shall be fixed individually for each plant.

9.6 Leakage monitoring

9.6.1 Requirements

The leakage monitoring system shall be designed such that it is capable of detecting and localizing leakages with sufficient accuracy in the reactor coolant pressure boundary during plant operation. This system shall be sensitive enough to detect those leakages which would not yet lead to an automatic activation of safety measures due to pressure build-up in the surrounding building or due to the measurement of other system parameters (e.g. drop in pressure or coolant level). The detection sensitivity of the leakage monitoring system shall be demonstrated.

9.6.2 Measurement procedures

(1) The following measured values, alone or in combination with other values, are suited for leakage monitoring:

a) air humidity or dew point temperature,

b) air temperature,

c) radioactivity of compartment exhaust air,

d) condensate or water level increase in the recirculating air coolers,

e) water level in building sumps.

(2) The corresponding measuring instruments shall be designed for the following ambient conditions:

a) temperature 100 °C,
b) relative humidity 100 %,
c) loadings by the leakage rate test of the containment (cf. Sec. 5.4 of KTA 3405).

(3) For the localization of leakages it is advisable to group together individual compartment areas.

(4) The leakage monitoring system should be designed as self-contained system for the individual compartment areas under para. (3). Available operational measuring equipment may be used for the evaluation provided its use is permitted for the changed ambient conditions upon the occurrence of leakages.

(5) The measurement points for air humidity or dew point and air temperature shall be located in the directed flow of the air recirculation system such that the localization of leakage is possible.

(6) If the air recirculation system is made up of partial systems that are correlated to different compartment areas, the condensate level increase in the recirculating air coolers shall be measured individually for each area.

(7) The radioactivity monitoring of the compartment exhaust air shall be used to determine whether or not the leakage is from a system that carries a radioactive medium.

(8) The water levels in the sumps of the building drain system shall be monitored individually.

(9) The measured values of the leakage monitoring system shall be adequately recorded. Selected measured values shall be displayed in the control room or in an adjacent or computer room such that the course of leakage development can be pursued over the time.

(10) Adequate threshold values shall be specified for selected measured values which, when being exceeded, would trip an alarm annunciation to the control room during power operation of the plant.

9.6.3 Leakage monitoring of the control rod drives

The pressure retaining wall of the control rod drives shall be integrally monitored for leakage during operation.

9.6.4 Monitoring of leakage between primary and secondary circuit

In plants with pressurized water reactors, the main steam shall be monitored for radioactivity. If leakage is detected, the measured values shall be evaluated with respect to the size of the leakage in the steam generator tubes.

9.7 Monitoring the primary circuit for loose parts

(1) For an early detection of damage and the localization of loose parts, the primary circuit shall be monitored by a loose parts monitoring system.

(2) The requirements for this system, the extent of reactor plant monitoring and the in-service inspections of this system are specified in DIN 25475-1.

(3) If the structure-bound sound monitoring system fails due to partial or complete failure of the measuring equipment, its reactivation may be postponed at the latest to the next regular scheduled pant shutdown.

9.8 Monitoring of the allowable RPV internal pressure

(1) The allowable internal pressure to KTA 3201.2 shall be calculated and be entered in the pressure-temperature diagram.

(2) The maintenance of the internal pressure shall be monitored to meet the requirements of the pressure-temperature diagram.

10 Participation in in-service inspections and operational monitoring

(1) The nuclear power plant user shall take the necessary steps to ensure that the tests and examinations listed in the test and inspection schedule are performed at the dates fixed.

(2) The authorized inspector shall participate in in-service inspections and operational monitoring measures on the basis of a respective order by the competent authority. The participation of the authorized inspector in the in-service inspections shall ensure that he is able to perform the evaluation as per **Figure 8-1** steps 2 to 7. The participation of the authorized inspector in the operational monitoring measures shall be fixed individually for each plant.

(3) Manual ultrasonic tests shall be independently performed and be evaluated by the plant owner and the authorized inspector.

11 Documentation

11.1 General

(1) The performance of in-service inspections, tests and operational monitoring as well as the results obtained shall be documented. The requirements specified in KTA 1404 apply.

(2) The qualification and certification of the NDT personnel and the calibration of the test equipment shall be documented.

11.2 Documents required for in-service inspections

(1) The documents required for documenting the automated ultrasonic tests are specified in **Figure 11-1**. Similar documents shall be established for other test methods.

(2) In accordance with KTA 1202, the test and inspection schedule **1** shall contain the basic specifications regarding areas, procedure, extent and interval of the tests and inspections. The details regarding the performance of the tests or inspections shall be specified in test instructions **2** relating to the specific test object or general standard instructions/specifications 3 for each test or inspection method.

(3) In order to be able to smoothly perform the tests at the test/inspection locations, documents **4** specific to the test/inspection areas shall be established. In the case of automated ultrasonic tests, these shall contain, e.g., the manipulator drive sequence, channel identification, sensitivity adjustment requirements.

(4) To be able to reproduce the test results, the essential data of the test equipment shall be documented in a technical manual **5**.

(5) The test shall be started on the basis of documents **1** to **5**. Should the conditions at the test location require that changes be made to the examination area documents or to the equipment data, these shall be documented in revision sheets **4a**.

(6) At first, all measured values (base data **6**) shall be recorded on data storage media. Upon evaluation of the test results **7** all indication liable to recording shall be entered in the list of indications **8**.

(7) All relevant indications shall be recorded in the relevant indication record **9**. The indication lists and the relevant indication records shall be contained in the test report (final test report **10**).

11.3 Period of document filing for in-service inspections

(1) The documents **1** to **5** and **10** shall be stored at the nuclear power plant for the operating life of the component.

(2) The base data storage medium **6** shall be filed at least until the completion of the next in-service inspection of the particular examination area of the component. Should the evaluation of indications show up changes with respect to the previous inspection (cf. Step 7 of **Figure 8-1**), the base data storage medium shall be filed for the operating life of the component.

(3) Since there are justified fears that over the period of storage and despite appropriate storage conditions documents or data storage media will show distorting data loss, the data shall be copied to new data storage media in time.

11.4 Documents required for the monitoring of mechanical and thermal loadings

For the purpose of documentation, the documents shall contain the following data on the:

a) measuring and evaluation system (systems and components to be monitored, their function and operational mode, requirements to be met by the measuring and evaluation system)

b) measuring system (temperature measuring range, response times, recording frequency, measuring accuracy)

c) location and site of measuring points, type of measuring points, recording frequency

d) measuring results and component-specific fatigue analysis.

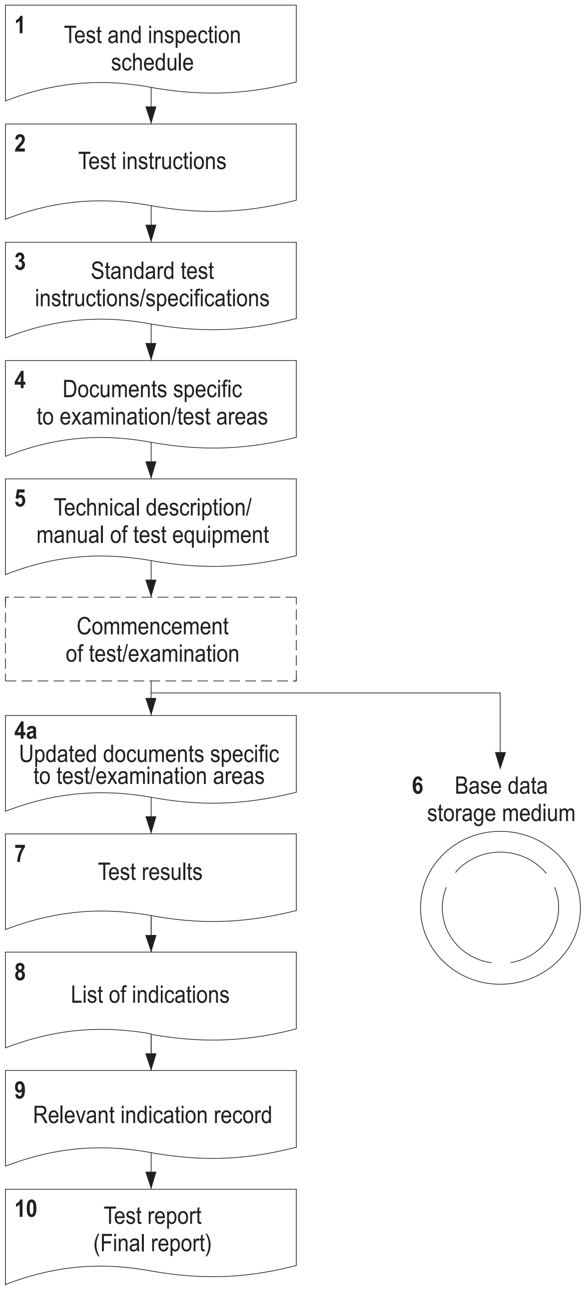


Figure 11-1: Documents for the documentation of automated ultrasonic in-service tests

Annex A

Regulations referred to in this Safety Standard

(The references exclusively refer to the version given in this annex. Quotations of regulations referred to therein refer to the version available when the individual reference below was established or issued.)

AtG		Act on the Peaceful Utilization of Atomic Energy and the Protection against its Hazards (Atomic Energy Act) of July 15, 1985 (BGBl. I, p. 1565), last Amendment by article 1 of the law dated 26th July 2016 (BGBl. I 2016, No. 37, p. 1843)
StrlSchV		Ordinance on the Protection against Damage and Injuries Caused by Ionizing Radiation (Radiation Protection Ordinance) dated 20th July 2001 (BGBl. I 2001, No. 38, p. 1714), at last amended by article 8 of the law dated 26th July 2016 (BGBl. I 2016, No. 37, p. 1843)
SiAnf	(2015-03)	Safety Requirements for Nuclear Power Plants (SiAnf) as Promulgated on March 3rd 2015 (BAnz AT 30.03.2015 B2)
Interpretations	(2015-03)	Interpretations of the Safety Requirements for Nuclear Power Plants of November 22nd 2012, as Amended on March 3rd 2015 (BAnz. AT 30.03.2015 B3)
Guideline “Radiological Protection“		Guideline for the Protection against Radiation of Personnel during the Execution of Maintenance Work, Modification, Disposal and the Dismantling in Nuclear Installations and Facilities Part II: The Radiation Protection Measures to be taken during the Operation or Decommissioning of an Installation or Facility (IWRS II) dated 17th January 2005 (Joint Ministerial Gazette (GMBl.) 2005, No. 13 p. 258)
KTA 1202	(2009-11)	Requirements for the testing manual
KTA 1404	(2013-11)	Documentation during the construction and operation of nuclear power plants
KTA 3201.1	(1998-06)	Components of the reactor coolant pressure boundary of light water reactors; Part 1: Materials and product forms
KTA 3201.2	(2013-11)	Components of the reactor coolant pressure boundary of light water reactors; Part 2: Design and analysis
KTA 3201.3	(2007-11)	Components of the reactor coolant pressure boundary of light water reactors; Part 3: Manufacture
KTA 3203	(2001-06)	Surveillance of the Irradiation Behaviour of Reactor Pressure Vessel Materials of LWR Facilities
KTA 3204	(2015-11)	Reactor pressure vessel internals
KTA 3405	(2015-11)	Leakage test of the reactor containment vessel
DIN EN ISO 2400	(2013-01)	Non-destructive testing - Ultrasonic testing - Specification for calibration block No. 1 (ISO 2400:2012); German version EN ISO 2400:2012
DIN EN ISO 3452-3	(2014-03)	Non-destructive testing - Penetrant testing - Part 3: Reference test blocks (ISO 3452-3:2013); German version EN ISO 3452-3:2013
DIN EN ISO 6520-1	(2007-11)	Welding and allied processes - Classification of geometric imperfections in metallic materials - Part 1: Fusion welding (ISO 6520-1:2007); Trilingual version EN ISO 6520-1:2007
DIN EN ISO 7963	(2010-12)	Non-destructive testing - Ultrasonic testing - Specification for calibration block No. 2 (ISO 7963:2006); German version EN ISO 7963:2010
DIN EN ISO 9934-2	(2015-12)	Non-destructive testing - Magnetic particle testing - Part 2: Detection media (ISO 9934-2:2015); German version EN ISO 9934-2:2015
DIN EN ISO 19232-1	(2013-12)	Non-destructive testing - Image quality of radiographs - Part 1: Determination of the image quality value using wire-type image quality indicators (ISO 19232-1:2013); German version EN ISO 19232-1:2013
DIN 25435-1	(2014-01)	In-service inspections for primary circuit components of light water reactors - Part 1: Automated ultrasonic inspection
DIN 25435-2	(2014-01)	In-service inspections for primary circuit components of light water reactors - Part 2: Magnetic particle and penetrant inspection
DIN 25435-3	(2006-12)	In-service inspections for primary circuit components of light water reactors - Part 3: Hydrotest
DIN 25435-4	(2014-01)	In-service inspections for primary circuit components of light water reactors - Part 4: Visual inspection

DIN 25435-6	(2014-01)	In-service inspections for primary coolant circuit components of light water reactors - Part 6: Eddy current testing of steam generator heating tubes
DIN 25435-7	(2014-01)	In-service inspections for primary coolant circuit components of light water reactors - Part 7: Radiographic testing
DIN 25475-1	(2004-05)	Nuclear facilities - Operational monitoring - Part 1: Monitoring of structure-borne sound for loose parts detection
DIN 25475-2	(2009-05)	Nuclear facilities - Operational monitoring - Part 2: Vibration monitoring for early detection of changes in the vibrational behavior of the primary coolant circuit in pressurized water reactors
DIN 25475-3	(2015-04)	Nuclear facilities - Operational monitoring - Part 3: Determination of thermal loadings
VGB-R 516	(2010)	Guideline "Methodology for Qualification of Non-Destructive Tests" (VGB-ENIQ-Guideline), 2nd edition, published by VGB PowerTech e.V.

Annex B (informative)

Changes with respect to the edition 2010-11

(1) The Section “Fundamentals“, first subpara. was adapted to take over the uniform text relevant to all KTA safety standards and the second subpara. was supplemented by the stipulations set by the Safety Requirements for Nuclear Power Plants as well as the Interpretations on the Safety Requirements for Nuclear Power Plants.

(2) The total safety standard was adapted to reflect the current standards, and the normative references in Annex A were updated.

(3) In Section 2 the definition of the new term “echo height evaluation” was added.

(4) The text in subpara. 4.2.3.2 was revised

a) to show that the testing technique is to be selected by only considering the testing task and the acoustical properties of the test object,
b) to clarify that in this case testing techniques are to be preferred which permit an echo height evaluation,
c) to indicate the pertinent testing techniques in an unbiased manner,
d) to make a proper distinction between standard and optimized testing techniques.

(5) In clause 4.2.3.3.2 the requirements for the reference block were put more precisely by taking over the requirements of KTA 3211.4 (2013-11) as regards the reference block diameter as well as the stipulations for the utilization of plane reference blocks and reference blocks without welds.

(6) The criteria mentioned in clause 4.2.3.3.3 regarding the suitability of techniques for the testing of butt welds and unclad base metals as well as the related Table 4-1 were revised and simplified. The revised stipulations now make a clear distinction between the cases where echo height evaluation is possible and the cases where pattern recognition is to be applied. The revision was made based on experience gathered with the application of the stipulations laid down in KTA safety standard 3201.4 (2010-11). The revision also took into account that case 2 permitted to Table 4-1 of KTA 3201.4 in edition 2010-11 will rarely occur in practice. Cases 1 and 2 now shown in Table 4-1 cover all relevant practical applications for the testing of butt welds and unclad base metals.

(7) In subpara. 4.2.3.3.4 (1) d) a wrong reference was corrected.

(8) The requirements for eddy-current testing in clause 4.2.4 were updated and put more precisely by taking over the following requirements of KTA 3211.4 (2013-11):

a) The reference objects of the reference block shall suffice with regard to dimensions and location so that statements on the detection capability of the testing technique are possible.
b) For wall thicknesses up to and including 8 mm a notch with a depth of 20% of the wall thickness, but not deeper than 1.5 mm shall be used.

In addition, the stipulation of subpara. 4.2.4.2.3 (4) a) was changed to be in accordance with the formulation of subpara. 4.2.7 (5) b).

(9) Clause 4.2.7 was changed to adapt to the changes in clause 4.2.3.3.3 as follows:

a) In subpara. (2) the requirements for accumulations of indications were put more precisely by taking over the formulations of KTA safety standard 3211.4 (2013-11).
b) In subpara. (5) the formulation of KTA safety standard 3211.4 (2013-11) was taken over to clarify that a sensitivity allowance of 6 dB is only reasonable for ferritic materials.

(10) In clause 8.2.2.2.2 the content was adapted and editorially revised on the basis of the changes made in clauses 4.2.3.3.3, 4.2.3.3.4 and 4.2.7.

(11) The stipulations of section 9.2.1 “Monitoring of quasi-static mechanical and thermal loadings” were updated as follows:

a) The requirements for the levels of attention in subpara. (6) were updated and adapted to KTA 3201.2 (2013-11).
b) In new subpara. (9) it was laid down that regarding the determination of thermal loadings the requirements of DIN 25475-3 apply. Consequently, former subpara. (9) containing stipulations for the checking of the measuring system was deleted as these stipulations are contained in DIN 25475-3.