

# Safety Standards

of the  
Nuclear Safety Standards Commission (KTA)

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**KTA 3201.4 (2010-11)**

**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 and 1999-06

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If there is any doubt regarding the information contained in this translation, the German wording shall apply.

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# KTA SAFETY STANDARD

2010-11

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

KTA 3201.4

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PLEASE NOTE: Only the original German version of this safety standard represents the joint resolution of the 50-member Nuclear Safety Standards Commission (Kerntechnischer Ausschuss, KTA). The German version was made public in Bundesanzeiger No. 199a on December 30<sup>th</sup> 2010. Copies may be ordered through the Carl Heymanns Verlag KG, Luxemburger Str. 449, D-50939 Koeln (Telefax +49-221-94373-603).

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#### 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 task of specifying those safety related requirements which shall be met with regard to precautions to be taken in accordance with the state of science and technology against damage arising from the construction and operation of the facility (Sec. 7 para 2 subpara 3 Atomic Energy Act) in order to attain the protection goals specified in the Atomic Energy Act and the Radiological Protection Ordinance (StrlSchV) and which are further detailed in the "Safety Criteria for Nuclear Power Plants" and in the "Guidelines for the Assessment of the Design of PWR Nuclear Power Plants against Incidents pursuant to Sec. 28 para 3 of the Radiological Protection Ordinance (StrlSchV) - Incident Guidelines" (in the version published on 18<sup>th</sup> October 1983).

(2) Criterion 1.1, „Principles of Safety Precautions" of the Safety Criteria requires, among other things, a comprehensive quality assurance for fabrication and erection. In addition, the Criterion 2.1, „Quality Assurance" requires the preparation and application of design rules, construction rules, testing and inspection rules as well as the documentation of quality assurance. Criterion 4.1 "Reactor Coolant Pressure Boundary" principally requires, among other things, the exclusion of dangerous leakage, rapidly extending cracks and brittle fractures with respect to the state-of-the-art. 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 in-service inspections 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  $\leq$  DN 50.

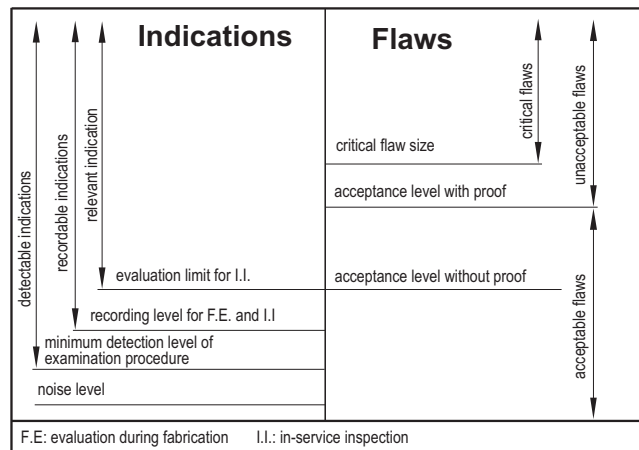
## 2 Definitions

### (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 exceeding the evaluation limit.

### (4) Operational flaws

Operational flaws are flaws due to operational damage mechanisms.

### (5) 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.

### (6) 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.

### (7) 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 12223 or calibration block no. 2 to DIN EN 27963,
- 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 462-1,
- 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.

### (8) Measured values

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

### (9) Detection threshold

Detection threshold is the lowest limit of detection of indications.

## (10) 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**.

## (11) Examination of surfaces

A surface examination is a non-destructive examination using techniques which allow detecting indications on the surface and near-surface regions in which case the depth examined depends on the method.

## (12) 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.

## (13) Quality

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

## (14) 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.

## (15) 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.

## (16) 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.

## (17) 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.

## (18) 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.

## (19) Damage mechanisms

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

## (20) 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.

## (21) 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.

## (22) 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.

## (23) 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. grooves, bores) adapted to the individual testing task.

## (24) 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.

## (25) 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.

Serial Number	Type of Test	Test Procedure	Test Technique
1	Examination of surfaces	Magnetic particle testing (MT)	e.g. field magnetization by magnetomotive force
		Liquid penetrant testing (PT)	e.g. dye penetrant testing
		Ultrasonic testing (UT)	e.g. surface waves, mode conversion, dual search units with longitudinal waves, phased-array technique
		Eddy-current testing (ET)	Single frequency, multiple frequency
		Radiographic testing (RT)	X-ray, Radioisotope
		Visual testing (VT)	Selective or integral visual examination with or without optical means
2	Volumetric examination	Ultrasonic testing (UT)	e.g. single 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 (ET) for thin walls	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

### 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 phenomena 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 evaluation shall be as follows:

- a) At first an evaluation 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-service 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.

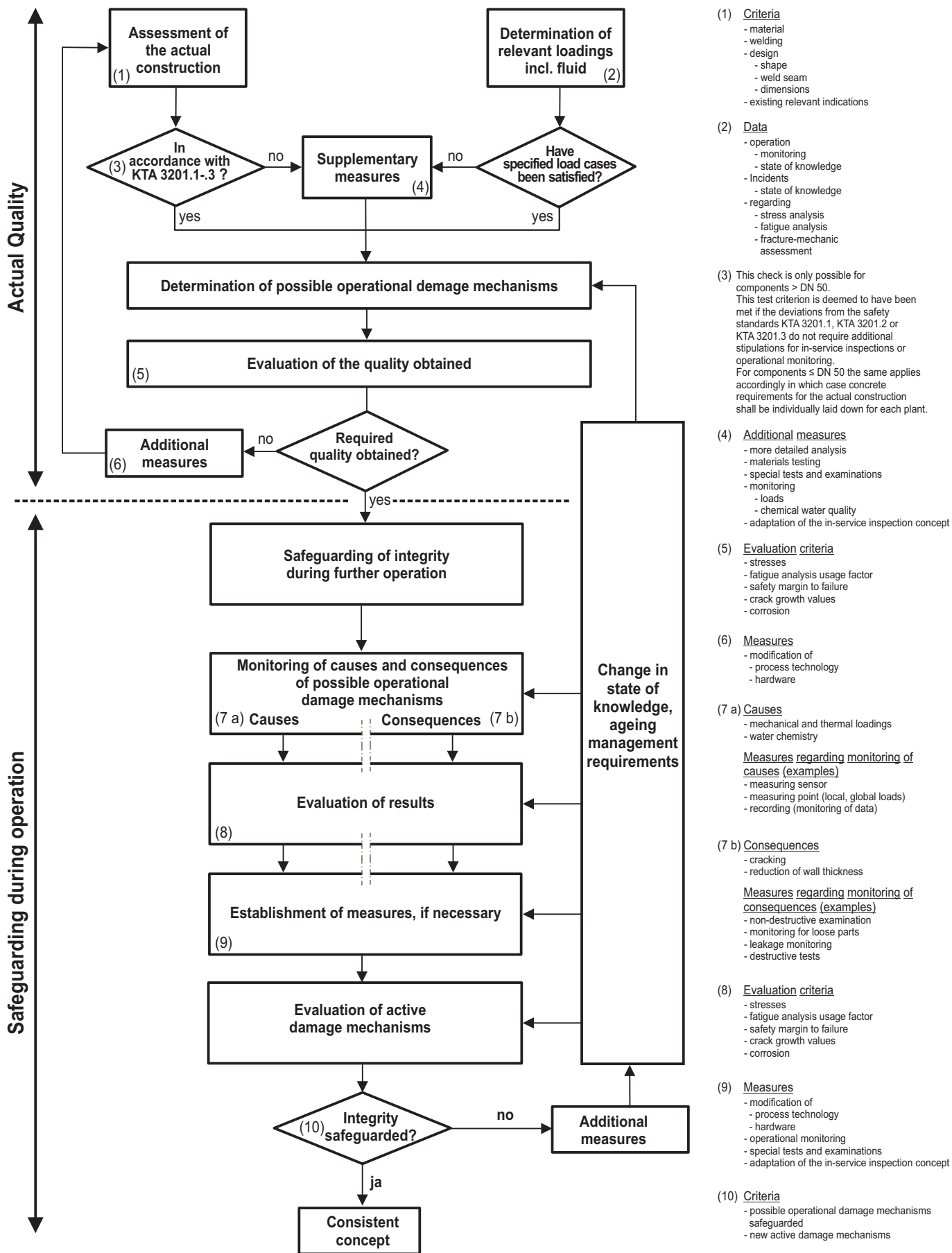


Figure 3-1: Safeguarding of component integrity during operation

## 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 liquid 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 austenitic 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 respec-

tive items to be examined. Here, eddy-current testing may be performed 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 authorized 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 radiographic images shall show the coordinates (e.g. item to be examined, zero point, direction of counting).

## 4.2 Examination of surfaces

### 4.2.1 Magnetic particle testing

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

### 4.2.2 Liquid penetrant testing

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

### 4.2.3 Ultrasonic examination procedures

#### 4.2.3.1 Surfaces and their near-surface regions close to the search unit

(1) When examining surfaces and their near-surface regions close to the search unit, an examination technique or several examination techniques with which the sensitivity to para. 4.2.3.3.4 can be obtained shall be employed to detect planar discontinuities.

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

#### 4.2.3.2 Surfaces and their near-surface regions away from the search unit

(1) When examining the surface away from the search unit with its near-surface regions for planar discontinuities, an examination technique or several examination techniques with which the sensitivity to para. 4.2.3.3.4 can be obtained shall be employed. A technique utilizing the corner effect shall preferably be employed. In this case vertically polarized transverse waves with the incident angle of the sound beam in the range between 35 and 55 degrees shall be employed. Examination techniques with an incident angle of the sound beam in the range between 65 and 70 degrees may also be employed. Furthermore, the following techniques may be applied:

- a) the wave conversion technique, where the transverse waves striking the examined surface with an incidence angle of 33 degrees are converted to longitudinal waves that run almost parallel to the surface and encounter the expected flaw in perpendicular direction,
- b) the wave conversion technique where the longitudinal waves reflected from the flaw of the surface away from the search unit are converted to transverse waves and in this mode reach the search unit.

(2) 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 examination technique or a combination of techniques shall be used, provided a prior verification of suitability was performed. Optimized examination techniques are, e.g.

- a) search units with flat angles of incidence, examination frequencies  $\leq 2$  MHz, highly attenuated transducers,
- b) Transmit-receive transducer techniques with signal overlapping in the half skip area,
- c) horizontally polarized transverse waves,
- d) longitudinal waves,
- e) tandem (pitch-catch) examination on the volumetric region adjacent to the cladding,
- f) imaging methods, e.g. for pattern recognition.

#### 4.2.3.3 Procedural requirements

##### 4.2.3.3.1 General requirements

(1) The sensitivity adjustment shall be performed on reference blocks with grooves where the reflecting surface is oriented perpendicular to the surface. Rectangular grooves, wedge-shaped grooves and spark-eroded slots may be used.

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

(3) In the case of mechanized examination with liquid column coupling an adjustment of the search unit is required where the radius of curvature of the part surface would lead to a gap  $\geq 0.5$  mm under the search unit. In the case of manual examination of curved surface parts the search units 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 grooves 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 grooves 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) 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 shear wave search unit 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 groove 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 groove to be selected as per **Table 4-2** by at least 4 dB.

(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 examination area to be covered on a reference block having grooves with varying depths. The grooves shall be provided as shown in **Figures 4-1 to 4-4**.

At least three rectangular grooves 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 groove depths. When performing the examinations as per subparas (7) and (8), one groove shall have a greater depth and one groove have a lower depth than the groove as per **Table 4-2** required to adjust the sensitivity

For the examination of clad surfaces as per subpara. (9) the echo heights of the edge simulating a through-wall crack and of grooves no. 1, no. 2 and no. 3 as per **Figure 4-4** shall be entered in a diagram in dependence of the groove depths. Where in the brittle fracture analysis an integrity proof of the cladding is required, groove no. 4 shall be included.

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

The test technique is considered to be suited if the criteria of subparas. (3) to (9) are satisfied.

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

- a) the echo heights rise with an increase in groove depth when scanning across the base metal of the reference block,
  - b) the echo heights do not decrease, with an increase in groove depth, to be less than the echo height of the groove to be selected as per Table 4-2 when scanning across the weld metal or the buttering of the reference block,
  - c) the echo height of the groove to be selected 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 sufficiently deep groove exceeds the echo height of the groove to be selected as per Table 4-2 by at least 4 dB in the case of angles of incidence as shown in Figures 4-1 to 4-3.
- (4) When examining clad surfaces the test technique will be

suitable if

- a) the echo heights do not decrease, with an increase in groove depth, to be less than the echo height of the reference reflector selected as per subpara. 4.2.3.3.4 (6),
- b) groove no. 2 as per Figure 4-4 exceeds the noise level by at least 12 dB and groove no. 3 is verifiable, where no integrity proof of the cladding is required in the brittle fracture analysis.
- c) groove no. 3 as per Figure 4-4 exceeds the noise level by at least 12 dB and groove 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 groove no. 1 exceeds the echo height of the reference reflector selected as per subpara. 4.2.3.3.4 (6) by at least 4 dB.

Demonstration of the suitability of test techniques for ultrasonic testing of butt welds and unclad base metal zones				
	Case 1	Case 2a	Case 2b	Case 3
Examination to subpara.	4.2.3.3.3 (3)	4.2.3.3.3 (5)		4.2.3.3.3 (6)
Difference in echo heights between edge simulating a through-wall crack and noise level (echo height dynamics)	≥ 16 dB	> 10 dB and < 16 dB		> 6 dB and ≤ 10 dB
Difference in echo heights between edge simulating a through-wall crack and the groove to be selected as per Table 4-2	≥ 4 dB	< 4 dB	≥ 4 dB	> 0 dB and < 4 dB
Reference groove	Groove to be selected as per Table 4-2	Groove with a depth less than the groove to be selected as per Table 4-2, but with a difference in echo height to the edge simulating a through-wall crack of ≥ 4 dB	Groove to be selected as per Table 4-2 or groove with a greater depths, but with a difference in echo height to the edge simulating a through-wall crack of ≥ 4 dB	Groove with a difference in echo height between groove and noise level ≥ 6 dB
Recording level	Groove to be selected as per Table 4-2 plus a sensitivity allowance of 6 dB	Reference groove plus a sensitivity allowance of 6 dB		Recording as of noise level
Difference in echo heights between recording level and noise level	≥ 6 dB	> 0 dB and < 6 dB		0 dB
Additional requirements for a sufficient conclusiveness of the examination	none	Where indications reach or exceed the recording level, an evaluation of these indications shall be made by pattern recognition until reaching the noise level		Evaluation of all indications in excess of the noise level by means of pattern recognition <sup>1)</sup>
		—	Safety-related evaluation <sup>2)</sup>	Safety-related evaluation <sup>2)</sup>

1) Within the course of the demonstration of suitability of the examination technique criteria shall be established according to which distinction is to be made between the reference groove pattern and the edge pattern simulating a through-wall crack.

2) Where the reference groove shows a greater depth than the groove to be selected as per Table 4-2

**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 to (3) and (4) cannot be satisfied, the following substitute measures shall be taken (see **Table 4-1** case 2):

- a) It shall be verified that the echo of the edge simulating a through-wall crack or the echo height of the additional sufficiently deep groove exceeds the noise level by at least 10 dB.
- b) The sensitivity shall not be adjusted on the groove to be selected as per para. 4.2.3.3.4, but on a reference groove having such a depth at which
  - ba) the echo of the edge simulating a through-wall crack or the echo height of the additional sufficiently deep groove exceeds the noise level by at least 4 dB.
  - bb) the echo height of this reference groove exceeds the noise level by more than 6 dB.
- c) In addition, the indications of the reference reflectors shall be recorded to provide a basis for a pattern comparison with respect to the characteristic features of the indication patterns obtained during the examination.
- d) Where the reference groove shows a greater depth than the groove to be selected as per **Table 4-2** (see **Table 4-1** case 2b), a safety-related evaluation shall be made regarding the conclusiveness of the examination 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 groove with a length corresponding to the entire area for which the reference groove with a greater depth than that of the groove to be selected as per **Table 4-2** is used).

(6) Where the criteria of (3) to (5) in parts of the examination area (e.g. in the case of dissimilar welds with buttering where the examination 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 3):

On the basis of the results obtained from reference block measurements the reference groove for sensitivity adjustment shall be a groove 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 grooves, further grooves with graded depths or realistic reference defects (cracks) shall be provided in the reference block. All grooves having a greater depth than the reference groove 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 signal pattern of the reference groove and the noise signals as well as a clear distinction between the reference groove pattern and the edge pattern simulating a through-wall crack. The evaluation procedure shall be fixed in the test instructions on the basis of reference block measurements (e.g. pattern recognition, correlation of indication patterns in the case of different angles of incidence and wave modes, crack-tip signal detection).

Where the reference groove shows a greater depth than the groove to be selected as per **Table 4-2**, a safety-related evaluation shall be made regarding the conclusiveness of the examination 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 groove with a length corresponding to the entire area for which the reference groove with a greater depth than that of the groove to be selected as per **Table 4-2** is used).

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

- a) Examination of the inner surface of welds between ferritic steels

Grooves 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 grooves 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) Examination of the inner surface of welds between austenitic steels

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

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

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

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

- a) Examination of the inner surface of welds between ferritic steels

Grooves 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 grooves 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 groove may also enter the base metal area.

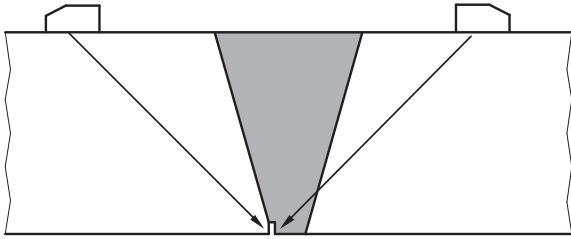
- b) Examination of the inner surface of welded joints between ferritic and austenitic steels with nickel-alloyed weld metal

Grooves 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 grooves shall be positioned in the weld metal and the buttering. Where the width of the weld metal (including the buttering) is less than 20 mm, the groove length shall be limited to the width of the weld metal (including the buttering) on the inner surface. The grooves shall be scanned from both sides with either test technique a or test technique b as shown in **Figure 4-3 a**.

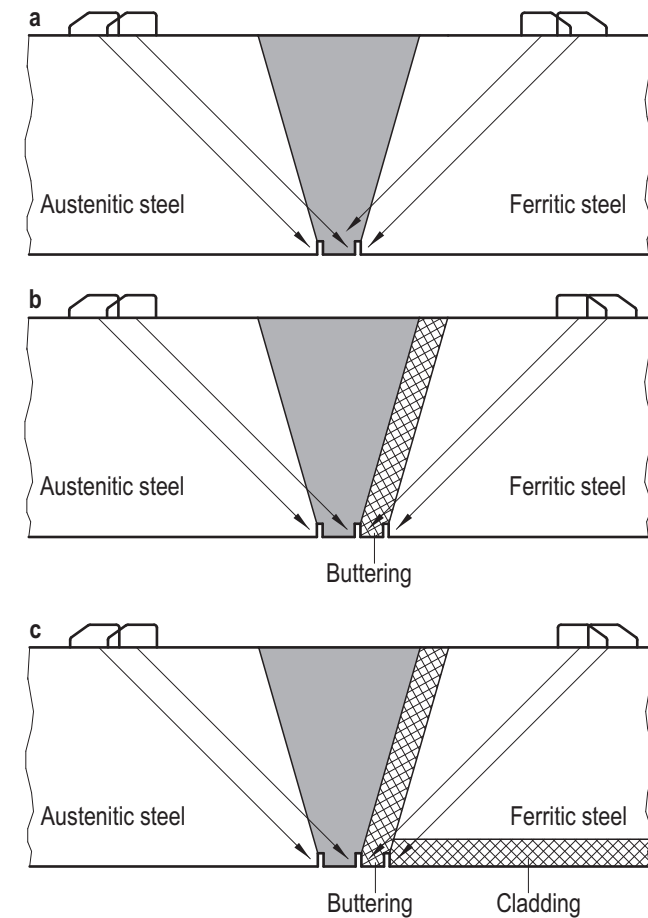
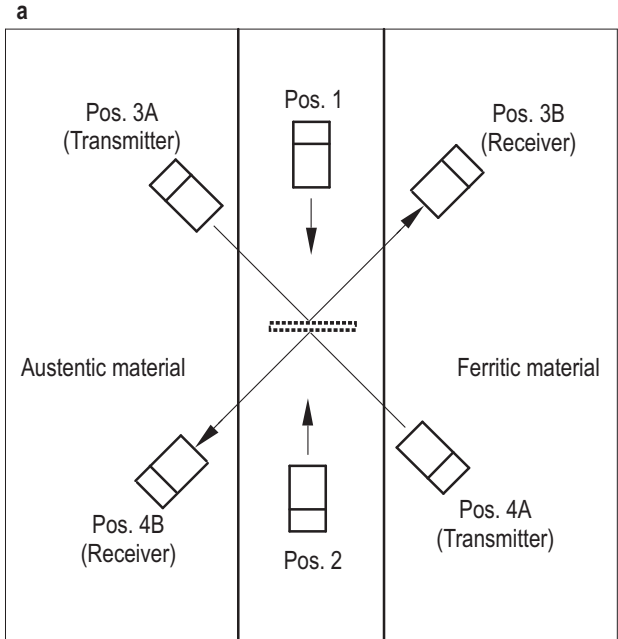
(9) When examining clad surfaces of ferritic components (base metal zone or welded joint areas), the grooves shall be provided as shown in **Figure 4-4**. Groove no. 4 is only required to demonstrate the suitability of the test techniques that are intended to be employed for the examination of clad surfaces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

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

- b) Groove no.2: Cladding thickness plus the depth of the groove to be selected as per **Table 4-2**,
- c) Groove no. 3: one millimeter less than the cladding thickness, or lesser value,
- d) Groove no. 4: half of the cladding thickness.



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

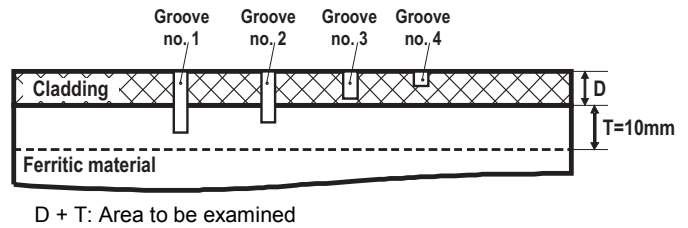


**Figure 4-2:** Location of grooves and beam angles for the examination for longitudinal defects of welded joints between ferritic and austenitic steels

Examination technique a: Scanning from positions 1 and 2 (single probe technique)

Examination technique b: Scanning from positions 3A and 4A (dual probe technique)

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



**Figure 4-4:** Location of grooves for the examination of clad surfaces

#### 4.2.3.3.4 Sensitivity adjustment

##### (1) General requirements

- a) **Table 4-2** shows the depth of the grooves 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 sensitivity shall be adjusted on a 1 mm deep groove.

Wall thickness s, mm	$8 < s \leq 20$	$20 < s \leq 40$	$s > 40$
Groove depth, mm	1.5	2	3

**Table 4-2:** Groove depth for adjusting the sensitivity on unclad test objects

- b) The sensitivity 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 the examination, it is found out that the V transmission echo deviates by 6 dB or more from the reference block echo, sufficient sensitivity 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 search units with other nominal frequencies, dual probe search units or wave conversion technique). Where the required sensitivity cannot be obtained even in the case of adapted examination techniques, the further procedure shall be fixed in consideration of subparas. 4.1.1 (10) and 4.1.2 (4).

##### (2) Examinations on ferritic materials

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

- (3) Examination 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 longitudinal defects

For the purpose of adjusting the sensitivity, the reference reflector as per **Table 4-2** and **Figure 4-1** or **Figure 4-2a** shall be subject to direct scanning over the examination area "weld-adjacent zone". For the examination 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) Examination 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 adjusting the sensitivity, the reference reflector as per **Table 4-2** and **Figure 4-2b** or **Figure 4-2c** shall be subject to direct scanning over the examination area "weld-adjacent zone". For the examination 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) Examination of the inner surface of welded joints between ferritic and austenitic steels with nickel-alloyed weld metal for transverse defects.

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

##### (6) Examination of clad surfaces

- a) For the purpose of adjusting the sensitivity, groove no. 2 as per 4.2.3.3.3 (9) 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,

groove no. 3 as per 4.2.3.3.3 (9) taken as reference reflector shall be subject to direct scanning for the purpose of adjusting the sensitivity in the clad area.

##### Note:

The sensitivity adjustment 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 subparas. 4.2.3.3.3 (5) or 4.2.3.3.3 (6) are used, the procedural requirements laid down in these subparas regarding sensitivity adjustment 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 examination 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 examination of surfaces it is required that coils 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 probe coils) oriented in parallel to the surface for the detection of flaws in any direction  
ad) using surface probe coils with two coils arranged mutually perpendicular to and above each other (so-called plus-point probe coils) 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 sensitivity shall be adjusted on reference reflectors in which case grooves 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 adjusting the sensitivity.

##### 4.2.4.2.2 Reference block

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

(2) The grooves shall not be wider than 0.3 mm. The groove length shall be greater than the effective probe width. The diameter of through-bores shall be 1.3 mm. In the case of flat-bottom 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 examination of steam generator tubes where the influence of discontinuities (tubesheet and spacers) is to be simulated appropriately:
  - aa) grooves 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 examination of threaded areas: grooves at thread root areas,
- c) for the examination of welded joints, claddings and other base material areas: grooves oriented in and transverse to the direction of probe travel,
- d) for the examination of pipes (base material): grooves longitudinal and transverse to the tube axis.

##### 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 characteristic 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) the recording levels required as per subpara. 4.2.7 (5) 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 Sensitivity adjustment

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

(2) During the examination of threaded areas, welds, claddings as well as base material zones, grooves as per **Table 4-2** shall be used as reference objects in dependence of their dimensions.

(3) During the examination of base material zones of austenitic steels for damage due to stress corrosion cracking the sensitivity shall be adjusted on a groove 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 sensitivity.

##### 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  $w \leq 40$  mm).

##### 4.2.6 Visual testing

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

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

- a) integral visual examinations are performed to evaluate the general condition of components
- b) selective visual examinations are performed as local visual examination for the unambiguous detection of specific characteristics

of the examined region.

(3) Visual examinations shall be performed as a direct visual examination by the human eye and, if necessary, with the help of optical instruments (e.g. magnifying glasses, mirror, endo-

scope) or as an indirect visual examination by the human eye and with the help of a system of equipment receiving, transferring and displaying or recording the image.

(4) During visual examinations 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 examination and the recognizability of details during indirect visual examination 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 liquid penetrant testing

The recording level corresponds to an indication with an extension of 3 mm. Linear or planar accumulations of indications shall also be recorded even if the extension of the individual indication is less than 3 mm. Indications suggesting planar flaws shall be recorded independently of their length.

(3) Ultrasonic testing

a) Examination of unclad surfaces

In the case of ultrasonic examinations both in close vicinity of the search unit 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 groove no. 2 as per subpara. 4.2.3.3.3 (9) 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 groove no. 3 as per subpara. 4.2.3.3.3 (9) 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 which reach the echo height of the reference groove plus a sensitivity allowance of 6 dB, in which case the characteristic features of the indicated patterns of these indications above the noise level are to be recorded and be evaluated.

d) Use of test techniques as per subpara. 4.2.3.3.3 (6)

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 radiographic images shall be recorded and be classified to DIN EN ISO 6520-1.

(5) Eddy-current testing

a) Examination 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) Examination of threaded areas, welds, claddings and base material zones

The recording level shall correspond to the signal height of the reference objects as per 4.2.4.3 (2) and (3) plus a sensitivity allowance of 6 dB.

(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 search unit 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 crystal search units, 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, the use of dual search unit ultrasonic 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 circular disc 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 search unit 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 circular disc reflectors as specified in **Table 4-2**.

Wall thickness s, mm	8 ≤ s ≤ 20	20 < s ≤ 40	s > 40
Circular disc reflector, mm	1.5	2	3

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

These recording levels shall be observed over the entire examination region. Where the test sensitivity 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 sensitivity adjustment may be performed on reference blocks with transverse bore holes. The resulting examination sensitivity shall be corrected such that it corresponds to the recording level specified in subpara. b).
- (2) During radiographic testing all indications recognizable on the radiographic images shall be recorded and be classified to DIN EN ISO 6520-1.

#### 4.4 Evaluation of the general condition

- (1) After shutdown and prior to restart of the unit, the examinations serving to assess the general condition of systems and components shall be performed. These examinations are usually performed within plant inspection without removing any insulation material.
- (2) During the evaluation of the general condition the following shall especially be taken into consideration:
- mechanical damage (points of friction, bends and tears),
  - indications of leakage, especially in system parts containing flange connections,
  - defects on
    - bolt connections (loosening, condition of the bolt locking devices),
    - connections of measuring points and instrument lines,
    - insulation,
  - 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 examined during plant shutdown. The requirements, extent, performance and documentation of these examinations 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 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:

- 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.
- 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.
- The holding time at test pressure shall be at least 30 minutes.
- 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 examinations following the pressure test

- (1) Subsequent to the periodic pressure tests non-destructive examinations shall basically be performed on components of the pressure boundary in areas more highly stressed by pressure testing
- (2) On the prerequisite that
- the condition remains unchanged upon proof by the last periodic inspection performed to (1) and
  - it is proved that no change is to be expected upon periodic pressure testing,

the non-destructive 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:

- the response pressure,
- 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 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 examination 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, 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 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  $\leq 30$  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 examination, shall be subjected to an integral visual examination.

##### 5.2.1.2 Reactor pressure vessel

(1) The extent of examinations 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  $\leq$  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 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 examinations shall be performed to a representative extent; the methods, extent and intervals of 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 examination of the external surfaces as per clause 4.2.6 for traces of leakage; the extent of examination 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 examination of the internal surfaces of the main coolant pump casing shall be performed. The extent of the examination shall be fixed with respect to the specific plant and to the design.

Note:

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

#### 5.2.1.8 Valves

On valves with a nominal diameter equal to or greater than DN 50, a selective visual examination of the valve body shall be performed in conjunction with an inspection (opening of the valve body). Where possible, the examination 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 examination.

In addition, liquid 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 examination 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 Evaluation of the general condition

The extent of evaluation 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 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 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 evaluation 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 <sup>1)</sup>	
Longitudinal and circumferential welds	UT <sup>2)</sup>	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 <sup>8)</sup>			
Nozzle-to-fitting welds (dissimilar welds) in BWR plants	UT <sup>3)</sup>	l and t <sup>4)</sup>	surface areas with their near-surface regions		
Connecting areas of thermal sleeves in BWR plants	UT or selective VT <sup>12)</sup>	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 <sup>5)</sup>	UT <sup>2)</sup>	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 <sup>7)</sup>	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 <sup>12)</sup>	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 <sup>9)</sup>	Within 5 years (4 years) <sup>6)</sup> 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) <sup>6)</sup> 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 <sup>10)</sup>	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		
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.				

**Table 5-1:** Non-destructive in-service 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 <sup>1)</sup>
Auxiliary welds	MT or UT	The requirements shall be specified in accordance with 5.2.1.1 (4).		
Outside surface	integral and selective VT <sup>12)</sup>	any	representative locations, the test extent shall be specified for each individual plant <sup>13)</sup>	5 years (4 years) <sup>11)</sup>
Abbreviations for the test procedures and techniques are explained in <b>Table 2-1</b> . l : longitudinal flaw    t : transverse flaw    r : radial flaw (e.g. for nozzle inside edges or ligaments in nozzle fields)				
<p>1) See clause 5.3 (7) as regards the applicable inspection interval.</p> <p>2) Where a confirmation of the cladding integrity is required in the brittle fracture analysis, the test sensitivity for examining the cladding shall be adjusted to 4.2.3.3.3 (9).</p> <p>3) Head spray nozzle: selective VT on fluid-wetted surface instead of UT.</p> <p>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 <math>\leq 3</math> mm is provided.</p> <p>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.</p> <p>6) VT of stud bolts (where accessible), nuts and washers after each unbolting of bolted joints.</p> <p>7) The test requirements shall be laid down for PWR and BWR plants in dependence of the test objective.</p> <p>8) On axial pumps only examination for longitudinal defects.</p> <p>9) Selective VT only where accessible, if stud bolts are not disassembled.</p> <p>10) For BWR plants: if stud bolts are disassembled for operational reasons.</p> <p>11) PWR cover: integral VT for traces of leakage during each overhaul.</p> <p>12) The test procedures / test techniques to be used shall be specified for each individual plant.</p> <p>13) For pipe connections with nickel alloyed weld metal see cl. 5.2.1.6 (2) c).</p>				

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

Item to be inspected	Test procedure / Test technique	Flaw orientation	Extent of testing	Test interval <sup>1)</sup>
Circumferential welds PWR <sup>2)</sup> 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 <sup>3) 4)</sup>	UT or RT or PT or ET	l and t	Inner surface	
CW no. 2 <sup>3)</sup> , 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 <sup>5) 6)</sup>	10 years (8 years) <sup>6)</sup>
Circumferential welds of control rod drive housing	UT	l	Outside surface of the connecting welds of 4 control rod drive housings <sup>5) 6)</sup>	
	ET selective VT	l and t any	Inner surface of the connecting welds of 4 control rod drive housings <sup>5) 6)</sup>	
Abbreviations for the test procedures and techniques are explained in <b>Table 2-1</b> .    l : longitudinal flaw    t : transverse flaw				
<p>1) See cl. 5.3 (7) as regards the applicable inspection interval.</p> <p>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.</p> <p>3) dissimilar metal weld</p> <p>4) Inspection only if pressure pipe is dismantled and latch units are pulled out.</p> <p>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.</p> <p>6) The extent of testing shall be laid down such that two welds each are examined at inspection intervals of 5 years (4 years).</p>				

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

Item to be inspected	Test procedure / Test technique	Flaw orientation	Extent of testing	Test interval <sup>1)</sup>
Base metal zones	UT	circumferential direction	entire extent of the fillets in the transition between tubesheet and crown, the inside surface with its near-surface regions	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 welds	UT or MT	l and t	connecting seam between tubesheet and crown, the outside and inside surfaces with their near-surface regions over the entire seam length	
Nozzle-to-shell welds $\geq$ DN 250	UT or MT		one reactor coolant nozzle, preferably the inlet nozzle, the inside and outside surfaces with their near-surface regions over the entire seam length	
Nozzle inside edges $\geq$ DN 250	UT	r	one reactor coolant nozzle, preferably the inlet nozzle, the inside and outside surfaces with their near-surface regions over the entire inside edge	
Primary side inner surface <sup>2)</sup>	integral and selective VT	any	cladding, partition wall, SG tube set-in weld, nozzle	
Steam generator tubes	ET	flaws on the outside and inside surface, wall thickness	in each steam generator 20 % of all tubes <sup>3)</sup> over the entire length down the lowest rolled-in joint	Every 5 years (4 years); however, within 3 years (2 years) one half of the steam generators shall be covered
Support bracket attachment welds	MT or PT	any	all tension loaded regions of outside surfaces	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
Other 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 <b>Table 2-1</b> . l : longitudinal flaw    t : transverse flaw    r : radial flaw (e.g. for nozzle inside edges)				
<sup>1)</sup> See cl. 5.3 (7) as regards the applicable inspection interval <sup>2)</sup> The test techniques to be used and the extent of testing shall be specified for each individual plant. <sup>3)</sup> 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.				

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

Item to be inspected	Test procedure / Test technique	Flaw orientation	Extent of testing	Test interval <sup>1)</sup>
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	I 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 <sup>2)</sup>	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 <b>Table 2-1</b> . 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 inspections on the steam generators, secondary side

Item to be inspected	Test procedure / Test technique	Flaw orientation	Extent of testing	Test interval <sup>1)</sup>
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 <sup>2)</sup>	inside and outside surfaces with their near-surface regions	
Pressurizer relief nozzle <sup>3)</sup>	UT or RT or PT	l and t <sup>2)</sup>	inside and outside surfaces with their near-surface regions of one weld seam	
Spray nozzle <sup>3)</sup>	UT or RT or PT	l and t <sup>2)</sup>	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 <sup>4)</sup>	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 <b>Table 2-1</b> . l : longitudinal flaw    t : transverse flaw				
<sup>1)</sup> See cl. 5.3 (7) as regards the applicable inspection interval <sup>2)</sup> 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 $\leq 3$ mm is provided. <sup>3)</sup> 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. <sup>4)</sup> 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 inspections on the pressurizer

Item to be inspected	Test procedure/ Test technique	Flaw orientation	Extent of testing PWR	Extent of testing BWR	Test interval <sup>1)</sup>
Weld seams on straight tubes and elbows DN $\geq$ 250 <sup>2)</sup>	MT or UT	l and t	<ul style="list-style-type: none"> <li>- all connection welds to the reactor pressure vessel <sup>3)</sup></li> <li>- connection welds and (if any) longitudinal welds of the highest loaded elbow in each loop</li> <li>- one further seam in each loop, changing seams from one test interval to the next</li> </ul> <p>In each case the outside and inside surface with their near-surface regions of the entire seam length shall be examined.</p>	<p>30 % of all pipe weld seams consisting of the following partial entities:</p> <ul style="list-style-type: none"> <li>a) all connections to the RPV <sup>4)</sup></li> <li>b) further attachment and connection welds to be selected in accordance with the following criteria: <ul style="list-style-type: none"> <li>- attachment welds on vessels, valves, pumps,</li> <li>- connection welds of T-joints and elbows,</li> <li>- operational loading also taking corrosion into account,</li> <li>- composite materials (only ferrites),</li> <li>- fabrication quality with regard to seam surface.</li> </ul> </li> <li>c) 4 % of all other attachment and connection welds even of pipes with stagnating steam; these shall vary from test interval to test interval.</li> </ul> <p>In each case the outside and inside surface with their near-surface regions of the entire seam length shall be examined.</p>	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 clad elbows $\geq$ 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 $\geq$ DN 250	MT or UT	l	connection weld of one nozzle <sup>5)</sup> 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 <sup>5)</sup> 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 <sup>6)</sup>	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 $\geq$ DN 250 not weld clad	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 $\geq$ 250 not weld-clad with steam flow-through <sup>7)</sup>	UT (wall thickness)	p	—	one elbow with a bend angle $\geq 90^\circ$ , wall thickness determination in a point grid	
Small lines ( $\leq$ 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 <b>Table 2-1</b> . l : longitudinal flaw      t : transverse flaw      p : flaw parallel to the surface					
<p>1) See cl. 5.3 (7) as regards the applicable inspection interval.</p> <p>2) As regards the in-service inspections to be performed on piping with <math>50 &lt; DN &lt; 250</math> in BWR plants, the requirements shall be laid down for each individual plant.</p> <p>3) All connection welds within 5 years (4 years).</p> <p>4) Connection welds of the feedwater line: all connection welds within 5 years (4 years).</p> <p>5) The selection of nozzles shall be based on the following criteria:</p> <ul style="list-style-type: none"> <li>- the loading is restricted to normal operation or to incidents, loading collective</li> <li>- fabrication quality.</li> </ul> <p>6) The test techniques to be used shall be specified for each individual plant.</p> <p>7) Bends and elbows through which steam flows continuously during normal operation.</p>					

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



Item to be inspected	Test procedure/ Test technique	Test procedure/ Test technique	Extent of testing	Test interval <sup>1)</sup>
Dissimilar metal welds on nozzles of PWR reactor coolant line surge line	UT or PT	l and t <sup>2)</sup>	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)
emergency core cooling and residual heat removal lines	UT or PT	l and t <sup>2)</sup>	Two <sup>3)</sup> weld seams <sup>4)</sup> ; 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.	
spray lines	UT or RT or PT	l and t <sup>2)</sup>	One weld seam <sup>4)</sup> ; 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 <sup>2)</sup>	One weld seam <sup>3) 4)</sup> ; 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 <sup>2)</sup>	25 % <sup>3)</sup> of all weld seams <sup>4)</sup> ; the outside and inside surface with their near-surface regions of the entire seam length shall be examined.	5 years (4 years)
Abbreviations for the test procedures and test techniques are explained in <b>Table 2-1</b> . l : longitudinal flaw    t : transverse flaw				
<p>1) See cl. 5.3 (7) as regards the applicable inspection interval.</p> <p>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.</p> <p>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.</p> <p>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:</p> <p>a) welds subject to operating temperatures &gt; 300 °C and weld repairs shall be tested in any case,</p> <p>b) welds subject to operating temperatures &gt; 300 °C (without weld repairs) as well as welds with repair weldings and subject to operating temperatures ≤ 300 °C shall preferably be tested,</p> <p>c) the other welds to be examined shall vary from one inspection interval to the next.</p>				

**Table 5-9:** In-service 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 examination areas shall be effected upon visual inspection.

(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 appearance 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 and penetrant testing shall be performed on reference standards.

(2) Liquid 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 inspection 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, DIN 25435-2, DIN 25435-3, 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 fulfill 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 evaluation 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 peculiarities 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 examinations 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.

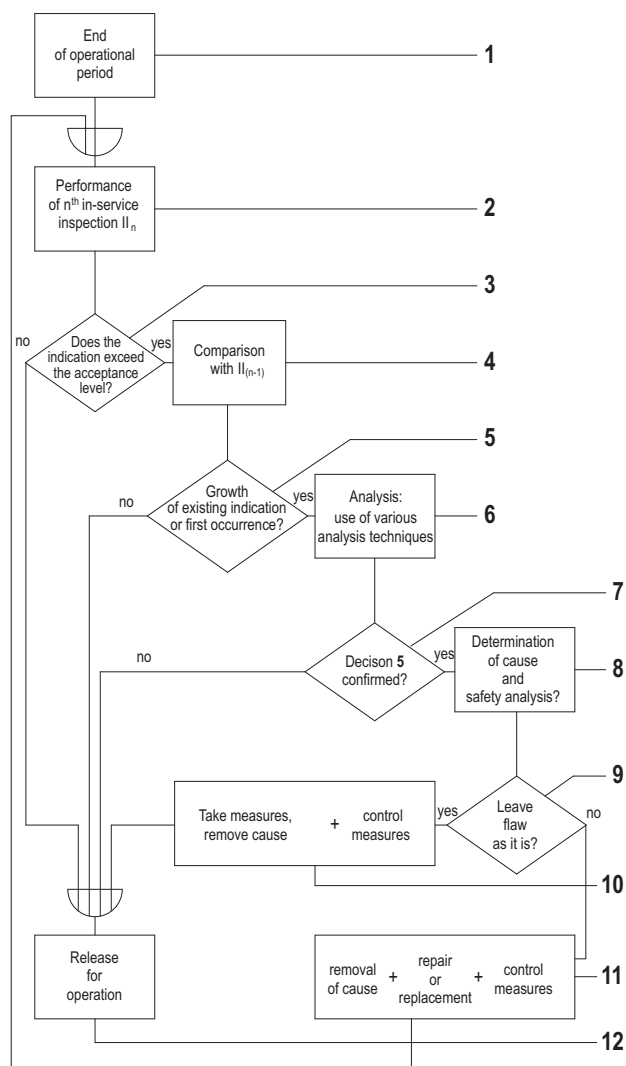
(3) When evaluating the results (Step 3) it shall be decided whether or not the indications have exceeded the acceptance level. If this is not the case, the component may be operated further (Step 12).

(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 examination 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 examinations 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 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 an examination 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 Examination of surfaces

#### 8.2.2.2.1 Magnetic particle and liquid 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<sup>2</sup>.

#### 8.2.2.2.2 Ultrasonic testing

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

- a) the echo amplitudes of the indications exceed the recording limit 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 limit 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  $\geq 20$  mm and less than 100 mm
  - bc) 50 mm in the case of wall thicknesses  $\geq 100$  mm
 in which case the linear dimension shall be determined by means of the half-value method; or
- c) the echo amplitude of an indication not yet documented reaches or exceeds the recording limit and this indication 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, or

- d) when employing test techniques as per cl. 4.2.3.3.3 (5).
- da) indications reaching or exceeding the recording level show characteristic features as regards the indication patterns obtained on the reference reflectors, or
- db) the longitudinal extension of the indication cannot be determined due to too little echo height differences between the indication and the noise level.

(2) When employing the test techniques to cl. 4.2.3.3.3 (6), the acceptance level is exceeded if indications show characteristic features of the indication patterns obtained on the reference reflectors in which case all indications above the noise level shall be evaluated.

#### 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 deemed 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-value method.

(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 examination

Conspicuous indications as per subpara. 4.2.7 (6) found by visual examination 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 deemed 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-value method.

(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 relevant 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 examination methods or techniques, e.g. radiographic test, ultrasonic test with improved defect detection capability at the reflector location, visual examination, 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 Evaluation of the general condition

If anything unusual is noticed in the course of evaluation of the general condition, then it shall be decided in each individual case whether or not further examinations and, if so, what kind of 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 relevant 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)  $D = 0.2$  for austenitic steels  
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,

- c)  $D = 0.4$  for ferritic steels  
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.

(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) The measuring system to monitor local thermal loadings shall be regularly checked for functional capability and measuring accuracy. Where a measuring deviation is exceeded to be intolerable, the system shall be calibrated.

### 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 examination 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 observed 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 accumulation 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 situation 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 program 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 plant 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.

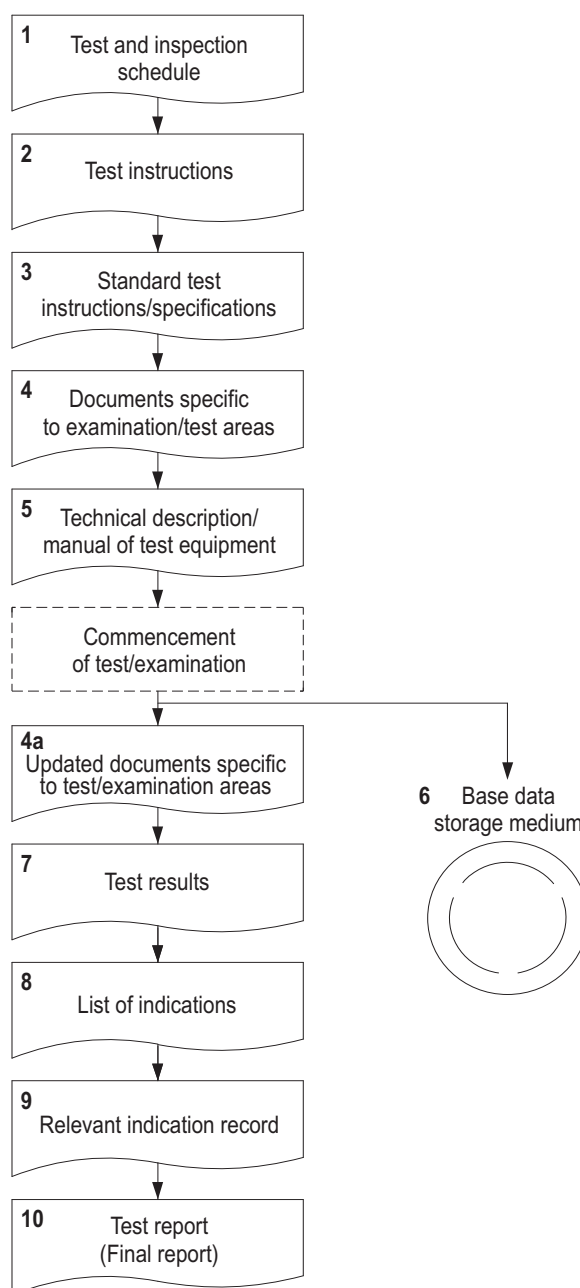
(2) The base data storage medium **6** shall be filed at least until the completion of the next in-service inspection of the particular examination area of the component. Should the evaluation of indications show up changes with respect to the previous inspection (cf. Step 7 of **Figure 8-1**), the base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

- 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)
- measuring system (temperature measuring range, response times, recording frequency, measuring accuracy)
- location and site of measuring points, type of measuring points, recording frequency
- 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.)

StriSchV		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 2 of the Law dated 29th August 2008 (BGBl. I 2008, No. 40)
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	(2001-06)	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	(1996-06)	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	(2008-11)	Reactor pressure vessel internals
KTA 3405	(2010-11)	Leakage test of the reactor containment vessel
DIN EN 462-1	(1994-03)	Non-destructive testing; image quality of radiographs; Part 1: image quality indicators (wire type); determination of image quality values; German version EN 462-1:1994
DIN EN ISO 3452-3	(1999-02)	Non-destructive testing - Penetrant testing - Part 3: Reference test blocks (ISO 3452-3:1998); German version EN ISO 3452-3:1998
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 9934-1	(2002-03)	Non-destructive testing - Magnetic particle testing - Part 1: General principles (ISO 9934-1:2001); German version EN ISO 9934-1:2001
DIN EN ISO 9934-2	(2003-03)	Non-destructive testing - Magnetic particle testing - Part 2: Detection media (ISO 9934-2:2002); German version EN ISO 9934-2:2002
DIN EN 12223	(2000-01)	Non-destructive testing - Ultrasonic examination - Specification for calibration block No. 1; German version EN 12223:1999
DIN 25435-1	(2005-09)	In-service inspections for primary circuit components of light water reactors - Part 1: Automated ultrasonic inspection
DIN 25435-2	(2003-05)	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	(2003-05)	In-service inspections for primary circuit components of light water reactors - Part 4: Visual inspection
DIN 25435-6	(2003-05)	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	(2003-05)	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 EN 27963	(1992-06)	Welds in steel; calibration block No. 2 for ultrasonic examination of welds (ISO 7963:1985); german version EN 27963:1992
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 1999-06 and explanations

(1) In the Section "Fundamentals" information on safety criteria relevant to KTA 3201.4 and subsequently the requirements for in-service inspections were specified more precisely.

(2) In Section 1 "Scope" the conditions were specified more precisely according to which the application of this Safety Standard is possible to components not designed, constructed and fabricated to the rules of KTA 3201.1 to KTA 3201.3.

By this precise specification evaluations performed to the state of science and technology are not affected as regards compliance with the principles of basic safety relating to the requirements for in-service inspections and operational monitoring.

In addition, more precise information was given

- a) in complicate with KTA 3201.3 (2007-11) for internals of shut-off valves required to isolate the pressure space and
- b) it was pointed out in new subpara. (8) that this Safety Standard also contains rules for piping  $\leq$  DN 50.

(3) Section 2 "Definitions" was revised to

- a) include new terms required for uniform application of KTA 3201.4,
- b) change the term "reference standard" in order to cover all NDT testing methods,
- c) put more precisely the term "examination of surfaces", so that the adjacent near-surface region also covers the cladding,
- d) delete in the term "recording level" the reference to the amplitude as this reference does not apply to all test methods,
- e) take over the term "authorized inspector" from KTA 3201.3 (2007-11).
- f) the definition of the term "volumetric examination" was changed analogously to the term "examination of surfaces" and reformulated, as the former definition excluded the examination of both the volume and near-surface regions by the same test method (e.g. RT),
- g) Figure 2-1 was revised editorially to take over the term "acceptance level",
- h) the terms contained in Figure 2-1 were added to provide verbal descriptions in which case the term "noise level" was defined on the basis of VGB Guideline R 515 (2001-01) "Evaluation of measuring results in the case of mechanised ultrasonic testing",
- i) further terms used in current standards and in KTA 3201.3 (2007-11), where relevant, were taken over.

(4) The requirements for the test methods and techniques to be applied in Table 2-1 were put more precisely according to the current practice of testing. Here, it was taken into account that integral and selective visual examinations to comply with DIN 25435-4 (2003-05) present procedures for the examination of surfaces. The test method "evaluation of the general condition" was taken over.

(5) Section 3 was renamed to read "Safeguarding of component integrity during operation" and was revised to describe in more detail the basic requirements for the evaluation and determination of actual component quality, the operational monitoring required and the in-service inspections including a foresighted assessment of component quality. Here, the reference to the "principles of basic safety" was replaced by a reference to the requirements of KTA 3201.1, KTA 3201.2 and KTA 3201.3, as these safety standards make clear references

possible and the principles of basic safety have been transposed accordingly. By this precision, the evaluations performed in due consideration of the state of science and technology to comply with the principles of basic safety relating to the requirements for in-service inspections and operational monitoring are not affected.

(6) Section 4 "Test procedures and techniques" was fundamentally revised to take over the following changes and supplements:

- a) The Section was restructured to specifically comprise, in separate clauses, the requirements for the selection of test methods and techniques (clause 4.1.1), the requirements for the proof of suitability of test methods and techniques (clause 4.1.2) and the process-related requirements for ultrasonic testing (clause 4.2.3.3).
- b) New requirements for the examination of base metal zones of austenitic steels for damage caused by stress corrosion cracking were included.
- c) In 4.1.1 (8) new requirements were included as to lay down when mechanised tests are to be performed.
- d) In 4.1.1 (11) reference was made to the tables in Section 5 and the text was supplemented to read that eddy-current testing may be used alternatively or generally as supplementary test.
- e) The suitability of test methods and techniques the application of which is not sufficiently described in standards shall be proved by applying the methodology of VGB Guideline R 516 (VGB-ENIQ-Guideline), unless qualified test techniques are available (clause 4.1.2).
- f) In clause 4.1.4 the reference to KTA 3201.3 was deleted since
  - fa) proceeding like during fabrication is not required,
  - fb) not all the sample forms required for KTA 3201.4 are contained in KTA 3201.3,
  - fc) the documentation requirements of section 11 are sufficiently regulated.
- g) In clause 4.2.3.3 new requirements for proof of suitability of ultrasonic test techniques and sensitivity adjustment were taken over. Here, on the basis of the requirements of KTA 3201.3 (2007-11) and in due consideration of the progress of knowledge, among others detailed requirements for the examination of surfaces of welded joints between ferritic and austenitic steels, for the examination of transverse defects and the examination of clad component zones were laid down.

The test technique is suited if the sensitivity can be adjusted such that the requested defect detection capability can be obtained and it is ensured that clear distinction between relevant indications and spurious echos can be made. In addition, criteria for the evaluation of indications were laid down so that even large and deep defects can be recognized as such and can be classified accordingly as to their safety-relevant importance, i.e. the echo height difference between the edge and the reference groove shall normally be at least 4 dB.

As regards the proof of suitability of test techniques for ultrasonic testing of butt welds and unclad base metal zones distinction is to be made between three cases (see **Table 4-1**):

- ga) In case 1 (demonstration of suitability to subpara. 4.2.3.3 (3)) the aforementioned criteria are satisfied. The difference in echo heights between edge simulat-

ing a through-wall crack and noise level shall be at least 16 dB. With this test technique sufficient proof of the test technique's suitability without additional conditions is obtained. This is usually ensured by standard test techniques (e.g. 45° transverse wave probe) when examining ferritic welds.

- gb) When examining welds between austenitic steels as well as welds between ferritic and austenitic steels, the difference in echo heights between edge simulating a through-wall crack and noise level of 16 dB cannot always be maintained. For this case (case 2) subpara. 4.2.3.3.3 (5) lays down specific requirements. To maintain a difference in echo heights between edge simulating a through-wall crack and reference groove of 4 dB, a new reference groove satisfying this criterion shall be determined, where required, by means of reference test block measurements. This new reference groove may be less deep (case 2a) or have a greater depth (case 2b) than the groove as per Table 4-2. The echo height of the reference groove plus a sensitivity allowance of 6 dB shall further be the recording level. In these cases, the difference in echo heights between edge simulating a through-wall crack and noise level shall exceed 10 dB. The difference in echo heights between recording level and noise level shall then be less than 6 dB so that, during the examination of the component, local structural indications at the weld circumference may occur which – if the length criteria are exceeded – shall be treated like relevant indications. The suitability of the test technique is restricted to the extent that in the case of indications reaching or exceeding the recording level an additional evaluation of the indications above the noise level is required by means of pattern recognition. In case 2B, a safety-related evaluation is required to demonstrate sufficient suitability if the reference groove shows a greater depth than the groove as per Table 4-2.
- gc) Clause 4.2.3.3.3 (6) (case 3) covers the proceedings where in parts of the examination area, e.g. in the case of dissimilar welds with extended buttering, the criteria to case 2 cannot be satisfied at the buttering-to-weld metal transition with the intended test technique. By means of reference block measurements a reference groove shall be determined the echo height of which exceeds the noise level by more than 6 dB, and any indication above the noise level shall be recorded and be evaluated. All indications shall be evaluated by comparing the patterns with the indications obtained from the reference block measurements. The evaluation procedure shall be fixed in the test instruction. A differentiation between the signal pattern of the reference groove and the noise signals shall be possible. Indications similar to the signal pattern of the reference groove shall be classified as relevant indications which have to be examined further and be subjected to a safety-related evaluation. The suitability of the test technique is limited so that for the conclusiveness of the examination
- an evaluation of all indications exceeding the noise level by means of pattern recognition is required,
  - a safety-related evaluation shall be performed where the reference groove has a greater depth than the groove as per Table 4-2.

Specific reference reflectors are laid down for the examination of clad surface areas (see **Figure 4-4**). Here, distinction is made between two cases:

- gd) The depth of the reference reflector is equal to the groove depth as per Table 4-2 plus the cladding thickness (groove no. 2), in which case groove no. 3 (thick-

ness of cladding minus 1 mm) shall be verified. At the sensitivity prescribed for this case, defects will be detected before they penetrate the cladding.

- ge) Where in the brittle fracture analysis it is required to confirm the integrity of the cladding, the depth of the reference reflector shall be equal to the thickness of the cladding minus 1 mm (groove no. 3), in which case groove no. 4 (half the cladding thickness) shall be verified. This is to detect defects with extensions which will not yet impair the load-bearing capability of the cladding.
- h) As this Safety Standard always refers to "grooves", the information in subcl. 4.2.3.3.1 (1) that rectangular grooves or slots can be used was deleted, and only the term "groove" will be used further in the text of this Safety Standard.
- i) Subclause 4.2.3.3.2 (3) was revised editorially so that the acoustically effective length of the grooves is to be 20 mm.
- j) Clause 4.2.4 "Eddy-current testing" was put more precisely to correspond to the state-of-the-art.
- k) For the test methods and techniques taken over in clauses 4.2.3 and 4.2.4, corresponding requirements were added to clause 4.2.7 "Recording levels". The recording level for magnetic particle and liquid penetrant testing was adapted accordingly to meet the requirements of KTA 3201.3 and to correspond to an indication with an extension of 3 mm.
- l) In clauses 4.2.5 and 4.3.2, the requirements for radiographic testing were put more precisely. Here, the wall thickness for double-wall radiography was reduced from 25 mm to 20 mm, as the application of radiographic testing is limited in KTA 3201.3 to radiographed wall thicknesses  $\leq 40$  mm and a reliable statement is to be ensured for the detection of planar flaws.
- m) The stipulations on the recording level during the examination of a close-to-probe depth region exceeding 10 mm were deleted as they are part of clause 4.3.3 and are already covered under its subpara. (1).
- n) In Section 4.4, stipulations for the evaluation of the general condition were taken over on the basis of the requirements for integral visual examinations, in which case requirements for the laying of pipes including support functions were supplemented.
- o) In compliance with the stipulations in KTA 3201.2, the requirements for the test conditions during pressure testing in clause 4.5.1 were specified more precisely and new requirements for the monitoring of the RPV allowable internal pressure were taken over in clause 9.8.
- p) In clause 4.5.2 it was laid down that, under certain conditions, the basically required non-destructive examinations may be omitted upon pressure testing. This regulation was considered adequate with regard to plant safety upon evaluation of the results obtained from the research project SR 2501 of the Federal Environment Ministry BMU (work paper 4.1), and shall contribute to the avoidance of unnecessary dose rate exposure of personnel and the optimisation of shutdown procedures where the safety-related requirements are satisfied. For the first time, the proofs to be rendered for this case require an evaluation of indications below the acceptance level.

When revising Section 4, the statements given by the Reactor Safety Commission on non-destructive examinations were evaluated and transposed into this safety standard.

(7) Section 5 "Extent of testing and test intervals" was largely revised to cover the following main points of interest:

- a) New requirements for examinations as to damage caused by stress corrosion cracking were taken over (among others, in Section 5.1, subpara. (6)).
- b) The requirements in clause 5.2.1.6 were put more precisely as regards piping with nominal sizes  $\leq$  DN 50. Here,

it was additionally laid down that once a year component connections with nickel-alloyed weld metal are to be subjected to visual examination for traces of leakage.

- c) In Tables 5-1, 5-2, 5-5 and new Table 5-9, detailed requirements for the examination of dissimilar welds were laid down.
- d) Requirements as regards the examination for presence of transverse defects and the areas of thermal sleeves to be examined were explicitly mentioned.
- e) In all tables, the requirements for visual examinations (distinction between selective and integral examination) as well as the items to be examined were put more precisely in order to lay down as clear as possible requirements.
- f) The examinations on the pressure-retaining wall of the control rod drives were revised. When laying down the extent of testing now provided in Table 5-2 it was taken into account that
  - fa) the comparableness of the control rod drive housing within one plant is very high and consequently systematic defects can be detected already at a very low extent of spot examinations,
  - fb) an inspection is only possible if the control rod drives are disassembled,
  - fc) the inspection can only be performed under exposure of assembly and test personnel to very high dosis rates and the rules on the minimisation of radiation exposure are to be observed.
- g) In Table 5-3 the extent of testing on steam generator tubes was doubled to increase the conclusiveness of spot examinations. The extent of 20 % results from the statement of the Reactor Safety Commission DKW (91<sup>st</sup> meeting on 30<sup>th</sup> / 31<sup>st</sup> March 2009).
- h) In Table 5-4 a visual examination of internal surfaces with unobstructed view was supplemented to comply with current practice.
- i) The double extent of testing on austenitic piping in BWR plants (Table 5-7) laid down in the former edition of this Safety Standard 1999-06 was again adapted to the extent of testing for PWR plants since
  - ia) due to the remedial and preventive measures taken the occurrence of damage cause by transgranular stress corrosion cracking need not be expected again,
  - ib) the present extensive results obtained from in-service inspections confirm the effectiveness of these measures.

The eddy-current test method was additionally taken over since qualified test techniques are available for this method.

- j) In clause 5.2.1.8 "Valves" the requirements were extended to cover all valves with nominal sizes > DN 50 and the tests to be performed put more precisely to adequately cover the pressure-retaining boundary isolating valves with nominal sizes of DN 100 in compliance with the extended range of application as per Section 1 (8). Where the damage mechanism "stress corrosion cracking" is to be assumed, an additional liquid penetrant test is to be performed since in this case an as early as possible detection of damage is required.
- k) In clause 5.2.1.9 "Bolted joints" a selective visual examination of the adjacent flange areas for damage and traces of leakage was taken over to comply with current test practices.
- l) For welded joints between austenitic and ferritic steels a new clause 5.2.1.10 was taken over to meet the specific test requirements, in which case the extent of testing on the respective component areas to be examined were included in the existing tables 5-1, 5-2 and 5-5, and the extent of testing on pipes was taken over in new table 5-9.

m) In Section 5.3 subpara. (7) the text of the safety standard was put more precisely since the former text was contradictory to the basically applicable Section 3 (and not only in the case where extended inspection intervals are to be applied).

(8) In Section 7 "Preparation and performance of tests" the following changes were made:

- a) In Section 7.1 new requirements for working conditions of test personnel were taken over. They were formulated to be general requirements since concrete requirements for workplace conditions (temperature, noise, radiation, etc.) have already been regulated in ordinances and directives for radiation protection and safety at workplace, and individual requirements can only be fixed in dependence of the respective testing task.
- b) As a result of the evaluation on the research project SR 2514 of the Federal Environment Ministry (BMU) new requirements for the instruction of test personnel were taken over in Section 7.2.
- c) A new requirement was laid down in Section 7.3 that the adjustment of the test system and the checking of the adjustment as well as the checking of the test media used in magnetic particle and liquid penetrant testing are to be performed on test blocks.
- d) A new Section 7.4 was included to cover the requirements regarding the qualification and certification of test personnel.
- e) The Section was editorially revised to consider the current DIN standards.

(9) In Section 8 "Evaluation of test results" the following changes were made:

- a) The requirements in new Section 8.1 "General" shall ensure that all evaluations are made and documented to the extent necessary as well as conclusion can be drawn from the results.
- b) In Section 8.2.1 "Decision-making process" the reference to the recognizability of recording levels in subclause (5) was deleted since this requirement is satisfied by the newly determined recording levels, and subclause (10) was supplemented to request that findings are to be included as locations to be tested in the test and inspection manual.
- c) Clause 8.2.2 "Acceptance levels" was largely revised in which case the acceptance levels for ultrasonic testing, eddy-current testing and visual testing were put more precisely.
- d) Clause 8.2.3 "Analyses if relevant indications occur for the first time or are enlarged" was taken over as new clause. With the requirements contained herein the proceedings for the analyses required as per subclause 8.2.1 (6) are regulated.

(10) Section 9 "Operational monitoring" was revised with the following main points of interest and was supplemented as follows:

- a) As the evaluation as per 9.1 (3) has always to cover the determination of the causes, the clause was supplemented accordingly for the purpose of clarification.
- b) A new subclause (4) was added to Section 9.1 requiring that the unchanged validity of the integrity proofs performed within the design calculations to KTA 3201.2 is confirmed.
- c) In clause 9.2.1
  - ca) the monitoring for unrestrained displacement of pipelines (subcl. 3) and
  - cb) the requirement for an evaluation of the monitoring results in due time (subcl. 4)
 were added as new clauses, and

- cc) the requirements for determining component fatigue (subcl. 5) were put more precisely,
  - cd) the stipulations as regards the recalculation of the predicted cumulative damage (usage factor) (subcl. 6) were adapted to the new regulations provided in KTA 3201.2, in which case specific requirements for clad components were renounced, as in such case the load-bearing ferritic wall is used as basis for the fatigue analysis,
  - ce) the requirements for the recording and documentation of measured values were put more precisely (subcl. 7 to 9).
  - d) In clause 9.2.2 the former subclause (2) was placed at the end of the clause and reformulated such that vibration monitoring is subject to the requirements of DIN 25475-2. Here, it was taken into account that this standard only applies to PWR.
  - e) The detection and assessment of dynamic impact loadings only generally required by former subclause 9.1(3) was formulated in more detail in new clause 9.2.3 "Monitoring for effects due to sudden impact loadings". For the purpose of clear definition to the new clause 9.2.3, the heading of clause 9.2.1 was put more precisely.
  - f) The requirements for monitoring of water quality were concretised (Section 9.3).
  - g) A new Section 9.4 was added to cover the requirements for the monitoring of accumulation of radiolysis gas.
  - h) A new Section 9.8 was added to cover the requirements for the monitoring of the allowable RPV internal pressure.
- (11) Section 10 was changed as follows:
- a) As the information contained in former Table 10-1 required a revision and the requirements as regards the participation of the authorized inspector in in-service inspections can be described better in the form of texts rather than by a table, Table 10-1 was deleted and Section 10 was revised accordingly.
  - b) When evaluating the research project SR 2514 of the Federal Environment Ministry (BMU) it was laid down that manual ultrasonic tests are to be performed and be evaluated independently by the plant owner and the authorized inspector to § 20 AtG.
- (12) Section 11.1 was supplemented to read that the qualification and certification of the test personnel as well as the calibration of the test equipment is to be documented.