

# Safety Standards

of the  
Nuclear Safety Standards Commission (KTA)

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**KTA 3201.4 (2016-11)**

**Components of the Reactor Coolant Pressure Boundary  
of Light Water Reactors**

**Part 4: In-service Inspections and Operational Monitoring**

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

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

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

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Editor:

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



# KTA SAFETY STANDARD

2016-11

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

KTA 3201.4

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PLEASE NOTE: Only the original German version of this safety standard represents the joint resolution of the 35-member Nuclear Safety Standards Commission (Kerntechnischer Ausschuss, KTA). The German version was made public in Bundesanzeiger BAnz of March 10<sup>th</sup> 2017. Copies may be ordered through the Carl Heymanns Verlag KG, Luxemburger Str. 449, D-50939 Koeln (Telefax +49-221-94373-603).

All questions regarding this English translation should please be directed to:  
KTA-Geschäftsstelle c/o BfE, Willy-Brandt-Strasse 5, D-38226 Salzgitter, Germany

#### 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:

|                        |                                                                                                                                                                                                                                                                              |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>shall</b>           | indicates a mandatory requirement,                                                                                                                                                                                                                                           |
| <b>shall basically</b> | 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 <b>shall normally</b> - are specified in the text of the safety standard, |
| <b>shall normally</b>  | indicates a requirement to which exceptions are allowed. However, the exceptions used, shall be substantiated during the licensing procedure,                                                                                                                                |
| <b>should</b>          | indicates a recommendation or an example of good practice,                                                                                                                                                                                                                   |
| <b>may</b>             | indicates an acceptable or permissible method within the scope of this safety standard.                                                                                                                                                                                      |

## Fundamentals

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

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

KTA 3201.1 Materials and Product Forms,

KTA 3201.2 Design and Analysis,

KTA 3201.3 Manufacture

as well as with

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

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

- a) reliable monitoring of operating conditions,
- b) adequate extent of non-destructive examinations and,
- c) documentation, evaluation, safety-oriented application and up-dating of operating experience,
- d) foresighted identifiability of changes of the as-fabricated condition of the reactor coolant pressure boundary by means of in-service inspections and operational monitoring,
- e) evaluation of the results of 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 mon-

itoring 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**.

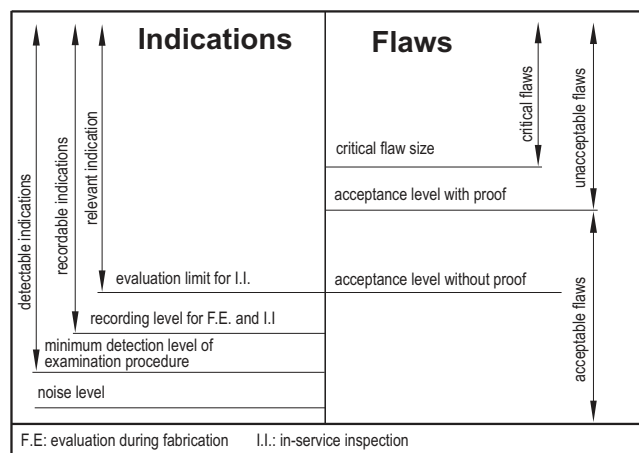


**Figure 2-1:** Indications and types of flaws

### (3) Relevant indication

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

### (4) Echo height evaluation

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

### (5) Operational flaws

Operational flaws are flaws due to operational damage mechanisms.

### (6) Higher stress locations

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

- a) compared to the general level of stress intensity are more highly stressed taking the frequency additionally into account
- or
- b) are more susceptible to corrosive action.

### (7) Integrity

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

### (8) Reference standard

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

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

### (9) Measured values

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

## (10) Detection threshold

Detection threshold is the lowest limit of detection of indications.

## (11) Types of tests, test procedures and techniques

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

## (12) Surface inspection

Surface inspection is the non-destructive testing of surfaces using techniques which allow detecting indications on the

surface and near-surface regions in which case the depth examined depends on the method used.

## (13) Volumetric examination

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

## (14) Quality

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

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

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

## (15) Noise

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

## (16) Noise level

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

## (17) Recording level

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

## (18) Representative locations, components or component parts

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

## (19) Authorized inspector

The authorized inspector for the tests and inspections to be conducted in accordance with this safety standard is the author-

ized inspector called in by the licensing or supervisory authority in accordance with Section 20 of the Atomic Energy Act.

## (20) Damage mechanisms

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

## (21) Standard instrumentation

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

## (22) Nozzle attachment and insertion weld

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

## (23) Welded joint

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

## (24) Reference block

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

contains reference flaws (e.g. notches, bores) adapted to the individual testing task.

(25) Acceptance level with proof

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

(26) Acceptance level without proof

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

### 3 Safeguarding of component integrity during operation

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

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

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

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

a) in-service inspections in representative areas, and

b) operational monitoring measures

shall be performed.

*Note:*

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

(5) Changes in the state of knowledge, e.g. due to new requirements for incident control, due to damage occurred, in the case of assessment of ageing 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.

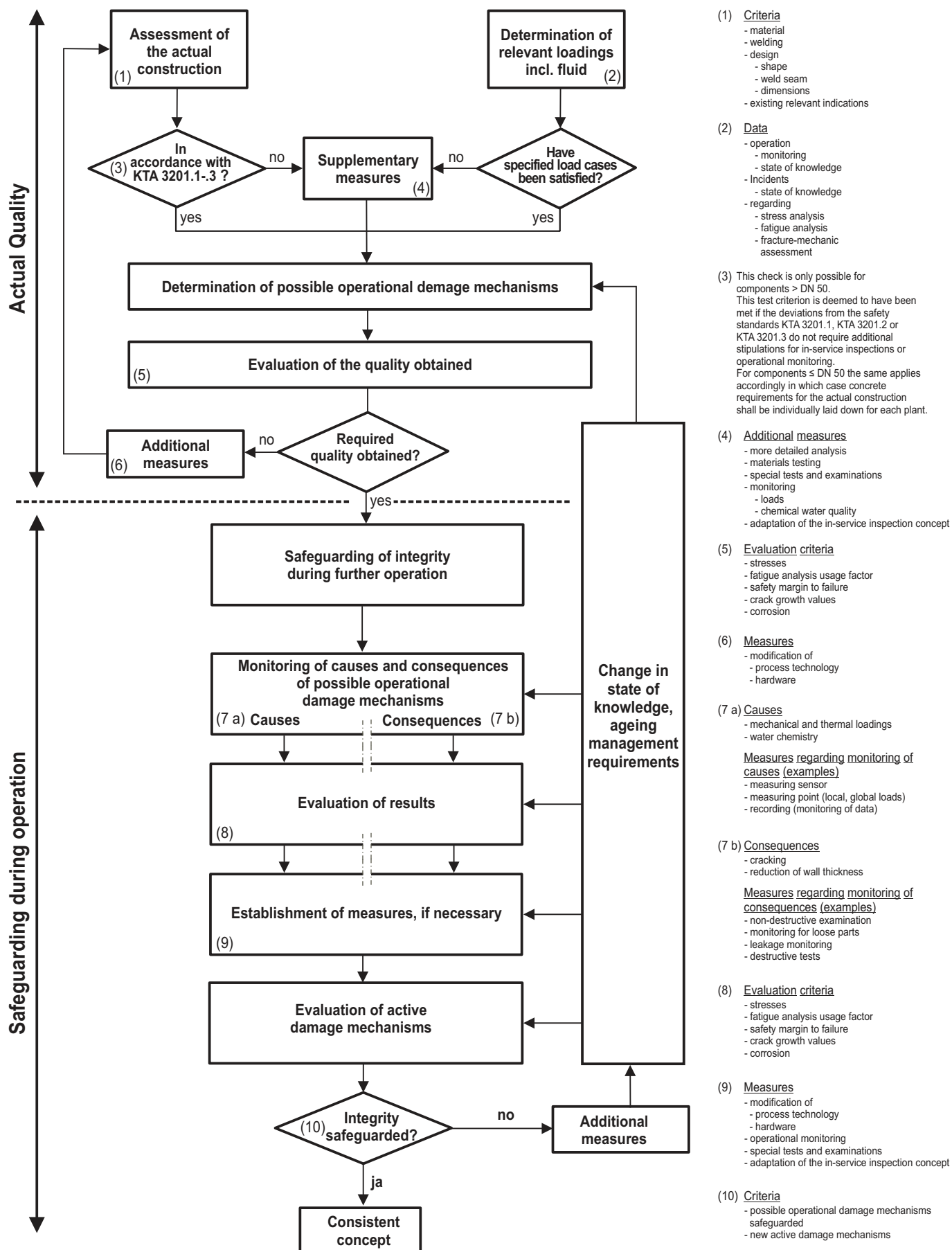


Figure 3-1: Safeguarding of component integrity during operation

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

## 4.2 Surface inspection

### 4.2.1 Magnetic particle testing

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

### 4.2.2 Penetrant testing

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

### 4.2.3 Ultrasonic testing procedures

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

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

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

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

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

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

- a) vertically polarized transverse waves with the incident angle of the sound beam in the range between 35 and 55 degrees (technique utilizing the corner effect),
- b) vertically polarized transverse waves with the incident angle of the sound beam in the range between 60 and 70 degrees,
- c) longitudinal waves,
- d) wave conversion techniques to KTA 3201.3, Annex C, Section C 7 and C 8,
- e) the angled pitch-catch technique to KTA 3201.3, Annex D.

*Note:*

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

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

- a) testing frequencies  $\leq 2$  MHz,
- b) probes with highly attenuated transducers,
- c) dual-element probe techniques with signal overlapping in the half skip area,
- d) horizontally polarized transverse waves.

#### 4.2.3.3 Procedural requirements

##### 4.2.3.3.1 General requirements

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

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

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

##### 4.2.3.3.2 Reference blocks

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

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

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

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

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

- a) The test object diameter does not require the use of contoured probes.
- b) The reflection behaviour is not impaired by the curvature of the opposite surface (ratio of wall thickness  $s$  to outer diameter  $d_a$  of the test object less than or equal to 0.2).
- c) No wave conversion technique is used.

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

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

##### 4.2.3.3.3 Demonstration of suitability of the test technique

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

- a) welded joints between ferritic steels and
- b) base metal zones

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

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

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

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

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

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

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

- a) the echo heights increase with an increase in notch depth when scanning across the base metal of the reference block,
- b) the echo heights increase with an increase in notch depth when scanning across the weld metal or the buttering of the reference block,
- c) the echo height of the notch to be selected (reference notch) as per **Table 4-2** exceeds the noise level by 12 dB

or more in the case of angles of incidence as shown in **Figures 4-1 to 4-3**,

- d) the edge echo or the echo height of the additional sufficiently deep notch exceeds the echo height of the reference notch by at least 6 dB in the case of angles of incidence as shown in **Figures 4-1 to 4-3**.
- (4) When testing clad surfaces the test technique will be suited if
- a) the echo heights increase with an increase in notch depth,
  - b) notch no. 2 as per **Figure 4-4** exceeds the noise level by at least 12 dB and notch no. 3 is verifiable, where no integrity proof of the cladding is required in the brittle fracture analysis,
  - c) notch no. 3 as per **Figure 4-4** exceeds the noise level by at least 12 dB and notch no. 4 is verifiable, where an integrity proof of the cladding is required in the brittle fracture analysis,
  - d) the edge echo or the echo height of notch no. 1 exceeds the echo height of the reference reflector selected as per subpara. 4.2.3.3.4 (6) by at least 6 dB.

|                                                                                                                                                                                                                                | Case 1                                                                         | Case 2                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------------|
| Evaluation method                                                                                                                                                                                                              | Echo height evaluation to subpara. 4.2.3.3.3 (1) or 4.2.3.3.3 (3)              | Pattern recognition to subpara. 4.2.3.3.3 (5)                   |
| Reference notch                                                                                                                                                                                                                | Notch to be selected to Table 4-2                                              | Notch to be selected to Table 4-2 or deeper notch <sup>1)</sup> |
| Difference in echo heights between reference notch and noise level                                                                                                                                                             | ≥ 12 dB                                                                        | ≥ 6 dB <sup>1)</sup>                                            |
| Difference in echo heights between edge simulating a through-wall crack and reference notch                                                                                                                                    | ≥ 6 dB                                                                         | ≥ 0 dB                                                          |
| Recording level                                                                                                                                                                                                                | Reference notch plus a sensitivity allowance of 6 dB                           | Noise level                                                     |
| Recording                                                                                                                                                                                                                      | Any indication the echo height of which reaches or exceeds the recording level | Any pattern recognition equal to or exceeding the noise level   |
| Evaluation                                                                                                                                                                                                                     | As per 8.2.2.2.2 (2)                                                           | As per 8.2.2.2.2 (3)                                            |
| <sup>1)</sup> Where the difference in echo height is less than the required value, a notch with greater depth is to be selected as reference notch which meets the requirement. In such case, a safety evaluation is required. |                                                                                |                                                                 |

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

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

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

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

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

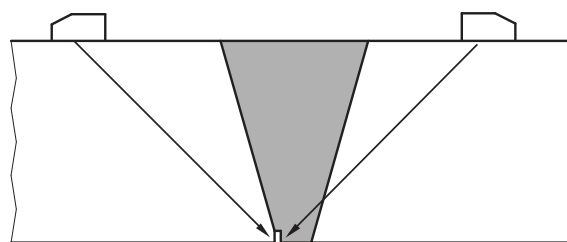


**Figure 4-1:** Location of notches and beam angles for the test of welded joints between ferritic steels and austenitic steels