Note:
This is a translation of the RSK statement entitled “Druck- und Dichtheitsprüfungen an Bauteilen der Druckführenden Umschließung (DFU) und der Äußeren Systeme, insbesondere nach Reparaturen”
In case of discrepancies between the English translation and the German original, the original shall prevail.

RSK Statement
(455th meeting on 21 February 2013)

Pressure and leak tests of components of the reactor coolant pressure boundary and external systems, especially after repairs

Contents

1 Request for advice

By the letter (file no: RS I 3 - 17018/1) of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) dated 27 February 2003 (consultation document [1]), the RSK was asked for a statement on the necessity of pressure and leak tests of pipes after repairs. In the opinion of the BMU, the repair concepts for pipes and connection nozzles of the reactor coolant pressure boundary presented to the RSK allow the operators to exercise discretion with regard to the necessity of a pressure and leak test. The BMU asks the RSK to determine whether ultrasonic testing (UT) may replace pressure testing in the case of modification or repair measures involving heat treatment, repair welding or restoration of a component in accordance with the state of the art in science and technology. The aim is also to examine whether existing repair concepts are in line with conventional and nuclear regulations and whether the nuclear regulations need to be concretised in this respect.

In the course of the deliberations by the RSK Committee on PRESSURE-RETAINING COMPONENTS AND MATERIALS, the advisory request was expanded in consultation with the BMU. In addition to the requirements for pressure and leak tests of pipes after repairs specified in the written request for advice, a statement is requested on the general conditions, such as the test pressure to be applied during the pressure test in comparison to conventional regulations.

2 Safety significance and requirements

The components of the reactor coolant pressure boundary and the external systems are a barrier for the safe confinement of radioactive substances and for ensuring safe operation and accident control. The safety significance lies in the maintenance of this barrier function.

The following principles apply:

In order to achieve a high quality standard and safe operation of the components of the reactor coolant pressure boundary and the pressurised walls of connected external systems, requirements are met during design and manufacture that guarantee basic safety for these components and rule out failure due to manufacturing defects. These components include the pressurised walls of pipes, fittings, valves, pressure vessels and pumps.

The basic safety concept comprises basic safety and further technical requirements and verifications. The implementation of the basic safety concept, taking into account all known damage mechanisms and the respective past and future specific operating conditions, is referred to in the KTA Safety Standards as the concept for ensuring integrity (integrity concept).

3 Assessment criteria

According to the Safety Requirements for Nuclear Power Plants, basic safety must be ensured for the reactor coolant pressure boundary and the pressure-retaining walls of components of the external systems with nominal diameters greater than NB 50 by complying with design and manufacturing requirements. If these requirements (basic safety) are realised, a catastrophic failure of these system components due to manufacturing defects need not be assumed. The external systems are defined as the pressurised and activity-carrying systems and components that are not part of the reactor coolant pressure boundary and which are of safety significance.

The requirements are specified in the RSK guidelines for nuclear power plants with pressurised water reactors (PWR) and their Annex 2 “General Specification for Basic Safety” as well as the relevant KTA Safety Standards of the series 3201 “Components of the Reactor Coolant Pressure Boundary of Light Water Reactors” and 3211 “Pressure- and activity-retaining components of systems outside the primary circuit”.

The RSK guidelines do not specify any explicit requirements for pressure testing of the reactor coolant pressure boundary during manufacture. It is clear from the text that an initial pressure test is a prerequisite. For example, the guidelines require that periodic pressure tests be carried out in such a way that a comparable safety-related statement is achieved as with the initial pressure test.

According to the RSK guidelines, a hydrostatic test with 1.3 times the design pressure must always be carried out for the external systems, followed by representative non-destructive tests (NDT) on weld seams. This is put in concrete terms in the General Specification for Basic Safety: as a rule, test pressure at 1.3 times the design pressure irrespective of the cold/hot yield strength ratio; for cast steel components, a hydrostatic test at 1.5 times the design pressure must be carried out.

In KTA Safety Standard 3201.3 ‘Manufacture’, requirements for an initial pressure test are specified in conjunction with KTA Safety Standard 3201.2 for the components of the primary circuit, supplemented by extensive specifications for the test procedure and accompanying non-destructive tests.

KTA Safety Standard 3211.3 also further specifies the requirements in accordance with the General Specification for Basic Safety for the pressurised walls of the external systems with regard to the performance of the test with a test pressure equal to 1.3 times the permissible operating pressure; in addition, non-destructive tests are required after the pressure test for the areas subject to higher stresses.

All in all, the nuclear regulations require a pressure test at the end of manufacture at 1.3 times the design pressure, or 1.5 times the design pressure for cast steel, in conjunction with representative non-destructive tests.

Corresponding requirements are specified in the nuclear regulations for the periodic pressure tests: the test pressure corresponds to 1.3 times the design pressure in conjunction with non-destructive tests in the areas subjected to higher stresses by the pressure test.

Conventional regulations (Pressure Equipment Directive 97/23/EC of the European Union) require that the acceptance of pressure equipment includes a pressure resistance test, which is normally carried out in the form of a hydrostatic pressure test. The pressure should correspond to at least the higher of the following values:

- 1.25 times the maximum load of the pressure equipment in operation, taking into account the maximum permissible pressure and the maximum permissible temperature, or

- 1.43 times the value of the maximum permissible pressure.

This requirement must be applied as a rule. If it is not applied, the manufacturer must demonstrate that appropriate measures have been taken to achieve an equivalent overall level of safety.

For the periodic strength test, the Technical Rules for Operational Safety (TRBS) 1201, Part 2 'Tests relating to hazards caused by steam and pressure' (2012 version) for pressure vessels, pipes and steam boilers generally require a pressure test with a test pressure corresponding to 1.3 times the operating pressure (for hydrostatic tests). If a sufficient internal inspection is not possible, the test pressure can be increased to 1.5 times the operating pressure.

4 Consultations

The starting point for the discussions of the RSK Committee on PRESSURE-RETAINING COMPONENTS AND MATERIALS were the repair concepts for pipes and connection nozzles of the reactor coolant pressure boundary presented in recent years and the periodic pressure tests and pressure and leak tests of pipes after repairs that were discussed in the course of the discussions on the findings on valve housings, repairs and replacements as well as the inspection measures at the Brunsbüttel (KKB) and Krümmel (KKK) nuclear power plants. Another occasion was the discussion of Module 4 of the BMU's nuclear regulations (draft version). The committee held consultations at the following meetings (consultation documents [2] to [14]):

57th meeting on 15 September 2005,
61st meeting on 08 March 2006,
63rd meeting on 02 May 2006,
74th meeting on 20/21 June 2007,
92nd meeting on 29 April 2009,
101st meeting on 19 May 2010,
102nd meeting on 16 June 2010,
115th meeting on 14 December 2011,
116th meeting on 08 February 2012,
117th meeting on 07 March 2012,
118th meeting on 04 April 2012,
119th meeting on 02 May 2012,

120th meeting on 12/13 June 2012,
122nd meeting on 12 September 2012 and
123rd meeting on 09/10 October 2012.

At the 61st meeting on 8 March 2006, the committee discussed the parts of the draft version of Module 4 that was available at the time in which the pressure test after repairs and the periodic leak and pressure tests are dealt with.

The RSK Committee on PRESSURE-RETAINING COMPONENTS AND MATERIALS held consultations on periodic pressure tests and pressure and leak tests of pipes after repairs at its 63rd meeting on 2 May 2006 and 74th meeting on 20/21 June 2007. For this purpose, the Committee received reports from GRS (consultation documents [5] and [9]) and the State Materials Testing Institute of the University of Stuttgart (MPA Stuttgart) (consultation documents [6], [10] and [11]). The reports dealt with the necessity of pressure and leak tests after repairs of pressurised components as well as the level of the test pressure for periodic pressure tests and the benefits of a pressure test.

In its report at the 63rd meeting, the MPA Stuttgart stated the key boundary conditions and influencing factors for carrying out the pressure test. From this, it derived different requirements for the initial pressure test and the periodic pressure test. The MPA Stuttgart came to the conclusion that the informative value of the hydrostatic pressure test as a periodic test is severely limited and cannot generally be assessed as a safety check. In contrast to the periodic pressure test, non-destructive testing (NDT) allows differentiated and quantitative test statements to be made, particularly in conjunction with fracture mechanics calculation methods. Non-destructive testing measures can be used for targeted testing. In [6], the MPA Stuttgart has presented a compilation of the test pressures specified in rules and guidelines.

At the 92nd meeting on 29 April 2009, the committee was informed about the current status of the findings on valve housings, repairs, the repair concept and further plans for the Krümmel nuclear power plant (KKK) and at the 101st meeting on 10 May 2010 about the current status of the findings on valve housings, repairs and replacements as well as the inspection measures at the Brunsbüttel nuclear power plant (KKB).

The last plant-specific consultation on the above-mentioned matter took place at the 102nd meeting on 16 June 2010 in connection with the treatment of inspection concepts for steam generator (SG) tubes under the influence of corrosion for the Unterweser nuclear power plant (KKU).

At the 115th meeting on 14 December 2011, the Committee entered into final deliberations on the submission of its statement, continuing these deliberations at the 117th, 118th, 119th and 120th meetings on 7 March 2012, 4 April 2012, 2 May 2012 and 12/13 June 2012. After presentation at the 449th meeting of the RSK on 12 July 2012, comments were received. The RSK requested that they be discussed by the Committee. At the 123rd meeting on 9/10 October 2012, the Committee discussed the comments received from the RSK and revised the statement in the present version. The RSK adopted the statement at its 455th meeting on 21 February 2013.

5 Consultation results

The RSK comments as follows on pressure tests (initial testing; periodic testing) and pressure and leak tests of pipes after repairs:

The *pressure test* is anchored in the regulations and is used for integral testing and safety checks after manufacture and during operation to determine and evaluate the as-is condition of the reactor coolant pressure boundary and the external systems with the aim of ensuring that the pressure-retaining wall has no leaks. Like other non-destructive tests, it provides a statement of the test results at the time of the test.

In the opinion of the RSK, the pressure test pursues the following main objectives:

- detection of damage and identification of defective component areas (cracks) and identification of defective components,
- reduction of stress peaks by introducing residual compressive stresses (plastic deformation),
- reduction of residual stresses from manufacture, in particular residual welding stresses, and
- checking and determining the leak-tightness of the component or system.

A categorisation of the pressure test, with reference to the time at which the pressure test is carried out, is based on the following definitions and requirements:

- The *initial pressure test*, which must be carried out after completion of manufacture with a defined test pressure above the design pressure, is an integral test and safety check with the following additional objectives:

  - integral testing and safety checking after manufacture,
  - detection of errors (resulting from the design or calculation),
  - detection of material mix-ups and
  - detection of damage/defects in the component as a result of manufacture due to significant deformation or breakage

- Essentially, the same objectives apply to the *pressure test* after repairs as to the initial pressure test, i.e. safety-related statements must be achieved that are at least comparable to those of the initial pressure test.

- The following must additionally be taken into account for *periodic pressure tests*:

  - possible crack initiation due to operating and load conditions,
  - ageing due to operation and
  - possible restrictions when shutting off pressure zones with the same load.

With regard to achieving the objectives described, a distinction must be made between the initial pressure test and pressure tests after repairs on the one hand and the periodic pressure test on the other, since - as shown above - different objectives are pursued when carrying out these pressure tests and therefore different procedures can be followed.

Initial pressure test

The initial pressure test with the required supplementary non-destructive tests continues to fulfil the requirements for the objective and purpose of this test in the form and at the required test pressure as specified in the regulations.

Periodic pressure test

Regarding the detection of

- possible crack initiation due to operating and load conditions and
- ageing due to operation,

the informative value of the hydrostatic pressure test is limited as the pressure test alone cannot provide any information on non-wall-penetrating defects, particularly in the case of thick-walled components, and therefore cannot generally be considered a safety check. In contrast to pressure testing, non-destructive testing measures (radiographic, ultrasonic (UT), etc.) can provide differentiated and quantitative test results, particularly in conjunction with fracture mechanics calculation methods. Non-destructive testing measures can be used for selective testing compared to integral pressure testing. For this reason, non-destructive tests are required in the nuclear regulations following the pressure test.

The RSK comes to the conclusion that the periodic pressure test currently required by the nuclear rules and regulations in conjunction with the periodic non-destructive tests specified in the KTA Safety Standards is suitable for providing information on the integral condition of the components at the time of the test. The periodic pressure test is particularly important for areas that are not accessible for the non-destructive testing measures or where these can only be carried out to a limited extent (e.g. accessibility or geometry).

Pressure and leak test after repairs

A pressure test after a repair, as required by the regulations, has the character of an initial pressure test. In the case of repairs, it must be ensured that the components are in the required quality condition, e.g. as characterised by the basic safety requirements. The execution of welding repairs (heat input) is of particular importance here.

If the pressure test after repairs is to be dispensed with, e.g. because the necessary isolation from areas with other requirements (materials, geometry, temperature) is not possible with reasonable effort or because the pressure zones are too large, it must be ensured that the objectives of the initial pressure test are nevertheless fulfilled. The freedom from defects can be confirmed by two diverse non-destructive test methods qualified in accordance with the KTA Safety Standards. This can be achieved e.g. by using test methods that are based on different physical interaction mechanisms with the material.

The following objectives of a pressure test cannot be achieved by non-destructive testing methods:

- reduction of stress peaks by introducing residual compressive stresses (plastic deformation) and
- reduction of residual stresses from production, in particular residual welding stresses.

In these cases, heat treatment is therefore required for ferritic materials to reduce welding stresses. Heat treatment may not be necessary for austenitic materials due to their greater toughness.

Continuous monitoring of the layer structure using NDT methods (e.g. magnetic flux leakage testing, penetrant testing) during weld seam production means that faulty production need not be assumed.

Individual new or repaired components that can no longer be pressure-tested after welding must be pressure-tested beforehand.

These requirements have not yet been included in the nuclear regulations.

The effects of the repair on the in-service inspection concept must be checked to ensure compliance with the safety level. If necessary, the NDT concept must be modified. If in the course of the repair methods are used for the periodic non-destructive testing that are different from those used for the manufacturing test, a basic test with the testing method intended for the periodic non-destructive testing is necessary before commissioning. This is also not yet required in the nuclear regulations.

Test pressure of the pressure tests

For components within the scope of KTA Safety Standards 3201/3211, including the component parts belonging to these components with NB ≤ 50 (K1, K2 or AS1, ASB, AS2), KTA Safety Standard 3201.2 and 3211.2 stipulate that the test pressure for the initial and periodic pressure test shall be

$$P_{Test} = 1.3 \cdot p_{Des}$$

The conventional regulations provide for higher test pressures (usually factor 1.43) for the initial pressure test. In the opinion of the RSK, this higher test pressure for the initial pressure test does not have to be applied for

the components corresponding to the nuclear rules and regulations, since compared with the conventional rules and regulations,

- only approved materials with high toughness are used,
- more stringent requirements are placed on production monitoring and testing,
- a reduced stress level (consideration of R_m) is the basis, and
- the scope and frequency of the periodic non-destructive tests are higher.

The test pressure required in the KTA Safety Standards is part of the self-contained set of regulations and increasing the test pressure for the initial pressure test, as specified in the conventional set of regulations, does not bring any additional safety gain. Overall, the requirement of the conventional regulations that suitable measures must be taken at a lower test pressure in order to achieve an equivalent overall safety level is fulfilled.

6 Recommendations

Initial pressure tests and periodic pressure and leakage tests shall be carried out in accordance with the KTA Safety Standards and the objectives specified therein. The integral pressure and leak test, in conjunction with the periodic non-destructive tests specified in the KTA Safety Standards, allows a statement to be made on the actual condition of the reactor coolant pressure boundary and the external systems at the time of the test.

A pressure and leak test must also be carried out after welding repairs. If the pressure test is to be dispensed with in justified cases, it must be demonstrated that at least an equivalent statement on the proof of integrity and leak-tightness is achieved through quality assurance measures during production and two diverse non-destructive test methods that differ in their physical interaction with the material to be verified.

In the case of repairs and omitted pressure testing, heat treatment is required for ferritic materials to reduce welding stresses. Heat treatment may not be necessary for austenitic materials due to their high toughness.

If different methods are used for periodic non-destructive testing than for production testing in the course of repair, a basic inspection using the testing method intended for periodic non-destructive testing is necessary before commissioning.

It is recommended that these above-mentioned quality assurance measures for checking the integrity of the repaired component through increased use of non-destructive testing methods and diverse testing methods be included in the regulations (KTA Safety Standards for the manufacture of pressurised components).

In addition, the RSK recommends including the requirements for checking the in-service inspection concept in the regulations (KTA Safety Standards for operational monitoring and periodic testing of pressurised components).

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[2] Ergebnisprotokoll der 57. Sitzung des RSK-Ausschusses DRUCKFÜHRENDE KOMPONENTEN UND WERKSTOFE am 15.09.2005/TOP 3

[3] Ergebnisprotokoll der 61. Sitzung des RSK-Ausschusses DRUCKFÜHRENDE KOMPONENTEN UND WERKSTOFE am 08.03.2006/TOP 7.1

[4] Ergebnisprotokoll der 63. Sitzung des RSK-Ausschusses DRUCKFÜHRENDE KOMPONENTEN UND WERKSTOFE am 02.05.2006/TOP 7 und 8.2

[5] Zur Notwendigkeit von Druck- und Dichtheitsprüfungen, Zwischenbericht über die GRS-Arbeiten für die RSK, Kopien von Folien, (63. Sitzung des RSK-Ausschusses DRUCKFÜHRENDE KOMPONENTEN UND WERKSTOFFE am 02.05.2006)

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[7] Weiterleitungsnachricht zu meldepflichtigen Ereignissen in Kernkraftwerken der Bundesrepublik Deutschland (WLN 2007/04) „Ansprechen von Sicherheitsventilen bei der Durchführung der RDB-Druckprüfung mit der Folge des Anrisses einer Impulsleitung“ im Kernkraftwerk Krümmel, am 31.08.2005, GRS 18.10.2007

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[9] Zur Notwendigkeit von Druck- und Dichtheitsprüfungen nach Reparaturen zu druckführenden Komponenten, Kopien von Folien, GRS, (74. Sitzung des RSK-Ausschusses DRUCKFÜHRENDE KOMPONENTEN UND WERKSTOFFE am 20./21.06.2007)

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[11] BMU-Vorhaben SR 2501, Zentrale Untersuchung und Auswertung von Herstellungsfehlern und Betriebsschäden im Hinblick auf druckführende Anlagenteile von Kernkraftwerken, Arbeitspaket 4, Zuarbeit der MPA Universität Stuttgart für den BMU und die Reaktor-Sicherheitskommission, Technischer Bericht 4.1, „Anmerkungen zur Höhe des Prüfdruckes bei wiederkehrenden Druckprüfungen und zum Nutzen einer Druckprüfung“, März 2007, Materialprüfungsanstalt (MPA) Universität Stuttgart

[12] Ergebnisprotokoll der 92. Sitzung des RSK-Ausschusses DRUCKFÜHRENDE KOMPONENTEN UND WERKSTOFE am 29.04.2009/TOP 6

[13] Ergebnisprotokoll der 101. Sitzung des RSK-Ausschusses DRUCKFÜHRENDE KOMPONENTEN UND WERKSTOFE am 19.05.2010/TOP 5

[14] Ergebnisprotokoll der 102. Sitzung des RSK-Ausschusses DRUCKFÜHRENDE KOMPONENTEN UND WERKSTOFE am 16.06.2010/TOP 7