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Safety Standards

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Nuclear Safety Standards Commission (KTA)

KTA 3706 (06/2000)

Ensuring the Loss-of-Coolant-Accident Resistance of Electrotechnical Components and of Components in the Instrumentation and Controls of Operating Nuclear Power Plants

(Sicherstellung des Erhalts der Kühlmittelverlust-Störfallfestigkeit von Komponenten der Elektro- und Leittechnik in Betrieb befindlicher Kernkraftwerke)

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KTA SAFETY STANDARD

June 2000	**Ensuring the Loss-of-Coolant-Accident Resistance of Electrotechnical Components and of Components in the Instrumentation and Controls of Operating Nuclear Power Plants**	KTA 3706

This safety standard was prepared by the Nuclear Safety Standards Commission on behalf of the German Electrotechnical Commission (DKE) within DIN and VDE.

Contents

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 BAnz No. 159a of August 24, 2000. Copies may be ordered through the Carl Heymanns Verlag KG, Luxemburger Str. 449, 50939 Koeln, Germany (Telefax +49-221-94373603).

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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, exceptions used shall be substantiated during the licensing procedure,
shall normally	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 the 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 Radiological Protection Ordinance (StrlSchV) and which are further detailed in “Safety Criteria for Nuclear Power Plants” and in “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”.

(2) In accordance with Criterion 2.2 “Testability” of the Safety Criteria, all plant components shall be designed such that, prior to commissioning and in regular intervals thereafter, the components can be tested to an extent corresponding to their safety relevance.

(3) General requirements regarding the organization, execution and evaluation of inservice inspections are contained in the safety standards

KTA 1202 Requirements for the Operating Manual,

KTA 1401 General Requirements Regarding Quality Assurance.

(4) Requirements regarding the proof of the resistance against design basis accidents (incidents) of electrotechnical components and of components in the instrumentation and controls are contained in the safety standards

KTA 3403 Cable Penetrations through the Reactor Containment Vessel of Nuclear Power Plants,

KTA 3502 Accident Overview Measuring Systems,

KTA 3504 Electrical Drives of the Safety System in Nuclear Power Plants,

KTA 3505 Type Testing of Measuring Transmitters and Transducers of the Reactor Protection System,

KTA 3506 Tests and Inspections of the Instrumentation and Control Equipment of the Safety System of Nuclear Power Plants,

KTA 3507 Factory Tests, Post-Repair Tests and Demonstration of Successful Service for the Instrumentation and Control Equipment of the Safety System,

KTA 3705 Switchgear Facilities, Transformers and Distribution Networks for the Electrical Power Supply of the Safety System in Nuclear Power Plants.

1 Scope

This safety standard shall be applied to operating nuclear power plants with the goal of ensuring a sustained resistance to loss-of-coolant accidents (LOCA) of electrotechnical components and of components of the instrumentation and controls that are required for the control and mitigation of LOCA in nuclear power plants.

2 Definitions

(1) LEI verification test

The verification test of the **L**oss-of-coolant accident resistance of **E**lectrotechnical components and of components of the **I**nstrumentation and controls (LEI verification test) is a check of specific characteristics of the electrotechnical components and components of the instrumentation and controls to verify their resistance to loss-of-coolant accidents.

(2) Special LEI test

The special test of the **L**oss-of-coolant accident resistance of **E**lectrotechnical components and of components of the **I**nstrumentation and controls (special LEI test) is a recurrent performance of relevant testing steps regarding the design-basis-accident resistance of electrotechnical components and of components of the instrumentation and controls to verify their resistance to the loss-of-coolant accidents.

3 Basics for Ensuring the LOCA Resistance Concurrently with Plant Operation

(1) Every component that would be subjected to the ambient conditions of a LOCA and is required for the monitoring and the control and mitigation of the LOCA shall be listed and each in such a way that they can be unambiguously identified. The proven term of sustained LOCA resistance for these components or their component parts shall be specified in this listing.

(2) The continued suitability of the components shall be proven concurrently with plant operation before the term of sustained LOCA resistance would end.

(3) Provided, the components are suitability proven for higher requirements than expected or their function is required for a shorter time interval (functional capability under LOCA conditions), an extended term of operation may be specified. The permissibility of the extended term of operation shall be proven.

Note:
Components certified for a LOCA resistance inside the containment can, thus, have a longer term of operation than certified when used under less stringent ambient conditions, e.g., in the annulus of PWR plants or, in case of BWR plants, in the reactor building outside of the containment.

(4) No further proofs under this safety standard are required, if the presented proofs of LOCA resistance specify a term of sustained LOCA resistance that is equal to or longer than the intended term of operation of the component during specified operation.

4 List Record of LOCA Resistant Components

(1) All components that would be subjected to the ambient conditions from a LOCA and would be required for the monitoring and for the control and mitigation of the LOCA shall be correlated to the individual LOCA in the course of which the specific component is required to function. The components of the corresponding functional chain shall be associated with the most unfavorable ambient conditions specified for the location of installation.

(2) It is permissible to differentiate between the spatially and sequentially applied loading to be expected in the course of a LOCA.

5 Determination of the Operational Loading

(1) For each of the components specified under Section 3 para. 1, the

a) temperature and

b) dose rate

shall be determined for the location of installation and term of operation. Insofar as this is relevant to the individual component, the following parameters shall, additionally, be taken into account:

c) frequency of actuation,

d) operating time of the component,

e) mechanical vibrations,

f) self-heating,

g) maintenance tasks.

(2) The radiation dose at the location of installation may be determined analytically or by measurement techniques. The time dependent integral of the radiation dose may be calculated from a proportional conversion of full-power days into the future or back into the past.

(3) The ambient temperature during operation shall normally be determined in the steady state condition with the reactor plant at full power.

(4) It is permissible to use analytically determined load parameters, provided, they cover the proven operational loading.

6 Ensuring a Sustained LOCA Resistance Concurrently with Plant Operation

6.1 General Requirements Regarding Proofs

(1) In the case of components for which a proof of sustained LOCA resistance is required as specified under Section 3 para. 1 which, however, have been certified for a sustained LOCA resistance of a shorter term than their intended term of operation, the permissible extension of the term of operation shall be determined. The following procedures may be used, individually or in combined form, to prove the permissibility of extended operation of the components:

a) verifying specific characteristics (LEI verification tests),

Note:
Cf. Section 6.2.2.3.

b) repeating relevant testing steps of the LOCA resistance proof (special LEI tests),

Note:
Cf. Section 6.2.2.4.

c) establishing analytical proofs.

Note:
Cf. Section 6.2.3.

(2) If the permissible extension of term of operation is not determined, the respective components or the component parts relevant to LOCA resistance shall be replaced before the end of the proven term of sustained LOCA resistance.

6.2 Determining the Permissible Extension of the Term of Operation

6.2.1 Determining the Loading History

(1) The advanced loading of higher-load components may be taken into account in determining the term of operation of lower-load components. The portion to be considered shall be determined as specified under paras. 2 and 3.

(2) In case the loading history is determined from comparison with an operation-related advanced loading, this may be used to a full extent in determining the term of operation of the lower-load component (cf. **Figure 6-1**).

Note:
The higher loads (e.g., temperature and dose rate) can have been applied at higher-load installation locations as well as exposed storage locations.

(3) In case the loading history is determined by comparison with an advanced loading caused by an additional, accelerated artificial pre-ageing, this may be used to specify the testing interval to the full extent of the ageing-related time span, provided, the effects of the accelerated pre-aging and sequential increase of loading are fully taken into account. The parameters of the individual steps during type testing shall be adjusted accordingly. In case the accelerating and sequential effects of pre-ageing cannot be taken into account, then the length of the subsequent testing interval shall be equal to no more than half the time length of the artificial pre-aging (cf. **Figure 6-2**).

Note:
An essential effect of the accelerated pre-aging may be an insufficient deterioration of the material from oxidation – caused by a reduced velocity of diffusion of atmospheric oxygen. Provided, this effect can be quantified, e.g. by determining the so-called dose rate effect in case of a radiological pre-ageing, then the term of sustained LOCA resistance may be determined directly from the duration of pre-ageing.

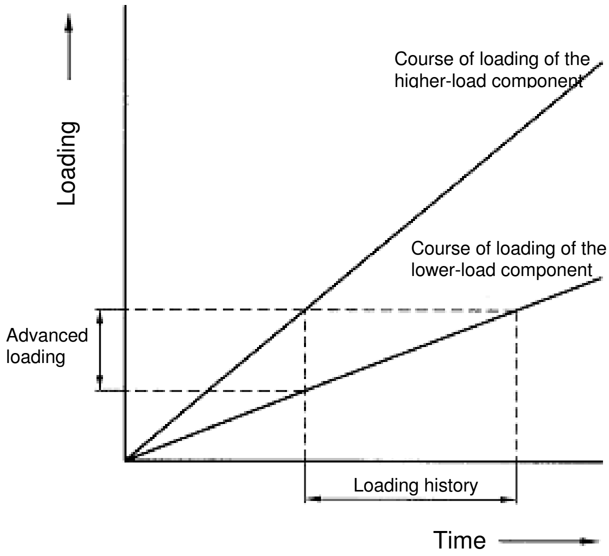

Figure 6-1: Exemplary graph showing the loading history for the proof as specified under Section 6.2.1 para. 2

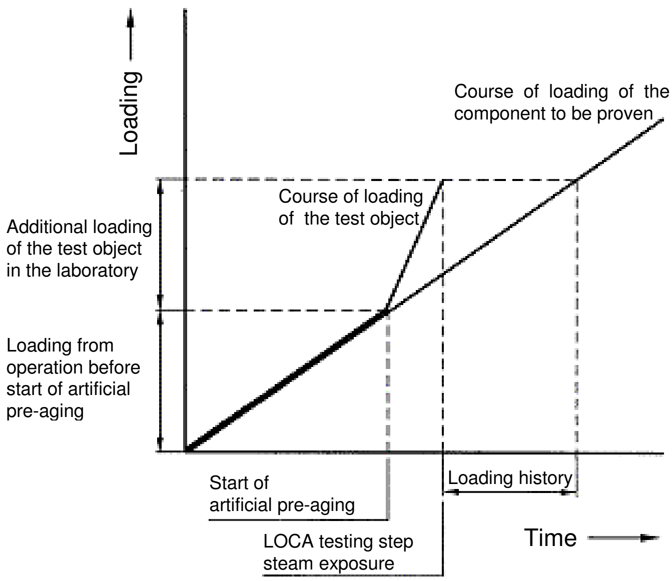

Figure 6-2: Exemplary graph showing the loading history for the proof as specified under Section 6.2.1 para. 3

(4) The testing interval for the proofs established concurrently with plant operation may be extended beyond the permissible time periods specified under paras. 2 and 3 for such components for which the ageing behavior and LOCA resistance can be determined over a longer period of time. The testing interval may be extended no further than the individually certified permissible term of operation of the components.

6.2.2 Requirements Regarding Experimental Proofs

6.2.2.1 General Requirements

(1) The components or the component parts relevant to LOCA resistance to be tested, the testing specifications and the required participation of experts (plant expert, expert personnel of the licensee, authorized expert und Sec. 20 Atomic Energy Act) shall be collated.

Note:
This is effected in the form of general testing specifications, test requirement specifications and parameter lists for the components and component parts to be tested.

(2) When specifying and executing the experimental proofs, the interfacing components or component parts shall be taken into account. An integral experimental proof for the component to be tested is not required, provided, LOCA resistance is ensured by other procedures.

(3) The testing specifications shall be established before the start of the test and shall be reviewed by the authorized expert under Sec. 20 Atomic Energy Act.

(4) The testing specifications shall include:

a) type of component and device, device identification and update status, name of manufacturer,

b) required design and testing of the interfaces,

c) description of the individual testing steps and instructions regarding execution of the tests,

d) sequence of the testing steps, the parameters to be determined and testing limit values not to be exceeded,

e) type and extent of the documentation.

(5) The testing limit values not to be exceeded shall be derived from the requirements regarding ensuring functional capability taking the contribution of the individual links of the functional chain into account.

(6) The tests performed shall be documented, and these test records shall normally contain the following information:

a) listing of the testing documents and testing equipment,

b) specification of the loading from operation in accordance with Section 5,

c) test results,

d) evaluation of the test results,

e) company, names and signatures of the participants and date of the test.

6.2.2.2 Choice of Test Objects

(1) For the experimental proof of LOCA resistance established concurrently with plant operation, representative test objects with regard to LOCA resistance shall be chosen from the components aged from operation in the nuclear power plant.

(2) Insofar as the storage of components lies in exposed locations in the nuclear power plant with ambient conditions causing a pre-ageing with respect to the actual location of installation, the test objects to be used for proofs established concurrently with plant operation may be taken from these components instead of from the components at their actual location of installation.

(3) The choice and number of test objects, the test procedure to be applied and the specification of the testing program and evaluation criteria shall be agreed upon by the authorized expert under Sec. 20 Atomic Energy Act.

6.2.2.3 LEI Verification Test

(1) In contrast to the type test, it is permissible in the LEI verification test to model LOCA loading by using only the essential loads.

Note:
Examples of LEI verification tests are the spray test, the submersion pressure test, the leak tightness test and the heating-up test. Temperature and humidity are examples of essential loads.

(2) Those loadings shall be specified for the LEI verification tests which, under LOCA conditions, would lead to a failure of critical component parts and thereby of the component itself.

(3) Before performing any LEI verification test, those component parts essential to ensuring LOCA resistance shall be determined and listed.

(4) Depending on the specific results under para. 2, the procedure shall be specified by which the condition of the individual component part with respect to its LOCA resistance can be determined.

(5) It is permissible to establish the proof by testing the component itself or by individual tests of those component parts relevant to LOCA resistance. It is important to first specify the parameters and limit values resulting from para. 4. The failure mechanisms shall be taken into account. The functional capability of the component shall be considered as proven if all tests were run successfully.

(6) The parameters and limit values to be measured during the LEI verification test of the test object shall be determined in comparative tests. For that purpose, the test object shall be subjected to the LOCA testing step of steam exposure as well as to the LOCA verification test.

Note:
Objective of the comparative testing is to determine a correlation between measured parameters of the LOCA testing step of steam exposure and of the LOCA verification test. Later, when applying the LOCA verification test, this correlation will serve in evaluating the condition of the component part or of the component with regard to LOCA conditions.

6.2.2.4 Special LEI Tests

(1) Special LEI tests may be performed to prove the characteristics ensuring LOCA resistance of components aged from operation. In this case it is permissible to disregard or modify certain testing steps of the type testing program, provided, the corresponding characteristics of the components have been proven by loading from operation.

(2) It is permissible to prove the sustained functional capability of electrotechnical components and of components of the instrumentation and controls under LOCA conditions within the framework of a special LEI test that is limited to relevant parts of the type testing. Provision is that the plant specifics and functional requirements are taken into account.

(3) The loading to be considered with respect to a LOCA shall be based on the LOCA conditions specified for the individual region of the nuclear power plant. It is permissible to use enveloping test curves (e.g. within the steel containment, the annulus, the reactor building).

Note:
The natural process of warming and cooling is described by an exponential function. For the sake of simplification, the usual test curves are, however, described by a polygonal sequence. This being an unnatural curve, this would generally result in a requirement for forced cooling during the cooling phase. If this is not possible or not wanted, e.g. to prevent water precipitation inside the testing chamber, the testing chamber should be allowed to cool down by natural heat loss, provided, this can be tolerated by the test object.

(4) The test related loading shall be specified in accordance with the engineering standards relevant to the component in relation to the expected loads at the location of installation.

(5) If the pre-ageing to be achieved shall apply to all locations of installation then the applied pre-loading shall be chosen such that it covers the location of installation with the most highly loaded component. An additional pre-loading is

not required if a time sequence as specified under Section 6.2.1 para. 2 is certified or, in the case of a radiological pre-loading, if the sum of the operational and LOCA load is less than 100 Gy.

(6) If the test related loads of the special LEI test are applied sequentially, then the order in which they are applied shall be as close to reality as possible.

Note:
Due to the damaging effects on organic materials from ionizing radiation, applying the mechanical loads sequentially after the radiological pre-loading will generally represent the higher overall loading. Therefore generally, the sequence is first thermal, then radiological, then mechanical pre-loading.

(7) In those cases where a LOCA would lead to influences from flooding, spray water or water jets at the location of installation, the specified degree of protection shall be proven as being sustained after the pressure, temperature and moisture loading.

(8) Components specified to be operable for a duration longer than 24 hours after onset of the LOCA (long term range) shall be subjected to an additional post-loading. This post-loading shall comprise all loadings expected for the test object in the course of one year after onset of the LOCA.

(9) No post-loading with regard to the long term range is required, provided, it is certified by other means that the functional capability of a component is not impermissibly impaired by a long term LOCA loading.

(10) The settings essential to the operation of the component for the individual function (e.g. measurement range, switch positions) shall be chosen such that all functions in a specified time period are ensured for the component collective to be covered.

(11) The test objects subjected to a special LEI test shall normally not be used anymore in safety related functions.

6.2.2.5 Evaluation of Experimental Test Results

(1) The tests are considered as having been passed if the functional capability of the test object has been proven.

(2) In the case that a testing step is not successful, a failure analysis shall be established.

(3) If the failure analysis shows that no systematic failure is involved, the failed test object may be repaired and the testing step repeated.

(4) If the failure analysis shows the presence of a systematic failure, the test shall be considered as having failed.

6.2.3 Requirements Regarding Analytical Proof

(1) An experimental proof of LOCA resistance to be performed concurrently with operation is not required, provided, it can be certified analytically that the materials and parts relevant to the LOCA resistance of a component will not experience any relevant ageing during the specified term of operation and under the reigning operating conditions taking maintenance measures into account.

(2) The analytical proofs shall show that the function of the component is ensured during specified normal operation and during the design basis accident to be mitigated and controlled.

(3) The analyses shall normally be based on well known procedures and correlations, on operating experience, on experience from experimental test or on a combination of any of these. New approaches to analytical solutions shall be comprehensibly documented including all assumptions and extrapolations.

(4) The analytical proof shall present information on the following factual situation:

a) design and materials relevant to ensuring LOCA resistance,
b) thermal and radiological stability of the relevant materials and structural elements,
c) evaluation regarding whether or not and in what manner the mechanisms and materials are sensitive to ageing,
d) thermal and radiological operating conditions at the location of installation,
e) evaluation of the influence of maintenance measures on LOCA resistance,
f) term of sustained LOCA resistance.

(5) It is permissible to determine the term of sustained LOCA resistance by extrapolating the relevant parameters over time. The trend analysis on which this is based shall be well documented with respect to its verifiability.

6.3 Requirements Regarding Replacement of Components or Component Parts

(1) If a proof of the LOCA resistance of components is not possible or shall normally not be established concurrently with plant operation, then the corresponding components or the component parts relevant to the LOCA resistance of the components shall be replaced.

(2) The replacement shall normally be performed within the certified term of sustained LOCA resistance taking the refueling cycles into account, and in one redundancy at a time.

(3) The components or component parts used as replacements shall be certified as being suitable.

7 Transferability of the Results from Proofs Established Concurrently with Plant Operation

(1) It is permissible to transfer the results of the experimental or analytical proofs established concurrently with plant operation to other components or component parts, provided, the following conditions are met:

a) comparability of the items in question regarding design, arrangement, function, operation and materials,
b) comparability of the loading from operation,
c) comparability of the loading occurring during LOCA,
d) comparability of the test parameters, i.e., the boundary conditions on which the effective proof established concurrently with plant operation was based shall also cover the components and component parts to which the results are to be transferred.

(2) The transferability of the results of the proofs established concurrently with plant operation shall be demonstrated within the framework of the suitability test.

8 History of the Term of Validity for Proofs Established Concurrently with Plant Operation

(1) The information required as specified under Section 3 para. 1 shall be documented for each nuclear power plant in an individual list record.

(2) This list record shall be continuously updated during the service life of the nuclear power plant.

Appendix

Regulation Referred to in this Safety Standard

Atomic Energy Act	Act on the peaceful utilization of atomic energy and the protection against its hazards (Atomic Energy Act) of December 23, 1959 (BGBl. I, p. 814) as amended on July 15, 1985 (BGBl. I, p. 1565), most recently changed by law on April 6, 1998 (BGBl. I, p. 694)