

Safety Standards

of the

Nuclear Safety Standards Commission (KTA)

KTA 2201.4 (2012-11)

**Design of Nuclear Power Plants against Seismic Events;
Part 4: Components**

**(Auslegung von Kernkraftwerken gegen seismische
Einwirkungen; Teil 4: Anlagenteile)**

The previous version of this safety
standard was issued in 1990-06

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

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KTA SAFETY STANDARD

November
2012

Design of Nuclear Power Plants against Seismic Events; Part 4: Components

KTA 2201.4

Previous versions of this safety standard: 1990-06 (BAnz No. 20a of January 30, 1991; Corrections: BAnz No. 115 of June 25, 1996)

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PLEASE NOTE: Only the original German version of this safety standard represents the joint resolution of the 50-member Nuclear Safety Standards Commission (Kerntechnischer Ausschuss, KTA). The German version was made public in the Bundesanzeiger (BAnz) of January, 23th, 2013. 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,
should	indicates a recommendation or an example of good practice,
may	indicates an acceptable or permissible method within the scope of this safety standard.

Basic Principles

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the task of specifying those safety-related requirements which shall be met with regard to precautions to be taken in accordance with the state of science and technology against damage arising from the construction and operation of the plant (Sec. 7 para. 2 subpara. 3 Atomic Energy Act - AtG) in order to attain the protective goals specified in AtG and the Radiological Protection Ordinance (StrlSchV) and further detailed in the "Safety Criteria" and in the "Design Basis Accident Guidelines".

(2) In accordance with Criterion 2.6 of the Safety Criteria, protective measures against seismic events are required, provided, earthquakes must be taken into consideration. Table I of the Design Basis Accident Guidelines classifies earthquakes as belonging to that group of design basis accidents that requires taking preventive plant engineering measures against damage and that is relevant with respect to radiological effects on the environment. The basic requirements of these preventive measures are dealt with in the safety standard series KTA 2201.

(3) The present safety standard KTA 2201.4 – as part of the series KTA 2201 entitled "Design of nuclear power plants against seismic events" – deals with the components. The series KTA 2201 is comprised of the following six parts:

Part 1: Principles,

Part 2: Subsoil,

Part 3: Design of structural components (*civil structures*),

Part 4: Components (*the present safety standard*),

Part 5: Seismic instrumentation,

Part 6: Post-seismic measures.

(4) In safety standard KTA 2201.4 the verifications required for the mechanical and electrical components including their support structures are broken down into individual verification steps, i.e.,

- a) Determining the excitation at the place of installation,
- b) Modeling and the determination of parameters,
- c) Analyzing the mechanical behavior,
- d) Verifying the limit conditions.

(5) These verification steps are dealt with for each of the four possible verification methods, i.e.,

- a) Verification by analysis,
- b) Verification by physical experiments,
- c) Verification by analogy considerations,
- d) Verification by plausibility considerations.

The earthquake safety of a component may be verified on the basis of an individual verification method or on the basis of a combination of various verification methods.

(6) Safety standard KTA 2201.4 presents the basis for fulfilling the requirements regarding the verification of the site-specific earthquake safety of components. With regard to analyzing the mechanical behavior of the individual components and verifying the fulfillment of their safety-related tasks, additionally, the respective component-specific KTA safety standards need to be consulted.

1 Scope

(1) This safety standard applies to nuclear power plants with light water reactors. It applies to the design of components against seismic forces in order that they meet the protective goals of

- a) controlling reactivity,
- b) cooling fuel assemblies,
- c) confining radioactive substances, and
- d) limiting radiation exposure.

(2) The present safety standard specifies the requirements with respect to verifying the earthquake safety of components. The task-specific and safety-related requirements that must be specified separately for each component – e.g., load-carrying capacity (stability), integrity and functional capability (cf. Section 3.1) – are not dealt with in this safety standard.

(3) In this safety standard, the term mechanical components refers to components such as vessels, heat exchangers, pumps, valves, lifting gear and pipe lines including their support structures in as far as these components are not considered to be civil structures in accordance with safety standard KTA 2201.3. Liners, crane runways, platforms and scaffoldings are not considered as being part of these mechanical components.

(4) In this safety standard, the term electrical components refers to the combination of electrical devices including all electrical connections and their support structures (e.g., cabinets, frames, consoles, brackets, suspensions or supports).

2 Definitions

(1) The application of the present safety standard relies on definitions of

- a) the general terms as defined in KTA 2201.1,
- b) the terms action (permanent, temporary and accidental), types of actions, combinations of actions, design situations, partial safety factor, ultimate limit state and serviceability limit state as defined in DIN EN 1990,
- c) the terms primary stress, secondary stress and peak stress as well as service limit level as defined in safety standard KTA 3204,
- d) the different requirement categories as defined in KTA-GS-78,

and on the following definitions.

(2) Required response spectrum

The required response spectrum is a response spectrum that is obtained by multiplying the design response spectrum by safety factors and test-signal specific magnification factors. Required response spectra may also be created as an enveloping curve of the response spectra at the various places of installation.

(3) Excitation, single-frequency

A single-frequency excitation has a time history in which at every point in time only a single excitation frequency (e.g., sine sweep, fixed frequency) occurs.

(4) Design spectrum

The design spectrum is an enveloping, widened and smoothed response spectrum that is used as the basis for the seismic design. In this context, it is differentiated between ground acceleration response spectrum (primary spectrum), building response spectrum (secondary spectrum) and component response spectrum (tertiary spectrum).

(5) Damping, modal

Modal damping for mechanical systems is the damping ratio of the respective natural vibration.

(6) Ductility

Ductility is the quotient of the maximum elasto-plastic displacement and the purely elastic displacement (displacement ductility).

(7) Limit frequency, lower

The lower limit frequency of mechanical components is that frequency below which no significant seismic response would occur.

Note :

The lower limit frequency may be specified as one half of the lowest eigenfrequency of the system.

(8) Major system

The major system is a heavy structure that supports one or more lighter-weight subsystems (cf. Definition (12)).

(8) Nonlinearity, geometric or physical

A geometric nonlinearity is the nonlinear relationship between the force values and displacement quantities resulting from the equilibrium and kinematic analyses of a deformed system. A physical nonlinearity is the nonlinear relationship between stresses and distortions resulting from a nonlinear material behavior.

(10) Test response spectrum

A test response spectrum is a response spectrum determined based on the actual motion of the shaking table.

(11) Center of gravity, dynamic

The dynamic center of gravity is that point on the approximated model of a structure that reduces the structure to one degree of freedom, at which point the acceleration is identical to the respective value of the response spectrum.

(12) Subsystem

A subsystem is a lighter-weight partial system that is supported by a heavy major system (cf. Definition (8)).

(13) Behavior coefficient

The behavior coefficient, q , is a reduction coefficient applied to the force values determined by linear analysis of earthquake events. This coefficient takes the dissipative effects into account that arise from the materials used, from the support structure and from the structural design.

3 General Requirements**3.1 Basics**

(1) The general design requirements for components are specified in safety standard KTA 2201.1, Sec. 4.1. They include classification of the components, i.e., their assignment to Class I, Class IIa and Class IIb, as well as the general requirements regarding the verification of their earthquake safety.

(2) It shall be verified for all Class I components that they are able to fulfill their safety-related tasks in the case of seismic events. The safety-related tasks shall be specified for each component. Typical safety related tasks are:

a) Load-carrying capacity (stability)

The load-carrying capacity is the capability of components to withstand the actions to be assumed on account of their strength, stability and secure positioning (e.g., their protection against falling over, against dropping down, against impermissible slipping).

The load-carrying capacity shall be verified for the component and its support. The building structure interaction loads shall be specified.

b) Integrity

Integrity is the capability of a component above and beyond its load-carrying capacity to meet the respective requirements regarding leak tightness and deformation restrictions.

The integrity of the components shall be verified based on requirements in accordance with the component-specific standards.

c) Functional capability

Functional capability is the capacity of a system or component above and beyond its load-carrying capacity to fulfill the designated tasks by way of its respective mechanical or electrical function.

In this context, it shall be differentiated between whether the functional capability of the component must be achieved

- after the earthquake or
- during and after the earthquake.

Furthermore, it shall be differentiated between active and passive functional capabilities.

An active functional capability of a component ensures that the specified movements (relative movements between individual parts) can be performed (closing of clearances, creating or changing of friction forces) and that the electrical functions are maintained.

A passive functional capability of a component means that permissible deformations and movements are not exceeded.

(3) For all Class IIa components it is required to be verified that on account of earthquakes they will not detrimentally affect the Class I components and civil structures in a way that these would not anymore be able to fulfill their safety-related tasks. In this context, it is generally sufficient to verify the load-carrying capacity. In certain cases it may be necessary to verify that limit deformations are not exceeded or that integrity (risk of flooding) is upheld.

(4) Ageing effects that might influence the verification objective shall be taken into account.

Note :

Details regarding ageing effects are dealt with in safety standard KTA 1403.

3.2 Verification Procedure

(1) The individual procedural steps of the verification procedure are shown in **Figure 3-1**.

(2) Depending on the verification objective, individual steps of the verification procedure may be combined, provided, the detailing of the model so allows. Intermediate results do not need to be determined.

(3) The site excitation parameters to be applied shall be the seismo-engineering parameters of the design basis earthquake in accordance with safety standard KTA 2201.1, Sec. 3.5, (i.e., ground acceleration response spectrum, reference horizon, directional components, strong-motion duration)..

(4) The modeling principles in accordance with safety standard KTA 2201.1, Sec. 4.3.2, shall be applied. Additional requirements dependent on the respective verification methods are specified below in Sections 4 through 7.

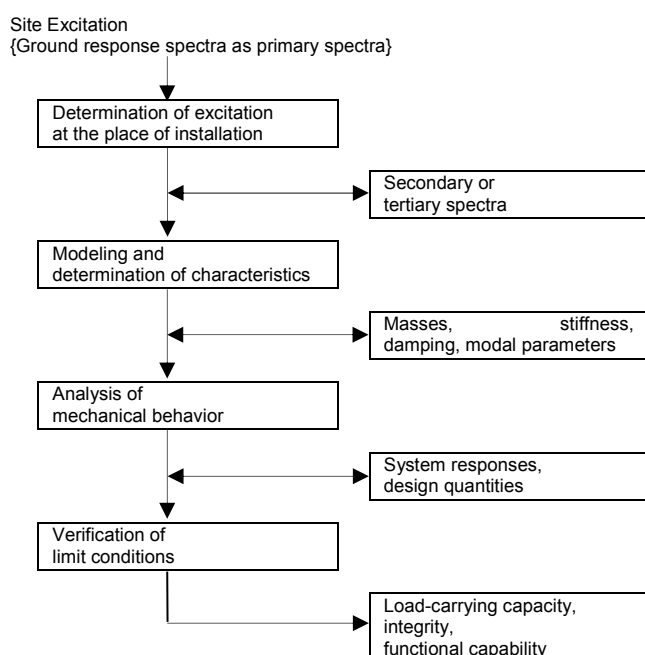


Figure 3-1: Procedural steps of the verification procedure

(5) In case of a linear system behavior, the mechanical behavior may be analyzed separately for the seismic actions and for the other continuous and non-continuous actions. The design quantities shall then be determined by superposition.

(6) In case of a non-linear determination of the system behavior, the entire action collective with safety margins and combination factors shall be analyzed simultaneously.

(7) For the verification of the limit conditions, the determined design quantities for the loads shall be correlated with the corresponding permissible strains.

3.3 Verification Methods

(1) The following verification methods are permissible either individually or in combination with each other:

- Verification by analysis (cf. Section 4),
- Verification by physical experiments (cf. Section 5),
- Verification by analogy (cf. Section 6),
- Verification by plausibility considerations (cf. Section 7).

(2) The verification methods to be applied shall be specified for each component with regard to its respective task.

Note:

In case of the verification of the functional capability of electro-technical components (e.g., contactors, relays, circuit breakers), preference is given to experimental verification methods.

4 Verification by Analysis

4.1 Summary

(1) The basic requirements regarding verification by analysis are specified in safety standard KTA 2201.1, Sec. 4.3. This concerns the combination of excitation directions, the modeling, the determination and application of the acceleration time histories as well as superordinate aspects of the analysis methods.

(2) The dynamic analysis procedures specified under Section 4.4.1 shall be applied to the verification by analysis. In well substantiated cases, simplified procedures are permissible. In the case of pipes, it is permissible to alternatively apply the respective guidelines for laying of pipes, provided, their technical basis includes the load case earthquake.

4.2 Excitation at the Place of Installation

4.2.1 Basics

(1) The excitation at the place of installation shall be determined by one of the following methods:

- as response time histories of the structural components or building response spectra (secondary responses in accordance with safety standard KTA 2201.3),
- as response time histories or response spectra of the component (tertiary responses as specified under Section 4.2.3.1),
- as artificial time histories which, in accordance with safety standard KTA 2201.1, Sec. 4.3.3, must be compatible with the response spectra of the building structure or component.
- as response spectra for tertiary responses with the substitution method, cf. Section 4.2.3.2.

(2) Suitable excitations shall be selected for each direction at the place of installation where the response spectra will cover the secondary design response spectra in the essential frequency range of the component or its substructure. The selected excitations shall be well substantiated.

(3) From the selected registered or artificial time histories suitable stress conditions shall be created under consideration of the assigned direction of excitation at the component (or at the building structure with the component). The creation of stress conditions shall be well substantiated.

Note:

Three stress conditions are sufficient in the case of a linear analysis of the component. A non-linear analysis will require in the order of 5 stress conditions if based on registered time histories and in the order of 7 stress conditions if based on artificial time histories.

(4) Alternatively, the components may be integrated into the model of the building structure and, thus, may be analyzed within the overall model.

(5) Aside from the methods involving time histories or the substitution method for determining the excitation at the place of installation, other mathematical procedures may be applied if they offer equivalent results.

4.2.2 Secondary responses

(1) The responses of the building structure – i.e., the (secondary) response time histories and the (secondary) response spectra – shall be determined within the framework of analyzing the structural components in accordance with safety standard KTA 2201.3.

(2) The mathematical engineering model provided for the structural components in accordance with safety standard KTA 2201.3 shall be expanded by the component as specified in Section 4.3 if the responses of this component must be determined directly as a secondary response and not as a tertiary response.

(3) The determined response time histories shall be provided in their digital form and the determined design spectra both in their graphical and digital form.