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# Design of nuclear power plants against seismic events —

## Part 4:
## Components

*Conception parasismique des installations nucléaires —*

*Partie 4: Composants*





Reference number
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# Foreword

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## Introduction

In accordance with IAEA Safety Standards Series No. SSR-2/1, protective measures against seismic events are required, provided earthquakes should be taken into consideration. Earthquakes comprise that group of design basis events that requires taking preventive plant engineering measures against damage and which are relevant with respect to radiological effects on the environment. The basic requirements of these precautionary measures are dealt with in ISO 4917-1.

ISO 4917-4 presents the basis for fulfilling the requirements regarding the verification of the site-specific earthquake safety of components.



 

# Design of nuclear power plants against seismic events —

## Part 4:
## Components

## 1 Scope

This document applies to nuclear power plants with water cooled reactors. For other nuclear facilities check the applicability of the document in advance, before it might be applied correspondingly.

This document specifies the requirements for the earthquake safety of components. The operation-specific safety-related requirements for each component, e.g. load-bearing capacity (stability), integrity and functionality (see 4.1) are not the subject of this document. With regard to analysing the mechanical behaviour of the individual components and verifying the fulfillment of their safety related functions, additionally, the respective component-specific standards need to be consulted.

In this document, the term *mechanical components* refers to components such as vessels, heat exchangers, pumps, valves, lifting gear, distribution systems and pipe lines including their support structures in as far as these components are not considered to be civil structures in accordance with ISO 4917-3. Liners, crane runways, platforms and scaffoldings are not considered as being part of these mechanical components.



In this document, 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).

Supplementary to this standard the seismic qualification of electrical components is reported in IEC/IEEE 60980-344.



NOTE This document is independent of national standards. Recommendations, given in Annex A, are mainly based on the Eurocodes-Design-Philosophy and European Standards. Alternatively other equivalent standards or regulations can be used in case the general requirements given in this document together with Annex A can be met.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4917-1:—, *Design of nuclear power plants against seismic events— Part 1: Principles*

ISO 4917-3, *Design of nuclear power plants against seismic events — Part 3: Design of structural components*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4917-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

**3.1**
**behaviour coefficient**
*q*
reduction coefficient applied to the force magnitude determined by linear analysis of earthquake events

Note 1 to entry: The coefficient, *q*, takes the dissipative effects into account that arise from the materials used, from the support structure and from the structural design.

**3.2**
**centre of gravity**
<dynamic> point of action of gravity, which can be considered as the point on the approximated single degree of freedom model of a structure, at which the acceleration is equal to the respective value of the response spectrum

**3.3**
**damping**
<modal> damping ratio of the respective eigenmode in mechanical systems

**3.4**
**demand response spectrum**
response spectrum that is specified for the design verification or qualification of structures, systems or components and that is usually obtained by multiplying the design response spectrum by safety factors and test-signal specific magnification factors

Note 1 to entry: Demand response spectra may also be created as an enveloping curve of the response spectra at the various places of installation.



**3.5**
**design spectrum**
enveloping, widened and smoothed single-degree-of-freedom response spectrum that is used as the basis for the seismic design



Note 1 to entry: In this context, it is differentiated between ground acceleration response spectrum (primary spectrum), building response spectrum (secondary spectrum) and component response spectrum (tertiary spectrum).

**3.6**
**non-linearity**
<geometric or physical> nonlinear relationship between the quantities of action and reaction resulting from the equilibrium and kinematic analyses of a system

Note 1 to entry: A physical nonlinearity is the nonlinear relationship between stresses and distortions resulting from a nonlinear material behaviour.

Note 2 to entry: A geometric nonlinearity is defined by a change of dynamic behaviour due to a change of shape, closing or opening of gaps, uplifting or sliding of a component.

**3.7**
**primary system**
heavy structure that supports one or more lighter-weight *secondary systems* (3.8)

**3.8**
**secondary system**
lighter-weight partial system that is supported by a heavy *primary system* (3.7)

**3.9**
**single-frequency excitation**
frequency, which has a time history in which at every point in time only a single excitation frequency (e.g. sine sweep, fixed frequency) occurs

**3.10**
**test response spectrum**
response spectrum determined based on the actual motion of the shaking table

**3.11**
**upper limit frequency**
frequency above which no significant seismic response in mechanical components would occur

Note 1 to entry: The upper limit frequency may be specified as the cut-off frequency of the excitation spectrum.

# 4 General requirements

## 4.1 Basics

The general design requirements for components are specified in ISO 4917-1:—, 4.1. They include classification of the components, i.e. their assignment to seismic category 1, seismic category 2, and seismic category 3, as well as the general requirements regarding the verification of their earthquake safety.

The design of components and civil structures against seismic events should meet the objectives specified in ISO 4917-1.

It shall be verified for all seismic category 1 components that they are able to fulfill their safety related functions in the case of seismic events. The safety related functions shall be specified for each component. Typical safety related functions are:



a) Load-bearing capacity (stability):

- The load-bearing capacity is the capability of components to withstand the loads 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-bearing capacity shall be verified for the component and its support. The building structure interaction loads shall be specified.



b) Integrity:

- Integrity is the ability of a plant component to fulfill its requirements with regard to leak tightness or deformation restrictions.

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

c) Functionality:

- Functionality is the ability of a system or component to fulfill its designated safety functions during and after the seismic event

- In this context, it shall be differentiated between whether the functionality of the component shall be achieved

  - after the earthquake, or

  - during and after the earthquake.

- Furthermore, it shall be differentiated between active and passive functionalities.

- An active functionality 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 functionality of a component means that permissible deformations and movements are not exceeded. Also, false signals should not appear in electrical equipment.

For all seismic category 2 components it is required to be verified that on account of earthquakes they will not adversly affect the seismic category 1 components and civil structures in a way that these would not anymore be able to fulfill their safety related functions. In this context, it is generally sufficient to verify the load-bearing capacity. In certain cases, it may be necessary to verify that limit deformations are not exceeded or that integrity (risk of flooding) is upheld.

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

NOTE Details regarding ageing effects are dealt with in IAEA Nuclear Energy Series No. NP-T-3.24.

In this document the verifications required for the mechanical and electrical components including their support structures are broken down into individual verification steps, i.e.

1) determining the excitation at the place of installation,

2) modeling and the determination of parameters,

3) analysing the seismic behaviour with respect to the safety requirement,

4) verifying the limit conditions.

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

i) verification by analysis,

ii) verification by testing,

iii) verification by analogy considerations,

iv) verification by plausibility considerations.



The latter two methods are to be understood as indirect methods according to IAEA SSG-67.



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.

## 4.2 Verification procedure

The individual procedural steps of the verification procedure are shown in Figure 1.

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.

The site excitation parameters to be applied shall be the seismo-engineering parameters of the design basis earthquake in accordance with ISO 4917-1:—, 4.5, (i.e. ground acceleration response spectrum, reference horizon, directional components, strong motion duration).

The modeling principles in accordance with ISO 4917-1:—, 5.3.2, shall be applied. Additional requirements dependent on the respective verification methods are specified below in Clause 5 to Clause 8.

 

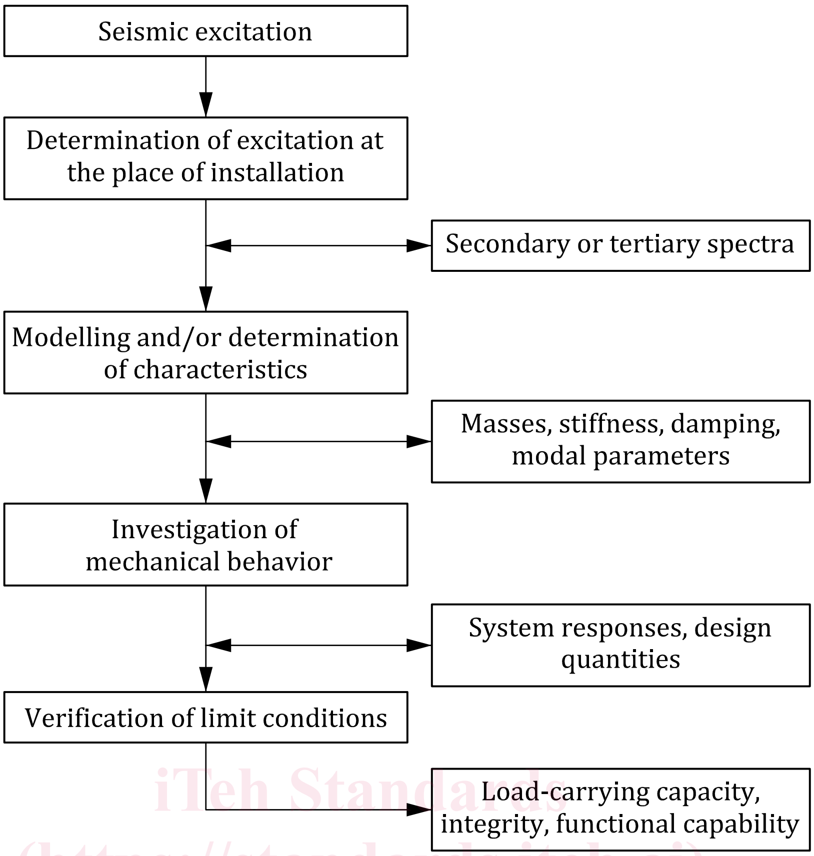


**Figure 1 — Procedural steps of the verification procedure**



In case of a linear system behaviour, the mechanical behaviour may be analysed separately for the seismic actions and for the other continuous and non-continuous actions. The design quantities shall then be determined by superposition. The effects of seismic actions in each direction and on each single mode may also be determined separately. The design quantity can then be determined by combination of these modal and directional contributions. Superposition shall generally be in accordance with ISO 4917-1: —, 5.3.1.

In case of a non-linear analysis of the system, all actions having a significant influence on the dynamic behaviour of the component shall be applied with safety margins and combination factors simultaneously.

NOTE Detailed approaches for addressing margins and combination factors can be found in the recommendations in the appendix and in the documents listed in the bibliography.

For the verification of the limit states, the determined design values of the actions are to be compared with the allowable capacities in the appropriate design codes.

## 4.3 Verification methods

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

a) verification by analysis (see Clause 5);

b) verification by testing (see Clause 6);

c) verification by analogy (see Clause 7);

d) verification by plausibility considerations (see Clause 8).

The verification methods to be applied shall be specified for each component regarding its respective task.

NOTE 1 In case of the verification of the functionality of electrotechnical components (e.g. contactors, relays, circuit breakers), preference is given to experimental verification methods.

NOTE 2 Verifications by analogy and by plausibility considerations are in line with IAEA SSG-67 indirect methods.

# 5 Verification by analysis

## 5.1 Summary

The basic requirements regarding verification by analysis are specified in ISO 4917-1:—, 5.3. 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.

The dynamic analysis procedures specified in 5.4.1 shall be applied to the verification by analysis. In well substantiated cases, simplified procedures are permissible.

For pipes or other distributed systems for which design guidelines exist and include seismic load provisions that adequately cover site conditions, it is sufficient that the pipes or distributed system be designed in accordance with those guidelines. Pipes and distributed systems can also be grouped by geometries and material properties, and entire groups can be verified at once using envelope configurations of the existing layouts.



## 5.2 Excitation at the location of installation

### 5.2.1 Basics

The excitation at the location of installation shall be determined by one of the following methods:



a) as response time histories of the structural components or building response spectra (secondary responses in accordance with ISO 4917-3);

b) as response time histories or response spectra of the component (tertiary responses as specified in 5.2.3);

c) as artificial time histories which, in accordance with ISO 4917-1: —, 5.3.3, shall be compatible with the response spectra and the other seismo-engineering parameters of the building structure or component,

d) as response spectra for tertiary responses with the substitution method, see A.1.

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

Appropriate load scenarios shall be formed from the selected or the artificial time histories, taking into account the directional assignment, with which the component (or structure with component) is to be excited. The formation of the load scenarios shall be substantiated.

NOTE Details regarding the minimum number of action combinations that have to be analysed can be found in ISO 4917-1:—, 6.3.3.

Alternatively, the components may be integrated into the model of the superstructure (e.g. building structure) and, thus, may be analysed within the overall model.

 