FINAL DRAFT

INTERNATIONAL STANDARD

ISO/FDIS 4917-1

ISO/TC **85**/SC **6**

Secretariat: **DIN**

Voting begins on:
2023-11-29

Voting terminates on:
2024-01-24

Design of nuclear power plants against seismic events —

Part 1: **Principles**

Conception parasismique des installations nucléaires —

Partie 1: Principes

Reference number
ISO/FDIS 4917-1:2023(E)

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Foreword

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This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 6, *Reactor technology*.

A list of all parts in the ISO 4917 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

In accordance with IAEA Safety Standards Series No. SSR-2/1, protective measures against seismic events are required, provided earthquakes must be taken into consideration.

Earthquakes comprise that group of design basis external events that requires taking preventive plant engineering measures against damage and which are relevant with respect to radiological effects on the environment.

This document will be applied under the presumption that the geology and tectonics of the plant site have been investigated with special emphasis on the existence of active geological faults and lasting geological ground displacements, and that the site has been deemed suitable for a nuclear installation.

Design of nuclear power plants against seismic events —

Part 1:
Principles

1 Scope

This document applies to nuclear power plants with water cooled reactors and, in particular, to the design of components and civil structures against seismic events in order to meet the safety objectives. For other nuclear facilities the applicability of the document must be checked in advance, before it might be applied correspondingly. Seismic isolation is not adressed in the series of ISO 4917.

The following safety objectives are defined in order to ensure the protection of people and the environment against radiation risks:

a) controlling reactivity;

b) cooling fuel assemblies;

c) confining radioactive substances;

d) limiting radiation exposure.

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.

IAEA Safety Standards Series No., SSG-67, *Seismic Design for Nuclear Installations*, INTERNATIONAL ATOMIC ENERGY AGENCY VIENNA, (2021)

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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
action
impact of an external force (e.g. seismic action)

3.2
action effect
internal force inside a structure (e.g. force, moment)

3.3
active geological fault
fault showing evidence of past movements (e.g. recent seismicity or geological evidence) within such a period that it is reasonable to assume that further movements can occur

Note 1 to entry: For areas of low seismicity evidence of last movements in the quaternary (until ≈ $2,6 \cdot 10^6$ a) or including Pliocene (until ≈ $5,3 \cdot 10^6$ a) can be appropriate to consider. For higher seismic areas shorter periods can be considered.

Note 2 to entry: A geological fault need also to be considered active if a structural relationship with a known active geological fault is demonstrated or likely. In this case the movement of one fault can cause the movement of the other.

Note 3 to entry: The definition is equivalent to “capable fault” in IAEA Glossary (2018).

3.4
beyond design basis earthquake
decisive level of ground motion which exceeds the design basis earthquake

3.5
civil structure
building structure that is connected to the ground and consists of structural and non-structural elements (building materials and structural members)

Note 1 to entry: It may be necessary to perform the verification of earthquake safety for “civil structures” in their entirety as well as for the individual parts (“structural members”).

3.6
complete quadratic combination
CQC
stochastically based superposition relationship for oscillating systems in order to take account of the coupling of eigenmodes in modal analyses

3.7
component
electrical, instrumentation and control, and mechanical equipment that ensures the operation of the nuclear facility, including distribution systems and their support structures

Note 1 to entry: This definition is necessary for the differentiation between “plant component” and “*civil structures* (3.5) or building structures”. In mechanical engineering, a component is one that is manufactured from product forms and represents the smallest part of a subassembly.

3.8
correlation coefficient
ρ_{xy} of two seismic time histories, x(t) and y(t), defined by the covariance σ_{xy} of $x(t)$ and $y(t)$ divided by the product of the related standard deviations s_x and s_y of the two time histories

3.9
damping ratio
dimensionless characteristic value D of a (velocity proportional) damped oscillating single-degree-of-freedom system, in percentage of critical damping

3.10
deaggregation
quantification of the relative contributions from earthquakes of different sizes and at different distances to the seismic hazard at a site

Note 1 to entry: Usually calculated for discrete ground motion levels from the probabilistic seismic hazard analysis (PSHA) and for intervals of *magnitude* (3.24) and distance or for seismic sources.

3.11
design basis earthquake
decisive level of ground motion for the design against seismic events

Note 1 to entry: The design basis earthquake (DBE) is equivalent to SL-2 earthquake as per IAEA SSG-67 or safe shutdown earthquake (SSE) in some national guidelines. It represents the seismic impact at the site, at least expressed in terms of *ground acceleration response spectra* (3.17) and *strong motion duration* (3.38).

3.12
epistemic uncertainty
aleatoric variability
epistemic uncertainty, based on uncertainty of the state of knowledge, (e.g. regarding models or parameters) and aleatoric variability, inherently connected with stochastic phenomena or processes (e.g. decrease of acceleration amplitudes with increasing distance)

Note 1 to entry: Epistemic uncertainties can be reduced by additional data, information or improved modeling (e.g. uncertainty in specifying the source region). Aleatoric variabilities usually cannot be reduced.

Note 2 to entry: Epistemic uncertainty and aleatoric variability is equivalent to “Epistemic uncertainty” and “aleatoric uncertainty” in IAEA Glossary (2018).

3.13
external event
event unconnected with the operation of a facility or the conduct of an activity that could have an effect on the safety of the facility or activity

Note 1 to entry: These events having either natural causes (e.g. high water, earthquake) or civilizational causes (e.g. aircraft crash, pressure wave from explosions).

3.14
focal depth
depth of the hypocenter beneath the surface of the earth

3.15
free field
location at or near the surface, where vibratory ground motion is not affected by structures and facilities

3.16
functionality
ability of a system or *component* (3.7) to fulfill its designated safety functions during and after the seismic event

Note 1 to entry: This definition is specific to components. In the case of *civil structures* (3.5), the adequate term would be “serviceability”.

3.17
ground acceleration response spectrum
response spectrum derived from a ground motion related to *free field* (3.15) or a reference horizon at depth

3.18
ground motion prediction equation
GMPE
function (typically empirical) for the prediction of ground motion

Note 1 to entry: Input parameters are *magnitude* (3.24), source to site distance, local site conditions and other parameters.

3.19
inspection level earthquake
level of ground motion that, if exceeded, causes a plant inspection

3.20
integrity
ability of a plant *component* (3.8) to fulfill its functions with regard to leak tightness or deformation restrictions

3.21
(macroseismic) intensity
classification of the strength of ground motion, based on the observed effects within a limited area, e.g. a village

Note 1 to entry: Basis for determining the intensity are phenomenological descriptions of the effects on humans, objects, buildings and the earths surface. The intensity is a robust measure for strength classification; the corresponding macroseismic classification scales (e.g. EMS 98) define twelve intensity levels.

3.22
internal event
event or group of events that result from failures of systems, structures or *components* (3.7) (SSC) or human failures originating within a nuclear power plant that cause an initiating event directly or indirectly and may challenge safety functions to achieve its safety objectives

Note 1 to entry: These are exceptional events caused by plant internal incidents (e.g. differential pressures, jet impingement and reaction forces, plant internal flooding due to breakage or leakage of pressurized components, load crash)

3.23
load-bearing capacity
ability of *components* (3.7) and *civil structures* (3.5), based on their material strength, stability and secure positioning, to withstand the impact from events

3.24
magnitude
measure of the size of an earthquake, approximately related to the energy released in the form of seismic waves

Note 1 to entry: The classic definition of seismic magnitude is the logarithm of the maximum amplitude of recorded seismograms taking the distance to the hypocenter (seismic focus center) into account. Different types of seismic magnitudes are, e.g. local magnitude, body wave magnitude, surface wave magnitude and moment magnitude.

3.25
operating basis earthquake
decisive level of ground motion that is likely to occur and affect the plant during its operating lifetime

3.26
paleoseismology
method used to search for indications of prehistoric earthquakes in geological sediments and rock formations and includes estimation of their *magnitude* (3.24) and of the age of the deformations due to earthquakes

Note 1 to entry: Paleoseismology serves to extend earthquake findings into the younger geological times. Paleoseismology is generally restricted to geological terrains of continuous sedimentation of the past ten thousands of years.

3.27
peak ground acceleration
maximum amplitude (absolute value) of the horizontal or vertical ground acceleration *components* (3.7) of the earthquake time history (accelerogram)

Note 1 to entry: It corresponds to the rigid-body acceleration of the *ground acceleration response spectrum* (3.17).